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HON. ARTHUR MEIGHEN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER

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EUGENE HAANEL, PH.D., DIRECTOR

PHOSPHATE

IN

CANADA

BY

Hugh S. Spence, M.E.

OTTAWA
GOVERNMENT PRINTING BUREAU
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AUTHOR'S PREFACE.

Between 1883 and 1891, phosphate mining was an important industry in Canada, the average annual output of apatite being about 25,000 tons. This amount appears comparatively trivial at the present time, when the world's total annual production is figured in millions of tons; but at the period mentioned the Canadian output constituted quite an important proportion of the total supply.

While the discovery in more recent years of enormous deposits of sedimentary phosphate in various parts of the world has reduced the Canadian apatite bodies to a position of relative unimportance, and has brought about an almost complete cessation of mining, owing to the cheapness with which the bedded deposits can be worked, Canada yet possesses quite material reserves of apatite. At the present time few uses are known for this mineral that cannot be met almost as well by the cheaper, sedimentary phosphate, and consequently the demand for it is small.

Apatite, however, differs from ordinary commercial phosphate rock mainly in that it is a definite mineral species, possesses crystalline structure, and contains a considerably higher percentage of phosphoric acid; sedimentary phosphate, on the other hand, is usually amorphous, and almost always contains an appreciable amount of impurities in the shape of organic matter, clay, lime, sand, etc., much of which remains even in the most carefully washed rock. While, therefore, there is little prospect of apatite being employed in the fertilizer industry, which at the present time consumes almost all of the phosphate rock mined, there still exists the possibility that industrial research may result in new uses being discovered for the purer crystalline phosphate, and that demand for this class of mineral may lead to a re-working of the old apatite mines, and to a search for new deposits.

In the following pages are given the available data on the phosphate mines in the Provinces of Quebec and Ontario, as well as on the Canadian phosphate industry in general.

With regard to the particulars here given of former conditions and work at the Canadian phosphate mines, the somewhat lengthy period that has elapsed since the majority of these mines were last worked has necessitated much of the data being compiled from old records and reports.

It should be explained that the field work for this report was carried out during 1911 and 1912, and that the data here presented forms only a portion of a more comprehensive report prepared by the writer, and submitted for publication in 1914. The report in question dealt with the occurrence of phosphate not only in Canada, but in all parts of the world, and discussed at length the more important of the world's phosphate deposits. In addition, one section of the report was devoted entirely to the technology of phosphorus products, and contained a full description of the methods of manufacture of phosphatic fertilizers, together with cuts of the various machines and appliances used in the industry, flow sheets, diagrams, etc.

In view of Canada's status, at the present time, as virtually a non-producer of phosphate, it was decided that it might be difficult to justify the publication of a comprehensive monograph of the above nature, and accordingly, the writer was instructed to condense the material as much as

practicable, and at the same time to divide the report into two parts, one of which should deal with phosphate and the phosphate industry in Canada, and the other with phosphate in foreign countries and the technology of phosphate. These instructions were followed, but publication of the revised reports was again deferred owing to the war. In view, however, of the numerous inquiries that are constantly being received by the Mines Branch, both from Canadian and foreign quarters, regarding the country's phosphate resources, and the possibility of obtaining supplies of Canadian apatite, it has been deemed a matter of expediency that the available information on this subject should be placed at the disposal of those interested. The following report is designed to serve that purpose. The material contained in it has been still further cut down since the first revision, and a large number of the original illustrations have been omitted. Statistics of production, exports, etc., have, however, been brought up to date, and the section dealing with the status of the phosphate industry—both in mining and manufacturing—has been revised in accordance with information procured in 1919-20. A few small shipments of phosphate have been made either from newly discovered deposits or from old mica-apatite mines since the original field work in the region was carried out; but conditions at the great majority of properties remain substantially as described in this report.

Although it has not been found expedient to make use in a published form of a great deal of the data collected from various sources regarding phosphate in foreign countries and the phosphate industry generally, the writer's thanks must be extended to the numerous individuals, companies, and departments of foreign governments that acceded so readily to requests for information, and contributed so much valuable data in the form of reports, statistics, drawings, maps, flow-sheets, etc. Much of this information was secured through the kind assistance of Mr. W. L. Griffith, Secretary to the High Commissioner for Canada, in London, who went to considerable trouble to obtain the desired data, and to whom the writer desires to express his grateful acknowledgments. Acknowledgments are also due to mine operators, company officials, and others in Canada, who have kindly afforded the writer useful data in connexion with various phases of the phosphate industry.

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PHOSPHATE IN CANADA.

CHAPTER I.

REVIEW OF THE PHOSPHATE INDUSTRY IN CANADA.

INTRODUCTORY.

The inception of the phosphate mining industry in Canada may be placed about the year 1870, there being a recorded output[1] during that year of 1,200 tons, valued at the mine at $13,600. The whole of this quantity was produced from two mines in the township of North Burgess, Lanark county, Ontario, part being shipped to Great Britain and part being consumed in the manufacture of superphosphate at the Brockville Chemical Company's works, Brockville, Ont. The mining for phosphate carried on previous to 1870, was of an exploratory nature only,[2] a few small surface pits having been opened in the townships of North and South Burgess, and North Elmsley, Ontario. Between 1870 and 1875, however, considerable interest began to be shown in the already known deposits of apatite in the Province, to which attention had been called in various reports of the Geological Survey[3]; and in the annual publications of the "Survey", between the years mentioned, are to be found numerous details of the mining operations carried on in search of apatite. Full references to the information contained in these reports will be found after the descriptions of the individual mines on pages 41-103; but it may be advisable to enumerate here the principal sources of information —

Report of Progress, 1870-71, pp. 316-320.
Report of Progress, 1871-72, pp. 123-129.
Report of Progress, 1872-73, pp. 173,177.
Report of Progress, 1873-74, pp. 109-139.
Report of Progress, 1874-75, pp. 108-112.

In the last named report, Mr. Vennor mentions an almost complete cessation of mining, and advances, as reasons for this state of affairs, the high prices demanded for mineral lands believed to carry phosphate; the injudicious expenditure of capital for expensive machinery; and the high freight charges to England prevailing at that time. The greater quantity of the apatite mined was marketed in Great Britain, a small amount, only, being shipped to the United States; while the remainder was consumed at the works of the Brockville Chemical Company. This company operated its own mines in North Burgess township for a certain period, and for some time, constituted practically the only producer in the Province.

Previous to 1875, little attention had been paid to the occurrence of apatite in the Province of Quebec, but with the temporary cessation of mining in Ontario, interest commenced to be shown in the phosphate deposits of the former Province. Between 1875 and 1880, a number of mines

[1]Geol. Surv. Can., Rep. Prog., 1871-72, p. 147.
[2]Geol. Surv. Can., Rep. Prog., 1863, pp. 469, 761; Rep. Prog., 1866, pp. 224-229.
[3]Loc. cit.

were opened up in the townships of Wakefield, Templeton, and Hull; and it was discovered that the mode of occurrence of the apatite in many of the deposits was even more favourable to the extraction of relatively large amounts of clean mineral than was the case in Ontario. Practically, the entire production of the Province found its way to superphosphate factories in Great Britain; and the Quebec deposits began to be regarded as an important and valuable source of rock phosphate. Not only the extent of the deposits, but also their favourable situation—located as they were, in many instances, within comparatively easy reach of water transport to the port of Montreal—caused hopes to be entertained, that an ever increasing industry would ultimately be established. The demand for raw phosphate by factories in Great Britain, and the purity of Canadian apatite, caused high prices to be realized at this period for shipments; and the highest representative[1] values ever secured for Canadian phosphate are shown by the statistical records for 1881-84. A fairly high level of prices was maintained for some ten years, continuing through the so-called "phosphate boom" of the late eighties and early nineties, after which, owing to the rapidly increasing production of the southern United States, prices suffered a speedy and serious decline.

It was during the period of this "boom" that the extensive apatite bodies of the Lièvre River district were opened up by syndicates and exploited on a large scale. The majority of the companies operating in this area were organized and capitalized in Great Britain and the United States; while one important operator was a French concern. Most of these companies installed large and expensive plants, and employed large numbers of men; by 1892, however, practically all had abandoned operations, and the majority of the mines have been idle ever since. It may reasonably be doubted—taking into consideration the expenditure upon machinery, etc., heavy working costs, transportation charges, and other details—whether the extraction of the phosphate bodies in this area proved a really profitable undertaking; and it seems probable that, while a margin of profit may have been maintained in some cases, the capital of many of the companies was gradually swallowed up in meeting working expenses.

That there was, however, a considerable margin of profit in the early days of mining for those operators who were fortunate enough to be working massive deposits of pure phosphate, and not bodies of mixed pyroxene and apatite; and who had not committed themselves to any excessive outlay for plant, is evident from figures quoted in the earlier numbers of the Canadian Mining Review. In 1883, for example, the cost of mining in the Lièvre River section was placed at from $4 to $7 per ton; while the price paid f.o.b. cars at Buckingham was from $15 to $20 per ton for mineral carrying 80 per cent tricalcic phosphate, with 0·4 cents rise per additional unit. The price went as high as $23 in some cases. Freight rates from Montreal to London and Liverpool for the year quoted were $2.50–$3 per ton, and rail freight from Buckingham to Montreal, $1.50. In 1885, ocean freight rates were reduced considerably, only 75c.-$1.25 being asked from Montreal to Liverpool. The cost of transport by scow from High Falls

[1]The disproportionately high unit values shown in Table III for shipments of Quebec phosphate in the years subsequent to 1898 can be taken as no correct indication of the true value of the mineral; the production for these years was, in most cases, small, and the declared value (as supplied to the Customs Department) cannot be considered as representing the actual market price.

to Buckingham in the same year was from 35 cents to 60 cents per ton.

Practically only 80 per cent mineral was shipped to Europe, the price for the lower grades sinking rapidly with every unit under this percentage. In 1886, however, several grinding mills were established at Buckingham, and these continued for some years to handle lower grade apatite for export to the United States. The amount of ground phosphate thus exported totalled 1,106 tons in 1886, 5,467 tons in 1887, and 6,913 tons in 1888.

It is difficult to form any estimate of the total output of any individual mine. Even the aggregate production figures, in the earlier years (see Table II) were obtained largely from statements furnished by the railway companies or their agents; or represented estimates formed by individuals interested in the industry. These figures are by no means exact, and no system of securing production returns from the various operators was then in vogue. It would probably be well within the mark to place the total phosphate output from the Province of Quebec at under 300,000 tons.

The price of 80 per cent mineral during the period of greatest mining activity, namely 1882-90 was as follows[1]:—

1882	17d.	+ 1/5 d. rise per unit of bone phosphate.
1883	16d.	"
1884	13d.	"
1885	13d.	"
1886	12½d.	"
1887	11¾d.	"
1888	11½d.	"
1889	12½d.	"
1890	15¾d.	"

per ton delivered at Liverpool. For lower grades, the prices in 1890 were: 70 per cent 12½d., 60 per cent 10d., with no rise. Wages in 1890 were:—

Foreman	$2.50
Miners	$1.25
Cobbing boys	50c.–70c.

