

Referred

CANADA
DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN MCLEISH, DIRECTOR

**INVESTIGATIONS OF
MINERAL RESOURCES AND THE MINING
INDUSTRY, 1929**

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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Annual reports on Mines Branch investigations are now issued in four parts, as follows:—

Investigations of Mineral Resources and the Mining Industry.

Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories).

Investigations of Fuels and Fuel Testing (Testing and Research Laboratories).

Investigations in Ceramics and Road Materials (Testing and Research Laboratories).

Other reports on Special Investigations are issued as completed.

MINES BRANCH INVESTIGATIONS OF
MINERAL RESOURCES AND THE MINING
INDUSTRY, 1929

I

THE WILBERFORCE RADIUM OCCURRENCE

Hugh S. Spence and R. K. Carnochan

This report deals with an occurrence of radium ore near Wilberforce, Haliburton county, Ontario, upon which development work has recently been undertaken and which seems more likely to prove of commercial grade than any other deposit of radioactive minerals hitherto found in Canada. This occurrence is sometimes called the Richardson property, after Mr. W. M. Richardson, the discoverer.

Occurrences of radioactive minerals are not uncommon in eastern Canada, and a number are recorded in the literature. The earliest of such references is probably that in *Geology of Canada*, 1863, where is mentioned an occurrence of uraninite at Mamainse, on the east shore of lake Superior. The mineral was first described by J. L. LeConte, in 1847, under the name of coracite; and was said to occur in a two-inch vein at the contact of trap and syenite. Search for this locality in recent years has proved unsuccessful.

Obalski, in 1894, mentions¹ the occurrence of uraninite at a mica mine near Murray Bay, Quebec. In 1903, Obalski records² tests made on this uraninite by Rutherford and the Curies, and the determination in it of the then newly-discovered element radium. In 1901, he mentions³ the occurrence of uraninite at the Villeneuve mica mine, on the Lièvre river; and of samarskite at the Maisonneuve mica mine, in Berthier county.

Most of the earlier discoveries of radioactive and rare earth minerals in Canada were thus made in pegmatite dykes in Quebec province, where they were found during mica mining operations.

Later, other discoveries of these minerals were made in similar association in pegmatites worked for either mica or feldspar, both in Quebec and Ontario, and now the list of localities where radioactive minerals are known is a fairly large one. All of such occurrences, however, are in normal granite pegmatites, the minerals being found usually disseminated irregularly and in small amount through the dyke mass or in small pocket zones in the dykes⁴.

¹ Report of Commissioner of Crown Lands, Province of Quebec, 1894, p. 99.

² Annual Report of Mining Operations in the Province of Quebec, 1903, pp. 65-68.

³ Mica in the Province of Quebec, Department of Colonization and Mines, Quebec, 1901, pp. 18-21.

⁴ For further information on the occurrence in Canada of radioactive minerals, see *Geol. Surv., Canada, Sum. Rept.* 1921, pt. D., pp. 51-70; *Sum. Rept.* 1923, pt. CI, pp. 6-20.

Up to the present, the only occurrence of a radioactive mineral that it seemed possible might have commercial possibilities has been that of euxenite, which was found in some quantity in a feldspar quarry in South Sherbrooke township, Lanark county, Ontario, in 1917. A small shipment of ore from this deposit was sent to the Mines Branch in 1919 for concentration tests and from it a few hundred pounds of concentrates were made; however, no attempt at commercial production was made by the owners. Euxenite is not particularly rich in uranium (7 to 9 per cent U_3O_8) and accordingly there is comparatively little market interest in it as a source of radium.

It should be noted that radioactive and rare earth minerals are not by any means peculiar to Canadian pegmatites. It is with this type of rock that such minerals are usually found associated the world over, and in some countries, notably in Norway and Sweden, as well as in India, Madagascar, and Tanganyika, pegmatites occur that are probably far richer in radioactive minerals than any found in this country prior to the Wilberforce discovery. However, except in Madagascar, no serious attempt at mining such pegmatites for their radium-bearing minerals has ever been made, though small amounts have been recovered during mica and feldspar mining operations. It is believed, however, that most of such material has found its way as specimens into mineralogical collections and not to have been used as a commercial source of radium. It does not appear likely, basing the belief on what appears to be the general world occurrence of pegmatitic radioactive minerals, that the ordinary run of pegmatites in Canada can be seriously regarded as a potential, commercial source of radium ore.

The Richardson deposit, while associated with pegmatite, differs in several important respects from other recorded occurrences of such minerals, either in Canada or (as far as the writer is aware) in other countries (see page 11), and the amount of uraninite thus far obtained from small surface workings greatly exceeds that yielded by all Canadian mica and feldspar mines. The total quantity of uraninite, amounting to several hundred pounds, thus far taken from the property, and all obtained practically from the surface, may be regarded as a promising indication that the occurrence will prove rich enough to work; and, accordingly, it has seemed of interest to describe the main features of the deposit and the results of development to date.

The data presented are based on visits by the senior author to the property in August and November, 1929, supplemented by information supplied by the operating company, The Ontario Radium Corporation, 539 Confederation Life Building, Toronto, and on the results of tests conducted by the Ore Dressing Division of the Mines Branch, at Ottawa, on a car-load shipment of ore. R. K. Carnochan had charge of these tests, and the radioactive determinations on the concentrate samples were conducted by H. V. Ellsworth, of the Division of Mineralogy, Geological Survey. The chemical analyses of the concentrates were made by R. A. Rogers, of the Ore Dressing Division, Mines Branch.

Location and Topography

The deposit is situated on lots 4 and 5 in concession XXI of the township of Cardiff, Haliburton county, about $1\frac{1}{2}$ miles east of the village of Wilberforce, on the Irondale, Bancroft and Ottawa branch of the Canadian National Railway. It lies one-half mile south of the Wilberforce-Bancroft road and of the railroad, on the north edge of the ridge bordering the valley through which the railroad runs. It can be reached by automobile from either the east or west, the distance by road from Toronto being about 150 miles and from Bancroft, 20 miles.

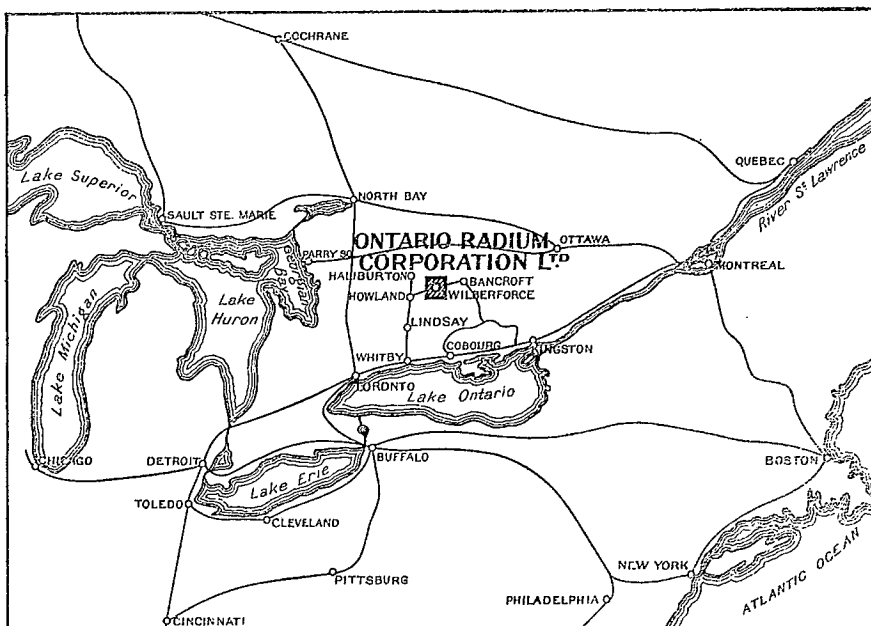


Figure 1. Key map, showing location of property.

The Ontario Radium Corporation owns a total of 456 acres, comprising the above-mentioned lots and also lots 4, 5, and 6 in concession XXII, immediately to the north.

Topographically, the region is one of medium relief. The altitude at the railroad, north of the deposits, is 1,200 feet, from which point southward the ground rises gently in a series of benches to an elevation of 1,500 feet at the main pit.

The overburden at the point of discovery is generally light, consisting of seldom over 20 inches of sandy or gravelly soil, and rock outcrops are abundant. The part of the property comprising the main discovery site has been burnt over and supports only a light growth of small timber.

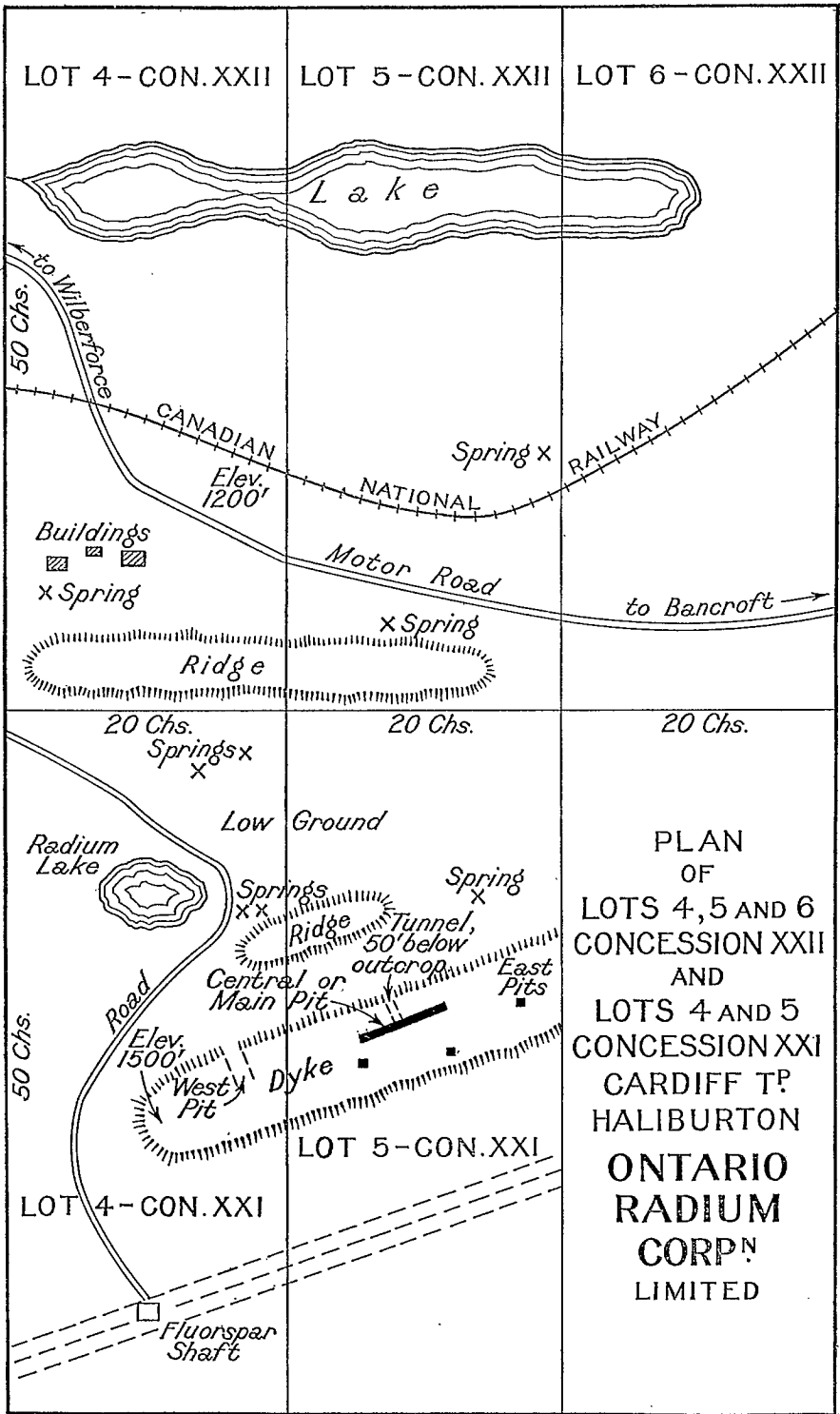


Figure 2. Plan of property, showing approximate location of workings, etc.
(Not to scale.)

A small lake occupies a depression on the second bench below the pits, being fed by springs issuing from the ridge. Several such springs have been located and are regarded by the company as assets of importance, since their water has been tested and found to be strongly radioactive, as is also the water of the lake.

History

The first discovery of radium ore in the Wilberforce district was made in 1922 by Mr. W. M. Richardson, a prospector and miner with Alaska and Yukon experience, who had come to Wilberforce in connexion with the finds of molybdenite that had been made near that place and had taken up residence about one-half mile northwest of the site of the present operations. In the course of prospecting the district, Mr. Richardson found a heavy, black mineral in surface outcrops of pegmatite at different points on the property, and having obtained a sample of Joachimstal pitchblende, identified this mineral as uraninite. He, therefore took up the mining rights on lots 4 and 5 in concession XXI, and on lot 4 in concession XXII, and proceeded to open up a number of small prospect pits and trenches.

A sample of the uraninite sent by Mr. Richardson to Ledoux and Company, of New York, for assay was reported by them to contain 58.35 per cent of uranium oxide (U_3O_8), equivalent to a radium content of 147 milligrams of radium per ton.

Late in 1922, Dr. W. G. Miller visited the property and described it briefly in the Canadian Mining Journal of January 11, 1924.

In 1923, Mr. Charles Baycroft was engaged by a Toronto syndicate to make an examination and report on the deposit. Mr. Baycroft opened a 30-foot trench on one of the westerly outcrops, and from this sent a 200-pound sample to Dr. T. L. Walker, in Toronto. Concentration tests were run on this sample, and Dr. Walker furnished the following report:

In making a preliminary test on the ore, I found that the material coarser than 10 mesh did not lend itself to concentration. The finer material, from 10 mesh down to fine sands, gave a fairly clean separation on the Willey table and apparently will give little trouble in concentration.

Values from electroscopic measurements on the head sample and concentrates were as follows:

| | Milligrams of radium per short ton |
|--|--|
| Original heads..... | 2.88 |
| Concentrates—Through 10 mesh on 40 mesh..... | 7.82 |
| Through 40 mesh..... | 5.70 |
| Slimes..... | 0.24 |

The above syndicate did not proceed with development, and except for further minor prospecting by Mr. Richardson, there was no other development until the present owners acquired the property in 1927.

In 1926, Dr. G. E. Richards, Director of the Department of Radiology, Toronto General Hospital, had visited the property and secured samples of the ore and spring waters. With respect to the latter, Dr. Richards reported that three samples of water taken at various points all showed distinct radioactivity.

In 1927, Mr. M. D. Kennedy made a report on the property to the present company, who in 1929 commenced their first development work. Up to this time, attention had mainly been focussed on several outcrops of

pegmatite that represented the points of original discovery of uraninite. Two of these outcrops lie fairly close together on lot 5, concession XXI, while a third, upon which most work had been done, lies about 2,000 feet to the west of the above, on lot 4. Prospecting of the ground between these two points early in 1929 led to the discovery of a well-defined break or vein, quite distinct from anything found hitherto. It is upon this lead that attention has since been centred and upon which work is proceeding at the present time. All of the three shipments of ore made to the Mines Branch in 1929, and upon which tests were run, came from this vein.

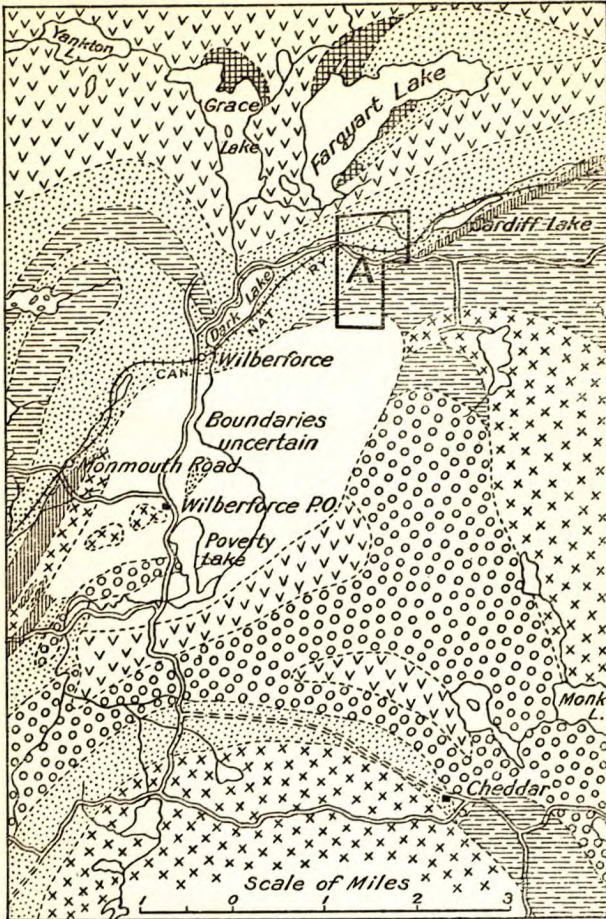
In addition to shipping ore to the Mines Branch for test, the company has recently forwarded a large sample of picked uraninite to the Imperial Institute, in London. As a result, they have enlisted the interest and services of that body, and also of the British and General Radium Corporation, in the matter of further development and of marketing of products, or of the eventual extraction of radium from the ore. In the last connexion, the company are highly desirous that Canada should receive the fullest benefit from the possession of a domestic supply of this precious element. In the event, therefore, of their deposit proving commercial, they wish, if this be possible, to have the extraction done in this country, and the recovered radium made available for Canadian hospitals, etc.

General Geology of Area

The only detailed geological report on the Wilberforce district is that of Adams and Barlow, published in 1908.¹ No special mention is made in this report of the area immediately around the deposit under consideration, and at that time the only local occurrences of economic minerals known were a few small deposits of mica and phosphate.

The map (Figure 3) accompanying the report shows the site of the uraninite discoveries to consist of a narrow east-west band of sedimentary gneiss, much invaded by granite (pegmatite) dykes. A parallel belt of white crystalline limestone occupies the whole of the valley below the deposit to the north, the gneiss-limestone contact crossing the north half of lots 4 and 5. This contact probably is more or less parallel to the pegmatite with which the ore is associated and not far north of it. An area of several square miles immediately to the south and west of the gneiss band is left blank as to geology. Surrounding this area, lies a complex assemblage of bands and islands of crystalline limestone, amphibolite, gneiss, nepheline syenite, and granite, the latter in part massive and in part gneissic. A large batholith of granite is shown south of the deposit, its northern rim being about five miles distant. This batholith connects by a narrow neck with a second mass of more gneissic granite lying to the northeast. From this, a tongue is shown extending westward to within about a mile of the property. The many areas of pegmatite shown invading the rocks adjacent to these granite masses are possibly genetically related to them, though this is only theory. The pegmatite with which the uraninite is associated contains little or no free quartz, and the same holds good for a number of other pegmatites examined by the writer in Cardiff and adjacent townships. In some instances these pegmatites cut, or are in close proximity to, areas of nepheline syenite, and for this reason, as

¹ Geol. Surv., Canada, Mem. 6, "Geology of the Haliburton and Bancroft Areas."



LEGEND









-  *White crystalline limestone.*
-  *Gneiss (probably altered sedimentary material) or quartzite.*
-  *Amphibolite.*
-  *Gabbro and diorite.*
-  *Gneissic granite with many amphibolite inclusions.*
-  *Gneissic granite.*
-  *Nepheline syenite and associated alkali-syenite.*
-  *Ontario Radium Corporation Limited*

Figure 3. Geological map of Wilberforce district.
(After Adams and Barlow.)

well as on account of certain conspicuous peculiarities in mineral composition, the writer is inclined to view them as pegmatitic phases of syenite rather than of granite.

Geology of Deposit

With respect to the geology of the uraninite deposit itself, the following notes are based on an examination made by the writer in September, 1929, supplemented by information supplied in part by the owners and in part taken from Mr. Baycroft's report made in 1924.

West Pit. Mr. Baycroft's report deals with that part of the property where the first discovery of uraninite was made in 1922 and upon which most of the development work was done prior to 1929. At this point is situated the most westerly opening on the deposit, a narrow open-cut about 6 to 8 feet deep and 50 feet long, entirely in pegmatite. The cut is at right-angles to the strike of the pegmatite, which has an approximately east and west direction. The opening does not disclose either of the walls of the dyke, which, according to Mr. Baycroft's report, is about 350 feet wide.

The character of the pegmatite is generally uniform for the whole length of the cut. The rock consists essentially of a coarse-grained, buff-coloured feldspar, probably orthoclase, though no samples were taken for analysis. There are numerous irregular, miarolitic cavities, some of them of considerable size, their walls being lined with well-developed feldspar crystals. Free quartz is conspicuously absent from the rock. Here and there through the dyke mass occur masses and large crystals of magnetite, the most abundant metallic mineral. Small amounts of molybdenite and chalcocopyrite also occur, as well as biotite mica and zircon. Only at one place in the east wall of the cut, is any uraninite now visible. At this point, there is a small mass of uraninite enclosed in feldspar, the latter carrying yellow and orange incrustations of uranium salts. According to the owners, however, considerable disseminated uraninite was encountered when the cut was made. This would appear to be borne out by the tests made by Dr. Walker on the 200-pound sample from the opening sent to him by Mr. Baycroft. This sample is stated to be representative of 30 feet of the cut and to have yielded over one per cent of U_3O_8 .

East Pits. Several small pits have also been opened on outcrops of what is presumably the same pegmatite at a point about 2,000 feet east of the above opening. The rock here is essentially similar to that in the west cut, being a medium- to coarse-grained syenite pegmatite; in one of the pits it contains considerable fluorite. Of interest is the occurrence in one of the exposures of a narrow stringer of fine-grained syenite porphyry cutting the pegmatite.

Small inclusions of uraninite are said to have been found in these easterly openings, but none were seen by the writer.

Middle Pit. This opening situated between the west and east pits represents the latest work done, and has been made on a discovery made in 1929. It lies 1,600 feet east of the west pit and 400 feet west of the easterly openings. Stripping operations were started here in the spring



A. Part of vein from which ore shipment was made to the Mines Branch for test. The stripped surface is gneiss, with a thin band of pegmatite bordering the vein. (Photograph taken November, 1929).



B. Western part of vein, showing 75 feet of surface working. The carload of ore shipped to the Mines Branch came from the pit in the foreground. Photograph taken November, 1929.)

of 1929 on a small outcrop and have disclosed a well-defined lead that has been uncovered for a length of 150 feet. This lead is in pegmatite and parallels the strike of the dyke. Its full length has not yet been determined, but it outcrops again at a point 300 feet east of the stripping and is exposed there for a width of 12 feet. It can also be traced for a short distance west of the stripping, but appears to be pinching out in this direction. It is probably safe to assume a total length of at least 500 feet. The width is greatest at the east outcrop, where it measures 12 feet. At the stripping, the greatest width is 8 feet and the average about 5 feet, though there are several narrow horses of pegmatite in the east end. The above measurements relate to the width between the outermost exposed walls. The gneiss country rock is only visible on the hanging-wall, the foot-wall being pegmatite. Insufficient stripping has been done on the foot-wall side to show whether any parallel leads exist, but this will be determined by the tunnel now being driven to tap the lead from a point 50 feet down the slope below the outcrop.

The dip of the lead at the surface is about 45 degrees south, or into the hill, steepening to 70 degrees at the bottom of a 20-foot pit sunk near the west end of the stripping.

The lead occurs in pegmatite at its contact with the enclosing gneiss and seems to have the character of a longitudinal, miarolitic cavity of unusual form and extent. Only a skin of pegmatite a few inches thick occurs on the gneiss hanging-wall (see Plate I A) and from it project numerous well-formed feldspar crystals up to 6 inches in length. The foot-wall of the lead, as far as is visible, is also pegmatite, but there has been insufficient stripping to give any idea of the total width of the dyke here.

The westerly 75 feet of stripping shows a single lead, 5 to 8 feet wide, (Plate I B), but for the remaining 75 feet the vein is split into four or five tongues of irregular width but ranging from 1 to 4 feet. These tongues are separated by narrow, 1- to 2-foot horses of gneiss and pegmatite, the walls of which are also lined with feldspar crystals (Plate II A). This part of the lead, therefore, represents a series of long, parallel miarolitic pockets or cavities, which toward the west run together into a single wider one. At the outcrop 300 feet east of the stripping, where there is 12 feet of lead exposed, there are no horses visible, the lead being uniform from wall to wall.

In its general character, the Richardson pegmatite resembles other pegmatitic bodies found in Cardiff and adjacent townships. As a type, these are quite distinct from the ordinary run of granite pegmatites so common in eastern Canada and are apparently peculiar to the Wilberforce district. The writer is inclined to view them as syenite, rather than granite, pegmatites, and to regard them as genetically related either to the nepheline syenite of the region or to the large batholithic masses that occur in Cardiff and Monmouth townships. These latter, it is true, are shown on Adams' and Barlow's map as granite, but in their report the writers note that the rock is never rich in quartz and often grades over into syenite.

A notable occurrence of another such pegmatite is found about one mile east of the Richardson property, where there is a large development of purple fluorite, mixed with calcite, apatite, hornblende, etc.; this deposit was worked at one time for fluorite. On the southwest end of the Richardson property, also, several small prospect pits were opened some years ago

on fluorite outcrops. Another occurrence lies about 10 miles to the south-east, in Faraday township, where cavities in pegmatite contain calcite and enormous crystals of black mica, as well as large apatite crystals and fluorite. The writer has examined several other such deposits in the region, all generally similar in type. Some of them carry small traces of radioactive minerals, but none are in any way comparable in this respect to the Richardson deposit.

In their general character, these pegmatites possess a marked similarity with the mica- and phosphate-bearing pyroxenites of the Ottawa district. These pyroxenites, which may be considered as basic counterparts of the Wilberforce syenite pegmatite, often contain large, irregular cavities lined with well-formed pyroxene crystals and carry a filling of calcite, in which are scattered large apatite and mica crystals; they do not yield radioactive minerals.

For the purpose of comparison, the principal characteristics of the two rock types are outlined below:—

Basic Type

| | |
|----------------------------------|--|
| Locality | Ottawa district. |
| Rock | Pyroxenite pegmatite. |
| Character | Medium- to coarse-grained rock in the form of irregular dykes and consisting mainly of grey to green pyroxene. Titanite and scapolite are common accessory constituents. Often contains large, irregular pockety cavities, lined with pyroxene crystals. |
| Mineral filling of cavities..... | Pink calcite, in which lie free crystals of phlogopite mica and apatite, often of very large size. |

Acid Type

| | |
|----------------------------------|---|
| Locality | Wilberforce district. |
| Rock | Syenite pegmatite. |
| Character | Medium- to coarse-grained rock in the form of irregular dykes and consisting mainly of pinkish buff feldspar. Zircon is a common accessory mineral. Often contains large, irregular pockety cavities, lined with feldspar crystals. |
| Mineral filling of cavities..... | White or pinkish calcite and dark purple fluorite, in which lie large crystals of apatite, biotite mica, hornblende, magnetite, and uraninite. |

The close structural similarity exhibited by these two rock types, and the fact that both often carry crystals of apatite and mica in a calcite filling of pockety cavities, provides strong evidence that the pyroxenites are of igneous, intrusive origin, rather than metamorphosed sediments as has often been believed.

The filling of the Richardson lead consists mainly of massive fluorite and calcite. Neither of these minerals was observed in the form of free crystals. Fluorite predominates in the greater part of the lead, but there are local enrichments of calcite, when the two minerals are present in about equal amounts: there is often an approach to banded structure. Scattered through this calcite-fluorite filling occur, in order of abundance, crystals of apatite, hornblende, magnetite, biotite, and uraninite.

At the outcrop, there has been considerable leaching of the calcite by surface waters, resulting in the formation of open cavities within the lead. These cavities contain a certain amount of dark reddish brown, earthy residue, and in this are often found loose crystals or lumps of uraninite.

From a search of the literature, the only recorded occurrence that in any way resembles geologically and mineralogically the Richardson orebody appears to be a deposit at Wölsendorf, in Bavaria. At the latter locality, dark purple, fetid fluorite is found in a lead with autunite, torbernite, and uranophane, all alteration products of pitchblende, traces of which also occur.

Minerals of the Deposit

Apatite. Apatite occurs in considerable amount as free crystals in the calcite-fluorite matrix. The crystals are sometimes of considerable size, ranging up to 30 pounds in weight. Several dozen loose individuals were taken by the writer from a small pocket, the calcite of which had been leached out by surface waters. The prism faces are well developed, but good terminations are rare, the ends of the crystals seeming to have been attacked and being pitted and rounded. There is apparently no development of compact, massive apatite.

The colour is usually brownish green to brown or yellow. Like the apatite of other smaller deposits in the district, and in contrast to that of most pyroxenite deposits, the mineral is clear and glassy and exceedingly brittle. Clear fragments of considerable size and without visible flaws can often be picked from broken crystals.

An interesting feature of the apatite of the Wilberforce district is that where crystals exhibit terminal faces there is always a conspicuous development of the basal plane. This is sometimes so pronounced that the crystals appear to have almost square ends. The basal plane is seldom, if ever, found on the pyroxenitic apatite of the Ottawa region.

Biotite. Biotite mica is stated to occur, sometimes in large plates, in the massive pegmatite of the west pit. It was not observed in noteworthy amount in the main, or middle pit.

Calcite. Calcite is one of the principal constituents of the lead. It is mostly rather fine-grained and has a faint pinkish colour. As in the pitchblende veins of Czechoslovakia, the colour deepens to a brownish red in close proximity to uraninite nodules or crystals, and thus dark-coloured calcite serves as an indicator for uraninite.

Feldspar. Feldspar, of a buff to reddish cast, is the principal constituent of the pegmatite with which the uraninite is associated. It is medium- to coarse-grained and probably is predominantly orthoclase (potash feldspar). There is possibly a certain amount of soda or lime-soda feldspar also present, but no information on this point, based on analyses or microscopic examination, is available.

The walls of themiarolitic cavities in the pegmatite are lined with well-formed feldspar crystals which often attain a length of several inches. This mineral always forms part of the pegmatite proper and it is not found as free crystals in the calcite-fluorite filling of cavities, as are the apatite, hornblende, magnetite, etc.

Fluorite. As one of the principal constituents of the filling of cavities in the pegmatite, fluorite is possibly the most interesting gangue mineral present.

When fresh, its colour is always of a dark reddish purple to violet shade, deepening in close proximity to uraninite to almost black. In this respect, it resembles the fluorite of other deposits of radioactive minerals throughout the world, and it may be taken as established that the dark colour is due to radioactive emanations. The colour of all such fluorites fades on exposure to light and the mineral eventually becomes colourless.

When disseminated through calcite, the fluorite is in the form of small shapeless grains. It also forms bands or stringers and is then usually fine-textured to dense and compact. The last type is always found in close association with uraninite, and thus serves as an indicator for that mineral.

A peculiarity of such compact fluorite is that it gives off a strong odour when crushed or freshly-broken. This odour is of practical service to the workmen as an additional indication that they are breaking into a pocket of uraninite. The smell resembles that of ozone and is believed to be due to free fluorine.

The conspicuously dense texture and almost black colour of the fluorite accompanying the uraninite, and the reddish colour assumed by the calcite in similar association, would prove a useful aid in preliminary rough-sorting of the ore enabling the rich material to be readily separated in the pit from the lower-grade or barren gangue.

Hornblende. Large, free crystals of hornblende, sometimes over 12 inches across, frequently occur in the calcite-fluorite filling of the main or middle lead.

Magnetite. Magnetite is fairly abundant, occurring as large crystals or irregular masses in miarolitic calcite-fluorite. It was observed in greatest amount in the west and middle pits.

It is frequently intergrown with uraninite, and sometimes also with apatite and hornblende.

Molybdenite. Small traces of molybdenite are stated to have been found in the massive pegmatite of the west pit.

Uraninite. This, as far as known, is the only radioactive mineral occurring in any important amount on the property. Small amounts of its alteration products, in the form of orange and yellow incrustations of uranium salts, as well as traces of torbernite, the copper uranium phosphate, are found in association with it, but these are hardly of commercial significance. Up to the present, none of the radioactive, rare earth minerals, not infrequently found in the ordinary granite pegmatites of eastern Canada, have been reported here.

The uraninite occurs as well-formed crystals and as nodular lumps. The crystals are often of unusual size, frequently measuring one inch or more across. They are of cubic habit, usually more or less modified by the octahedron. The lumps range from small individuals the size of a pea to masses weighing several pounds.

In the massive pegmatite of the west pit, the uraninite is stated to have been found chiefly associated with black mica and often enclosed in

mica "books." Unlike its occurrence in the middle pit, it does not seem to occur here inmiarolitic cavities.

In the lead of the middle pit, the uraninite crystals and masses occur scattered through the calcite-fluorite filling, apparently without any regular system, but, as noted above, always in close association with dark purple fluorite. The same distribution holds at the outcrop 300 feet east of the middle pit.

As regards the relative abundance of uraninite in the deposit, Mr. Baycroft's report states that a sample taken across 30 feet of pegmatite at the west pit yielded a little over one per cent U_3O_8 , equivalent to 28.56 pounds of uraninite per ton. The carload shipment sent to the Mines Branch, and representative of the ore of the middle lead, showed a recoverable uraninite content of 4.56 pounds per ton.

Two complete analyses of the uraninite have been made and are given below. The first is by E. W. Todd¹ and the second by H. V. Ellsworth.² Both analyses were made on selected, clean mineral, and it is interesting to note that they differ considerably in uranium content. The sample analysed by Ellsworth is noted by him to have consisted of severely altered material, to which fact is attributed the low UO_2 content as compared with that of the sample analysed by Todd. Much of the uraninite mined during 1929, and examined by the writer, was observed to be similarly altered, the outer portions both of crystals and lumps consisting of a blackish green earthy material soft enough to be readily rubbed off by the fingers. The alteration is especially pronounced in the uraninite taken from leached cavities in the lead and would seem to have been effected by surface waters. The uraninite broken out of fresh fluorite or calcite has a much fresher and more lustrous appearance and probably more nearly approaches in composition that analysed by Todd, which came from the massive pegmatite in the west pit. The specific gravity of the latter is given as 9.082. No figure is given by Ellsworth for the sample analysed by him, but determinations on two specimens—one a crystal and the other a massive lump—from the shipment sent to the Mines Branch in 1929 showed a mean of 8.83:

Analyses

I

| | |
|---|-------|
| UO ₂ | 45.18 |
| UO ₃ | 24.90 |
| ThO ₂ | 11.40 |
| Ce ₂ O ₃ , etc..... | 1.82 |
| Y ₂ O ₃ , etc..... | 2.74 |
| MgO..... | 0.19 |
| CaO..... | 0.28 |
| MnO..... | 0.04 |
| PbO..... | 10.40 |
| Fe ₂ O ₃ | 0.58 |
| H ₂ O..... | 0.61 |
| SiO ₂ | 0.43 |
| He..... | 0.35 |
| Total..... | 98.92 |
| Equivalent to U ₃ O ₈ | 69.71 |
| Specific gravity = 9.082 | |

¹ Contributions to Canadian Mineralogy, University of Toronto Studies, 1924, p. 43.

² Geol. Surv., Canada., Sum. Rept. 1923, Pt. CI, p. 20.

II

| | |
|---|---------|
| H ₂ O at 100°C..... | 1.49 |
| H ₂ O above 100°C..... | 0.11 |
| Insoluble..... | 0.67 |
| SiO ₂ | 0.58 |
| PbO..... | 11.05 |
| ThO ₂ | 13.56 |
| UO ₂ | 13.55 |
| UO ₃ | 52.04 |
| Ce group oxides..... | 1.85 |
| Yt group oxides..... | 1.24 |
| Fe ₂ O ₃ | 0.47 |
| Al ₂ O ₃ | 0.11 |
| MnO..... | 0.003 |
| TiO ₂ | 0.001 |
| CaO..... | 0.25 |
| MgO..... | 0.07 |
| CO ₂ | 0.67 |
| SO ₄ | 0.58 |
| P ₂ O ₅ | 0.04 |
| F, alkalis..... | Present |
| Loss on ignition..... | 4.42 |
| Total..... | 98.33 |
| Equivalent to U ₃ O ₈ | 61.64 |
| Specific gravity not stated. | |

It may be noted, in passing, that the mineral uraninite is of scientific interest as enabling the geologic age of the rocks in which it occurs to be calculated from the contained lead-uranium ratio. Such calculations based on Todd's analysis show an age for the Wilberforce pegmatite of 1,239 million years. Ellsworth's analysis indicates 1,299 million years. The difference is possibly to be accounted for by the probability that altered uraninite may yield a somewhat higher lead ratio than fresh mineral from the same occurrence.

Zircon. Zircon is a minor rock-forming constituent of the pegmatite dyke, in which it occurs as small crystals measuring about $\frac{1}{8}$ by $\frac{3}{8}$ inch. It appears to have rather a zonal distribution, being quite abundant in some parts of the rock while not visibly present in others.

Development Work

Previous to 1929, the largest opening made for uraninite on the property was the west pit, a trench 50 feet long by 6 feet wide and about 6 to 8 feet deep. This was entirely in massive pegmatite containing scattered miarolitic cavities, and from it a few pounds of uraninite have been obtained.

Some distance south and west of this opening, there are several small pits, also in massive pegmatite, which were made in search of fluorite: these are not known to have yielded any uraninite.

The east pits consist of three or four small, shallow openings on outcrops of pegmatite, in which traces of uraninite are stated to have been found.

The middle pit, opened in 1929, is the most important working. It lies 400 feet west of the east pits and 1,600 feet east of the west trench, on the strike of a line joining these workings. Stripping of a light dirt cover has disclosed a well-defined east-west lead for a distance of 150 feet (Plate



A. East part of vein-stripping, about 75 feet in length, showing tongues of vein separated by narrow horses of gneiss and pegmatite. (Photograph taken November, 1929.)



B. View of vein, looking west from east end of stripping. Total length shown is about 150 feet. (Photograph taken November, 1929.)

II B). This lead lies between pegmatite walls, and the calcite portion of its filling has been dissolved at the surface, resulting in the formation of abundant pockety cavities. It is widest at a point about 30 feet from the west end of the stripping, and here an inclined pit 6 feet square and 20 feet deep has been sunk on the dip. The width here is about 8 feet and the dip at the surface 50 degrees south, increasing to 70 degrees at the bottom of the pit. Lumps and crystals of uraninite were encountered from top to bottom of this pit, scattered through the calcite-fluorite filling and also loose in leached cavities in the latter.

The carload of ore sent to the Mines Branch in October 1929 was taken from the lead at a point a few feet east of the above pit. To secure this ore, the lead was worked from the surface to a maximum depth of 15 feet and over a length of 20 feet (see Plate I B). Horseshoes of pegmatite encountered were left in place, only vein filling being shipped.

It was originally intended to drive a tunnel into the hill from a point about 80 feet below the west pit, with the idea of cross-cutting the pegmatite and possibly striking other parallel leads. A start was made on this work, but the results of surface operations at the middle pit proving so encouraging, it was decided to drive the tunnel from a point below this pit and about 50 feet down the hill from it. Work is now proceeding here, and provided that the dip of the ore-body remains constant, it is expected that the ore-body will be struck at about 90 feet. The tunnel will facilitate mining operations and provide drainage for the upper workings: it will also test the ground north of the main lead, about which nothing is known but in which it is thought other parallel leads possibly may occur.

The company has thus far installed no equipment on the property and only two or three men have been employed.

Tests by the Mines Branch Ore Dressing Division

Three shipments of ore, in all, were received by the Mines Branch from the Ontario Radium Corporation.

The first shipment was received on July 9th, 1929, and consisted of two lots each containing 40 bags and weighing about 2,000 pounds. These lots were numbered 1 and 2 and were taken from the west and east ends, respectively, of the discovery, corresponding to the west and east pits as described in this paper.

The second shipment, received on August 22nd, 1929, consisted of a bag of 50 pounds of hand-picked uraninite, both lumps and crystals. This lot was numbered 3, and was taken from the main, or middle, pit as described in this paper.

The third shipment, received on November 12th, 1929, comprised 603 bags of ore, weighing 71,596 pounds, and one bag containing 80.5 pounds of hand-picked uraninite, in the form of lumps and crystals. This shipment, numbered lot 4, came, like lot number 3, from the middle pit, and is understood to be representative of the main lead on the property. The bag of clean uraninite is stated to have been picked out by hand during mining of the ore.

Considerable laboratory work was conducted on the material of these various shipments, but only the results of the large-scale test made on lot

number 4 are given here, since this was the only shipment that could be considered properly representative of the ore and from which useful data from the commercial angle could be expected.

Lot No. 4

Character of Ore. The ore consisted of uraninite in a gangue of purple fluorite, calcite, apatite, magnetite, hornblende, biotite, mica, and feldspar. The relative abundance of the gangue minerals was approximately of the order indicated. Very little uraninite was visible. The hand-picked uraninite was mostly clean mineral and contained only a relatively small amount of adhering gangue.