In this year, also, the cost of apatite placed aboard scow on the Lièvre river had advanced to as high as $8; the increased cost being due to deeper mining, pumping, etc. The average expense entailed per ton for shipment from mine wharf to Europe in 1890 amounted to about $5.

The effects of the competition by Florida phosphate upon the Canadian industry were first felt in August 1890, and in the following year two of the largest producers, the Emerald and North Star mines, were closed down. Almost simultaneously with the discovery of the Florida deposits—which discovery effectually killed Canadian phosphate mining— a project was floated in London, that had for its ostensible objective the acquiring, control, and development of the whole of the Canadian phosphate mines. It was evidently designed to corner the Canadian phosphate supply. The name of the syndicate which chose this unfortunate time for its operations, was the Phosphate Corporation, Ltd., and its promoters numbered amongst them many eminent financiers. The concern was capitalized at $5,000,000, and steps were promptly taken to acquire a large acreage of phosphate lands, including the High Falls, Ross Mountain, and Murphy mines. Before any attempt at systematic mining could be undertaken, however,

[1]Liverpool market quotations: 1d.=2 cents.

it became evident that, in the face of the increasing output of cheap Florida phosphate, it was hopeless to expect to mine apatite at a profit, hence the project ended in failure.

While not comparing with the Province of Quebec as regards output, Ontario, also, experienced a revival in the phosphate industry during the late eighties, and an annual production of about 2,000 tons was maintained for some years.

The year 1894, however, marks the final activity in either Province amongst phosphate operators. Since that date, the production of Ontario has been practically negligible, while in Quebec the annual output has only rarely exceeded the thousand ton mark. Exports of phosphate from Canada have entirely ceased, and the small home demand is supplied by imports of Florida and Tennessee mineral, augmented by small amounts of apatite derived from domestic mica mines. The mica mines which produce these small quantities of phosphate, as a by-product, are located chiefly in Quebec province, the productive mica-bearing leads in Ontario seldom carrying apatite in any large amount. Mica operators store the apatite they extract until several hundred tons have accumulated—the time needed to collect this quantity often being several years. In some years, however, practically no such apatite stocks are found to be on hand, and the consequent shortage leads to desultory mining of small scattered deposits of more or less pure phosphate.

The principal consumers of phosphate rock in Canada are the Electric Reduction Company and the Capelton Chemical and Fertilizer Company, both located at Buckingham, Que., and producing phosphorus and superphosphate respectively; the Standard Fertilizer Company, of Smiths Falls, Ont., a small concern, which manufactures acid phosphate and small amounts of phosphatic fertilizer; Gunn's Ltd., Toronto; and the Steel Company of Canada, Hamilton, Ont. The last named imports, annually, some 1,000 tons of low grade, calcined, phosphate rock, for use in increasing the phosphorus content of pig iron. The three first named firms are the only concerns which figure at all as consumers of domestic phosphate; the first two, being located within a few miles of the mines, constitute, at the present time, practically the only market for the Quebec production. The total annual consumption of raw phosphate in Canada to date, has probably not exceeded 10,000 tons, of which amount domestic mineral represents a negligible percentage. According to R. W. Stone[1], the United States exports of phosphate rock of all grades to Canada, in 1918, totalled 14,243 long tons, valued at $105,702.

The price offered in Buckingham for the highest grade of apatite (80 per cent and over tri-calcium phosphate) averages about $11 per ton; while the highest bids of European consumers during recent years have not much exceeded $10 per ton c.i.f. European ports. The prices offered, both in the local market and by foreign consumers, are, thus hardly sufficient to encourage any active mining; and except in rare instances, where large bodies of relatively pure apatite are encountered in mica mines, operators seldom trouble to extract the mineral. Where clean apatite occurs in quantity with mica, it is usually stock-piled, little more labour being entailed in sorting out and stacking the apatite than is required to handle dead rock.

[1]Mineral Resources of the United States, 1918, Part II, p. 206..

Little attention is paid to second grade mineral, consumers preferring the clean, lump phosphate. and offering a very low price for the screened "seconds."

From the foregoing it will be apparent that the phosphate mining industry in Canada has been steadily declining during recent years. From Table I it will be seen that the production in 1919 (24 tons) was the lowest ever recorded since the commencement of mining.

The cause of the final decline of the industry is due to the fact that foreign (chiefly Florida and Tennessee) phosphate can be imported into Canada more cheaply than the domestic mineral can be mined and delivered at the works. Florida pebble phosphate can be laid down at Buckingham, Que., at about $10 per ton, $5 to $6 of which represents freight charges; there is, thus, a saving of at least $1 per ton in favour of the imported mineral[1]. Additional factors are (1) that the amount of domestic phosphate available under present conditions is not adequate to supply the entire needs of consumers, who would, in any case, have to import a certain quantity of foreign mineral; (2) that the domestic supply is decidedly intermittent, being derived almost entirely from small mines; and (3) that in some cases, sedimentary phosphate is preferred to the massive, crystalline, apatite of the Canadian deposits, owing to its being more readily soluble in acid.

That large amounts of apatite still exist in the formerly exploited Canadian deposits, more especially in those of the Lièvre River district, in the Province of Quebec, is unquestionable. When the large mines in this area closed down in the early nineties, it was simply on account of the drop in price of the mineral, and not because the deposits were exhausted.

The deepest mine in the district—the North Star, in the township of Portland East—was shut down with large bodies of apatite still in sight at 600 feet; and there is no reason to suppose that the majority of other large mines in the district, opened on deposits of a similar nature and carried, in most cases, to only shallow depths, were by any means worked out. The accessible portions of many of these mines still display considerable quantities of phosphate in pockets and bunches in the walls of the openings; and there is little doubt that large bodies of mineral still remain, both in the deeper portions of the deposits and also in some cases, in the pyroxenic rock adjacent to the main openings. Whether these bodies of phosphate can ever become available is highly problematical. The enormous deposits of sedimentary phosphate which have been discovered in various parts of the world, more particularly in the United States—deposits that can be easily and cheaply mined by means of dredges, steam shovels, or ordinary quarry methods—provide a source of raw mineral phosphate, the extent of which it is difficult to estimate, and compared with which Canadian apatite resources would show as an almost negligible quantity.

At the present time, the greater number of fertilizer works in Canada import the acid phosphate which they consume, in the prepared state;

[1]It must be added that there is, properly speaking, no real domestic market quotation for apatite at the present time, the current value being simply the price offered by the two works at Buckingham. These concerns offer a slightly higher price per ton than that for which they can import foreign mineral, owing to the higher percentage of tri-calcium phosphate contained in apatite, while the producers, on principle, usually stipulate for a yet higher price; the latter amount, however, does not pretend to represent the amount for which apatite can be mined on a commercial scale.

finding it cheaper to do this than to go to the expense of installing an acidulating plant, and importing crude rock.

Although the use of fertilizers in Canada is increasing, and must necessarily continue to do so, more especially in the Prairie Provinces, it is practically out of the question that the domestic apatite deposits can ever be exploited economically to meet the home demand for crude phosphate. The distance of the deposits from the grain-growing districts, also, would dispose of any question of shipping acid phosphate from the east, especially as extensive deposits of sedimentary phosphate have been shown to exist in Montana and Wyoming—deposits which will constitute a far readier and more accessible source of supply of crude mineral.

Experiments have been conducted in many countries to test the fertilizing properties of finely ground, crude phosphate rock, and the results point to the fact that the phosphoric acid of very finely powdered, untreated phosphate is capable of being assimilated by plant growth. A *sine qua non* in employing raw phosphate rock, however, is that an abundance of decaying organic matter be present in the soil, the decomposition of which promotes the growth of soil bacteria which, in turn, produce so-called humus or soil acids, these attacking the phosphate and liberating available phosphoric acid from the insoluble rock. It is doubtful, however, whether the crystalline apatite of the Canadian deposits, even in a very finely ground form, is capable of being readily attacked by soil acids, and induced to part with its phosphoric acid content. For use as "floats," amorphous, sedimentary phosphate is better adapted, being more readily soluble, and requiring to be less finely ground. Experiments in the use of ground, crude phosphate, have been conducted in Canada at the Ontario Agricultural College, Guelph, Ont., and at the Central Experimental Farm, Ottawa, but up to the present only negative results have been obtained[1].

Considering all aspects of the case, therefore, it can but seem highly improbable, at the present time, that the apatite mining industry in Canada will experience a recrudescence, or that the deposits can be drawn upon, to any extent, to furnish a supply of crude mineral phosphate for the manufacture of fertilizers. The mica mines, doubtless, will continue to produce small amounts of apatite, which may find a local market; the quantity annually produced, however, is now practically negligible, and in view of the uncertainty of supply, domestic factories would probably prefer to employ foreign, amorphous phosphate entirely, in preference to using two varieties of raw material.

The outlook for the re-establishment of apatite mining in Canada, therefore, can hardly be regarded as encouraging, and any attempt to exploit deposits of the mineral on a large scale can only be considered as a risky undertaking. Save, perhaps, in the case of the exceptionally rich deposits of the Lièvre River district, in the Province of Quebec, mining of apatite with the aid of large and expensive plants has almost always proved a failure, and the value of the mineral is too low to justify any large initial expenditure upon machinery. The nature of the deposits, also, in many instances, renders the employment of steam drills both costly and impracticable. This was found to be the case in the Ontario mines during the eighties; and steam, for drilling purposes was, in many instances discarded

[1]Communications from Professor R. Harcourt, Department of Chemistry, Ontario Agricultural College, Guelph, Ont., and Dr. F. T. Shutt, Dominion Chemist, Central Experimental Farm, Ottawa, 1913.

in favour of hand work. The erratic nature of the mineral bodies, too, has usually discouraged any attempt at deep mining, the general practice being to look for a new surface showing, rather than to follow a deposit to any depth; two hundred feet is an exceptional depth to be reached, and the depth of most of the mines does not much exceed one hundred feet.

As regards the sedimentary phosphate reported in 1915 as having been discovered near Banff, Alberta, there is little possibility that the deposits can, under present conditions at least, be drawn upon for a supply of crude phosphate rock for an eventual western fertilizer industry. The writer made a detailed examination of the area of original discovery in 1915, and in the following year extended his investigation of the phosphatic horizon as far south as the International boundary. Nowhere in the region examined did either the phosphoric acid content of the rock or the thickness of the beds justify the opinion that the deposits can be of any immediate value as a source of phosphate. (See also Chapter IV.)

HISTORY OF PHOSPHATE MINING.

The first discovery of extensive bodies of crystalline phosphate of lime, or apatite, in Canada, dates from the year 1829, when a Lieut. Ingall recorded the existence of the large Lièvre River deposits, in the Province of Quebec. Little or no attempt was made to exploit any of the occurrences until the late sixties or early seventies, the first serious work being undertaken in the township of North Burgess, Ontario, by Messrs. Cowan and Robertson, of Brockville, the mineral being utilized in the preparation of superphosphate at the Brockville Chemical and Superphosphate Company's works. The first apatite produced in Canada, therefore, was mined for domestic consumption. The growing demand in Europe for raw phosphate for fertilizer purposes, however, soon led to active mining being conducted in both Ontario and Quebec, the mineral produced being exported chiefly to Great Britain and Germany. A small proportion, also, found its way to the United States, this latter amount consisting chiefly of ground mineral produced at Buckingham, Que. While Ontario was the first Province to yield any quantity of phosphate—there having been a small annual production between 1870 and 1877—the amount mined annually in Quebec, subsequent to the latter year, completely eclipsed the output of the former Province. The years of highest activity are shown by the period 1880-1891; while the largest amount mined in any one year was 31,753 tons, in 1890, 26,591 tons of this quantity being produced by Quebec. By 1896, the total annual output had decreased to 570 tons; and for the past decade, 1910-19, the average annual production has been under the five hundred ton mark. At the time of writing, there seems but little prospect that any materially increased production may be looked for in the near future, there being no actual phosphate mine in operation; and practically the whole amount recorded as produced during the past few years representing mineral derived as a by-product from mica mines.

Many of the companies enumerated in the following pages, as operating mines, both in the Lièvre River and Templeton phosphate districts in Quebec, were highly capitalized, the stock being subscribed principally in the United States, England, and France. It may be questioned at the present day whether many of these companies ever made a very great suc-

cess of their mining operations. The rapidly increasing demand for phosphate during the eighties, which caused the development on a large scale of the Quebec apatite deposits, was, unfortunately for the companies concerned, met in the early nineties by the discovery of extensive sedimentary phosphate bodies in Florida, and later by still other deposits in Tennessee, U.S.A.

The smaller private operators who shipped apatite during the late seventies and early eighties, undoubtedly realized large profits, the average price obtained per ton, as calculated from the records of tonnage and values, reaching as high as $21. In some instances, even higher prices were obtained by individual operators, but from 1s. to 1s. 1d. per unit, for 80 per cent apatite, was the usual price paid at this time. Few of these small operators used any but the simplest machinery in their mines; and the majority operated entirely by hand-work. When, however, the larger companies commenced mining in the Lièvre River district, very large sums were expended upon steam plants, camps, road building, tramway construction, etc.—larger sums, indeed, than many of the deposits warranted. The advent of a large number of producers, and the rapidly increasing output, naturally caused prices to decline. Little definite indication of the true market prices can be gained, however, from the tables of production and value: the two sets of figures referring to all grades of mineral, whilst the returns themselves cannot be too implicitly relied upon. Almost before the companies might have been expected to obtain a return for the amount of capital expended on plant, etc., and after only a few years' operation (certain concerns acquired phosphate lands and mines which they never worked at all) the bottom fell out of the market, owing to the competition from the southern United States, and prices dropped suddenly. An indication of the fall may be gained by a glance at Table I, the average value of $13.19 per ton, in 1892, falling to $7.85 in 1893. This latter year saw the cessation of operations at all the larger mines, and the properties have remained abandoned ever since. A few scattered deposits in Quebec province have been worked from time to time during recent years, and small quantities of apatite extracted to supply a somewhat sporadic demand for the mineral, the shipments representing, chiefly, trial consignments to Europe. The amount of phosphate derived from the mica mines has been steadily decreasing of late years, and, at the present time, only a few operators—at whose mines considerable quantities of apatite occur associated with the mica—trouble to save the mineral.

The cause of the falling off in production, and the present almost complete cessation of mining is due to the cost of extraction and transportation—chiefly to the former. It is regarded as practically impossible to mine apatite for home consumption at the present day at any more than the smallest margin of profit, whilst export is completely out of the question. This refers to the extraction of small amounts of mineral at favourably located points with only the simplest and cheapest form of plant, or with hand labour alone. The sole domestic market—with the exception of an intermittent consumption of a few tons at Smiths Falls, Ont.—has for years been at Buckingham, Que., situated within a few miles of the majority of the Quebec mines, and the quantity annually shipped to the two works located there has been steadily decreasing of late years, until, at the present time, it is practically negligible. The demand at Buckingham is

now chiefly supplied by imported sedimentary phosphate from Florida.

Various inquiries have been addressed during the past few years to the Mines Branch by interested parties in European countries regarding the existence of bodies of even low grade phosphate in Canada, and the feasibility of mining the same for export to Europe. It has not been possible to answer these inquiries in any encouraging manner; and it must be stated, for the information of those who may be considering the exploitation of phosphate deposits, that the Canadian apatite bodies do not offer, at present, any opportunity for successful and profitable development. The known phosphate deposits are situated, both in the Provinces of Ontario and Quebec, in more or less well settled country. Many of the larger, abandoned mines, are surrounded by farms, and practically all the properties, so far worked, are favourably situated as regards transportation, many of them being within easy reach of river, lake, or railway communication. But even though these favourable facilities exist, no re-development of any of the older properties has been attempted since 1893, the year in which the majority of the mines closed down; and each year the prospect of any successful re-opening grows more remote .

MODE OF OCCURRENCE OF APATITE.

The high cost of extraction is due, as will be apparent from the descriptions of the geologic occurrence of the apatite bodies given in subsequent pages, to the sporadic and uncertain occurrence of the phosphate on the veins. Persistent bodies of massive phosphate are rare, the mineral occurring rather as irregular leads of quite problematical extent. A number of such leads may exist within a small area, and it may be possible to extract their contents by means of one large excavation, from which drifts and levels can be run along the mineral shoots. Such deposits are rare,

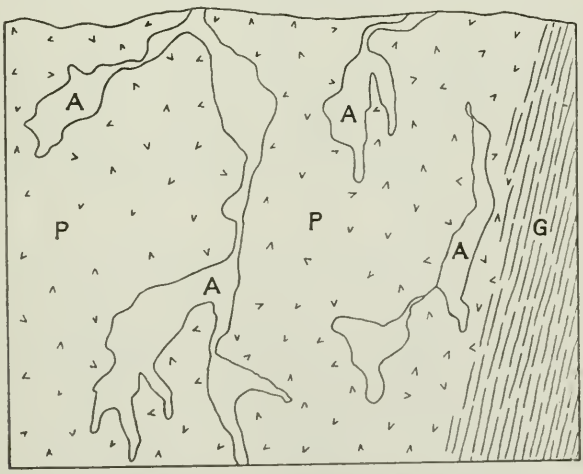


Fig. 1, Pockety form commonly assumed by Canadian apatite bodies. A, apatite leads and pockets; P, pyroxenite; G, country gneiss.

however; the more usual type of occurrence being either scattered pockets, necessitating numerous small openings upon the individual outcrops, or

else veins. Such veins, however, cannot be compared with metalliferous leads or true fissure veins. They appear to be, rather, local segregations or enrichments along more or less defined zones in the crystalline rocks of the district (chiefly granite-gneiss, with belts of pyroxenite and crystalline limestone), and they are often very irregular in width and impersistent. Except in the case of the exceedingly rich deposits of the Lièvre River region, in Quebec Province, it has seldom proved profitable to follow apatite deposits to any depth, the general procedure being to extract the contents of surface pockets or veins to a depth of some 40-75 feet, and then to transfer operations to a new surface showing. Both pockets and veins have a dip commonly ranging from 45° to vertical; though, in some instances

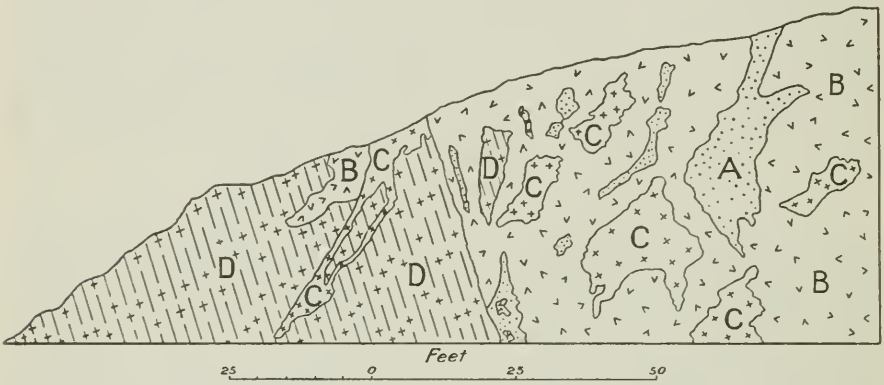


Fig. 2, Section in north side of cut on west side of North Star hill, township of Portland East, Que. (After Penrose.) A, apatite; B, pyroxenite; C, feldspar; D, country granite-gneiss.

deposits have been worked which occupied almost a horizontal position. A common dip for veins is between 60° and vertical, while that of the pockety deposits is difficult to determine, but is usually vertical rather than horizontal. It will be evident that the cost of exploiting deposits of this uncertain nature, occurring in a hard, crystalline rock, is far greater than that of extracting the material of bedded, sedimentary deposits, whose thickness is more or less uniform, and which lie, as a general rule, within a short distance of the surface.

The exploitation of a Canadian apatite deposit involves, as a general thing, the handling of a great deal of dead rock—that is, if it is intended to extract a large amount of mineral rapidly, with the aid of machine drills. Often, however, the nature of a deposit almost precludes the use of such drills; and it was frequently found, especially in the more vein-like deposits of Ontario, that hand drilling proved the more satisfactory method of extraction after a moderate depth was reached. Then, again, a considerable quantity of phosphate adhering to, or disseminated through, large masses of wall rock has to be discarded, owing to the expense of hand cobbing, or of crushing large quantities of hard, granitic rock containing a percentage of phosphate. The low value of phosphate precludes the handling of great quantities of dead rock in the exploitation of a deposit, and this factor, alone, is a deterrent, as far as the majority of Canadian

apatite bodies are concerned. Added to the pockety nature and uncertain extent of the occurrences, it has discouraged any attempt at a re-development of the older mines, and, save in a few instances, has rendered the exploitation of more newly discovered deposits a matter of questionable success.