Weights

| | Pounds |
|---|----------|
| Gross weight of 603 bags of milling ore, wet..... | 71,595.5 |
| Tare..... | 1,205.0 |
| Net..... | 70,390.5 |
| Moisture at 1.786 per cent..... | 1,257.0 |
| Net weight of milling ore, dry..... | 69,133.5 |
| Ore not milled, dry..... | 89.5 |
| Total ore milled, dry..... | 69,044.0 |
| Milling ore received, dry..... | 69,133.5 |
| Hand-picked uraninite, dry..... | 80.5 |
| Total ore received, dry..... | 69,214.0 |

TREATMENT OF MILLING ORE

The ore was crushed in a gyratory and Symons disk crusher, and then screened on a 12-mesh Newaygo screen. The plus 12-mesh was crushed in a small set of rolls in closed circuit with the screen. A head sample was taken from the minus 12-mesh.

The balance of the minus 12-mesh was classified in a Richards launder classifier into three sizes. The coarsest size was tabled on a large Wilfley table; the medium size on a one-quarter size Butchart table; and the finest size was first thickened in a Callow cone and then tabled on a one-quarter size Wilfley table. Each of the three tables made a magnetite-uraninite concentrate.

The table concentrates were dried and run separately over an Ullrich magnetic machine, using a very low current in order to lift only magnetite. The magnetic products were very clean magnetite and the non-magnetic were mostly fluorite with some uraninite.

The Ullrich non-magnetic products were re-tabled separately and good uraninite concentrates were obtained.

Results (Weight of ore milled: 69,044 pounds)

| | Pounds |
|--------------------------------|--------|
| Coarse table concentrates..... | 1,702 |
| Medium table concentrates..... | 160 |
| Fine table concentrates..... | 42 |
| Total..... | 1,904 |

Magnetic Separation of Table Concentrates

| | |
|--|--------|
| | Pounds |
| Coarse Ullrich non-magnetic product..... | 245.0 |
| Medium Ullrich non-magnetic product..... | 42.0 |
| Fine Ullrich non-magnetic product..... | 16.5 |
| Total..... | 303.5 |

Re-Tabling of Ullrich Non-Magnetic Products

| | |
|--------------------------------|--------|
| | Pounds |
| Coarse table concentrates..... | 79.0 |
| Medium table concentrates..... | 4.31 |
| Fine table concentrates..... | 1.31 |
| Total..... | 84.62 |

These concentrates were analysed for U_3O_8 with the following results:—

| Product | Weight | U_3O_8 | U_3O_8 |
|-------------|--------|----------|----------|
| | Pounds | Per cent | Pounds |
| Coarse..... | 79.0 | 44.44 | 35.11 |
| Medium..... | 4.31 | 52.62 | 2.27 |
| Fine..... | 1.31 | 56.14 | 0.74 |
| Total..... | 84.62 | 45.05 | 38.12 |

The above concentrates were recovered from 69,044 pounds of ore. From the total of 69,133.5 pounds of milling ore received, there would have been recovered 84.73 pounds of concentrates. From the total ore received = 69,133.5 pounds of milling ore plus 80.5 pounds of hand-picked uraninite = 69,214 pounds, there would be recovered by milling 84.73 pounds of concentrates. Therefore, from one ton of ore there would be obtained by milling:

Concentrates from Milling Ore, per Ton

| Weight | U_3O_8 | U_3O_8 |
|--------|----------|----------|
| Pounds | Per cent | Pounds |
| 2.448 | 45.05 | 1.103 |

TREATMENT OF HAND-PICKED ORE

The hand-picked uraninite was re-picked, and from the 80.5 pounds received, 64.75 pounds of clean uraninite was obtained. The residue of 15.75 pounds was crushed in a small set of rolls to all pass 20-mesh and was screened on 40 and 100. Each of the three sizes obtained was tabled on a small Wilfley table. The table concentrates were dried and run through the Ullrich machine to remove magnetite. Very clean uraninite concentrates were obtained in this way.

Results (Weight of ore treated: 80.5 pounds)

| <i>Picking</i> | | Pounds |
|---|--|--------|
| Hand-picked uraninite received..... | | 80.50 |
| Re-picked clean uraninite..... | | 64.75 |
| Residue..... | | 15.75 |
| <i>Magnetic Separation of Residue</i> | | Pounds |
| -20 + 40 Ullrich non-magnetic product..... | | 3.69 |
| -40 + 100 Ullrich non-magnetic product..... | | 2.92 |
| -100 Ullrich non-magnetic product..... | | 1.80 |
| Total..... | | 8.41 |

The concentrates obtained were analysed for U_3O_8 with the results shown below. No analysis for U_3O_8 was made on the re-picked uraninite, but it was assumed to run 69.0 per cent. This figure was obtained by considering it to be 95 per cent clean and to contain 72.44 per cent U_3O_8 , this being the content of a clean piece of uraninite from the same property analysed by Dr. Ellsworth. The assumed figure is probably nearly the actual, since it is reasonable to suppose that the re-picked uraninite would be slightly higher in U_3O_8 than the best concentrate obtained; that is, rather better than 67.48 per cent, which was the value obtained for the coarse Ullrich product:

| Product | Weight | U_3O_8 | U_3O_8 |
|----------------|--------|----------|----------|
| | | Per cent | Pounds |
| -20+40..... | 3.69 | 67.48 | 2.49 |
| -40+100..... | 2.92 | 67.28 | 1.96 |
| -100..... | 1.80 | 67.32 | 1.21 |
| Re-picked..... | 64.75 | 69.00 | 44.68 |
| Total..... | 73.16 | 68.81 | 50.34 |

The above products were obtained from 69,214 pounds of ore, equivalent, per ton of ore, to:

Concentrates from Hand-Picked Ore, per Ton.

| Weight | U_3O_8 | U_3O_8 |
|-------------------|----------|----------|
| | Per cent | Pounds |
| 2.114 pounds..... | 68.81 | 1.454 |

Total Recoveries, per Ton of Ore

| From | Weight | U_3O_8 | U_3O_8 |
|----------------------|--------|----------|----------|
| | Pounds | Pounds | Pounds |
| Milling ore..... | 2.448 | 45.05 | 1.103 |
| Hand-picked ore..... | 2.114 | 68.81 | 1.454 |
| Total..... | 4.562 | 56.05 | 2.557 |

The uranium content of the concentrates from one ton of ore would be:
 $2.557 \times 0.8481 = 2.169$ pounds.

The amount of radium contained in the concentrates from one ton of ore would be:

$$\frac{2.169 \times 453.59 \times 1,000 \times 3.3}{10,000,000} = 0.3247 \text{ milligram.}^1$$

At \$70 per milligram, the value of the radium contained in the concentrates from one ton of ore would be \$22.73.

CONCLUSIONS

The ore is easily concentrated and the concentrates obtained are of good grade.

The tests showed a value of \$22.73 for the radium contained in the concentrates obtained from one ton of ore. Whether the ore is commercial will depend on the tonnage available; cost of mining and milling; cost of chemical treatment of the uraninite concentrates; amount of loss of uranium and radium in treatment; and the price obtainable for the refined products.

Commercial Possibilities

The results of the work thus far conducted on the property, particularly that done during 1929, which has proved the existence of a well-defined, uraninite-bearing lead believed to be at least 500 feet long, and in places 10 to 12 feet wide, cannot but be considered as encouraging, as far as a supply of ore is concerned. While little can be said at this juncture regarding the probable downward persistence of this ore-body, the fact that it appears to represent a marginal deposit along a large pegmatite body, of which it forms an integral part and to which it is genetically related, suggests that it very possibly extends to a considerable depth. Being of miarolitic character, it bears a striking resemblance to the pyroxenitic calcite-apatite-mica bodies of the Ottawa region, some of which have been mined to depths of over 500 feet without exhaustion. Such bodies are, however, often pronouncedly pockety and pinch and swell very irregularly.

From the angle of development, the deposit enjoys the advantage of being situated close to rail and on a surface that could hardly be bettered for easy and cheap mining. Lying along the brow of a ridge sloping almost directly from the outcrop, it is so placed that in the event of a mill being built, ore would fall into the bins by gravity. There is a hydro-electric power site capable of producing 500 h.p. within two miles of the property.

The ore, as shown by the large-scale test made by the Mines Branch, is easily crushed and concentrated, and only limited mill equipment, consisting of crusher, rolls, classifier and tables, is required to make a uraninite-magnetite concentrate. This can be readily treated on a magnetic separator, with the production of a uraninite tailing that, on re-tabling, yields a clean product.

¹ NOTE: The factor used $\frac{3.3}{10,000,000}$ is based on a radium content in uranium of 3.3 parts in 10 million.

Authorities differ as to the exact figure.

In addition to the radium value, there is the value of the uranium. The value of the associated thorium is problematical, since the world's supply of this element is believed to be supplied entirely from treatment of the mineral monazite, large supplies of which are available. The value of the thorium oxide content in 1 ton of the pure uraninite, based on the current market price of 64 cents per pound, is \$160, or 36 cents per ton of ore.

Market for Radium and Uranium and World Supply
Radium

The world demand for radium for therapeutic purposes continues to be as insistent as ever and can hardly be met owing to the extraordinarily small supply and the high price demanded. According to the latest volume of Mineral Industry, the price quoted in the United States during 1928 was \$70,000 per gramme. The same figure appeared throughout 1929 in the market quotations of Engineering and Mining Journal.

Outside of its use in surgery and therapy, for which it is chiefly in demand, radium has also been employed to a considerable extent as an ingredient of luminous paint, used principally on the dials of instruments and watches. For this purpose it is mixed with specially prepared crystalline zinc sulphide, in the proportion of 0.1 to 0.25 milligram of radium to 1 gramme of the sulphide. Owing to the attendant danger to workpeople employed in using such paint, which danger has recently received considerable publicity by actions for damages in the United States courts, efforts have been made to have its use prohibited by law, and it is likely that action along such lines will be taken in all countries. A satisfactory substitute for radium for the above purpose has been found in mesothorium.

While no exact figures are available, it has been recently stated¹ that the total world supply of radium existing and available for therapeutic purposes is only 300 grammes, or a little over half a pound.

Most of the supply is now obtained from deposits in the Belgian Congo, which are operated by the Union Minière du Haut Katanga, the ore being shipped to Belgium for the extraction of the radium. In 1928, this company reported a production of 40 grammes which was double the amount produced in 1926. It is stated that the Belgian works are being enlarged to care for a further increased output, the Union having adequate supplies of ore at their mines to produce on a much larger scale. Considerable secrecy seems to have attended this company's operations, and it has incurred much criticism on the score of maintaining a radium monopoly and charging exorbitant prices, out of all proportion to the cost of production, for a substance whose chief usefulness consists in the alleviation of human suffering. In a recent press article² the Union has come out in its own defence and has endeavoured to show that since 1923, when it came into active production, it has repeatedly lowered its prices, and that it is due to its entry into the field that the former high price of \$120,000 per gramme, which obtained when the United States was the principal producer, has been reduced to the present level.

¹ Die Umschau, December 21st, 1929.

² Montreal Star, December 16th, 1929.

Prior to 1921, most of the radium production was supplied by American companies extracting the element from carnotite ore mined in Colorado and Utah; this ore was worked primarily for its vanadium content, the radium being recovered as a by-product. Owing to its low grade (about 2 to 5 per cent U_3O_8), as compared with uraninite (60 to 90 per cent U_3O_8), production has gradually fallen off and in 1928 no radium was isolated in the United States.

In Czechoslovakia, the present radium production is stated to be at the rate of about 3 grammes per year. It is obtained from pitchblende, the same mineral that occurs in the Belgian Congo, and of which the Wilberforce ore is a crystallized variety. It was in this ore that the element radium was first detected by the Curies, and prior to the development of carnotite mining in the United States, Czechoslovakia was the world's most important source of radium ore.

The total present annual world production of radium is thus practically confined to the Belgian Congo output of 40 grammes and the 3 grammes produced by Czechoslovakia. Allowing for a further small production from unrecorded sources, it would seem that the total world production is under 50 grammes per year.

Deposits of radium-bearing minerals are known in a number of other countries, including Portugal, South Australia, Mexico, Madagascar, Transvaal, Cape Province, Russian Turkestan, England (Cornwall), etc. Development work has been conducted in some cases, but it is not known that any of the deposits have been shown to be rich enough to work under existing market conditions.

It has recently been reported that investigation of pitchblende deposits in the Transvaal, north of Johannesburg, has shown the existence of ore in commercial quantities; and it has even been stated that an annual production of 25 grammes of radium may be expected from this source. The report, however, lacks official corroboration. It was also stated in 1929 that an English company had been formed to take over certain Czechoslovakian occurrences, and the Cornish and South Australian deposits. The Turkestan occurrences, which have produced small amounts of ore, are now being further investigated by the Russian Government.

The Katanga uraninite deposits in the Belgian Congo are at the present moment by far the most important occurrence of radium-bearing minerals known. They seem capable of a greatly-increased output and exercise complete control of the market. It is held, however, that every effort should be made to discover sources of radium within the Empire, and the results of the work now proceeding on the occurrence with which this paper deals will, therefore, be awaited with much interest.

The present situation with respect to radium has recently been reviewed by R. B. Moore.¹ Professor Moore notes that between 1915 and 1917 work of the U.S. Bureau of Mines on the extraction of radium from American carnotite ore showed that the element could be isolated from material carrying only between 2 and 3 per cent U_3O_8 at a cost of about \$40 per milligram. Treating high-grade pitchblende running 40 per cent, or better,

¹ Mining and Metallurgy, February, 1930, pp. 91-2.

U_3O_8 , he estimates the cost of extraction from Congo ore at not over \$10 per milligram, and a total cost of \$15 to \$18 per milligram to cover mining and extraction.

Professor Moore states that the amount of radium element extracted to date from American carnotite ore is almost 200 grammes. Of this quantity, a large proportion was used for war purposes and a considerable amount, also, in luminous paint, so that probably less than 50 grammes out of the 200 grammes produced is presently efficiently available for cancer treatment.

Professor Moore's estimate of the total world supply of radium now available for medical purposes is about 250 grammes, which, at an estimated average price paid of \$90,000 per gramme, represents the colossal sum of over \$22,000,000 as the value of a little over half a pound of material.

Canada, in 1926, imported radium to the value of \$38,902; in 1927, \$21,118; and in 1928, \$17,590.

Uranium

The trade in uranium and uranium compounds is small and it is difficult to obtain figures. Most of the supply of the element is marketed in the form of the oxide or other salts, principally the nitrate or sulphate, or as ammonium or sodium uranate.

In the form of the metal, uranium finds its principal use as ferro-uranium, an alloy employed, either alone or in conjunction with tungsten, for hardening and toughening steel. Uranium carbide has been used to a limited extent as a pyrophoric agent and as a catalyst in the manufacture of ammonia.

Various uranium salts are used in the porcelain and glass industries to impart a yellow, opalescent colour. In the textile trade, such salts find employment as mordants in silk, wool, and calico printing; and in the dye industry, in conjunction with potassium ferrocyanide, to produce brown shades. Uranyl nitrate and acetate are employed as reagents in the chemical laboratory. Uranium salts are also used in photography.

As regards the world production of uranium, statistics are reported in such various terms as to be comparatively useless in many cases as the basis of a market survey. However, the bulk of the supply may be taken as derived from the Belgian Congo and Czechoslovakia. In 1928, Belgium reported exports of uranium oxide (presumably all produced from Congo ores) totalling 84 long tons; and Czechoslovakia, a production of 19 long tons. France, in 1927, reported exports of 18 long cwt. of uranium oxide and other uranium salts, presumably produced from imported ore, possibly from Portugal or Madagascar. The above 1928 figures show a total of 104 long tons of uranium compounds traded in.

Countries reporting a production or exports of uranium minerals in recent years include Portugal, with exports of 529 long tons in 1926, and 296 tons in 1927; Madagascar, with a production of 5 tons in 1926; and Russia, with a production of 35 tons in 1926 and 53 tons in 1927. The United States reported a small production of a few tons in 1928.

The Portuguese ore is believed to carry principally the minerals torbernite and autunite, which are, respectively, the phosphate of copper and

uranium and of calcium and uranium. These minerals usually occur as alteration products of pitchblende. The Madagascar shipments consisted chiefly of the minerals euxenite and betafite, which are complex compounds of the rare earths and uranium. The Russian production is presumed to consist entirely of tyuyamunite, a uranovanadate of calcium, akin to carnotite, mined in Turkestan and treated at the Russian Government radium extraction plant at Kame. The United States output was made up of carnotite, a compound of vanadium, uranium, and potassium oxides, and torbernite and autunite, the first mined in Colorado and Utah and the latter in New Mexico.

The commercial importance of the minerals mentioned above as either a present or a potential source of uranium is small, and they could hardly be considered as capable of supplying any large amount of the element unless found in deposits much richer than any yet known. The same holds good for the many known occurrences of pegmatitic uranium-rare earth minerals throughout the world, and thus the market for uranium will almost certainly continue to be supplied in the main from deposits of pitchblende (uraninite).

In 1928, imports of uranium oxide and salts of uranium into the United States totalled 165,378 pounds, valued at \$145,557. These figures show a very large increase—nearly 100,000 pounds in quantity and over \$86,000 in value—over those for 1927.

Summary

There exists on the Richardson property near Wilberforce, Cardiff township, Ont., a deposit of radium-bearing ore larger than anything of the kind hitherto known in Canada, and on which development work done during 1929 suggests has commercial possibilities.

The ore is uraninite (the crystallized form of pitchblende) disseminated in the form of large crystals and lumps in a lead of calcite and fluorite, which also carries large crystals of apatite. This lead is believed to have a length of at least 500 feet, and its width ranges from 5 to 12 feet.

The deposit is well situated in respect both to ease of mining and to transportation. The ore is soft and easily crushed; and concentration is readily effected by tabling, followed by magnetic separation of the associated magnetite and re-tabling of the uraninite tailing. Much of the contained uraninite, also, can be recovered by hand-picking of the crude ore.

Tests by the Mines Branch on a carload shipment of ore showed that 1 gramme of radium, worth at the current market price \$70,000, would be recoverable from the concentrates obtained from 3,422 tons of ore, allowing a loss of 10 per cent in chemical treatment. The U_3O_8 content of the concentrates obtained from 1 ton of ore was 2.56 pounds.

Uraninite is the richest ore of radium known and is the material from which the bulk of the world's supply of this element has been obtained. Similar ore is being mined at the present time in the Belgian Congo and in Czechoslovakia and is treated chemically for the isolation of the contained radium.

The present world supply of radium (in the form of radium salts) is stated to be about 300 grammes, and this amount is being increased at the rate of probably less than 50 grammes annually.

II

NOTES ON ANHYDRITE

L. H. Cole and R. A. Rogers

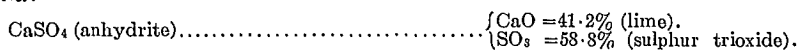
Anhydrite, anhydrous calcium sulphate, has been considered for many years to be of little commercial value, and when encountered in association with gypsum it has been usually considered as an impurity, and discarded.

Recently, however, attempts to find commercial uses for anhydrite have produced such encouraging results that the mineral promises to become an article of considerable industrial importance.

The successful development of further uses for anhydrite is of great importance to Canada, as large deposits of the mineral are found associated with gypsum, not only in Nova Scotia but also in Ontario, New Brunswick, Manitoba, Alberta, and British Columbia; and at many quarries in these provinces large quantities of anhydrite have already accumulated on the waste dumps.

Mineralogy

Anhydrite is anhydrous calcium sulphate and has the following formula:—



It is rarely found in crystalline form, its most usual occurrence being massive with a vitreous to pearly lustre. Its colour is usually white, but has sometimes a greyish, bluish, or reddish tinge, with a greyish white streak. Its fracture is uneven, sometimes splintery and brittle. It has a hardness of 3 to 3.5 and a gravity of 2.899 to 2.985.¹ One hundred parts of water at 18.75°C. dissolves 0.2 parts of anhydrite. It is soluble in hydrochloric acid.

It occurs in rocks of various ages especially in association with gypsum and also very commonly in beds of rock salt.

When exposed to the atmosphere over long periods of time it slowly absorbs moisture and changes to gypsum. Extensive beds are sometimes thus altered to gypsum in part or throughout. Thus it is thought by many that the gypsum deposits of the Maritime Provinces are due in large part to the alteration from anhydrite. Dyer² in his work on the gypsum deposits of Ontario has concluded that:—

The calcium sulphate is divided vertically into three zones: in the first zone, from the surface to a depth of 225 feet, the material is entirely in the form of gypsum; the second zone, the zone of transition, between 225 and 275 feet, consists of a mixture of anhydrite and gypsum; while in a third zone, below 275 feet, the material is nearly all in the anhydrous form.

¹ Dana's Mineralogy, 6th Ed. 1909, p. 611.

² Dyer, W. S.: Ontario Dept. of Mines, 34th Ann. Rept., vol. XXXIV, pt. II (1925).

The greater part of the calcium sulphate was deposited in the first instance as the anhydrous variety, but towards the surface it was changed to gypsum by circulating meteoric waters.