That large bodies of apatite still remain—more especially in the Quebec phosphate region—is unquestionable. Many of the larger mines are reported to have closed down with considerable reserves of phosphate in sight at depths of several hundred feet; and numerous bodies of apatite associated or not with mica, have been discovered during more recent years. A number of these deposits have been worked for their mica content, the apatite sometimes being saved as a by-product. Many of the dumps of the old phosphate mines, also, have been worked over during recent years, for the discarded mica which they contained. Fresh discoveries of phosphate and mica leads are constantly being made, steady search for new deposits of the latter mineral being maintained at the present time, and the two minerals occurring, as a general thing, in intimate association. While these discoveries may be regarded as adding to the country's potential phosphate reserves, deposits of sufficient width and extent to admit of a possibility of any profitable development are seldom met with. But while, perhaps, it would be unwise to assume that the largest apatite deposits have already been discovered and worked, it still remains a fact that, outside of the great phosphate belt bordering the Lièvre river, in Quebec province, and upon which the majority of the more important mines were located, few large apatite bodies have been uncovered. The greater part of the production of recent years has come from small vein or pocket deposits, a number of which have been developed for the mica that they carried. Though not invariably the case, it is, however, usually found that deposits carrying much mica contain relatively little phosphate, and vice versa; while, should mica be present in any amount, upon a phosphate vein, the crystals of the former mineral are often much crushed and yield only a small percentage of marketable sheets. Thus, it is seldom that both minerals can be won simultaneously in quantity from a single deposit; though, infrequently, small mica veins are found cutting across, or in close proximity to, veins or pockets of massive apatite.

The abandoned deposits along the Lièvre river, in Quebec, still constitute, probably the largest reserves of apatite, notwithstanding the quantity of mineral already extracted therefrom. The development of phosphate of lime throughout this belt has been very great, and it is unreasonable to suppose that the deposits are in any measure exhausted. The deepest mine in the region, with a shaft down over 600 feet, disclosed large bodies of massive apatite at that level, and no limit of depth for the phosphate bodies can be assigned. There can be little doubt that the hills along the Lièvre river still contain large bodies of high grade apatite. Large deposits exist, also, at certain points in the Templeton district, farther to the west. Whether or not it will ever become profitable to re-exploit the mines of this region is a question which only time can answer. At present, with a plentiful supply of cheap sedimentary phosphate available in the United States, Africa, the Pacific, and other parts of the world, little hope of a revival of the Canadian apatite mining industry can be entertained.

In this connexion, it may be as well to add that, while the designation "large" or "extensive" has frequently in these pages been applied to Canadian apatite bodies, this term is relative only; and that while the contents of many sedimentary phosphate deposits may be reckoned in millions of tons and the annual output from the same be figured in hundreds of thousands, and even, also, in millions of tons, the annual production of apatite in Canada has only twice been slightly in excess of 30,000 tons. It is probable, also, that this figure could hardly be increased during any eventual revival of mining, however great the demand, on account of the difficulty of extracting large quantities of mineral in a short time from a number of small pockets and narrow leads—a difficulty which becomes greater with increasing depth. Whether or not apatite bodies persist to great depths is a much debated question. That they widen and narrow to an extreme degree is established, and many leads have been abandoned on account of such narrowing at a relatively slight depth. On the other hand, wide veins or shoots of mineral have been encountered at depths of several hundred feet. Such shoots, however, seldom proved persistent. Naturally, the difficulty and expenses of following such erratic deposits to even moderate depths are very considerable; and although the existence of large bodies of apatite in depth at many of the old mines is practically assured, it is out of the question that they can be profitably mined without a very considerable rise in the price of the mineral.

POSSIBILITY OF RECOVERING WASTE APATITE.

As already emphasized, the cost of mining Canadian apatite, plus that of hand picking or cobbing the mined mineral, in order to ensure a high grade product containing about 80 per cent of tricalcium phosphate, is prohibitive at the present day, and, in most cases, allows of little or no margin of profit either in a domestic or foreign market. Inquiry has frequently been made of the Mines Branch whether there is not some possibility of utilizing waste, lower grade material consisting of apatite more or less intimately mixed with mica, pyroxene, pyrites, and with gneissic or calcareous gangue. The dumps of many of the old phosphate mines, and those, also, of many of the mica mines, contain considerable quantities of such material. The apatite content, however, varies greatly, and it is highly questionable whether the greater part of the phosphate contained in the old dumps, present as it usually is in the form of small stringers or pockety accumulations in large blocks of pyroxene rock, can profitably be recovered, owing to the great amount of material that would have to be handled to extract a very small quantity of phosphate. Any means of recovery of the apatite other than the simplest and cheapest would be impracticable, and no method entailing more than a rapid handling of the rock and the passing of the actual, visibly apatite bearing material through a jaw crusher, with subsequent hand picking, could possibly be entertained. The resulting product from such treatment of the dump material, might, of course, be made of almost any desired grade, according to whether only clean apatite or mixed mineral was picked. It is impossible to generalize as to the amount of dump material to be handled in order to secure one ton of phosphate owing to the wide variation in the apatite content of the phosphate bearing pyroxenite at the different mines. Some pyroxen-

ites are hard and compact, and contain little apatite throughout their mass, whilst others are coarse grained and often carry a considerable amount of apatite disseminated in grains or small crystals through them. Such variation in the phosphate content of the rock mass is not confined to different mines, but is encountered, also, in different parts of the same mine. Thus, one section of one and the same dump might yield material comparatively rich in apatite, whilst another might show only rock carrying little or no phosphate. Probably, in the majority of cases, not less than 12-15 tons of rock would have to be put through the crusher in order to obtain one ton of phosphate; while the quantity of dump material actually yielding one ton of apatite, that is, including the rock discarded as not being worth crushing, might well amount to double this. These estimates do not claim to be based upon results achieved in actual practice, since no such attempt at recovery of apatite from low grade rock has ever been attempted in Canada; they represent, rather, the impression formed from a close examination of the material forming the waste dumps at phosphate and mica mines throughout the district, and, as such, are to be regarded as merely indicative of the class of material to be dealt with, should any attempt of the recovery of the phosphate contained in such dumps be contemplated. Probably, in the case of certain individual mines, the above proportion of crude rock to concentrates would be found excessive, while for others it would prove an underestimate. The cost of unit production, assuming that 15 tons of material have to be handled, crushed, and hand picked to yield one ton of phosphate, can be estimated somewhat as follows. It is assumed that a jaw crusher, having a 12 by 16 inch opening, is employed, and that the crushed material falls to a hopper, with automatic feed, to a conveyer belt, where it is hand picked, passing thence to loading bins. For an output of 50-60 tons of crushed rock (about 4 tons of phosphate) per diem, the following would be necessary:—

2 labourers to sledge rock for crusher	$ 7.00
3 loaders	10.50
1 tram man	3.00
1 engine man	5.00
2 men feeding crusher	7.00
3 men for picking table	9.00
1 foreman	6.00
	$47.50

If another $5 be added to the above to cover repairs, cost of fuel, horse, interest on plant, etc., we have $52.50 per diem as the cost of operation of the plant. Thus, one ton of phosphate would cost about $13 to recover, there being, in addition, a small amount of low grade fines from the crusher. No account has yet been taken of haulage charges from the mine. These vary according to the distance from the nearest shipping point, but would, in the generality of instances, add another $5 per ton, making altogether $18 per ton f.o.b. cars. Since the price offered at Buckingham, Que., for 80 per cent apatite is about $11 per ton, it will be readily apparent that a cost on rail of $18 per ton is a prohibitive one.

A considerably lower production cost might be realized in working the dumps of certain mica mines. Here, although, in many instances, the

phosphate has been saved as a by-product, only the purest apatite was picked out, and little attention has been paid to cobbing ore; consequently, the dump material at many mica mines will be found to be far richer in apatite than that of the old phosphate producers, and less rock would have to be handled to secure a ton of phosphate. In some instances, a proportion of such dump rock contains as high as 40-50 per cent apatite, and a ton of phosphate might be recovered from as little as 8-10 tons rock. Even so, however, with production costs plus haulage charges as low as $12 per ton, the project of recovery of the apatite cannot be regarded as commercially practicable.

It has been assumed in the foregoing, that the actual owners of the dumps are working them over. An outside party undertaking the work would have a royalty of probably not less than 25-50 cents per ton added to the above cost.

USES OF APATITE.

The principal uses to which apatite may be put are, as raw material in the manufacture of acid phosphate for fertilizer, and of phosphorus. For both these purposes, apatite is as suitable as sedimentary phosphate; and since it contains a considerably higher percentage of phosphoric acid than even the best grades of phosphate rock, it is more valuable, ton for ton, than the latter.

Phosphate is sold on the basis of its phosphate of lime content: the commercial grades of rock on the American continent consisting of material ranging from 77 per cent, in the case of Florida hard rock, to 72 per cent for Tennessee phosphate. Analyses of a number of samples of picked apatite from Canadian deposits showed an average content of 86 per cent phosphate of lime, often expressed as B.P.L., or "bone phosphate of lime." Phosphate containing more than 3 per cent combined iron and alumina is not considered suitable for acid phosphate manufacture by the sulphuric acid process, owing to the tendency of the acid phosphate prepared from such material to "revert", that is, to change to a form insoluble in water.

The Ceramic Division of the Mines Branch has had under investigation the substitution of apatite for bone ash in the manufacture of bone china. References to this investigation are contained in Mines Branch Summary Reports for 1916, pp. 108-11, and 1918, p. 167, and the results show that apatite may be used very satisfactorily for the above purpose.

STATISTICS OF PRODUCTION, EXPORTS, IMPORTS, ETC.

The following table shows the production of phosphate in Canada since 1870, the figures being compiled from reports of the Geological Survey and of the Mines Branch. Difficulty was experienced in the earlier years in securing full and accurate returns from operators, and the totals given in the following table can be regarded as only approximate. In many instances it was found impossible to form any estimate of the actual production from the incomplete returns sent in, and from the failure of many operators to furnish any returns at all. In such cases, recourse was had to the returns of the railway companies, figures of export and of known domestic consumption, the resulting totals being admittedly open to criticism.

The figures of production by provinces, also derived from the above sources, and shown in Table II, present but little similarity in the majority of cases with the figures given by the Annual Reports of either the Ontario or the Quebec Bureau of Mines. In the latter reports, the production figures relate, in many cases, to mineral mined but not sold, while the quantities and values shown in Table I, represent actual sales and shipments during the years in question. In addition, the figures quoted in the Provincial Reports for the earlier returns, relate to the fiscal year, while those in the accompanying table are for the calendar year.

TABLE I.

Annual Production of Phosphate from 1870 to 1919.

Year.	Amount.	Value.	Average value per ton.	Year.	Amount.	Value.	Average value per ton.
	tons.	$	$		tons.	$	$
*1870	1,200	13,600	11·33	1895	1,822	9,565	5·25
*1871	200	2,100	10·50	1896	570	3,420	6·00
1872	No Records.			1897	908	3,984	4·39
1873				1898	733	3,665	5·00
1874				1899	3,000	18,000	6·00
1875				1900	1,415	7,105	5·02
1876				1901	1,033	6,280	6·07
**1877	2,823	47,084	16·68	1902	856	4,953	5·79
1878	10,743	208,109	19·37	1903	1,329	8,214	6·18
1879	8,446	122,035	14·45	1904	817	4,590	5·62
1880	13,060	190,086	14·55	1905	1,300	8,425	6·48
1881	11,968	218,456	18·25	1906	850	6,375	7·50
1882	17,153	338,357	19·73	1907	824	6,018	7·30
1883	19,716	427,668	21·69	1908	1,596	14,794	9·26
1884	21,709	424,240	19,54	1909	998	8,054	8·07
1885	28,969	496,293	17·13	1910	1,478	12,578	8·51
**1886	20,495	304,338	14·85	1911	621	5,206	8·38
1887	23,690	319,815	13·50	1912	164	1,640	10·00
1888	22,485	242,285	10·77	1913	385	3,643	9·46
1889	30,988	316,662	10·21	1914	954	7,275	7·62
1890	31,753	361,045	11·37	1915	217	2,502	11·53
1891	23,588	241,603	10·24	1916	203	2,514	12·38
1892	11,932	157,424	13·19	1917	149	1,486	10·00
1893	7,890	61,962	7·85	1918	140	1,200	8·57
1894	6,861	41,166	6·00	1919	24	331	13·80
				Total	338,055	4,686,145	

*Production solely from Ontario.

**From 1877 to 1886, figures represent exports only, no direct production returns having been furnished previous to the latter year. The "average value" figures are not to be regarded as representing current market prices, several grades of phosphate often being included in the returns.

TABLE II.

Annual Production of Phosphate by Provinces, from 1886 to 1919.*

Year.	Province of Quebec.		Province of Ontario.		Total.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	tons.	$	tons.	$	tons	$
1886	19,435	288,603	1,060	15,735	20,495	304,338
1887	19,589	264,452	4,101	55,363	23,690	319,815
1888	20,396	219,779	2,089	22,506	22,485	242,285
1889	27,552	287,400	3,436	29,262	30,988	316,662
1890	27,172	309,980	4,581	51,065	31,753	361,045
1891	20,244	206,416	3,344	35,187	23,588	241,603
1892	10,231	134,964	1,701	22,460	11,932	157,424
1893	7,650	60,076	240	1,886	7,890	61,962
1894	6,861	41,166	0	0	6,861	41,166
1895	1,822	9,565	0	0	1,822	9,565
1896	570	3,420	0	0	570	3,420
1897	908	3,984	0	0	908	3,984
1898	632	3,160	101	505	733	3,665
1899	1,279	7,674	1,721	10,326	3,000	18,000
1900	1,270	6,090	145	1,015	1,415	7,105
1901	1,033	6,280	0	0	1,033	6,280
1902	856	4,953	0	0	856	4,953
1903	1,329	8,214	0	0	1,329	8,214
1904	817	4,590	0	0	817	4,590
1905	1,300	8,425	0	0	1,300	8,425
1906	600	4,500	250	1,875	850	6,375
1907	408	3,410	416	2,608	824	6,018
1908	598	5,900	998	8,894	1,596	14,794
1909	525	4,800	473	3,254	998	8,054
1910	1,456	12,386	22	192	1,478	12,578
1911	586	4,909	35	297	621	5,206
1912	164	1,640	0	0	164	1,640
1913	385	3,643	0	0	385	3,643
1914	554	4,875	400	2,400	954	7,275
1915	200	2,400	17	102	217	2,502
1916	190	2,340	13	174	203	2,514
1917	123	1,230	26	256	149	1,486
1918	140	1,200	–	–	140	1,200
1919	22	300	2	31	24	331
Total	176,897	1,932,724	25,171	265,393	203,239	2,207,894

*The figures in the above table are derived, for the earlier years, in part from returns by the railway companies, statements of producers and consumers, and figures of exports, while subsequent to 1900, they are compiled from producers' returns by provinces.

TABLE III.

Annual Exports of Phosphate from 1878 to 1919.

Year	Ontario		Quebec		Total	
	Amount	Value*	Amount	Value*	Amount	Value*
	tons	$	tons	$	tons	$
1878	824	12,278	9,919	195,831	10,743	208,109
1879	1,842	20,565	6,604	101,470	8,446	122,035
1880	1,387	14,422	11,673	175,664	13,060	190,086
1881	2,471	36,117	9,497	182,339	11,968	218,456
1882	568	6,338	16,585	302,019	17,153	308,357
1883	50	500	19,666	427,168	19,716	427,668
1884	763	8,890	20,946	415,350	21,709	424,240
1885	434	5,962	28,535	490,331	28,969	496,293
1886	644	5,816	19,796	337,191	20,440	343,007
1887	705	8,277	22,447	424,940	23,152	433,217
1888	2,643	30,247	16,133	268,362	18,776	298,609
1889	3,547	38,833	26,440	355,935	29,987	394,768
1890	1,866	21,329	26,591	478,040	28,457	499,369
1891	1,551	16,646	15,720	368,015	17,271	384,661
1892	1,501	12,544	9,981	141,221	11,482	153,765
1893	1,990	11,550	5,748	56,402	7,738	67,952
1894	1,980	10,560	3,470	29,610	5,450	40,170
1895	0	0	250	2,500	250	2,500
1896	1	5	299	2,990	300	2,995
1897	70	450	165	400	235	850
1898	21	240	702	8,000	723	8,240
1899	215	1,850	93	1,725	308	3,575
1900	6	0	0	0	0	0
1901	.....	.....	.....	.....	6	120
1902	.....	.....	.....	.....	70	1,880
1903	.....	.....	.....	.....	1	20
1904	.....	.....	.....	.....	191	5,348
1905	.....	.....	.....	.....	40	1,253
1906	.....	.....	.....	.....	0	0
1907	.....	.....	.....	.....	0	0
1908	.....	.....	.....	.....	1	30
1909	.....	.....	.....	.....	895	15,735
1910	.....	.....	.....	.....	0	0
1911	.....	.....	.....	.....	3	100
1912	.....	.....	.....	.....	0	0
1913	.....	.....	.....	.....	0	0
1914	.....	.....	.....	.....	247	677
1915	.....	.....	.....	.....	179	1,860
1916	.....	.....	.....	.....	103	1,543
1917	.....	.....	.....	.....	14	200
1918	.....	.....	.....	.....	0	0
1919	.....	.....	.....	.....	0	0

*The above figures of value bear no relation to those given in the Table of Production; production values are calculated upon a spot valuation basis, while export figures include, also, freight, insurance, commission, and other charges.

In addition, these exports do not correctly represent the production of either province, a quantity of Ontario mineral having been cleared from the port of Montreal and being included in the Quebec export returns.

TABLE IV.

Imports of Canadian Apatite into Great Britain, 1882-1894, showing the percentage of Canadian Mineral to total Imports of Phosphate Rock.*

Year	Canadian Apatite		Percentage of Canadian Apatite to Total Imports
	Amount	Value	
	Long tons	$	
1882	8,187	194,074	6·5
1883	16,531	324,897	8·2
1884	15,716	255,042	8·1
1885	21,484	370,992	12·1
1886	18,069	309,196	12·0
1887	19,194	321,293	10·7
1888	12,423	205,957	7·7
1889	23,123	345,950	10·1
1890	21,089	318,595	7·8
1891	15,918	264,124	8·6
1892	7,814	86,506	2·7
1893	5,068	57,149	1·9
1894**	3,192	32,989	0·8

*Annual Reports on Mines and Quarries. Home Office, London.
**The imports subsequent to 1894 are negligible.

TABLE V.

Destination of Exports of Phosphate, by Countries, for the Fiscal Years 1878-79 to 1918-19.*

Year	United States		Great Britain		Germany		Miscellaneous**		Total	
	Amount	Value	Amount	Value	Amount	Value	Amount	Value	Amount	Value
	tons	$	tons	$	tons	$	tons	$	tons	$
1878-79...	2,018	28,818	9,385	177,949	336	6,050	188	3,478	11,927	216,295
1879-80...	1,182	11,492	6,792	108,390	.....	.....	.....	.....	7,974	119,882
1880-81...	2,402	29,129	13,199	210,364	.....	.....	....	.....	15,601	239,493
1881-82...	2,080	28,976	13,197	258,391	1,469	31,300	435	9,000	17,181	327,667
1882-83...	220	2,400	12,263	255,816	1,995	44,500	....	.....	14,478	302,716
1883-84...	32	250	21,328	451,092	.....	.....	111	1,980	21,471	453,322
1884-85...	745	8,980	16,878	327,508	1,361	25,800	....	.....	18,984	362,288
1885-86...	532	6,817	23,718	407,314	1,724	17,820	....	.....	25,974	431,951
1886-87...	733	6,223	20,465	360,313	1,595	29,613	10	300	22,803	396,449
1887-88...	1,100	13,011	18,638	345,602	2,111	38,880	...	.....	21,849	397,493
1888-89...	2,911	32,463	19,695	322,269	552	9,850	....	.....	23,158	364,582
1889-90...	3,192	34,182	25,792	355,845	729	11,720	....	.....	29,713	401,747
1890-91...	1,825	22,350	22,062	393,250	370	6,600	....	.....	24,257	422,200
1891-92...	1,324	11,857	14,273	336,745	861	17,800	785	14,060	17,243	380,462
1892-93...	2,663	18,188	8,309	97,737	918	16,550	....	.....	11,890	132,475
1893-94...	1,580	8,295	3,366	32,095	.....	.....	....	.....	4,946	40,390
1894-95...	720	4,210	3,469	29,600	.....	.....	....	.....	4,189	33,810
1895-96...	.....	.....	528	5,280	....	.....	....	.....	528	5,280
1896-97...	.....	.....	21	210	.....	.....	....	.....	21	210
1897-98...	91	690	165	400	.....	.....	....	.....	256	1,090
1898-99...	20	90	719	8,100	122	1,100	....	.....	861	9,290
1899-00...	73	1,635	.....	.....	76	650	....	.....	149	2,285
1900-01...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1901-02...	70	1,880	.....	.....	.....	.....	....	.....	70	1,880
1902-03...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1903-04...	190	5,337	.....	.....	.....	.....	....	.....	190	5,337
1904-05...	40	1,253	.....	.....	.....	.....	....	.....	40	1,253
1905-06...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1906-07...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1907-08...	1	30	.....	.....	.....	.....	....	.....	1	30
1908-09...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1909-10...	895	15,735	.....	.....	.....	.....	....	.....	895	15,735
1910-11...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1911-12...	.....	.....	.....	.....	.....	.....	3	100	3	100
1912-13...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1913-14...	187	497	.....	.....	.....	.....	....	.....	187	497
1914-15...	60	180	.....	.....	.. .	.....	....	.....	60	180
1915-16...	282	3,403	.....	.....	.....	.....	....	.....	282	3,403
1916-17...	14	200	.....	.....	.....	.....	....	.....	14	200
1917-18...	.....	.....	.....	.....	.....	.....	....	.....	0	0
1918-19...	.....	.....	.....	.....	.....	.....	....	.....	0	0

*Trade and Navigation Annual Reports.
**Under Miscellaneous are included France, Denmark, Spain, and Holland.

CHAPTER II.

MANUFACTURE OF PHOSPHORUS PRODUCTS IN CANADA.