The absorption of water by anhydrite is, however, so slow under normal conditions that it is unsuitable for the manufacture of plasters by ordinary methods since it does not "set" like plaster of Paris and has no strength.

Occurrences of Anhydrite in Canada

Anhydrite occurs in extensive deposits (generally associated with gypsum) in the Maritime Provinces, in Ontario, in Manitoba, in Alberta, and also in British Columbia.

Nova Scotia. Probably the most extensive deposits of anhydrite to be found in Canada are located in Nova Scotia. On the island of Cape Breton massive cliffs composed entirely of anhydrite are found in the area between Baddeck and Ross Ferry in Victoria county, as well as in the area along the Washaback river near Cain mountain, Victoria county, to the south of St. Patrick channel. In the gypsum quarries of the Newark Plaster Company at Ottawa brook, Victoria county, large masses of anhydrite were encountered.

At Ingonish, Victoria county, in the quarry recently operated by the Canada Cement Company, extensive lenses of anhydrite were appearing in the floor of the quarry before it was closed down; at Aspy bay, Victoria county, a series of drill holes put down by the Atlantic Gypsum Corporation, encountered anhydrite at depths varying from 70 to 100 feet below the surface.

At Cheverie, Hants county, extensive cliffs of anhydrite are exposed along the shore to the east of the wharf, while large masses of anhydrite occur in many of the larger quarries in the Windsor district, Hants county.

New Brunswick. In New Brunswick extensive cliffs of anhydrite occur in Albert county in the gypsiferous area to the east and south of Hillsborough, and in the quarries of the Albert Manufacturing Company near Hillsborough there are large dumps of waste material, the greater part of which is anhydrite.

Ontario. In Ontario anhydrite is encountered beneath the gypsum deposits in the Grand River valley and, according to Dyer¹, at a depth of 275 feet the formation is practically all anhydrite.

Manitoba. In the gypsum quarries of northern Manitoba principally the deposit known locally as "The White Elephant" owned and operated by the Gypsum, Lime and Alabastine, Canada, Ltd., lenses of anhydrite are of frequent occurrence, and the material is at present being piled on the waste dumps.

Alberta. In the drill holes drilled for salt in the vicinity of McMurray, Alta., frequent beds of calcium sulphate were encountered, and according to the analyses made by the Alberta Government, these beds were composed mostly of anhydrite.

¹ Op. cit.

British Columbia. In the Falkland deposits of the Gypsum, Lime and Alabastine, Canada, Ltd., lenses of anhydrite are encountered and the material is placed on the waste heaps at the present time.

A number of samples of anhydrite have already been collected from several of these deposits for the purpose of testing and the tests are now being carried on in the laboratories of the Ore Dressing Division of the Mines Branch at Ottawa. Further samples will be collected during the field season of 1930.

Analyses of five of these samples are here given in order to show the nature of the material available.

| | 3-A-29 | 4-A-29 | 5-A-29 | 6-A-29 | 7-A-29 |
|--|--------|--------|--------|--------|--------|
| | % | % | % | % | % |
| Insoluble..... | 0.42 | 0.32 | 0.80 | 0.44 | 0.26 |
| Fe ₂ O ₃ (Ferric oxide)..... | 0.06 | 0.04 | 0.06 | 0.06 | 0.04 |
| Al ₂ O ₃ (Alumina)..... | 0.06 | 0.08 | 0.02 | 0.02 | 0.04 |
| CaO (Lime)..... | 39.09 | 40.94 | 39.96 | 37.68 | 40.10 |
| MgO (Magnesia)..... | 0.49 | 0.23 | 0.10 | 0.16 | 0.10 |
| SO ₃ (Sulphur trioxide)..... | 54.45 | 57.48 | 54.65 | 52.68 | 52.97 |
| H ₂ O (Water at 22°C)..... | 4.44 | 0.53 | 2.85 | 8.02 | 3.90 |
| CO ₂ (Carbon dioxide)..... | 1.07 | 0.31 | 1.14 | 0.49 | 1.89 |
| Total..... | 100.08 | 99.93 | 99.58 | 99.55 | 99.30 |
| <i>Hypothetical Combination:—</i> | | | | | |
| Gypsum (CaSO ₄ ·2H ₂ O)..... | 21.21 | 1.52 | 14.57 | 40.99 | 19.94 |
| Anhydrite (CaSO ₄)..... | 75.81 | 96.62 | 81.20 | 56.60 | 74.03 |

R. A. Rogers—Analyst.

Localities from which above samples were obtained:—

- 3-A-29 Ottawa brook, Victoria county, N.S., from property of the Newark Plaster Co.; mixed anhydrite and gypsum.
 4-A-29. Ottawa brook, Victoria county, N.S., from property of the Newark Plaster Co.; clear, dark bluish grey anhydrite.
 5-A-29. Cain mountain, Washaback river, Victoria county, N.S.
 6-A-29. From cliffs of anhydrite on north side of road running from Baddeck to Ross Ferry, Victoria county, N.S., and $\frac{3}{4}$ mile east of latter place.
 7-A-29. From the property of J. H. McLeod, at the head of Baddeck bay, Victoria county, N.S.

It will be seen from these analyses that practically all the samples contain varying amounts of the hydrated calcium sulphate (gypsum), consequently in making use of this material for any purpose this gypsum content will have to be taken into consideration since it will be practically impossible to obtain an anhydrite that is gypsum free. For a number of uses this gypsum content will not be detrimental.

Uses of Anhydrite

At the present time there is in the neighbourhood of 25,000 tons of anhydrite shipped from deposits in Nova Scotia each year to the southern United States bordering on the Atlantic seaboard, where it is ground and used as fertilizer for the peanut crops.

In England and Europe considerable tonnages of anhydrite are being employed in the process of making ammonium sulphate for fertilizer pur-

poses, and recent investigations in the United States and elsewhere have demonstrated that it is possible to use as much as 50 per cent anhydrite with gypsum as a retarder for Portland cement.

However, the greatest interest has recently centred in the use of anhydrite for the manufacture of commercial plasters and many patents have been filed in Canada, the United States, and Europe, in which anhydrite forms the base for such plasters. The pioneer work in this line in Canada has been carried on by Professor A. E. Flynn, professor of Mining Engineering at the Nova Scotia Technical College, Halifax, N.S., and his report entitled "Anhydrite Plasters and Cements" published by the Department of Public Works and Mines, Halifax, Nova Scotia, shows that plasters made from anhydrite with the addition of varying small proportions of certain chemical salts as catalysers, would "set" and in a number of cases produce a tensile strength comparable to many gypsum plasters now on the market.

The Mines Branch, Department of Mines, Ottawa, is now engaged in an investigation of the anhydrite deposits of Canada, and laboratory tests are now under way at Ottawa on the samples already collected.

III

BITUMINOUS SANDS OF NORTHERN ALBERTA—OPERATIONS DURING 1929

S. C. ELLS

The following report dealing with the Mines Branch investigations of the bituminous sands of northern Alberta, and associated problems, during the field season of 1929, is subdivided as follows:—

1. Field operations in the McMurray area.
2. Operations in the McMurray area by privately controlled companies.
3. Experimental work at Jasper, Alberta.

Field Operations in the McMurray Area

Field work in the McMurray area during 1929, constituted a continuation of Mines Branch activities during the three preceding years.

In 1926 an internally heated, two-drum mixing plant for the manipulation of bituminous sand for paving purposes was designed and constructed at Edmonton, Alberta. At the same time a bituminous sand quarry was opened up on Clearwater river, in sec. 14, tp. 89, R. 9. The mixing plant was successfully operated at Jasper, Alberta, for a short period in 1926 and during the summer of 1927, approximately 31,000 square yards of 2-inch compacted surface being laid. Cost data on the above work were subsequently compiled, but for the following reasons it was recognized that these did not represent costs which might reasonably be anticipated were operations conducted on a commercial scale and under commercial conditions¹.

1. Absence of labour-saving equipment seriously handicapped quarrying and shipping of bituminous sand. Consequently, cost of this material delivered on cars at Waterways, was unduly high.

2. Special equipment for unloading bituminous sand at the mixing plant were not available and unloading costs were equivalent to approximately 75 cents per ton.

3. The mixing plant was constructed primarily as an experimental unit, and consequently its throughput capacity, approximately 600 square yards of 2-inch compacted surface per 10 hours, was small. As a result neither plant crew nor road crew operated to capacity. No provision was made for the usual labour-saving devices such as elevators and crusher, the absence of which implied high labour costs. In spite of the above adverse factors, cost per square yard of completed surface was sufficiently low to warrant further quarrying and paving operations on a larger scale

¹ Mines Branch, Dept. of Mines, Canada; Repts. Nos. 684, 694.

and with more complete equipment. Consequently, the field program for 1929 provided for:

(a) Opening up another bituminous sand quarry near McMurray, and improvement of loading facilities at Waterways.

(b) Consideration of types of mechanical equipment best adapted to excavation of bituminous sand on a commercial scale.

(c) Consideration of the problem of unloading bituminous sand from railway cars.

NEW QUARRY

The Mines Branch quarry from which bituminous sand was secured in 1926-7, was exhausted in the fall of the latter year. Consequently, during the fall of 1928, a small adjacent area was sampled by the use of hand augers. Results¹ appeared to indicate the presence of a workable bed of bituminous sand.

As a preliminary step a substantial, six-compartment log wharf, approximately 140 feet in length, was constructed (Plate III B), sides and bottom being tightly lined with plank and rough lumber (Plate IVA).

Stripping of overburden was effected by the use of a No. 1 slip scraper operated by a $\frac{1}{2}$ -inch cable and winch, the excavated material being dumped over the edge of the river bank immediately adjacent. The lead line of the scraper passed through a block secured to a plank tower, 35 feet high, erected at the river's edge (Plate III B). A pump, installed on a barge moored at the shore line, supplied water through a $2\frac{1}{2}$ -inch hose, and this sluiced the overburden either into the crib work of the log wharf or to an adjacent disposal site. Pump and winch were operated by gasoline tractors, the entire operation involving the services of four men. In all some 2,700 cubic yards of overburden was stripped at a cost—apart from capital expenditure—of approximately 59 cents per cubic yard.

Overburden removed consisted for the most part of stiff boulder and other clays and shales. Underlying these and immediately above the bituminous sand a soft unimpregnated sandstone, varying in thickness from one to four feet, was encountered. This could be excavated with difficulty by means of the scraper, and it was found advantageous to loosen it by the use of explosives. It may be noted that, had the quantity of overburden been sufficient to warrant its use, the materials encountered could have been readily removed by hydraulicking, steam shovel, or drag line equipment, at a very low cost.

Having removed the bulk of the overburden, "cleaning up" of the quarry floor was undertaken. Although approximately horizontal, it was found that the upper surface of the bituminous sand itself is marked by irregular depressions varying in depth up to 18 inches. Removal of material from these shallow depressions involved the use of hand tools and required considerable time, although as in the case of the overburden proper, it could have been readily handled by the use of hydraulicking equipment. The quantity of bituminous sand rendered available by the above stripping operations is estimated at 7,000 tons.¹

¹ Mines Branch, Dept. of Mines, Canada; Rept. 710-1, pp. 18-20.

During the progress of the above work, a demonstration separation unit had been installed immediately adjacent to the quarry by Dr. K. A. Clark of the Scientific and Industrial Council of Alberta. In order to deliver bituminous sand to this plant, an aerial ropeway, with towers, carrier, and skip, was installed (Plate VA). As in the preceding year, Mr. Paul Schmidt acted as field assistant, and was in immediate charge of quarrying operations.

CONSIDERATION OF EQUIPMENT ADAPTED TO EXCAVATING BITUMINOUS SAND

Large commercial development of bituminous sand has not, as yet, been attempted in the McMurray area. Shipments by the writer in any one year have not exceeded 3,000 tons—an amount insufficient to warrant the installation of mechanical excavators. Consequently up to the present time, all excavation has been carried out by the use of hand tools and explosives. Following the removal of overburden, holes may be readily drilled by the use of hand augers.¹ Depth and spacing of holes, as well as thickness of cover, vary with height of working face, tonnage desired from a single shot, and size of lumps that can be conveniently handled. It appears that, when large charges of explosives are used, one pound of slow explosive will break down approximately $1\frac{1}{2}$ tons of bituminous sand. The bituminous sand itself serves as an excellent tamping material.

Obviously large commercial development will imply a maximum use of labour-saving equipment, and various types of excavators have been considered. In reaching a decision, however, the variable character of the bituminous sand, both horizontally and vertically, must be recognized.

From a comparison of material passed through during the course of shafting operations in 1924² and that exposed along adjacent outcrops, it became clear that marked variation exists between weathered and unweathered bituminous sand. This was further verified by conditions observed in the quarry opened by the Mines Branch during the past season.

Thus, bituminous sand comprising the zone adjacent to an outcrop, and varying in width from 15 to 25 feet, is sufficiently hard to render ineffective the cutting action of a heavy grub hoe or pick axe. Beyond this hardened zone, however, the bituminous sand becomes notably softer and, indeed, may be spaded off in slices up to two inches in thickness without undue difficulty (Plate VB). Bituminous sand comprising the harder weathered zone constitutes in the aggregate a very considerable tonnage, and it is thus desirable to secure equipment which will excavate both the harder and softer varieties.

The character of the bituminous sand as well as factors which will determine methods of excavation, have been fully described in various reports prepared by the writer since 1913.³ It is, therefore, unnecessary at this time to refer in detail to these considerations.

For many years⁴ the writer has maintained that the use of excavating equipment of a type somewhat similar to the shale planer appears well

¹ Mines Branch, Dept. of Mines, Canada; Rept. No. 684, pp. 3-4.

² Mines Branch, Dept. of Mines, Canada; Rept. No. 632, pp. 53-57.

³ Mines Branch, Dept. of Mines, Canada; Repts. Nos. 281, 285, 346, 421, 454, 500, 574, 605, 616, 632, 684, 689, 694, 696, 710-1.

⁴ Mines Branch, Dept. of Mines, Canada; Rept. No. 632.

adapted to the economic excavation of bituminous sand. In order, if possible, to arrive at some definite conclusion, the opinion of manufacturers of excavating equipment was invited. Accordingly, in August, 1929 Mr. D. S. Watters, representing the Bucyrus-Erie Company, South Milwaukee, Wis., and Mr. Theo. Aulmann, representing the Eagle Iron Works of Des Moines, Iowa, visited McMurray and inspected the Mines Branch quarry and representative outcrops of bituminous sand. Subsequently, conclusions arrived at by the above representatives together with provisional cost estimates were submitted to the writer.

In the writer's opinion, either power-operated shovels or shale planers will excavate the softer unaltered bituminous sand in a satisfactory manner. In the case of altered, and harder, bituminous sand the use of shovels presents certain difficulties. It is true that heavy duty shovels may dig the harder material without blasting, but the effort required would impose a severe strain on the machinery. Moreover, the bucket could be filled only with difficulty, and the time required per cycle would be increased to a point where the operation would not be economical. Therefore, it appears that in order to obtain satisfactory results the bituminous sand should first be loosened by the use of explosives. On the other hand the use of planers appears to have certain advantages. (a) The use of explosives—and consequent undesirable¹ production of large lumps—would be avoided. (b) Bituminous sand delivered from the planers would be in fragments not exceeding 2 to 3 inches. If passed through a separation plant adjacent to the quarry this would constitute a distinct advantage. If shipped by rail as raw bituminous sand the material would undoubtedly consolidate compactly on the cars. On the other hand, shipment of any considerable tonnage for paving purposes will definitely imply the use of an adequate mechanical device for unloading,² since bituminous sand shipped in a fine or coarse condition rapidly consolidates. (c) The product delivered from any type of chain or belt excavator, of which the shale planer is an excellent example, would constitute a blend of material representing the full thickness of the bed or deposit. At the Mines Branch quarry on Clearwater river, the bitumen content of sand ranges from 10 to 17 per cent³, and under such conditions a composite product is almost essential if the material is to be used for paving purposes. (d) First cost and operating cost of the planer type of equipment would apparently be less than in the case of power shovels. In one instance with which the writer is familiar the substitution of planer equipment for power shovels in the excavation of clay shales reduced excavation costs from 20.3 cents to 5.43 cents per ton. It is of interest to note that the softer, unaltered bituminous sand does not adhere to digging tools as does the altered material adjacent to outcrops.⁴ Minor gumming up, however, should it take place either in the case of shovels or planers, can be prevented by the use of a small steam or water jet playing against the cutting tools.

¹ Mines Branch, Dept. of Mines, Canada; Rept. No. 632, pp. 56-7.

² Mines Branch, Dept. of Mines, Canada; Repts. Nos. 632, pp. 160-1; 684, pp. 26-7; 694, p. 22.

³ Mines Branch, Dept. of Mines, Canada; Rept. No. 710-1, pp. 18-20.

⁴ Mines Branch, Dept. of Mines, Canada; Rept. No. 632, p. 56.

In connexion with excavation of bituminous sand during the past 17 years, the writer has used at various times 20, 40, and 60 per cent dynamite, Black Powder Pellets, No. 1 Black Blasting Powder, and Stumping Powder. Experience has definitely indicated that fast burning powder is not adapted to breaking down bituminous sand. In dry holes, No. 1 Blasting, in wet holes, Black Powder Pellets, have given best results. It may be noted that, during the period 1913-14, it was the writer's practice when firing heavy shots, to spring the holes before loading. It was found, however, in small-scale operations, that heavy charges of explosives broke down more bituminous sand than could be immediately removed, and that lumps produced were much larger than could be conveniently handled. As a result—more especially during warm weather—much of the broken material reconsolidated under its own weight, and its subsequent removal involved considerable labour and expense. Undoubtedly, however, springing the holes, when broken down bituminous sand can be immediately removed, will result in real economy. In August, 1929, Mr. R. A. Gorman of the Canadian Explosives Co., Ltd., visited the Mines Branch quarry at McMurray. Views expressed in a report subsequently submitted to the writer by Mr. Gorman coincide with opinions as outlined above.

From the foregoing it appears that, with mechanical equipment now available on the market, actual mining of bituminous sand may be undertaken at a cost not exceeding .15 cents per ton.

During recent years methods adapted to large-scale stripping operations have attained a high state of perfection. Only specialists thoroughly familiar with the most recent practice are competent to express an opinion regarding procedure best adapted to individual problems. It is clear, however, that dragline, power shovels, or hydraulicking methods will be found suitable for the removal of the gravel, boulder clay, and other somewhat loosely compacted sediments which constitute much of the overburden which will be encountered in the McMurray area¹. If large-scale operations are undertaken, cost per cubic yard should not exceed 15 cents.

In 1920², the writer undertook a detailed examination of certain promising bituminous sand areas on Horse river (secs. 5 and 8, tp. 89, R. 9), during which 20 test pits were sunk, and test borings carried into the underlying bituminous sand. A detailed topographical map of the area was also prepared on a scale of 1 inch equals 200 feet, and on which contours of 10-foot interval were indicated. Estimates of apparent tonnage of bituminous sand available were then prepared, together with an estimate of corresponding yardage of overburden to be removed, should commercial development be undertaken. These estimates indicated that the mining of approximately 3,360,000 tons of bituminous sand would involve the removal of 3,190,000 cubic yards of overburden.

In the McMurray field a number of areas have been recognized within which mining of bituminous sand can be undertaken which will involve the removal of a somewhat smaller relative quantity of overburden³.

¹ Mines Branch, Dept. of Mines, Canada; Rept. 632, pp. 153-160.

² Mines Branch, Dept. of Mines, Canada; Repts. Nos. 574, 692.

³ Secs. 20, 21, and 29, tp. 92, R. 9; secs. 25, 26, 36, tp. 93, R. 11; secs. 18, 19, 20, tp. 94, R. 10; secs. 19, 23, 29, 32, tp. 94, R. 11; secs. 21, 27, 33, 34, tp. 95, R. 11; secs. 4, 5, tp. 98, R. 7.

Assuming, however, the removal of one cubic yard of overburden per ton of bituminous sand, total excavating cost per ton of the latter will not exceed 30 cents.

Not more than 50 tons of bituminous sand was excavated from the newly opened quarry during the past season, but, as in shafts sunk by the Mines Branch in 1924¹, Cretaceous wood was encountered. One tree trunk, not less than 6 inches in diameter and embedded in the bituminous sand in an almost vertical position, was partially excavated and a section sent for examination to the Bussey Institution for Research in Applied Biology, Forest Hills, Boston, Massachusetts. Commenting on this specimen, Dr. I. W. Bailey writes in part as follows:—

It has taken considerable time to examine the Cretaceous wood that you sent to me, due to the fact that it has been essential to infiltrate the material with nitrocellulose. We now have sections which reveal the structure. The cells are much compressed and it is rather difficult to make out many of the structural details.

The wood is that of a *Gymnosperm*. It is entirely unlike any genus growing in North America at the present time. It most closely resembles *Sciadopitys* which grows in Japan.