The manufacture of phosphatic fertilizers in Canada, and the utilization of domestic apatite for such purpose, dates from about the year 1869. In that year, Messrs. Cowan and Robertson established the Brockville Chemical and Superphosphate Company, near the town of that name in Leeds county, Ontario; the works continuing in operation until the early nineties. In 1887, the Standard Fertilizer and Chemical Company was formed, with a small plant at Smiths Falls, Ontario; and this concern still produces small quantities of acid phosphate and fertilizer. In 1889, the manufacture of superphosphate was commenced at Capelton, Quebec, where G. H. Nichols and Company installed a plant for the production of fertilizer, utilizing acid prepared from the sulphide ores of their mines at the same place. The works were in operation for some years, but the manufacture appears to have been discontinued about the year 1902. In the late eighties and early nineties, three apatite grinding mills were in operation at Buckingham, Que., the nearest railway shipping point to the Lièvre River mines.

One of the plants, that of the Lièvre Basin Phosphate Mining and Milling Company (F. S. Shirley), was located at Bassin du Lièvre, close to Buckingham station, and was run by turbine, power being derived from the falls of the Lièvre river close by. The mill contained a cylindrical dryer, with automatic conveyer to a crusher and pulverizer, from which the mineral passed to an 80-mesh screen, and then to bags. The plant was only a small one, with a capacity of 25 tons per diem; and, although phosphate from various mines was ground, producers still continued to ship practically all their mineral in the rough.

Another mill was that of Messrs. Lohmer, Rohr and Company, of Montreal, who also erected a plant at Buckingham, about the year 1890. This plant had a capacity of 50 tons per diem, and employed about 25 men. The machinery comprised rotary dryers, crushers, pulverizers, trommels, screens, etc., the finely ground mineral being air-floated.

A third plant, with a small capacity of under 10 tons per diem, was operated by the Canadian Phosphate Company, who milled a portion of the mineral derived from their own Crown Hill and Star Hill mines. With the closing down of the larger mines in the Lièvre River district, work at all these mills was discontinued a few years after their erection.

The total quantity of phosphate crushed at Buckingham in the year 1888 amounted to 1,625 tons. Practically the whole of this amount was shipped to Chicago, while the total of crude rock phosphate shipped to Montreal for transport to Europe during the same period was 14,725 tons.

In 1897, the Electric Reduction Company erected a plant at Buckingham, and commenced the manufacture of phosphorus from high grade apatite, subsequently enlarging their plant and producing, in addition, ferro-phosphorus, ferro-silicon, and ferro-chromium.

In 1902, the Nichols Chemical Company discontinued the preparation of superphosphate at their works at Capelton, and in the following year a

new firm, the Capelton Fertilizer and Chemical Company, was formed to undertake the manufacture, at Masson, near Buckingham, of acid phosphate and complete fertilizers. Neither the last named concern nor the Electric Reduction Company at present consumes any large quantity of domestic apatite, both firms of late years importing almost their entire supply of crude mineral from Florida.

The firms enumerated above comprise those domestic concerns which have at various times utilized Canadian apatite for the manufacture of phosphorus products.

The present state of the Canadian apatite mining industry is evident, when, as noted above, two important consumers of phosphate rock, with works located within a few miles of the apatite mines, find it cheaper to import their entire supply of raw mineral from the southern United States than to purchase domestic apatite.

In addition to the above-mentioned companies which, originally, at least, constituted a domestic market for Canadian apatite, a number of fertilizer works using phosphatic materials have been established in recent years, many of them in connexion with packing houses and similar businesses. These factories, however, employ, almost exclusively, prepared acid phosphate imported from the United States. The more important of such works are the following:—

FERTILIZER FACTORIES.

ALBERTA.

Swift Canadian Co., Edmonton.

Manufacture ammoniates only. Dry mixing plant, without rock grinding or acidulating equipment. Use imported acid phosphate.

BRITISH COLUMBIA.

Victoria Chemical Co., Ltd., Victoria.

Complete fertilizer plant, with acid chambers. Use bone char from sugar refineries, as raw material for acid phosphate, as well as phosphate rock imported from Idaho.

NEW BRUNSWICK.

Provincial Chemical Fertilizer Co., Ltd., St. John.

These works were established as an acidulating plant in 1889. For a number of years past, however, prepared acid phosphate has been imported from the United States. The works are situated at Little River, East St. John, and have a capacity of 5,000 tons of mixed fertilizer per annum. Large quantities of tankage, bones, fish scrap, and abattoir refuse are used. The acid phosphate is brought to the works by schooner, the plant being located on tide water. The market for the finished product is chiefly among the potato and fruit growers of the St. John district.

Dominion Fertilizer Co., Ltd., St. Stephen.

These works were established as a dry mixing plant exclusively, in 1911, with a capacity of 10,000 tons per annum. The factory is located on tide water, on the left bank of the St. Croix river, and the acid phosphate is brought up by schooner from Carteret, N.J., to the Company's

wharf. Considerable quantities of animal and fish tankage, as well as sardine waste from the Maine factories, are consumed. The Company is affiliated with the International Agricultural Corporation.

NOVA SCOTIA.

Colonial Fertilizer Co., Windsor.

The plant of this Company has a capacity of 15,000 tons of mixed goods per annum. The works were originally started in 1889, by the Pidgeon Fertilizer Co., who conducted a ground bone business, this being later extended to complete fertilizer manufacture. The present Company acquired the works in 1911, and have erected a large mill building, containing bin space for 10,000 tons. The raw materials, acid phosphate, bones, etc., are procured chiefly from the United States, and a quantity of abattoir refuse from the Province is also handled, there being three digesters to treat this class of goods. The plant is situated on tide water, about a half-mile from Windsor. The market for the Company's goods is chiefly within the Province, a certain quantity being consigned, also, to growers in New Brunswick, and the Eastern Townships. The present Company does business under various other names besides that of the Colonial Fertilizer Co., as, for example, the Pidgeon Fertilizer Co.; New England Fertilizer Co.; Essex Fertilizer Co.; Lowell Fertilizer Co.; and Parmenter and Polsey Fertilizer Co. All the foregoing, with the exception of the Pidgeon Fertilizer Co., are subsidiary concerns of the Consolidated Rendering Co., of Boston, who, in turn, are affiliated with the Swift Packing Co.

Nova Scotia Fertilizer Co., Halifax.

This plant was established in 1878, and has a capacity of about 5,000 tons of mixed goods per annum. The plant handles most of the abattoir refuse, etc., from the Halifax district, as well as local fish offal. Whale bones are imported from Newfoundland, and acid phosphate from Baltimore. Ammonium sulphate is secured from Sydney, C.B. The works are located on tide water at Fairview, Bedford Basin.

ONTARIO.

The Standard Fertilizer and Chemical Company, Smiths Falls.

This Company was established in 1887, and has continued to manufacture small quantities of acid phosphate up to the present time. In addition to making acid phosphate, the Company also prepares mixed fertilizers. Formerly, the sulphuric acid used was manufactured at the works, sulphur being obtained from Japan, and later from Sicily. In recent years, acid has been purchased.

A number of years ago, attempts were made to introduce ground, crude apatite as a fertilizer, but results did not prove satisfactory, the farmers who were persuaded to try the mineral on their land reporting that they could perceive no results at all from its use.

In addition to fertilizer acid phosphate, this firm has also engaged in the manufacture of acid phosphate for use as a substitute for cream of tartar in baking powder used in the preparation of self-raising flour. In making this substance, crude acid phosphate from the den is spread over large, shallow wooden trays lined with coarse sacking. Water is let into the trays, and the soluble acid phosphate is leached out and flows into

lead lined trays beneath, whence it is led to a collecting vat. Here the liquid is evaporated and concentrated to a syrupy consistency, being afterwards mixed with a starch dryer. The residue remaining on the leaching trays, consisting principally of gypsum ("phosphate-gypsum" or "superphosphate-gypsum," as it is termed, according to whether it is completely freed from, or still contains a proportion of soluble acid phosphate), finds use as an absorbent purifier in lavatories, stables, etc.

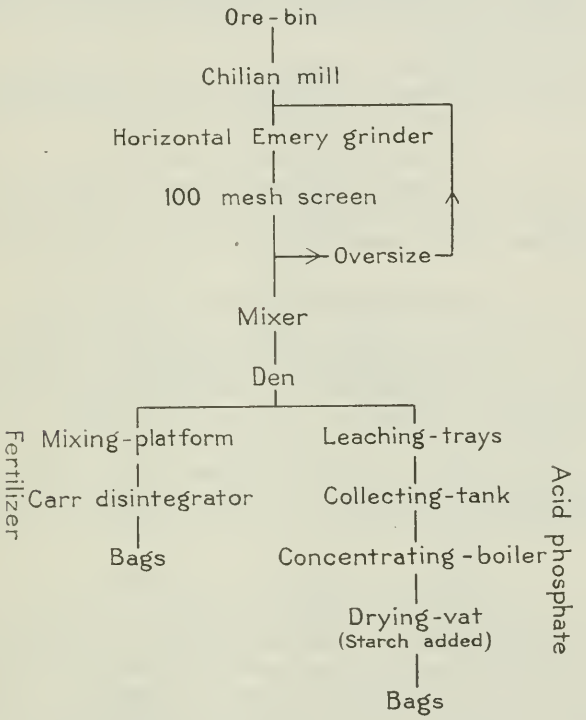


Fig 3. Flow sheet at Standard Fertilizer and Chemical Company's works, Smiths Falls, Ont.

The original plant was a small one, and a further reduction in size has been effected by the closing of the sulphuric acid portion of the works. Being situated on the Rideau lakes, and within easy reach of the Ontario apatite mines, the works were very favourably situated for obtaining supplies of apatite in former days.

Chemical Products of Canada, Ltd., Trenton.

This Company has lately taken over the plant of the British Chemical Company, and proposes to undertake the manufacture of acid phosphate. The plant is equipped with acid chambers.

Gunn's, Ltd., Toronto.

This packing house has operated a dry mixing plant for a number of years, and recently installed an acidulating department. The capacity of

the works is given as 10,000 tons of mixed goods per annum. Tennessee phosphate is used, and acid is procured from Hamilton. Packing house refuse, such as hair, horn, skin, etc., is also acidulated. Ammonium sulphate is procured from Montreal and Hamilton.

Ontario Fertilizers, Ltd., Toronto.

Formed by the amalgamation, in 1912, of the fertilizer departments of the William Davies Company and the Harris Abattoir Company. The plant has a capacity of 10,000 tons of mixed goods per annum. Dry mixing solely is carried on.

Formerly, the principal market for this and other local fertilizer firms' goods, was the Niagara fruit district, but increasing quantities are now being taken by Ontario farmers for use on wheat and other lands.

William Stone Sons, Ingersoll.

A dry mixing plant, with a capacity of about 5,000 tons of complete goods per annum. Abattoir refuse is obtained from the Ingersoll Packing Company, tankage being prepared in a section of the plant devoted to rendering, etc.