Subsequent examination of additional samples of Cretaceous wood has been provisionally reported on by Dr. Bailey as follows:

The lignites are extremely interesting and deserve very careful study. At first I did not have much hope of being able to do much with them. The structure was so badly compressed, but I have had much better success during the last week.

This wood is entirely unlike that which you sent me previously. It appears to belong to the genus *Keteleeria* which is closely related to *Abies*. The *Keteleerias* are found at present in China and Formosa. One of the pieces of "seam" wood belongs to Gothan's extinct genus *Xenoxylon*.

I have received three shipments of lignite. The first is *Sciadopitys*, the second is *Keteleeria* and *Xenoxylon*, and the third and last I have not examined as yet. *Xenoxylon* is known from the Jurassic with one doubtful find in the Trias. In other words it is a rather common and typically Jurassic genus.

Woods resembling *Sciadopitys* and *Keteleeria* have been described from Spitsbergen, King Charles Land, England, and other regions of northern Europe, under the names of *Phyllocladoxylon* and *Protopicoxylon*. The association of these woods with *Xenoxylon* in your deposits is therefore very significant.

It is evident that the material you are finding deserves very careful and systematic investigation.

CONSIDERATION OF THE PROBLEM OF UNLOADING BITUMINOUS SAND FROM RAILWAY CARS²

Apart from present mining and freight charges, cost of unloading railway cars constitutes the most important single item in any cost estimate on the commercial use of bituminous sand for paving purposes. Heretofore cost and speed of unloading has depended on weather conditions and on the character of the material itself. During cool weather, as for example under 40° F., the lumps do not compact to any serious extent. During warm weather, the whole mass on the car, whether in the form of large or small lumps, tends to consolidate. Low-grade material can be unloaded more readily than the richer grades.

In California, in 1915, unloading costs were greatly reduced by the City Street Improvement Company, through the use of two large wooden trays placed on the deck of each car. The corners of these trays were fitted with heavy lugs and on reaching the paving plant, the trays were lifted from the

¹ Mines Branch, Dept. of Mines, Canada; Rept. No. 632, p. 55.

² Mines Branch, Dept. of Mines, Canada; Repts. Nos. 684, pp. 20-27, 694, pp. 22-23.

cars by means of a derrick and the contents expeditiously dumped. Cost of returning trays to the quarry, however, and maintenance charges on the trays themselves were high.

Having in view the above conditions, the writer constructed in 1929, at a point immediately adjacent to the Mines Branch quarry on Clear-water river, a plank platform 18 feet in length and corresponding in width to the deck of a standard flat car. Ends and sides were boarded up to a height of 5 feet. Across this deck—and with one end projecting a few inches beyond the edge—short lengths of steel rails were placed at intervals of 4, 4½, 5, and 5½ feet. The platform was then loaded with bituminous sand to a depth of 3½ feet, and this was allowed to consolidate for a period of 16 days. Records kept during this period indicated lower temperatures than would prevail during summer months, but in spite of this the bituminous sand consolidated to a considerable extent. At the end of this period a timber overhead frame was constructed, a half-inch cable passed through a pair of double blocks and led to a winch operated by a gasoline tractor. A chain from the lower block was then secured in turn to the projecting end of each steel rail, and the rails dragged into an upended position through the mass of bituminous sand. The disruptive action of the rails was such as to loosen up the bituminous sand for a distance of quite two feet on either side of each rail. It is clear that the use of a method somewhat similar to the above will very materially reduce time and cost involved in the unloading of railway cars.

OPERATIONS IN THE McMURRAY AREA BY PRIVATELY CONTROLLED COMPANIES

During the past season two companies were active in the McMurray area, namely, the Bituminous Sand Extraction Company and International Bitumens, Ltd.

Bituminous Sand Extraction Company. Since operations by this company represent the most ambitious attempt at 'in situ' recovery as yet undertaken in the McMurray area, and since it appears desirable that some record of methods adopted be available, operations will be described in some detail. The following statement is based in part on information furnished by Mr. J. O. Absher, Field Engineer for the Bituminous Sand Extraction Company, and in part on inspections by the writer during the progress of the work.

In April, 1926, a plant was set up in sec. 14, tp. 89, R. 9, about 40 feet east of Mines Branch shaft No. 2.¹ Overburden was approximately 8 feet in thickness, and consisted of clays and loosely compacted sediments. Equipment used is diagrammatically indicated in Figure 4.

The casing, with saw teeth cut in the lower end, was rotated by hand, steam being introduced through pipe (b). Steam at 30 to 40 pounds pressure readily loosened the materials passed through. At intervals pressure was increased to 80 pounds and the cuttings blown clear of the bore. At 8 feet bituminous sand was encountered, and this was penetrated for approximately 27 feet. Cap (d) was then screwed into place and a second pipe (a) inserted. This pipe projected from 1 to 2 inches below the cap.

¹ Mines Branch, Dept. of Mines, Canada; Rept. No. 632, pp. 55-57.

During progress of drilling the lower end of pipe (b) was held at an elevation of 6 to 15 inches below the lower end of casing (c), but when drilling was completed it was raised to a point 12 to 15 inches above the bottom of the well.

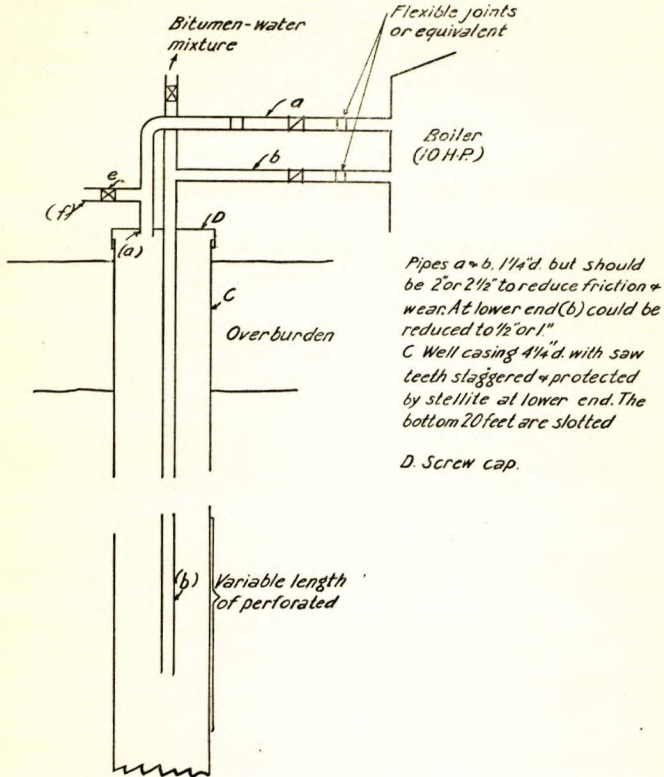


Figure 4. Diagram illustrating equipment used by Bituminous Sand Extraction Company for "in situ" recovery of bitumen by steam in 1926.

Recovery of bitumen was attempted by the use of steam. It was found that when steam entered the well through pipe (b), the pipe became very hot, silt baked onto the metal, and this in turn burned. Moreover the steam agitated the sand-water-bitumen mixture in the well, and this resulted in an impure product. Consequently steam was introduced through pipe (a) and the product recovered through pipe (b). Best results were obtained when using steam pressures of from 30 to 40 pounds. Following a period of heating, valve (e) was opened and bitumen forced to the surface through pipe (b). The bitumen flowed in a small stream about $\frac{1}{4}$ inch in diameter, and was almost pure. A part of the moisture passed off as steam. Operations were continued for a period of $2\frac{1}{2}$ days at the end of which time a fissure developed in the bituminous sand and the steam pressure could no longer be maintained in the bore. It should be noted that, when passing through coarse sand, walls of well stood up much better than when passing through finer aggregates.

During the latter part of May, 1926, operations were resumed at Wheeler's Point in sec. 24, tp. 97, R. 11, using the same method and the same equipment. An old well drilled by the Spokane-Athabaska Company in 1918, was utilized. Owing to the loose nature of the overburden, steam was introduced through pipe (b), and the product withdrawn through pipe (a). During 2½ days, a mixture consisting of 40 barrels of sand, water, and bitumen was ejected. A new well was then drilled at a point about 30 feet distant from the first. This passed through about 5 feet of sand and boulders and was continued into the bituminous sand to a total depth of about 50 feet. At first, a strong flow of sand, water, and bitumen was discharged, but overburden about the casing became loosened and the product from the well seeped up about the casing and spread over the adjacent ground. For purposes of economy, quantity of steam used was varied. Under heavy pressure the mixture from the well was discharged through (f) almost horizontally for a distance of about 20 feet, and gave the appearance of a small gusher. Total time occupied in operations in section 24 was about three weeks.

In June, 1926, a jetting rig was secured and set up in sec. 24, tp. 88, R. 8, on the right-of-way of the A. & G. W. Ry., at Mile 276. Overburden was 175 feet thick and bituminous sand 180 feet thick. The upper part of the bed was found to be fine-grained, but became coarser toward the bottom. At about 75 feet from the upper limit of the bituminous sand, an unusually rich stratum was passed through, and for 15 feet the drilling tools almost sank under their own weight. Casing, 4¼ inches in diameter, was inserted to a point about 30 feet below the top of the bituminous sand, and below this, 2½-inch casing was used. Rate of drilling, using warm water with the jetting rig, was about 40 feet per 10 hours. Equipment used was the same as that used in 1926, but before definite results were obtained, a string of small pipe was lost in the well and this resulted in stoppage of operations.

In June, 1927, a new well was drilled at a point 30 feet distant from that drilled in June, 1926, and 20 feet of 5-inch, followed by 4¼-inch casing, was inserted. The smaller casing became set as a result of caving in the bituminous sand, and only 215 feet of the 355 feet was cased. On completion of drilling, which as before was carried out by the use of warm water and a jetting rig, the well filled with bitumen to a depth of 70 feet in one night. It is stated that this bitumen did not contain more than 10 per cent of foreign matter. Pipe (c) in Figure 4, was then lowered into place, superheated steam turned in through pipe (a), and as a result about 10 barrels of sand, bitumen, and water was discharged. These products came to the surface intermittently, the sand being practically free from bitumen and the bitumen being almost free from sand.

A modification of the piping arrangements was then tried, as indicated in Figure 5. Steam from the boiler was introduced through pipe (b), and pipe (c) raised to uncover perforations in small pipe (e). This permitted the steam to pass through perforations in well casing, and to effect melting of bitumen in adjacent sand. On opening valve (f), a mixture of sand, water, and bitumen was sucked up and discharged through pipe (c). The amount of mixture entering pipe (c) was regulated by raising or lowering pipe (c), thus covering or uncovering perforations in extension pipe (e).

In July, 1928, another well was commenced on the same location, but was discontinued on account of drilling difficulties before bituminous sand was reached.

In June, 1929, operations were resumed on the Draper lease, sec. 29, tp. 89, R. 8. Overburden consisted of 4 feet of sandstone. A casing, $4\frac{1}{4}$ inches in diameter, was sunk by the use of steam to a total depth of 25 feet.

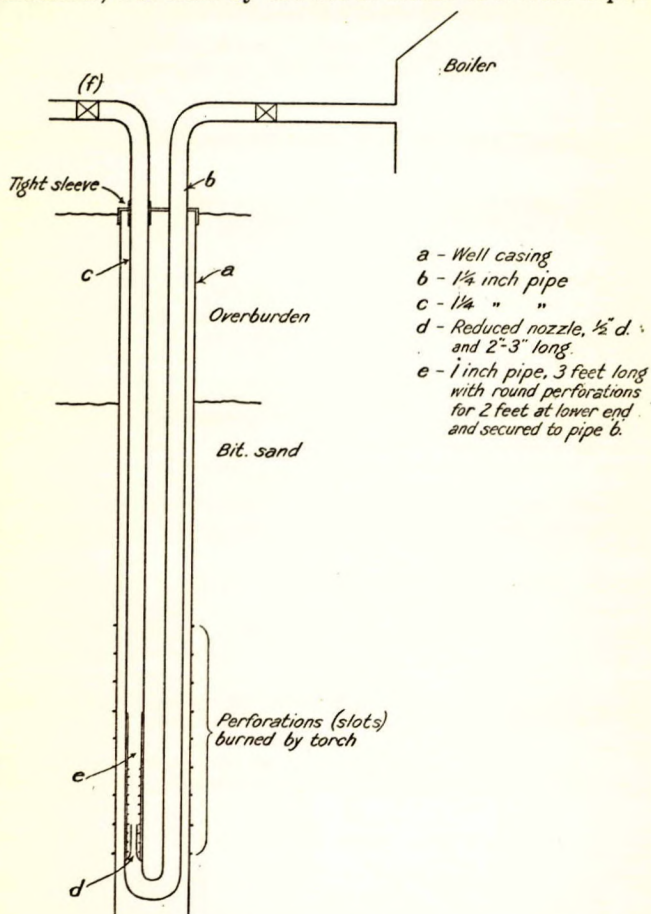
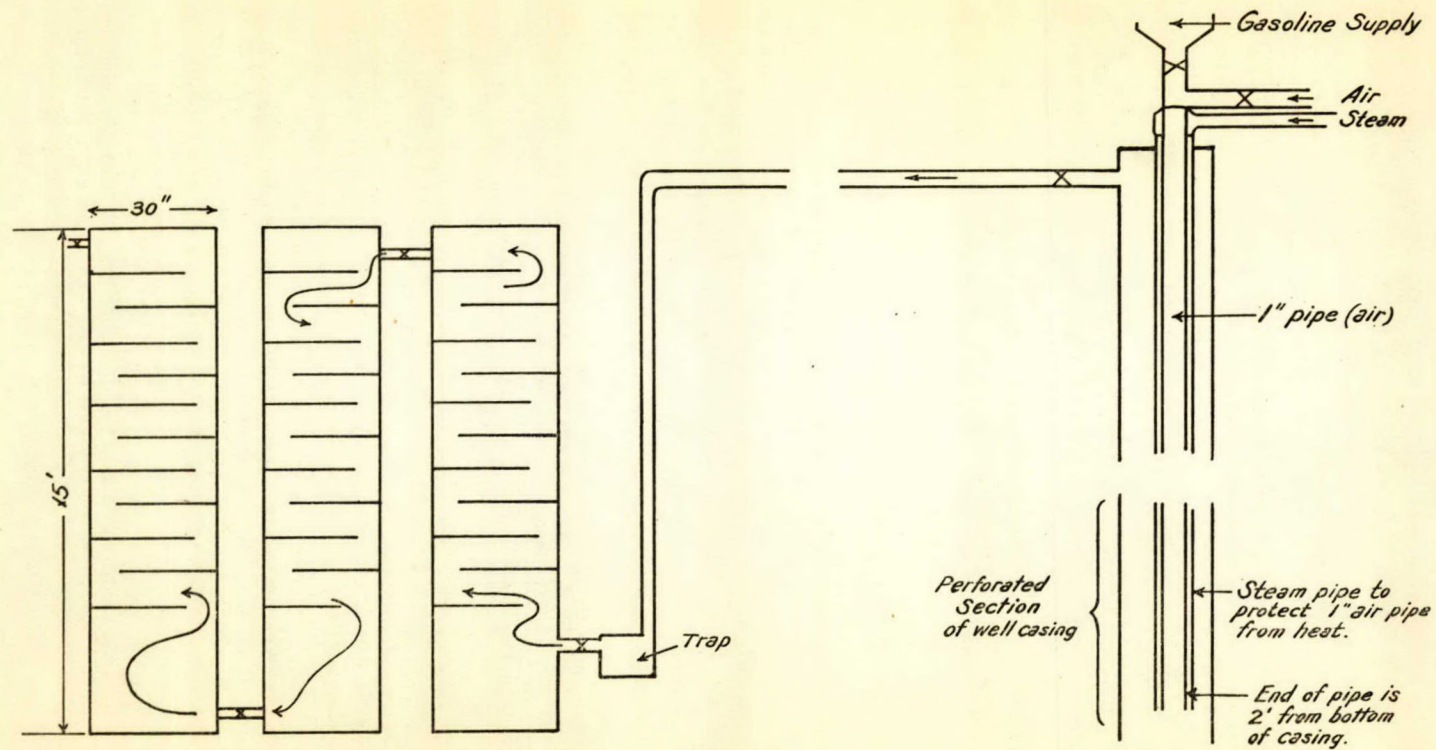


Figure 5. Diagram showing modification of equipment used in 1927.

The lower 20 feet was perforated by horizontal slots, and the edges of the slots hammered in, leaving the maximum opening toward the top. A 1-inch pipe was lowered to a point 2 feet from the bottom and equipped with a simple type of burner. Fire was started by introducing a small amount of gasoline, and sufficient air to support combustion was supplied by a small pump. By the time the gasoline was consumed the melted bitumen had become ignited. As heat increased, the low boiling fractions volatilized and passed up with the products of combustion. The gases finally became



*Condensing Towers
(16 gauge metal)*

Figure 6. Diagram illustrating equipment used by Bituminous Sand Extraction Company for "in situ" recovery of bitumen by ignition. 1929-30.

so hot that they flashed above the top of the casing. The supply of air was then stopped, but the foggy oil vapour continued to be given off for 30 minutes. A cold plate held in this vapour rapidly gathered drops of distillate. It may be noted that after the gases became ignited, the flame from the top of the casing was 10 to 15 feet in height (Figure 6).

In July, 1929, a new site was selected in sec. 10, tp. 89, R. 9, on a hogback immediately to the east of Saline creek, and some 250 yards south of the Waterways-McMurray road. A method similar to that installed during the previous month was again used. By August 4, 4 wells had been sunk. The first was 55 feet deep and was abandoned as a result of water seepage from the adjacent stream. The second, 105 feet deep, was cased to a depth of 20 feet and the remainder of the bore left open. Following ignition, heat generated caused the bituminous sand to cave, and the well was abandoned. The third well was cased and the lower 60 feet of the casing perforated by vertical slots.

In operation, the top of the casing was left open until a sufficiently high, but as yet undetermined, temperature was attained. This condition was recognized by the appearance and odour of the gas given off. The cap was then placed on the top of the casing, and the vapour line to the condensers connected. The general arrangement is indicated in Figure 6.

During August and the early part of September, a number of trial runs were made, but certain difficulties developed.

1. The intense heat generated in the well, burned off the casing and the air pipe, and in No. 3 well more than 60 feet of casing was destroyed in a few hours. In an attempt to overcome this difficulty, a steam line enclosing the 1-inch air line was installed. This protection proved insufficient, and the use of Plibrico was resorted to. This also failed, and finally the lower end of the air pipe was protected by asbestos cement and wicking.

2. Water, either as condensed steam or as seepage through the perforated casing, may extinguish the fire in the well.

3. Control of temperatures, depending on regulation of air and steam, has been found difficult. This is partly due to constricted space in which reactions take place. Determination of actual temperatures in the well has not yet been possible.

4. Oil vapours tend to condense in the upper portions of the offtake pipe, and consequently do not reach the condensers proper. At times the excessive amount of carbon black tended to block the gas line leading to the condensers.

5. Coking or fusing of sand about the perforated casing, limits radius of action of heat. The extent to which this may take place has not been determined.

In October, 1929, the original installation was somewhat modified, the general arrangement being illustrated in Figure 7.¹ The overburden was cased off by 8-inch casing fitted with a cap (b), the bore being continued without casing into the bituminous sand itself. Pipe (c), $\frac{1}{4}$ inch in diameter, perforated at the lower end (d), and protected by perforated shield (e), and pipe (f), 2 inches in diameter, were then inserted. The lower end of pipe (f) is sealed off and perforated, the upper end being

¹ Patent pending.

fitted with a cap. The bore below casing (a) was then solidly packed with gravel.

In operation, a small quantity of gasoline is introduced through pipe (f) and ignited through opening (g), which is fitted with a cap. A mixture of air and hydrocarbon gas is then introduced under pressure of 60 pounds, more or less, through pipe (h) and becomes ignited. The hot gases of combustion pass out through the perforations in the lower end of pipe (f), and being forced downward through the gravel packing and the adjacent bituminous sand, enter the lower end of pipe (c) and reach the condenser through automatically regulated valve (j). It is hoped that reactions will

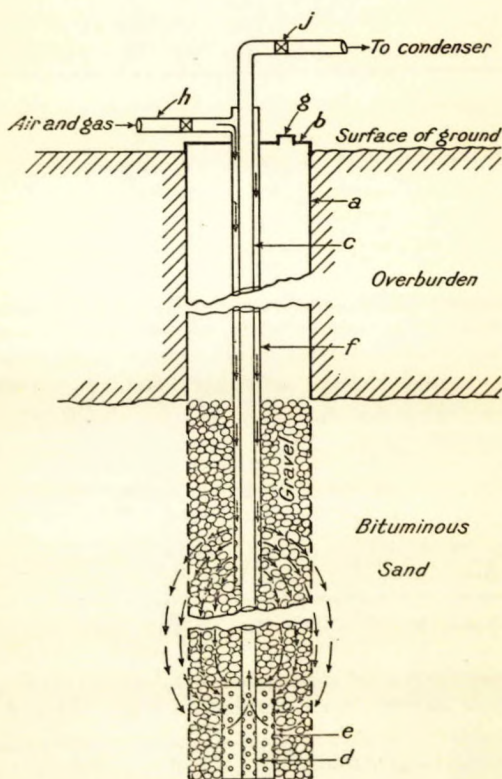


Figure 7. Diagram showing modification of equipment used in Figure 6.

take place at high temperatures whereby hydrogenation may be effected, and that such action may tend to prevent formation of coke in the bituminous sand immediately adjacent to the bore.

In November, 1929, an experimental run was undertaken, and several gallons of oil collected in the condenser towers. Distillation of this oil in the laboratory yielded 32 per cent gasoline, 34 per cent kerosene distillate, and 34 per cent residue.

Radius of action of dry heat will determine the effectiveness of the above method. It is interesting to note that, in the Trinidad coal-fields of Colorado where sandstones and shales have been intruded by igneous dykes, heat action has not extended laterally to a distance of more than 10 feet. On Last Chance creek, Wayne county, Utah, intruded dykes have not affected oil sands to a distance greater than the width of the dykes themselves.

International Bitumens, Ltd., R. C. Fitzsimmons, Field Manager. During a considerable part of each year since 1925 (incl.), R. C. Fitzsimmons has been conducting operations in sec. 36, tp. 96, R. 11, and in secs. 28, 31, and 32, tp. 96, R. 11. A considerable sum of money has been expended on camp buildings, roads, and drilling. A force of from 5 to 12 men has been employed.

It is claimed that, within the area noted above, unusually rich strata of bituminous sand have been encountered during drilling operations. The object of the present work is to recover the bitumen from these reported rich strata by use of "in situ" methods.

As yet work has been largely confined to preliminary preparation. Three wells have been drilled, and in one instance steam was turned into the bore in order to effect separation. A strong flow of cold water negated the action of the steam.

The above operations were inspected by the writer in September, 1925, in 1927, and in September, 1929.

Experimental Work at Jasper, Alberta

During the period, June 30 to July 9, a number of trial batches were run through the internally heated, drum type mixing plant installed by the writer at Jasper, Alberta, in 1926.¹

The first series of mixtures consisted of "D" grade asphalt combined with clean aggregate. Rapid heating and mixing was readily effected, batches being discharged at any desired temperature up to 400° F. Discharge from mixing-drums was, however, unsatisfactory. Discharge chutes were set at an angle of 42 degrees to the horizontal, and in 1926-27, high penetration bituminous sand mixtures had flowed rapidly into the street trucks. On the other hand, the lower penetration "D" grade mixtures did not flow readily, and the necessity of much steeper inclination of discharge chutes is definitely indicated. Discharge of batches of bituminous sand and crushed gravel, equivalent in a general way to a 6 per cent black base mixture, presented the same difficulty.

In previous reports,² the writer has indicated that variation exists in gravity and penetration of bitumen associated with bituminous sand. Bitumen associated with the finer grained aggregates usually exhibits a higher penetration and gravity than in the case of medium or coarse sands.³ This variation is of practical interest if the bituminous sand is to be heated for paving purposes.

At Jasper in 1926-27, of approximately 2,400 batches heated, only 3 became ignited.⁴ On the other hand in 1929, frequent ignition of batches

¹ Mines Branch, Dept. of Mines, Canada, Repts. Nos. 684, 694.

² Mines Branch, Dept. of Mines, Canada, Rept. No. 632, pp. 67-8.

³ Mines Branch, Dept. of Mines, Canada, Rept. No. 710-1, p. 5.

⁴ Mines Branch, Dept. of Mines, Canada, Rept. No. 694, p. 32.

was a constant source of trouble. It was therefore necessary to hold the temperature of batches well below 300° F., and to extend the normal period of heating. It may be noted that a marked feature of the bituminous sand used in 1929 was its fine texture, a typical screen analysis being as follows:

| | | | | | | | | |
|--------------|-----|-----|----|----|----|----|----|----|
| Passing mesh | 200 | 100 | 80 | 50 | 40 | 30 | 20 | 10 |
| Per cent | 4 | 61 | 0 | 30 | 3 | 1 | 1 | 0 |

In order to determine the variation which may be expected in bitumen associated with bituminous sand, of varying sand grading and of varying degrees of freshness, four samples have been examined at the Mines Branch Laboratories, Ottawa.¹ These samples were:

- No. 6452. Unaltered bituminous sand from Mines Branch quarry, Clearwater river, taken at a point 35 feet from weathered outcrop.
 No. 6453. Fine-grained bituminous sand used at Jasper, July, 1929.
 No. 3055. Bituminous sand from Mines Branch shaft. Clearwater river, taken at depth of 52 feet from surface of ground.
 No. 2734. Weathered bituminous sand from outcrop adjacent to Mines Branch quarry, Clearwater river.

Report on the above samples is as follows:

| Laboratory No..... | 6452 | 6453 | 3055 | 2734 |
|---------------------------------------|----------------------|----------------------|----------------------|----------------------|
| Description | | | | |
| Bitumen content % Wt. (by extraction) | 9.1 | 13.5 | 13.5 | 11.5 |
| <i>Analysis bitumen extract—</i> | | | | |
| Sp. gr. at 25°C..... | 1.030 | 1.020 | 1.020 | 1.050 |
| Viscosity (Redwood)..... | 61 mins. (210° F) | 16 mins. (210° F) | 11 mins. (206° F) | 44 mins. (205° F) |
| Flash point in Cleveland open cup... | 360° F. | 300° F. | | |
| Fire point..... | 430° F. | 350° F. | | |
| <i>Distillation range—</i> | °F | °F | °F | °F |
| 1st drop..... | 183 | 164 | 170 | 180 |
| 5% volume at..... | 356 | 508 | 551 | 559 |
| 10% "..... | 556 | 538 | 581 | 590 |
| 15% "..... | 554 | 572 | 600 | 610 |
| 20% "..... | 590 | 574 | 611 | 631 |
| 25% "..... | 608 | 573 | 617 | 648 |
| 30% "..... | 613 | 601 | 617 | 654 |
| 35% "..... | 647 | 614 | 630 | 658 |
| 40% "..... | 656 | 616 | 644 | 662 |
| 45% "..... | 670 | 610 | 648 | 666 |
| 50% "..... | 672 | 614 | 648 | 682 |
| 55% "..... | 679 | 618 | 672 | 685 |
| 60% "..... | 680 | 620 | 676 | |
| 65% "..... | | 636 | 680 | |
| 70% "..... | | 662 | | |
| Distillate recovered..... | 61% | 75% | 67% | 58% |
| Sp. gr. distillate at 60° F..... | 0.912 | 0.906 | 0.911 | 0.934 |

From the above it is evident that sample No. 6452 was distinctly less volatile than sample No. 6453, but softer and more volatile than sample No. 2734.

¹ Analyses and report by G. P. Connell and A. A. Swinerton.



A. Franklin Ave. (main street), McMurray, Alberta.



B. Mines Branch quarry site prior to commencement of stripping. Wharf and tower in foreground.

PLATE IV



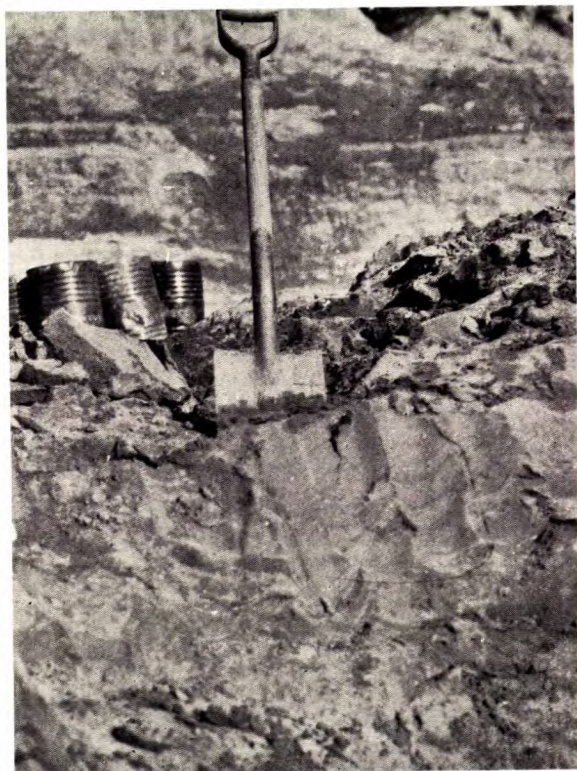
A. South end of crib wharf partly filled with material stripped from quarry site.



B. Commencing stripping of overburden; slip scraper and top of plank tower.



A. General view showing newly opened quarry on left, and separation plant building on right.



B. Soft, unaltered bituminous sand (at a distance of 40 feet from weathered outcrop), showing marks where the sand has been spaded out by hand.

IV

LIMESTONE IN INDUSTRY

M. F. Goudge

The purpose of this article is to point out the manifold industrial uses of limestone; to indicate the types of limestone desired by some of the principal industries; and to give some information on the resources of limestone in Canada so that an idea may be obtained of the present and future possibilities for limestone production.

The word limestone is used in the usual broad sense to include both high-calcium limestone and the highly magnesian variety known as dolomite, as well as all intermediate types. Lime is simply calcined limestone and in this general paper its uses have been included with those of raw limestone.

It is of interest to glance over the early history of the utilization of limestone; in so doing we see that limestone has been of importance to mankind since the beginning of civilization and has contributed in no small measure to the development of a number of the arts and sciences.

One of the first, if not the first, uses of limestone was for making lime for plastering purposes. This use antedates civilization. In the day of the ancient Greeks and Romans the art of plastering had been brought to a state of perfection that is not nearly approached by the modern artisan. The recognition of the value of lime as a plastic binder made possible the construction of stone buildings and thus formed the basis of modern architecture. How long lime mortars have been used we do not know, but the Great Pyramid of Gizeh, believed to have been built more than 5,600 years ago, has its huge limestone blocks bound together by a lime mortar which, so authorities state, is similar in all respects to our lime mortars of to-day.

Limestone and marble, the latter being simply crystalline limestone, have since earliest times been favourite building and ornamental materials—limestone on account of its pleasing appearance, ease of quarrying and ease of dressing; marble on account of its beauty. Excavations now in progress among the ruins of Ur, the capital of the ancient Chaldean empire, have disclosed that marble slabs were used to decorate the mud temples of that early civilization; and marble is still the favourite material for the ornamentation of the finest modern buildings. Since the days when the master sculptors of ancient Greece wrought blocks of snowy Grecian marble into bas-reliefs and statuary of incomparable beauty, marble and the art of sculpture have been associated. For sculptural purposes it has never been surpassed.

These were the principal uses of limestone in early times. They waxed and waned in importance with the varying importance of architecture and sculpture down through the centuries. The ancients had knowledge of some of the chemical properties of lime such as its bleaching, causticizing, and sanitation value. It was also a material of importance to the

alchemists but there was little opportunity for the industrial application of this knowledge. It was not until well on in the 19th century when the era of great manufacturing industries dawned, that there began that great expansion in the sphere of usefulness of limestone which in the present century was to render it one of the most important of raw materials in industry.

To-day limestone surpasses any mineral, metallic or non-metallic, in the number and diversity of its uses. This statement may, by some, be considered extreme because articles in common use composed entirely of limestone are not numerous, but upon consideration of the number and importance of the manufacturing processes into which limestone and lime enter as essential ingredients, the truth of the statement becomes apparent. The iron and steel industry as at present constituted could not exist without large supplies of limestone. In other branches of metallurgy limestone plays an important part. Limestone is indispensable to the pulp and paper industry. In the manufacture of calcium carbide and cyanamide, limestone is the principal raw material. The glass industry requires limestone for most of its products. Limestone is essential to the manufacture of sodium carbonate and many other important chemicals. Large quantities are consumed in the refining of sugar. Lime is used in medicine. In the agricultural industry limestone finds important applications as a fertilizer and as a corrective for soil acidity; lime forms an important base in the compounding of fungicides and insect poisons. Limestone is pre-eminent in construction—the cement industry is based upon the use of limestone; the crushed-stone industry is practically a limestone industry; the sand-lime brick industry depends upon lime; the importance of lime for mortar and plaster is known to all; and limestone has always been a popular building material. Either in the raw or calcined state limestone is used in the textile and leather industries, the paint and varnish industries, the petroleum-products industry, the rubber industry, the wood-products industry, and many others. Calcined magnesian limestone or dolomite is used as a refractory material, it is also a source of magnesia and metallic magnesium. Many other uses of limestone could be listed, for, by reason of the number and diversity of its functions, it has literally hundreds of applications particularly in chemical processes but mention has been made of a sufficient number of its more important uses to show the indispensability of limestone in our modern industrial system.

Despite the fact that limestone is such an important raw material, it has received but little detailed study in comparison with other materials entering various processes, and detailed specifications for limestones are rare. Exact specifications are difficult to prepare because, although pure limestones are desirable for chemical purposes, it is often possible to use a cheaper and less pure material provided that impurities especially deleterious to the process are not present in too great amount.

The *metallurgical industries* consume enormous quantities of limestone. For the production of one long ton of pig iron more than 1,100 pounds of limestone is required, and a further 250 pounds of limestone is used in converting the pig iron to steel. Dolomite either raw or calcined is used for patching and lining the floors of basic open-hearth furnaces; for this purpose an average of 100 pounds of dolomite per ton of steel is required.

In Canadian blast furnace practice only high-calcium limestones are used for flux. None of the limestones in present use have a content of more than 4 per cent magnesium carbonate, although amounts up to 15 per cent are not considered troublesome. A non-crumbly stone between 1½ and 4 inches in size is desired. One of the main functions of limestone being to flux off the silica in the ore, a limestone low in silica is preferred, but a silica content up to 10 per cent is not prohibitive if the stone is available at a sufficiently low price. It is simply a question of balancing the increased operating expense of slagging the additional silica, against the lower price of the low-grade limestone. The alumina content of a blast furnace flux should be below 2 per cent. Sulphur and phosphorus are very objectionable impurities; and the content of neither should exceed 0.1 per cent.

The basic open-hearth process requires a high-calcium limestone for flux. The limestone must be purer than that for blast furnace use. Silica should not exceed 5 per cent, alumina 1½ per cent, magnesium carbonate 10 per cent. Sulphur and phosphorus must be low. The usual size for open-hearth flux is between 4 and 8 inches. Crushed high-calcium lime is used by some mills to the extent of 100 pounds per ton of steel to thicken the slag towards the end of the open-hearth process. The lime for this purpose must be pure, and especially low in phosphorus.

High-calcium lime is used as a lubricant and acid neutralizer in the process of steel-wire drawing. For this use it must be absolutely free from grit.

In coke by-product plants a pure high-calcium lime is used in the preparation of ammonia and of ammonium sulphate.

In 1928, according to the Dominion Bureau of Statistics, the Canadian iron and steel industry used 714,715 tons of limestone valued at \$1,011,516. The greater part of this was imported from the United States and Newfoundland. This is due not to any lack of suitable limestone in Canada but to the fact that the foreign limestone could be obtained more cheaply owing to its more favourable location with respect to the steel mills.

In the metallurgy of copper, nickel, lead, zinc, gold, silver, and other metals, both lime and limestone are used—limestone as a flux in smelting, lime as a reagent in flotation plants and cyanide mills. Quantities of lime up to 20 pounds per ton of ore are used in the selective flotation of copper, lead, molybdenite, and graphite from mixed sulphide ores. The function of the lime is to prevent sulphides of iron and zinc from floating. In the cyanide process of extracting gold and silver from their ores, from 3 to 5 pounds of lime per ton of ore is added for the twofold purpose of maintaining a protective alkalinity in the solution, thus preventing excessive consumption of the expensive cyanide, and of aiding in the settling of the slimes. The lime for these uses must be made from a high-calcium limestone; for use in cyanide mills it must be absolutely free from bits of charcoal and coke.

The *pulp and paper industry* is a large user of lime and limestone. In the making of a ton of sulphite pulp 375 pounds of limestone is consumed if the acid-tower system is employed, and 200 pounds of lime is required if the milk-of-lime system is used. A further 130 pounds of lime is needed in bleaching each ton of sulphite pulp. The sulphate pulp process requires 500 pounds of lime per ton of pulp produced. For the making of a ton of

bleached soda pulp about 600 pounds of lime is needed. In the two latter processes it is possible to recover most of the lime for further use. Rag paper requires from 120 to 250 pounds of lime per ton of rags depending on the kind of rag used. During 1928, according to the Dominion Bureau of Statistics, the pulp and paper industry used 187,325 tons of limestone and 95,448 tons of lime having a total value at the mills of \$1,573,520. Most of this material was from Canadian sources and all of it could have been so supplied.

There are wide variations in the type and purity of limestones used in sulphite pulp manufacture. Some companies prefer high-calcium limestone, others magnesian limestone, and some prefer dolomite. Limestones with a total of 6 and even 8 per cent of silica, alumina, and iron oxides are used at some mills but in general the purer the stone the better, especially with regard to the content of iron oxide which renders the pulp dark in colour and hard to bleach. Flakes of mica, graphite and other carbonaceous material make the limestone in which they occur, worthless for acid tower purposes because they are carried over into the pulp and remain as specks on which the bleaching solution has no effect. The grain of the stone should be from medium to fine. Coarse-grained limestone tends to crumble and choke the towers; extremely fine-grained stone dissolves so slowly as to reduce the acid-making capacity of the towers. The most desirable size for the stone is lumps 8 to 14 inches in diameter.

Milk-of-lime systems requires a lime made from a pure dolomite and it must be free from dark-coloured specks. The lime is used either as quicklime or hydrate. High-calcium lime is debarred from this use on account of the formation of insoluble calcium sulphate which forms in sufficient quantity to clog the system.

In the manufacture of sulphate and soda pulp, lime performs the same function in each case—that of causticizing the cooking liquor. The lime should be made from a pure high-calcium limestone, but in practice some limes having a total of 7 per cent of silica, iron oxides and alumina are used. Magnesia is the most troublesome impurity as it is very slow in settling, and a lime with less than 2 per cent magnesia is desired. A fast settling, lightly burned lime is preferred.

Bleaching solution for wood pulp is prepared from liquid chlorine and milk of lime. Hydrated lime is generally used, as it is necessary that the temperature of the solution be kept low. The lime should be made from a very pure high-calcium limestone and preferably should be slow in settling.

The *calcium carbide industry* within recent years has attained a prominent place among chemical industries; calcium carbide, aside from its value as a source of acetylene, is the base for the manufacture of many valuable chemicals and solvents. It is made by melting limestone and coke in the electric furnace. Practically two tons of limestone is used in the making of one ton of carbide. Present practice is to calcine the limestone before charging it to the electric furnace. For this use an extremely pure limestone is required. The phosphorus content must be below 0.01 per cent and magnesia should be less than 2 per cent in the stone. Likewise the silica content should be under 3 per cent.

Calcium cyanamide is made by treating fused calcium carbide with nitrogen. It is used chiefly for nitrogenous fertilizers and as a source of

cyanide. Impurities in limestone for the making of cyanamide are not of such great importance as for carbide manufacture, but, on account of the extra expense in fusing them, a pure high-calcium limestone is required. A large tonnage of Canadian limestone is used annually in the manufacture of carbide and cyanamide.

The *sugar refining industry* is a large user of limestone and lime. Approximately 700 pounds of limestone is needed for the refining of one ton of beet sugar by the carbonation process. A particularly pure limestone having less than 1 per cent silica and less than 1 per cent magnesia is required. Silica becomes colloidal in the sugar juices and forms a film on the sugar crystals, retarding their growth and lowering the purity. Magnesia also tends to lower the purity of the sugar and may give trouble in the presses. The presence of iron oxides adversely affects the colour of the sugar. The limestone is desired in pieces varying from 2 to 6 inches in size. It is burned in a mixed-feed kiln at the refinery and both the lime and the CO₂ gas are used in the process.

Lime in much smaller quantities is used in the defecation process of refining cane sugar. A similarly pure limestone is necessary to make lime for this purpose.

The Dominion Bureau of Statistics figures for 1928 show 1,339,741 pounds of lime and 18,879 tons of limestone with a combined value of \$51,484, used by the sugar refineries in that year.

In the manufacture of *soda ash* by the ammonia-soda process, about 1½ tons of limestone is used per ton of soda ash produced. The limestone, in pieces 1 to 6 inches in size, is burned in a mixed-feed kiln with coke as fuel. The CO₂ gas is recovered and used in the process. The lime is used in the recovery of ammonia. A high-calcium limestone is required. Chemical purity, though not essential, is desirable.