W. A. Freeman Fertilizer Co., Hamilton.

This Company is one of the oldest established in Western Ontario, having been in operation since 1886. Originally an acidulating plant, treating imported rock with acid procured from Tweed, Ont., the works since 1911 have imported prepared acid phosphate. The output is stated to be about 10,000 tons of mixed goods per annum.

A large part of the Company's business is the obtaining of animal by-products from abattoir refuse, etc., and quantities of tallow, stearine, oils, and fats are produced, the tankage being utilized as a fertilizer ingredient.

Canadian Fertilizer Co., Chatham.

This concern which was established in 1914, and operates a dry mixing plant, has a reported capacity of 60 tons of mixed fertilizer per diem. In addition to the production of mixed goods, limestone, obtained from St. Mary's, is ground for agricultural purposes. Waste beet sugar liquor from the refineries at Chatham, Wallaceburg, and Kitchener, is also utilized. Acid phosphate is imported from Baltimore. This is the most westerly fertilizer works in Ontario.

QUEBEC.

The Capelton Chemical and Fertilizer Company, Masson.

Organized in 1902, this Company, for a number of years, employed domestic apatite from the Lièvre River and Templeton phosphate districts, in the manufacture of acid phosphate. The works are located on the Lièvre river, at Masson, near Buckingham, Que., the power used being obtained from the falls alongside the plant.

In recent years, Florida pebble phosphate has almost entirely taken the place of domestic apatite. Prior to the war, the average cost of pebble was 13 cents per unit for 80 per cent and over, laid down at the works.

In the manufacture of acid phosphate at this plant, the phosphate is first fed to a crusher, and is then elevated to an inclined, rotary dryer. The dried phosphate is elevated to a hopper, from which it falls to a No. 1

Sturtevant ring-roll mill, passing thence to an inclined 80-mesh shaking screen. The oversize is elevated back to the mill, and the fines pass to a hopper, from which they are bagged (200 lb. bags). Four bags (800 lbs.) of phosphate constitute a single charge for the mixer, and are agitated with about the same weight of sulphuric acid (50° Bé.). The mixer is of the shallow, rotary type with rotating stirrers. From the mixing pan the acid phosphate falls to a wooden den of 40 tons capacity; this quantity can be

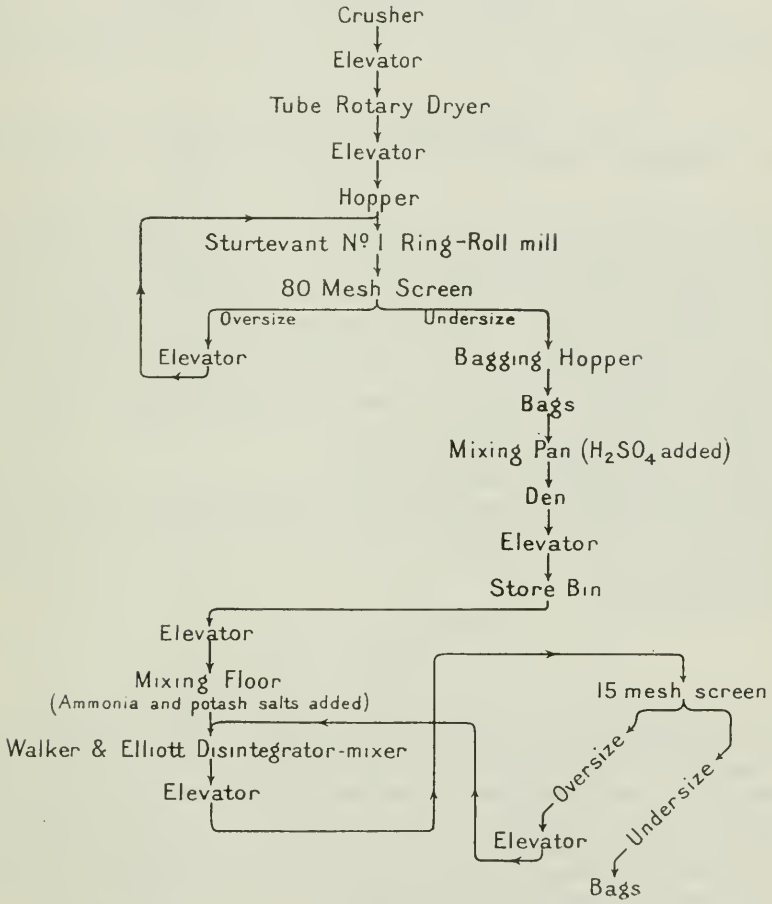


Fig. 4, Flow sheet, Capelton Chemical and Fertilizer Co., Buckingham, Que.

produced in about 3 hours. From the den the acid phosphate is shovelled to an elevator, and conveyed to a store bin of 120 tons capacity. From this bin it is elevated, as needed, to the mixing floor, where ammonia and potash salts, tankage, and filler are added, the whole being then passed through a Walker and Elliott disintegrator, in which it is thoroughly pulverized and mixed. The complete fertilizer is then elevated to the maturing bin, located outside the main building, where it is allowed to age for

some months. For bagging, it is elevated back to the mixing floor and passed over a 15-mesh screen. The fines pass direct to bags, while the oversize is fed back to the distintegrator until of the required fineness. The filler used is finely ground slag, the residue from the electric, phosphorus furnaces of the Electric Reduction Company, at Buckingham. This slag contains a small percentage of available phosphoric acid, and a large amount of lime.

Lesage Packing and Fertilizer Co., Montreal.

A dry mixing concern with a reported capacity of 2,000 tons of mixed goods per annum.

Tanguay and Co., Quebec.

A small dry mixing plant with a reported capacity of 5,000 tons per annum. Supplies mainly the district around Quebec.

As will have been noted, practically all of the fertilizer works in the country are located in the east, the largest concerns being in New Brunswick and Nova Scotia, where large quantities of fertilizer are used by potato and fruit growers; also in, or adjacent to, the agricultural region of southwestern Ontario. There is only one firm manufacturing fertilizer in the Prairie Provinces, and that in a very small way, namely, Swift and Co., at Edmonton, Alberta. The cost of transporting fertilizer ingredients for assembling in the west is practically prohibitive at the present time. The cost of acid phosphate laid down in Edmonton, for example, is more than double that of the material at eastern points.

The great bulk of the fertilizer turned out by Canadian firms consists of mixed goods prepared from imported raw materials. Only four of the concerns listed above are equipped with acidulating machinery for treating phosphate rock, and of these four, only two are in active operation at this date (March 1920).

PHOSPHORUS WORKS.

The Electric Reduction Company, Ltd.

This concern has been operating steadily since 1897, the works being located at the Upper Falls, at Buckingham, Que. When visited in 1913, the sole product manufactured was phosphorus, but at various times such compounds as ferro-silicon, ferro-chromium and ferro-phosphorus, have been produced in small quantities. Some years ago, two electric furnaces for smelting steel were installed, but were dismantled after a short run.

The quartz consumed in the manufacture of phosphorus is obtained locally, being derived from quartz veins and pegmatite dikes of the Archæan rocks to the north of Buckingham.

The price offered for domestic apatite, 75 per cent standard, is about $11 per ton delivered. The supply, however, has been negligible during the past few years, and at the present time Florida pebble phosphate is used almost entirely.

The entire plant is run by power derived from the falls close by, the developed H.P. being 3,000.

About 90 per cent of the phosphorus manufactured is exported, the

remainder being consumed by domestic match factories. No details of production, manufacture, or of the processes employed are divulged.

BASIC SLAG GRINDING WORKS.

There is one basic slag grinding plant in Canada, that of the Cross Fertilizer Co., located at Sydney, C.B.—a branch of Alexander Cross and Sons, of Glasgow. The works were completed, and operations commenced, in January, 1912, since when the plant has been running continuously. The capacity of the works is 40,000 tons per annum, and 40 hands are employed. The buildings are all substantial brick structures, the mill proper having three floors, and the storehouse for the bagged product being capable of taking practically capacity output. Box cars are run direct into this building, down the centre of which run the tracks, with a raised, concrete platform on either side.

Power for the grinding machinery is furnished by a 650 H.P. compound, tandem, direct drive engine.

The works are situated adjoining the Dominion Iron and Steel Company's plant, from which the slag is obtained. The slag is received at the works in 15-ton blocks, which are broken on the dump by a chain and ball "skull-cracker." The broken slag is then loaded on to tip cars, run to an elevator outside the mill building and hoisted to the feed hoppers on the third floor, from which it falls to the ball mills. (Plates II and III.)

The type of ball mill used in the above described plant is an improved type of the Löhnert-Jenisch mill, specially constructed for basic slag work (Plate IV). In this machine, an axle is dispensed with, the drum being mounted at the feed end on rollers and at the opposite end on a trunnion. By this means, pieces of slag up to 6 inches in length can be fed to the mill, and the risk of axle breakage, due to over-charging the drum, is eliminated. The machine is fitted with coarse screens only, mounted on wrought iron frames.