The *glass industry* requires limestone for most of its products. Limestone may form as much as 30 per cent of the total raw materials in some grades of bottle and window glass. Either dolomite or high-calcium limestone can be employed but the latter type is in most common use in Canadian glass plants. Iron oxides and alumina are the most objectionable impurities, the former should not exceed 0.50 per cent, nor the latter, 2 per cent. The silica content is not of great importance as long as it is uniform and it may run as high as 10 per cent without affecting the value of the limestone for glass-making purposes, although it is customary to use limestone having less than 3 per cent silica.

Canadian *tanneries* utilize between 3,500 and 4,000 tons of lime per year in the removing of hair from hides. Lime for this purpose should be low in content of iron oxides and magnesia. It should be free from grit and preferably be slow in settling.

Bleaching powder is simply hydrated lime saturated with chlorine gas. The lime must be white and high-calcium in composition. The magnesia content must be less than 1½ per cent; it is one of the most objectionable impurities, for it forms magnesium chloride which absorbs water from the air giving a sticky powder. The iron oxide content must be low because iron decomposes and discolours the bleaches. It has been found that some limes are much better suited to the manufacture of bleaching powder than others, even though the chemical composition may be almost identical.

Caustic soda in Canada is mostly produced by electrolytic methods, but in pulp mills and in some other industries, solutions of caustic soda are made by causticizing a solution of soda ash with quicklime. Approximately one ton of limestone is required to furnish the requisite amount of lime to convert one ton of sodium-carbonate to caustic soda. The requirements of a lime for this purpose have been mentioned in connexion with the lime used in sulphate and soda pulp manufacture. However, for commercial production of caustic soda a purer lime than that used in the pulp industry should be employed.

In *water softening and purification*, both for domestic and industrial use, high-calcium lime fulfils an important function. Lime enters into nearly every common process of water treatment. It is very efficient in rendering water bacterially safe. Calcium oxide is the only active material and, as impurities reduce the value of the lime and also add to the quantity of sludge to be removed, a pure lime is desired.

In the *textile industry* lime is used in the bleaching and dyeing of certain fabrics. A pure high-calcium lime practically free from iron is necessary.

The *hardwood distillation industry* uses lime chiefly in the production of calcium acetate. Calcium oxide is the only active constituent of the lime in this process, therefore a high-calcium lime is used. About 800 pounds of lime is required to produce 1 ton of calcium acetate.

The *sand-lime brick industry* is based upon the use of lime as a binder for silica sand. The usual proportion is 10 pounds of quicklime to 100 pounds of sand. The lime after complete hydration is mixed with the sand and the mixture is pressed into bricks. The bricks are then hardened by a high-pressure steam process. The United States Bureau of Standards specification for quicklime for this purpose stipulates that the lime shall contain at least 85 per cent calcium oxide and not more than 5 per cent magnesia.

Within recent years a large and growing demand has arisen for *non-metallic mineral fillers*. Of these, whiting and whiting substitute are the most widely used. Whiting is prepared from imported chalk; whiting substitute is prepared by the fine grinding of a suitable limestone. These materials are of importance in the manufacture of numerous products. For instance putty is simply 85 per cent of whiting and 15 per cent linseed oil. Whiting may form 15 per cent of linoleum. In cold-water paints or kalsomines, whiting functions as a pigment of high opacity and usually forms 80 per cent of such paints. Whiting is more generally used in the compounding of rubber than is any other material except sulphur. Some cigarette papers contain as much as 30 per cent whiting or precipitated chalk; its use accelerates the burning of the paper by reason of the fact that the heat of the burning cigarette drives off the CO_2 gas from the whiting, this opens the pores of the paper and promotes combustion. Whiting is also used in polishes, fireworks, inks, dyes, ceramic glazes, in the manufacture of certain electrical appliances, and for many other purposes. In practically all of these uses the substitute may replace the true whiting to a varied extent.

The estimated annual consumption of whiting and whiting substitute in Canada is 25,000 tons, nearly all of which is imported. There are large

importations of whiting substitute from the United States. Chalk does not occur in Canada, so true whiting cannot be made from domestic materials, but there are limestone deposits from which a high-grade whiting substitute could be prepared. The limestone for this purpose should be high-calcium in composition, fine-grained, and free from grit. On fine grinding it should yield a snowy white powder. Chemical purity is not essential but is desirable. A great deal of misunderstanding exists regarding whiting substitute. Some manufacturers after trying one whiting substitute and finding it unsatisfactory for their purpose have assumed that all whiting substitutes will likewise prove unsatisfactory, whereas each limestone deposit will yield a whiting substitute with individual characteristics, the suitability of which for various uses can be determined only by actual trial.

Precipitated chalk finds use as a filler and is used in tooth pastes, polishes, and other materials. It may be prepared by saturating milk-of-lime with CO_2 gas. A pure high-calcium lime is required for this purpose.

Pulverized limestone is extensively used in rock-dusting coal mines, and as an asphalt filler. The first-mentioned use requires a non-siliceous limestone preferably one which will yield a light-coloured dust. The British specifications require that 100 per cent shall pass through a 20-mesh screen and 50 per cent through a 200-mesh screen. The chief requirement for an asphalt filler is that it be ground sufficiently fine so that from 65 to 85 per cent will pass a 200-mesh screen and all pass a 30-mesh screen.

The uses of limestone and lime in the *agricultural industry* have been mentioned. Pulverized limestone, applied directly to the soil, functions in correcting soil acidity and also in lightening heavy clay soils by increasing their porosity. It also serves as a plant food. It is used as an active filler in some varieties of chemical fertilizers to counteract the acidity of some of the chemicals. A limestone pulverized to the extent that more than 50 per cent will pass an 80-mesh sieve, 65 per cent pass a 60-mesh sieve, and all will pass a 20-mesh sieve, is said to be very satisfactory for general purposes. It is now generally conceded that dolomite and high-calcium limestone will give equally satisfactory results. Chemical purity is not essential but naturally the limestone with a high percentage of the carbonates of calcium and magnesium will prove more effective on the ton basis than will an impure stone. The Dominion Bureau of Statistics records show 24,962 tons of agricultural limestone valued at \$81,273 used in 1928.

High-calcium lime forms the base in the compounding of fungicides and insecticides such as Bordeaux mixture, lime-sulphur and calcium arsenate. A hydrated lime is used for this purpose and one of the chief requirements is that it be free from grit, because grit will ruin the pumps by means of which the mixtures are sprayed on the trees and crops. Lime is also used in fertilizers and for soil conditioning. The amount of lime reported used for all agricultural purposes during 1928 was 2,874 tons valued at \$22,714.

The *Portland cement industry* is a limestone industry. A finished Portland cement should analyse 60 to 65 per cent CaO , 20 to 25 per cent SiO_2 , 5 to 12 per cent combined Al_2O_3 and Fe_2O_3 , and less than 4 per cent MgO . At several places in Canada an impure limestone is obtainable which on burning will yield a true Portland cement, but in most cases the limestone is too pure, and, to obtain the correct chemical composition, clay or shale must be added before burning. Magnesia is the important factor in

connexion with a limestone for Portland cement manufacture. As previously stated the amount of magnesia in the cement must not exceed 4 per cent. This restriction usually makes it impossible to use any limestone having a content of more than 8 per cent magnesium carbonate. A limestone as low as possible in magnesia is preferred. The production of cement in Canada during 1928 was 11,023,928 barrels, valued at \$16,739,163.

The *crushed stone industry* is practically a limestone industry, 90 per cent of the tonnage of crushed stone, rubble, and riprap being derived from limestone deposits. Rubble is used in building construction; riprap in the construction of wharves, breakwaters, and for protecting the banks of streams and canals against erosion. Crushed stone is used chiefly for road metal, concrete aggregate, and railroad ballast. The impure, siliceous varieties of limestone are utilized for these purposes. Chemical composition is immaterial, the chief requirements being that the limestone be relatively hard and tough and not subject to disintegration under the action of frost and weathering. A minor branch of the crushed stone industry is engaged in the production of stucco dash and poultry grit from white crystalline limestones. The total Canadian production of crushed limestone products for 1928 amounted to over 6 million tons valued at nearly 5½ million dollars.

The uses of limestone as a *building* and *ornamental material* are so well known as to require but passing mention. In this field the physical properties such as weather-resisting properties, hardness, evenness and thickness of bedding, ease of chiselling, colour, evenness and size of grain, and general appearance are the factors which take precedence over chemical purity. Similarly in limes used for building construction, the physical characteristics such as plasticity, time of set, colour, hardness, and strength are of great importance, whereas chemical composition is immaterial except indirectly, inasmuch that limes made from limestones of different purity and composition usually have definite physical characteristics. Thus magnesian limes in general are more plastic than high-calcium limes and are preferred for "finishing" purposes.

The Dominion Bureau of Statistics records show that during 1928, building and ornamental stone (including marble) to the amount of over 309,021 tons valued at \$1,374,257 were produced from Canadian limestone deposits.

There are many other uses for limestone and lime than those above outlined. This is especially true of lime which, by reason of its activity as a chemical base, and on account of its functioning as a precipitant and a solvent, as an oxidizer and a reducer, as a dehydrator and a hydrolizer, is used in the production of a great number of chemicals and in a great number of manufacturing processes.

During 1928 it is estimated that about 11,000,000 tons of limestone was quarried in Canada, which when fabricated into the primary products such as lime, cement, and stone for various purposes, had an initial selling value of \$29,000,000. A preliminary estimate for 1929 places the amount quarried at more than 12,000,000 tons and the value of the products at \$33,000,000. These are tremendous figures and serve very well to show the importance of limestone among our mineral resources. The handicap under

which Canadian industry would labour were these supplies of limestone not available can be easily imagined.

Production of limestone is carried on in seven of the nine provinces—Prince Edward Island and Saskatchewan being the exceptions. The lime industry is established in each of these seven provinces, and Portland cement plants are operated in five of the provinces—the Maritimes and Saskatchewan being the exceptions in the latter case.

Over the eastern half of Nova Scotia, including the island of Cape Breton, there are hundreds of deposits of high-calcium limestone and dolomite, many of which are of excellent quality. Stone for flux, lime, refractory materials, whiting substitute, sulphite-pulp manufacture, and for agricultural purposes, are the chief products.

In southern New Brunswick are large deposits of pure dolomite and high-calcium limestone. Smaller deposits of high-calcium limestone are found in the upper valley of the St. John river and in the northern part of the province. The chief products are lime, agricultural limestone, and stone for sulphite-pulp manufacture.

Quebec has great resources of pure high-calcium limestone but very little pure dolomite. Limestone is well distributed over the southern part of the province and along the north shores of the Ottawa and St. Lawrence rivers between Fort Coulonge and Murray Bay. Limestone also occurs along the Gaspé coast and around lake St. John. The limestone is quarried for a great variety of purposes. At Phillipsburg is the largest marble quarry in Canada.

Ontario has vast resources of both high-calcium limestone and dolomite, and leads the Dominion in the production of limestone and limestone products. From the Ontario deposits, materials for practically every use mentioned in this paper are being supplied. The principal limestone areas are in that part of the province south of the Ottawa river and include some of the finest deposits in the Dominion, both from the standpoint of chemical purity and extent. Other limestone deposits, principally dolomite, occur near lake Timiskaming and on the islands along the north shore of lake Huron. South of James bay a large limestone area is being made accessible by the extension of the Temiskaming and Northern Ontario railway. Western Ontario contains no limestone aside from some calcite veins and some deposits of very impure dolomite. It is into this area that limestone from the United States is imported.

There are two large areas of limestone in Manitoba, one, a belt 100 miles wide extending northwesterly from near Winnipeg to The Pas; the other in the northeast corner of the province bordering on Hudson bay. From the deposits within the first-mentioned area, dolomite and high-calcium limestone of excellent quality are obtained. The Tyndall limestone, quarried north of Winnipeg, has a Dominion-wide fame as a building and ornamental stone. On the Hudson Bay railway, north of The Pas, two marble quarries have recently been opened in deposits of pink dolomite. Quarries are also worked for stone for lime, cement, whiting substitute, crushed stone, sulphite-pulp manufacture, and other purposes.

A belt of limestone crosses northern Saskatchewan but it is far removed from transportation facilities at present.

The limestone resources of Alberta are confined chiefly to the Rocky Mountains area. The eastern ranges of the Rockies are largely limestone, principally high-calcium with some dolomite. The high-calcium limestones are the only ones worked at present. The products are stone for lime, cement, agricultural purposes, and for the rock-dusting of coal mines.

In British Columbia, throughout the interior of the province and along the sea coast are many deposits of limestone, some of which are of great size and many of which are very pure. Deposits of pure dolomite are available but are not common, although bands of dolomite are present in many high-calcium deposits. Production is confined to the high-calcium deposits, and stone for lime, cement, flux, sulphite-pulp manufacture, agricultural purposes, and marble is quarried.

This brief survey has shown that Canada is well supplied with resources of this exceedingly useful mineral. Furthermore the resources are, in the main, well distributed with regard to present and prospective consuming centres, which is a very important factor in considering the supply of any low-priced commodity.

In considering the future possibilities of the utilization of limestone and its products in industry, it is of significance to remember that the use of limestone for such diverse purposes and on such a large scale, has come about practically within the past 50 years. Up to that time the chief use of limestone was for building purposes. To-day there are two main divisions for the use of limestone: 1, construction purposes; 2, chemical and general manufacturing purposes. For structural purposes limestone and its products have always been important materials and doubtless will continue to be for a long time to come. Increasing demand for these materials may be expected with the development of the country and consequent increase in the construction of buildings, canals, piers, concrete and macadam roads, and similar works.

The second and newer division of the use of limestone—that for chemical and general manufacturing purposes—has increased in importance at a very rapid rate within recent years and gives promise of much greater expansion in the future. At present about 1½ million tons of limestone, either raw or calcined, is annually used in Canada for chemical and general manufacturing purposes. This is much more than the total yearly production of limestone for all requirements 25 years ago. For the past five years the Canadian lime industry has annually achieved a new high record in production. This has been brought about almost wholly by the increase in use of lime for chemical purposes. Of the present production of 674,087 tons about 65 per cent goes for chemical uses—the highest percentage on record—whereas 25 years ago these uses accounted for but a very minor part of the production. The amount of lime now used for chemical purposes alone, exceeds by more than two and one-half times the total amount of lime produced for all purposes 25 years ago. The fact that limestone is essential to a great variety of Canadian industries, all of which are capable of great expansion, will ensure its increasing consumption for chemical purposes as time goes on.

Little mention has been made of the chemical uses of dolomite but there are great future possibilities for this variety of limestone in the production of magnesia and metallic magnesium. Magnesia has numerous

uses as a high-temperature insulating material and for refractory purposes. Metallic magnesium may be used in place of aluminium for many purposes and is quite superior for some requirements. It is one-third lighter than aluminium. It is strong, easily machined, and forms valuable alloys. Twenty years ago aluminium was practically unknown. To-day it is a common metal. A similar development may be in store for magnesium. Already production costs are in sight which will enable it to compete in price with aluminium. Dolomite is the most common ore of magnesium and may become the chief source of that metal in Canada.

There are many other potential uses for limestone which undoubtedly will be developed in the future, and there is every reason to believe that owing to its wide distribution, its availability, its cheapness, its great chemical activity when calcined, and its inherent suitability for many uses, limestone will always prove to be a very important material in industry.

V

PRELIMINARY REPORT ON THE LIMESTONES OF BRITISH COLUMBIA

M. F. Goudge

Along the sea coast of British Columbia and throughout the interior of the province are many deposits of limestone, some of which are of great size and many of which are very pure.

The chief products of the quarries include marble, lime, stone for Portland cement, for flux, for use in sulphite-pulp manufacture, and for agricultural purposes.

High-calcium limestones predominate and present production is confined to this variety. Large deposits of pure dolomite are available but are not common, although bands of dolomite occur in many of the high-calcium deposits.

The limestones belong to a number of different formations ranging from Precambrian to Jurassic in geological age. Owing to the action of igneous intrusives and to the action of mountain-building agencies, most of the limestones have been greatly metamorphosed and many are decidedly crystalline. The degree of alteration has naturally varied in different areas, and limestones of the same age, and probably originally quite similar in appearance and composition, are now widely diverse in these two particulars. This diversity renders it very difficult to make general statements about the limestones of any given formation and therefore in this preliminary report a departure is made from the plan followed in the reports on the limestones of other provinces, namely that of generalizing on the characteristics of the limestone of any particular formation and of outlining the distribution thereof, and, instead, brief descriptions are given of the limestone available at properties now being worked, together with a mention of the more important unexploited deposits.

One of the finest deposits of limestone on the entire Pacific coast, from the standpoints of size, quality, and accessibility, occurs on Texada island. This island, 32 miles long and 5 miles wide, is situated in the strait of Georgia. Blubber bay, at the north end of the island, where three companies are operating, is about 70 nautical miles northwest of Vancouver. A belt of high-calcium limestone up to 2 miles in width extends along the northeast coast for 6 miles from the north tip of the island, then turning southerly it crosses to within one-quarter mile of the southwest coast. The land is high and many quarry sites are available. The limestone is enclosed in and invaded by igneous rocks. The igneous intrusions have altered the greater part of what was originally a fine-grained, dark blue limestone to a grey and light blue, medium-grained marble. The larger part of this great limestone belt is high-calcium in composition and very pure, but in some localities are numerous interbeds of dolomite very similar in appearance to the high-calcium material. These dolomite beds, which vary in thickness

from a few inches to an observed maximum of 8 feet, are entirely absent in other areas. The depth to which the limestone extends is not known. At Vananda the shaft of the Marble Bay mine was sunk to a depth of 1,700 feet in the limestone without completely penetrating it and the miners state no change could be discerned in the characteristics of the stone from top to bottom of the shaft.

The Pacific Lime Company of Vancouver operates six vertical draw-kilns at Blubber bay and expect to have a rotary kiln in operation early in 1930. The capacity of the six kilns is 90 tons of lump lime per day. The marketed products include lump lime, crushed lime, hydrated lime, agricultural limestone, and crushed stone for flux and for Portland cement manufacture. Slabs and sawdust from a sawmill operated by the lime company are used as fuel in the vertical kilns. The quarries are adjacent to the lime plant and within 200 feet of the sea. No. 1 quarry, the largest, is 200 feet in diameter and has been worked to a depth of 120 feet. Although the present floor is 50 feet below sea-level the quarry is dry. The stone quarried is indistinctly bedded, blue-grey in colour, fine-grained, and very pure as is shown by the following analyses. It will be observed that the magnesium carbonate content has greatly decreased at depth.

| | A | B |
|--------------------------|--------|--------|
| Silica..... | 0.52 | 0.20 |
| Ferric oxide..... | 0.15 | 0.13 |
| Alumina..... | 0.23 | 0.08 |
| Calcium carbonate..... | 95.07 | 99.09 |
| Magnesium carbonate..... | 4.16 | 0.56 |
| | 100.13 | 100.06 |

A. Top 17 feet in quarry No. 2.

B. Middle section of 47 feet in quarry No. 1.

On the east side of Blubber bay is the newly opened quarry and crushing plant of the British Columbia Cement Company. This quarry has been started to augment the output of the main quarry at Bamberton, Vancouver island. The limestone exposed in the new quarry is apparently all high-calcium, no dolomitic beds being observed. It differs in appearance from the stone quarried by the lime company in being lighter in colour and coarser in grain. Numerous small crystals of pyrite were observed.

Between these two properties is that of Western Lime Products Company, Inc., of Seattle. This company operates a grinding plant for the production of chicken grit and agricultural limestone. The capacity of the plant is 75 tons of pulverized material per day. A vertical, externally-fired lime-kiln constructed of reinforced concrete is also ready for use but was not in operation during 1929. A small quarry has been opened to supply material for the grinding plant. Most of the limestone seen on the property is fine-grained, dark blue, and high-calcium in composition, but interbeds of dolomite are fairly common at the surface. On the south side of a wide dyke of trap rock which bisects the property from east to west, is an

irregular area of pure, white crystalline limestone of medium to fine grain practically free from all visible impurities. It forms a small hill and is in a good position for quarrying. The two analyses below are indicative of the types of stone available on the surface of this property.

| | A | B |
|--------------------------|--------|-------|
| Silica..... | 0.76 | 0.54 |
| Ferric oxide..... | 0.37 | 0.14 |
| Alumina..... | 0.17 | 0.21 |
| Calcium carbonate..... | 92.82 | 97.96 |
| Magnesium carbonate..... | 6.41 | 0.38 |
| | 100.53 | 99.23 |

A. Sample across 30 feet of stone exposed in old quarry 300 feet south of lime-kiln.

B. General sample of white limestone over an area 200 feet square at eastern end of outcrop of this white stone.

At the southeast corner of Sturt (Marble) bay on the east coast of the island, the Powell River Company, Ltd. operates a quarry to supply the limestone requirements of the sulphite mill at Powell River. In this vicinity all the limestone has been altered to a light-coloured marble. The quarry has been worked back from the beach for 100 feet. The present face is 60 feet high and extends for 200 feet parallel to the shore. The stone exposed is interbedded high-calcium limestone and dolomite; the dolomite is greenish grey and generally fine-grained, the high-calcium stone is blue to nearly white and usually medium- to coarse-grained. The apparent dip is inland at an angle of 30 degrees. Small quantities of serpentine are present along joint planes and bedding planes, and tiny crystals of chalcopyrite impregnate the stone in some places. The broken stone is loaded on scows and towed across to Powell River. An average sample of the 60-foot face yielded analysis A. The composition of individual beds is indicated by analyses B and C which were furnished by the Powell River Company.

| | A | B | C |
|--------------------------|--------|--------|--------|
| Silica..... | 2.30 | 0.72 | 0.88 |
| Ferric oxide..... | 0.31 | 0.65 | 0.36 |
| Alumina..... | 0.36 | | |
| Calcium carbonate..... | 84.11 | 62.48 | 98.50 |
| Magnesium carbonate..... | 14.64 | 36.15 | 0.30 |
| | 101.72 | 100.00 | 100.04 |

The Tacoma Steel Company of Tacoma, Washington, formerly burned lime at Sturt bay and also at Limekiln bay at the northwest tip of the island, but both plants have been shut down for a number of years. The limestone burned at Sturt bay was the variable type now being quarried by the Powell River Company for use in the pulp mill; that utilized at Limekiln

bay was a dark blue, fine-grained stone in many respects similar to that in the quarries of the Pacific Lime Company, except that interbeds of dolomite are much in evidence.

The part of the limestone belt extending southerly from Sturt bay across the island to near the southwest coast consists mostly of medium-grained, light blue, high-calcium limestone apparently very pure. There is an enormous quantity of this limestone available in the cliffs, near the southwest shore, which rise to a height of 800 feet or more. The lack of a harbour is the chief drawback.

About halfway down the southwest coast is a separate area of comparatively unaltered, fine-grained, grey and blue, high-calcium limestone. At the southern end of this area cliffs of limestone rise to a height of 900 feet within one mile of the shore. The Tacoma-Texada Lime Company has partly constructed a road, 3,500 feet long, to the limestone from the shore just a short distance south of the point between Mouat bay and Davis bay. The deposit at this place is composed of fine-grained, brittle, grey, high-calcium limestone with which is interbedded an occasional magnesian layer. A series of analyses of the stone over this area shows an average of 2 per cent silica, oxides of iron and alumina, 92 per cent calcium carbonate and 6 per cent magnesium carbonate, with the limits of the latter constituent varying from 1 to 18 per cent in individual beds.

Vancouver island contains a great number of limestone deposits, principally high-calcium, but only three are now being worked.

At Rosebank on Esquimalt harbour the Rosebank Lime Company obtains limestone for the manufacture of lime and also for road metal, chicken grit, agricultural purposes, and for asphalt filler. The products of the lime plant, which consists of two vertical draw-kilns, are lump lime and hydrated lime. The fuel used in the kilns is the waste from an adjoining sawmill operated by the lime company. The limestone deposit takes the form of a low ridge from 100 to 500 feet in width which curves westerly for more than a mile from the shore of Esquimalt harbour. The limestone, which is light blue in colour, very fine-grained, and much fractured, is entirely enclosed in volcanic rock, and dykes of this material varying in thickness from a few inches to 50 feet cut the limestone in all directions. A number of quarries of the side-hill type have been opened along the ridge; the one from which the stone for lime is obtained is 3,000 feet from the kiln and is connected by a narrow gauge railway. The stone differs in quality, particularly as to the silica content, in different parts of the ridge. The following analysis furnished by the lime company represents the composition of the stone delivered to the kilns.

| | |
|---------------------------------|-------|
| Silica..... | 0.95 |
| Oxides of iron and alumina..... | 0.29 |
| Calcium carbonate..... | 98.89 |
| Magnesium carbonate..... | 0.40 |

100.53

The British Columbia Cement Company obtains limestone for the manufacture of Portland cement from the quarry adjacent to the plant at Bamberton on Saanich inlet. The limestone occurs in the form of an almost vertical lens in the face of the mountain. Volcanic rock surrounds the

limestone lens and tongues of it penetrate the latter in all directions to such an extent that the deposit is suitable only for the purpose to which it is being put.

Limestone for use in the Port Alice plant of the British Columbia Pulp and Paper Company is being quarried on an island near the head of Quatsino sound on the west coast of Vancouver island. This locality was not visited by the writer. An analysis supplied by the paper company of the average quality stone as delivered to the mill is as follows:—

| | |
|---------------------------------|-------|
| Silica..... | 1.3 |
| Oxides of iron and alumina..... | 0.6 |
| Calcium carbonate..... | 92.1 |
| Magnesium carbonate..... | 6.0 |
| | 100.0 |

Particularly large deposits of crystalline high-calcium limestone are reported to occur in the vicinity of Nootka sound¹ and Nitinat lake² also on the west coast.

At Beaver cove on the northeast coast of Vancouver island a belt of crystalline high-calcium limestone forms a high bluff along the west side of Tsultan creek about 1½ miles from tidewater.

A deposit of fine-grained, grey-blue, high-calcium limestone covering about 90 acres occurs on the property of Mrs. Walter Luney at Cobble Hill near Shawnigan lake at the southern end of the island. Much of this deposit is highly siliceous but some portions seem very pure. Many other deposits of similar stone but of smaller extent are reported in this part of the island.

In addition to the limestones on Texada and Vancouver islands there are along the sea coast, from Jervis inlet to Portland canal, a great number of limestone deposits enclosed in igneous rocks. The deposits are of all degrees of purity and practically all are highly crystalline. Many consist of intermingled high-calcium limestone and dolomite, with the former as the main constituent; others are almost wholly calcium carbonate.

On the northwest shore of Nelson island near the head of Blind bay, the Blind Bay Lime Company is quarrying limestone for use in pulp mills from a vertical band of white, crystalline limestone averaging 90 feet in width and which can be traced up the mountain side to an elevation of 900 feet. The limestone is intersected by a network of igneous dykes, which causes a great deal of waste in quarry operations. The igneous material, intimately associated as it is with the limestone, does not appear to have caused any silicification. An analysis furnished by the British Columbia Pulp and Paper Company of the average grade of stone shipped from this deposit to their mill at Woodfibre is:

| | |
|---------------------------------|-------|
| Insoluble..... | 0.83 |
| Oxides of iron and alumina..... | 0.50 |
| Calcium carbonate..... | 97.78 |
| Magnesium carbonate..... | 0.10 |
| | 99.21 |

¹ Parks, W. A.: "Building and Ornamental Stones of Canada", vol. V, Mines Branch, Dept. of Mines, Canada, Rept. 452, pp. 163-171 (1917).

² Clapp, C. H.: Geol. Surv., Canada, Mem. 13, p. 44 (1912).

This deposit is owned by the Nelson Island Lime Company, Vancouver.

The Coast Calcite Company, Vancouver, has opened a small quarry in a very large deposit of white, coarse-grained crystalline limestone which outcrops on the north shore of Smith inlet about 3 miles from the head. The limestone is seen on both shores of the inlet but has its greatest width, about 2,300 feet, on the north shore. It can be traced for a long distance up the mountain side. As is the case with most other deposits along the coast the limestone is traversed by a great number of dykes of trap rock. Most of these dykes follow the trend of the limestone belt but there are also some transverse dykes. Rarely is there a width of 25 feet of limestone free from the igneous material. The major part of the deposit is an intimate mixture of high-calcium limestone and dolomite, each of a high degree of purity. The mixture of the two, while undesirable for many purposes, is not detrimental in limestone for use in the tower system of sulphite-pulp manufacture, many sulphite mills desiring a stone intermediate in composition between a high-calcium limestone and a dolomite.

The Beale Limestone Quarries property is on the south side of Cunningham island, off Gunboat passage, 22 miles from Ocean Falls. At this place a wide band of white, coarsely crystalline, high-calcium limestone extends inland for at least 3 miles. A quarry face of 40 feet across a width of 600 feet of limestone is available above high water, and inland the band attains a height of 700 feet or more. Dykes of trap rock and an occasional tongue of granite intersect the limestone at the south termination of the band, but these intrusions are much less noticeable at other points farther north. A noteworthy feature is the absence of streaks and masses of dolomite so characteristic of the majority of the limestone deposits along the coast. The only visible impurities other than the dykes are films of serpentine, pyrite, and brown mica which have a limited development in the limestone adjacent to some of the large igneous intrusions. This impure limestone is not quarried. Three quarries of the side-hill type and an underground chamber have been opened at the southern tip of the belt. The stone as quarried is shipped on scows to Pacific Mills, Ltd., at Ocean Falls where it is crushed and afterwards converted to lime in an oil-fired rotary kiln. The lime is used in the manufacture of both sulphite and sulphate pulp. An analysis supplied by the paper company as being representative of the average grade of stone from Beale Limestone Quarries is:

| | |
|---------------------------------|-------|
| Silica..... | 1.00 |
| Oxides of iron and alumina..... | 0.29 |
| Calcium carbonate..... | 98.66 |
| Magnesium carbonate..... | trace |
| | 99.95 |

Previous to 1927 the Granby Consolidated Mining, Smelting and Power Company quarried limestone for flux at Swamp point on the Portland canal where a blue siliceous limestone with a low content of magnesium carbonate was obtained.

There are many other deposits of limestone along the coast aside from those already mentioned. Of these, important ones in point of size and quality occur at the following places: at the head of Kumealon inlet, off Grenville channel; on the east shore of Aristazable island; near the mouth

of Koey river off Fitz-Hugh sound; at False inlet on the north shore of Rivers inlet; at the southeast end of Harbledown island; at Open bay on the south side of Quadra island.

Within the interior of the province limestone deposits are very numerous adjacent to rail and lake transportation.

In the lower Fraser River valley there are a number of deposits which although quite siliceous have a low content of magnesium carbonate. The more accessible of the large deposits have been acquired by parties interested in their future possibilities for the manufacture of Portland cement. At Popkum a siliceous blue limestone is being quarried and pulverized for agricultural purposes by Western Canada Lime Company. On analysis a sample of pulverized limestone from this property showed:—

| | |
|--------------------------|--------|
| Silica..... | 10.48 |
| Ferric oxide..... | 0.26 |
| Alumina..... | 0.16 |
| Calcium carbonate..... | 87.09 |
| Magnesium carbonate..... | 2.10 |
| | 100.09 |

Between Agassiz and Yale only a few narrow bands of impure limestone were observed, but along the valley of the Thompson river from Spence Bridge to Ashcroft are many large exposures of fine-grained, light blue, high-calcium limestone associated with argillite. Some of the outcrops are of a limestone filled with flinty nodules and also intersected by dykes of trap rock, but others again are of good quality. Illustrative of the latter is an extensive deposit adjacent to the Canadian National railway, 7 miles north of Spence Bridge. The analysis of a 75-foot width of this deposit is as follows:—

| | |
|--------------------------|-------|
| Silica..... | 1.44 |
| Ferric oxide..... | 0.27 |
| Alumina..... | 0.17 |
| Calcium carbonate..... | 97.68 |
| Magnesium carbonate..... | 0.42 |
| | 99.98 |

North and east of Kamloops are many outcrops of blue, medium- to fine-grained, high-calcium limestone containing nodules of flint, but deposits comparable in quality to that shown in the above analysis are also available. The most extensive outcrop of the pure stone is well up on the slope of the hill on the north side of the South Thompson river, 12 miles above Kamloops.

Limestone deposits of large size and apparently good quality are found in the vicinities of Salmon Arm and Armstrong. Three and one-half miles northeast of Armstrong a quarry was opened by Land Limes, Ltd., in a 25-foot vertical band of fairly pure, high-calcium limestone, enclosed in slate, to obtain stone for agricultural purposes. The plant has not been in operation for the past several years.

On Upper Arrow lake, at Arrowhead, and on Lower Arrow lake, 5 miles north of Deer Park, are extensive deposits of high-calcium limestone.

North of both shores of Sidmouth lake and in the vicinity thereof are a number of deposits of crystalline limestone enclosed in gneisses, schists,

and granite. Quarries have been started in several of the deposits to obtain material for marble, flux, and lime. The only quarry being worked at present is that of the Canadian Marble and Granite Company north of Marblehead station on the Lardeau-Gerard branch of the Canadian Pacific railway. At this point a band of blue and white crystalline limestone outcrops immediately west of the track and at the same elevation. The band has a thickness of at least 100 feet and can be seen at intervals for 1,000 yards along the track. It dips at 40 degrees to the northeast. The greater part of the band is blue, but extending horizontally through the blue is a 15-foot zone of white and bluish white marble varying from fine to moderately coarse in grain. It is the white stone which is sought by the marble company. The workings consist of a tunnel about 35 feet long opening into a large underground chamber which has been developed by a steam channelling machine. Massive bedding permits the extraction of large blocks. The greater part of the band with the exception of the lower 10 feet of the white zone is pure limestone. In the lower portion of the white zone are a great many veinlets and lenses of highly siliceous material. Analysis A is from a channel sample across 25 feet of blue stone above the white. Analysis B is representative of the top 5 feet of the white stone.

| | A | B |
|--------------------------|-------|--------|
| Silica..... | 0.36 | 0.24 |
| Ferric oxide..... | 0.45 | 0.16 |
| Alumina..... | 0.01 | trace |
| Calcium carbonate..... | 90.75 | 99.07 |
| Magnesium carbonate..... | 8.42 | 0.71 |
| | 99.99 | 100.18 |

On the same line of railway about one-half mile north of Lardeau is a quarry from which the smelter formerly in operation at Nelson obtained limestone for flux. Thin interbeds of quartzite would impart a high silica content to shipments from here.

Other deposits on the shores of Kootenay lake consist of intermingled high-calcium limestone and dolomite, the two being so intimately associated as to preclude the separate quarrying of either. The principal deposits are at the Bluebell mine opposite Ainsworth and at the old marble quarry opposite Kaslo.

Dolomite of a high degree of purity is available in unlimited quantity on the mountain side east of Windermere lake. An entire spur of the mountain one mile southeast of Fairmont Springs and immediately south of Fairmont creek is composed of fine-grained, massive, blue dolomite of very uniform composition.

The following analyses of samples taken at widely separated points on this mountain spur indicate the quality and uniformity of the dolomite:

| | | |
|--------------------------|--------|--------|
| Silica..... | 0.70 | 0.24 |
| Ferric oxide..... | 0.43 | 0.50 |
| Alumina..... | 0.20 | 0.12 |
| Calcium carbonate..... | 55.70 | 55.66 |
| Magnesium carbonate..... | 43.58 | 43.95 |
| | 100.61 | 100.47 |

The dolomite was sampled at this locality on account of it being the nearest to railway transportation, Radium station on the Canadian Pacific railway being 2 miles to the west. There are numerous other places in the vicinity where dolomite of similar appearance is available.

On both sides of the Kootenay river near Wardner are many extensive outcroppings of blue-grey limestone. In most of the outcrops there is either much flint or else much interbedded shale, but in several places a high-grade limestone similar in composition to that shown in the analysis below is available for quarrying.

| | |
|--------------------------|-------|
| Silica..... | 0.14 |
| Ferric oxide..... | 0.07 |
| Alumina..... | 0.09 |
| Calcium carbonate..... | 93.59 |
| Magnesium carbonate..... | 5.82 |
| | <hr/> |
| | 99.71 |

The sample from which this analysis was made was obtained from the ridge immediately to the west of and above the railway cutting about 4 miles north of Wardner, where there is a very large deposit of pure limestone. Elsewhere in the vicinity the limestone contains much more magnesium carbonate.

In the area between and to the north of Fife, Grand Forks, and Midway, limestone deposits are very abundant. North of the station of Fife on the Kettle Valley branch of the Canadian Pacific railway the Consolidated Mining and Smelting Company obtains limestone for use as flux in the Trail smelter. The deposit occurs in the form of a belt 400 to 800 feet in width enclosed in volcanic rock. It can be traced for more than two miles from a point above the east shore of Christina lake up over a high ridge. As is the case with the majority of deposits enclosed within igneous rocks, tongues of the igneous material penetrate the limestone in all directions. The greater part of the limestone is blue in colour and is medium-grained. In composition it is high-calcium but somewhat siliceous. It is won by glory-hole methods, the glory holes being located at the highest point on the deposit about 1,000 feet above the railway. From the glory-hole tunnel the broken stone is conveyed by cable cars down to the siding on the Canadian Pacific railway. An analysis of the limestone free from igneous dykes is as follows:

| | |
|--------------------------|-------|
| Silica..... | 2.72 |
| Ferric oxide..... | 0.16 |
| Alumina..... | 0.18 |
| Calcium carbonate..... | 96.11 |
| Magnesium carbonate..... | 0.53 |
| | <hr/> |
| | 99.70 |

The Similkameen valley contains a number of limestone deposits. At Hedley lime is produced in a pot kiln by F. Lyon. The entire production is taken by the Hedley Gold Mining Company for use in the cyanide mill. The quarry is located in a 30-foot band of massive, light-blue, medium-grained limestone which occurs about 500 feet up from the base of Nickel Plate mountain. The band is overlain and underlain by siliceous altered

limestone. The stone is drilled by hand, blasted out with dynamite and rolled down the steep talus slope to the kiln at the base of the mountain. A sample taken across the 30-foot band yielded the following analysis:

| | |
|--------------------------|-------|
| Silica..... | 2.90 |
| Ferric oxide..... | 0.20 |
| Alumina..... | 0.29 |
| Calcium carbonate..... | 93.43 |
| Magnesium carbonate..... | 2.86 |
| | 99.77 |

There are many other belts of limestone in Nickel Plate mountain, indeed the mountain is largely composed of limestone into which have been injected numerous tongues and sills of igneous rock. The greater part is impure and studded with nodules of flint. Similar stone is seen across the Similkameen river.

The Marble mountains between Lillooet and Clinton are, as the name implies, composed principally of limestone much of which is exceedingly pure as is indicated by the following analysis made of a sample obtained at the eastern end of the Marble canyon on the highway from Cache Creek to Pavilion.

| | |
|--------------------------|-------|
| Silica..... | 0.20 |
| Ferric oxide..... | 0.08 |
| Alumina..... | 0.06 |
| Calcium carbonate..... | 99.02 |
| Magnesium carbonate..... | 0.59 |
| | 99.95 |

The Pacific Great Eastern railway serves this district.

Along the line of the Canadian National Railway between Jasper, Alberta, and Prince Rupert, limestone is also available. One mile east of Grant Brook station a band of dolomite, averaging 400 feet in width and dipping almost vertically, outcrops in a series of cliffs along the mountain to the north of the track. The entire belt has been altered to a fine-grained marble of pink and bluish white tints through which are irregular veins of yellow, green, and white. An occasional stringer of white quartz was observed in some zones. Toward the edges of the belt thin seams of shale occur between the dolomite beds. The variation in composition between the edges and the centre of the belt is illustrated by the following analyses:

| | A | B | C |
|--------------------------|--------|--------|--------|
| Silica..... | 5.42 | 1.24 | 3.96 |
| Ferric oxide..... | 0.62 | 0.44 | 0.61 |
| Alumina..... | 1.66 | 0.51 | 0.81 |
| Calcium carbonate..... | 52.62 | 55.09 | 53.43 |
| Magnesium carbonate..... | 40.19 | 43.43 | 41.94 |
| | 100.51 | 100.71 | 100.75 |

A. Pink marble 25 feet thick along south edge of belt.

B. White and bluish white marble 100 feet thick adjoining the pink band.

C. Deep-pink marble 50 feet thick on north edge of belt.

Three miles west of Urling a spur track over a mile long has been built to a large outcrop of fine-grained, crystalline, magnesian limestone on the banks of Ptarmigan creek. The stone was used for railway ballast. In chemical composition the deposit is extremely variable.

East of Prince George between Lindup and Hansard, high-calcium limestones are available in quantity. Just west of Hansard a ridge of fine-grained, blue limestone having the following analysis occurs immediately south of the railway track.

| | |
|--------------------------|-------|
| Silica..... | 1.68 |
| Ferric oxide..... | 0.33 |
| Alumina..... | 0.35 |
| Calcium carbonate..... | 95.41 |
| Magnesium carbonate..... | 0.90 |
| | 98.67 |

Eighty miles east of Prince Rupert, near Shames, a very large deposit of crystalline, light-coloured limestone is exposed on the mountain side north of the railway.

MINES BRANCH
DEPARTMENT OF MINES

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