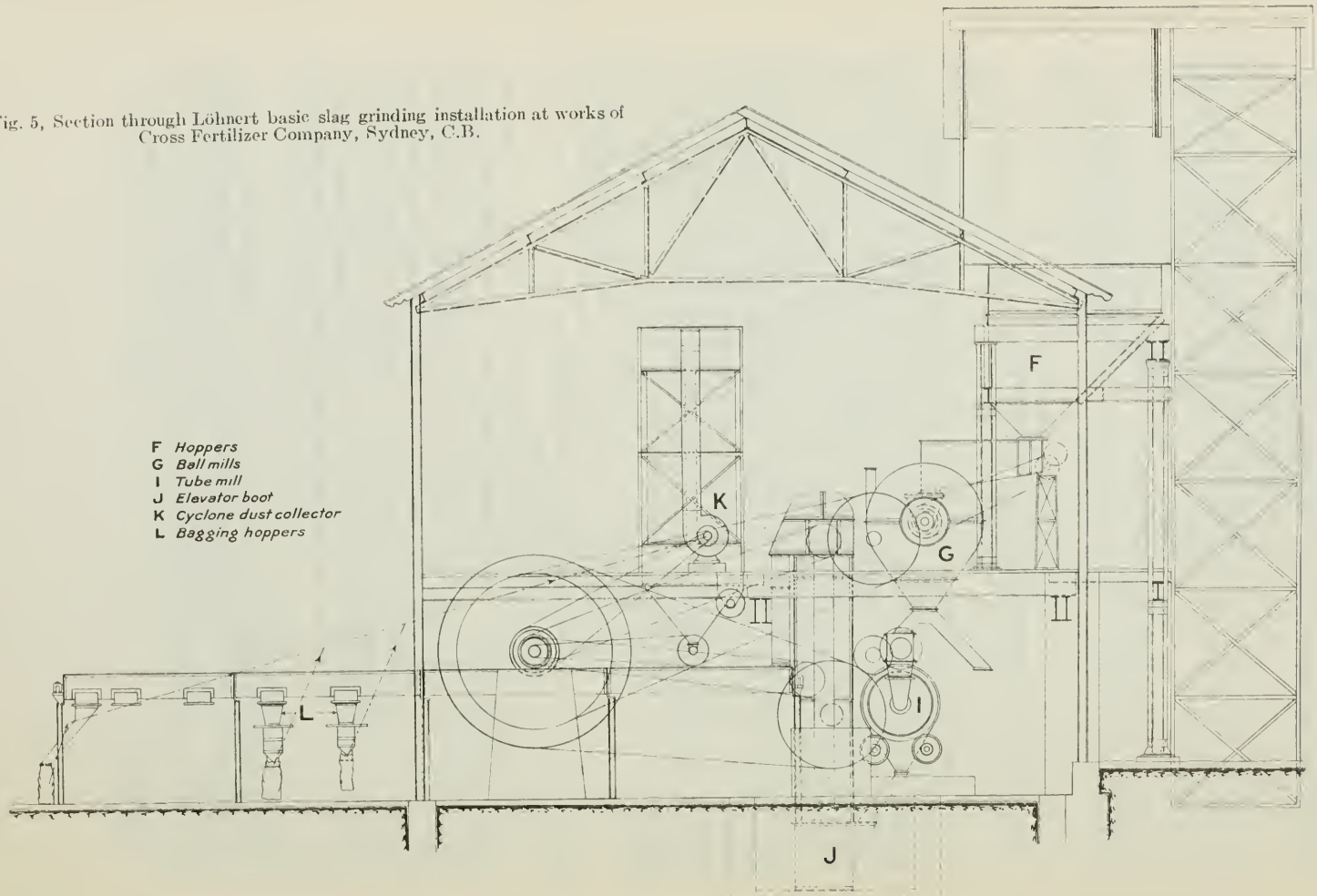
The Löhnert axleless ball mill is made in four sizes, the diameter of the drum ranging from $7\frac{1}{4}$ to $8\frac{1}{2}$ feet. The number of revolutions per minute is 24, and the H.P. required is from 30 to 60, according to the size. The capacity is from 26 to 52 tons per hour.

The tube mill used in conjunction with the above ball mill has also been designed expressly for grinding basic slag. The drum of this mill consists of a welded tube, which is supported on rollers and runs on heavy rings (Plate V). The slag grit is fed in at the hopper end, is completely pulverized by steel balls while passing through the drum, and discharges through a sieve-drum at the farther end. This sieve automatically separates any steel fragments still remaining in the meal. The mill is made in three sizes, all of similar diameter, but ranging in length from 23 to 26 feet. The drum makes 28 revolutions per minute, and requires from 110 to 160 H.P. to drive it. In place of silex lining plates, chilled steel plates can be substituted.

The ground slag is weighed in a 3-hopper, automatic "Libra" bagging scale, manufactured by the Automatic Scale Co., of Gliesmarode-Brunswick, and is put up in bags of 200 pounds. The slag is ground to 100-mesh, and the market value at the works is $15 per ton.[1]

[1]October, 1919.

Fig. 5, Section through Löhnert basic slag grinding installation at works of Cross Fertilizer Company, Sydney, C.B.



The whole of the grinding installation was designed and erected by the Hermann Löhnert Company, of Bromberg, Germany, specialists in slag grinding machinery.

The market for the ground slag was originally chiefly within the Province of Nova Scotia, but an increasing amount is now being shipped to inland points.

In Fig. 5 is shown a section through the mill building.

Basic slag[1] is a by-product obtained in the dephosphorizing of steel. The process by which it is formed was first applied in 1879, by Gilchrist and Thomas, of Battersea, England. At first regarded as of no value, basic slag has come to be used in ever increasing quantities as a fertilizer. The total amount consumed in 1912 reached the large total of four million metric tons.

Although experiments between 1880 and 1890 conclusively demonstrated the value of finely ground basic slag as a fertilizer, it was not until the citric acid solubility test for the phosphoric acid contained in it was introduced as a standard that fertilizer manufacturers were induced to favour its use. It was mainly as a result of the endeavours of German chemists and manufacturers, notably of G. Hovermann, of Hanover, that basic slag came to be recognized as a valuable fertilizer, and Germany in 1912 headed the world's production with nearly 2,500,000 metric tons annually.

Formerly, iron ore containing over 0·025 per cent of phosphorus was considered useless for the production of good steel, owing to the brittle qualities imparted to it by the phosphorus. The Thomas process, whereby ores rich in phosphorus are rendered utilizable, has since become the basis of manufacture of the major portion of the world's production of steel.[2]

Briefly stated, the dephosphorizing of phosphoric pig iron is effected in what is known as a basic Bessemer converter (Plate VI). In the ordinary Bessemer process, the converter is lined with a siliceous material. In the basic converter, the siliceous lining is replaced by shrunk dolomite, known as "basic" material, rammed with anhydrous tar. This lining, together with lime additions made during the blow, allows of the formation of a phosphate of lime (tetracalcic phosphate) which is not decomposed by metallic iron at the high temperature of the converter, and thus practically the whole of the phosphorus present in the iron is removed in combination with the lime in the slag.

A basic Bessemer plant does not differ radically from an acid plant, the only additional requirements being facilities for conveying large quantities of lime to the converter and for removing the large amount of slag produced. The latter operation is effected by pouring the slag either onto the pit floor, where it is watered, broken up with bars and wheeled away red-hot ("poured slag"), or direct into iron dump cars ("block slag"), which transport it to the slag dump. "Poured slag" is harder and more homogeneous than "block slag."

Pig-iron containing as high as 3·5 per cent phosphorus may be used in the manufacture of steel by the basic Bessemer process.

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[1]German "Thomas-Schlacke", French, "Scorie de déphosphoration".

[2]See P. Wagner "Die Thomasschlacke" Darmstadt, 1887; M. Passon, "Das Thomasmehl, seine Chemie und Geschichte", 1901; F. W. Harbord "The Metallurgy of Steel", 1904.

The basic Siemens or open-hearth process for the removal of phosphorus depends, in the same manner as the foregoing, on the formation of stable phosphates, and the dephosphorization is effected in the same way by means of a basic or neutral furnace lining, and by lime additions during the working of the charge (Plates VII and VIII). Pig iron with 2–3 per cent of phosphorus may be employed with the basic Siemens process.

The following represents the average composition of a basic slag produced by the open–hearth process:—

	Minimum.	Maximum.	Average.
SiO_2	2·70	12·00	7·96
FeO, Fe_2O_3	7·77	25·00	13·19
MnO	0·55	5·62	3·91
CaO	28·00	58·91	48·29
MgO	1·14	8·10	4·89
P_2O_5	11·39	22·97	17·25

The P_2O_5 content, thus, ranges from 11 to 23 per cent. Basic slag slakes in the air, the caustic lime absorbing moisture and carbonic acid, and the ferrous iron oxidizes. Porous portions of a slag mass exhibit tables, needles, and prisms of tetracalcic phosphate ($4CaO.P_2O_5$).

In the early days, it was considered that basic slag needed to be treated with acid in order to render its phosphoric acid available for plant food. Scheibler prepared precipitated phosphate ("Thomas precipitate") by treating 100 parts of powdered basic slag with 120-150 parts of hydrochloric acid, and precipitated the phosphoric acid with milk of lime (German Patents No. 24,130 and No. 25,020). Franke proposed to decompose the slag with magnesium chloride (German Patent No. 27,106) and to convert the phosphoric acid into phosphate of magnesia. Meyer's process (German Patent No. 47,984) consisted in treating the still fluid basic slag with its own weight of acid sulphate of potash.

It was established by Reis and Arens, however, that the P_2O_5 in basic slag is soluble in water containing carbonic acid, and that, for this reason, there is no necessity to resort to methods of treatment in order to render the P_2O_5 available. It is from the date of the researches by the above chemists that the use of basic slag in agriculture dates.

It has been shown, however, that slags from different smelters exhibit by no means constant, active fertilizing properties, even when possessing equal contents of phosphoric acid and when ground to a similar degree of fineness. Assuming 100 as the efficiency of a good slag, some goods have been found to possess only 60, 50, and as low as 40 per cent. This fact has led to the adoption of the citric acid solubility test as a basis of valuation, in place of the earlier guarantee of fineness. Higher efficiency in a slag corresponds, almost invariably, to a higher silica content, and it is thus possible by the addition of sand to the fluid slag to increase its value as a fertilizer, at little or no extra cost.

The formation of tetracalcic phosphate in the furnace is represented by the following equations:—

$$Ca_3(PO_4)_2 + Ca_2SiO_4 = Ca_4P_2O_9 + CaSiO_3$$
$$Fe_3(PO_4)_2 + 2Ca_2SiO_4 = Ca_4P_2O_9 + Fe_3Si_2O_7$$

Silica, therefore, plays a very important part in basic slag.

The decomposition of tetracalcic phosphate by water containing carbonic acid proceeds according to the equations:—

1) $Ca_4P_2O_9+CO_2+4H_2O=CaH_4(PO_4)_2+2Ca(OH)_2+CaCO_3$

or 2) $Ca_4P_2O_9+2CO_2+H_2O=2CaHPO_4+2CaCO_3$.

There is thus formed either 1) the monocalcic phosphate found in acid phosphate, or 2) "precipitate".

At Hoerde, in Westphalia, so-called "patent phosphate meal" was formerly manufactured by the Scheibler process (German Patent No. 34,416 and No. 41,303). This method consisted in adding slightly less lime to the iron in the converter than is required for complete dephosphorizing. This slag, rich in P_2O_5, is then run off, lime is added to the steel in the converter, and the low percentage slag which results is employed as reducing material for a new charge.

If phosphatic chalk be substituted for lime in the converter, with or without the addition of sand, a slag richer in phosphoric acid is obtained.

The photographs shown at the end of this report were taken at the Dominion Iron and Steel Company's works at Sydney, Cape Breton, where what is known as the "Duplex" process is practised. This consists in combining the basic Bessemer and open-hearth processes, whereby the phosphorus of the ore is all removed in the converter, and the blown metal is then charged to the open-hearths for complete deoxidation. By this means, the time required for the open-hearth treatment is reduced to about two hours, as against 11-12 hours normally.

The blown metal from the Sydney converter contains on an average:—

Carbon	·03
Phosphorus	·07
Sulphur	·05

and the slag:—

Silica	13·0	—14·0
Alumina	1·0	
Lime	48·0	—51·0
Magnesia	2·0	— 4·0
Phosphoric acid	17·0	—19·0
Manganous oxide	1·5	
Ferrous oxide	13·0	—15·0

For a description of the above Duplex process, see Can. Min. Journ., Vol. 33, No. 18, 1912, pp. 632–637.

BIBLIOGRAPHY OF ACID PHOSPHATE MANUFACTURE.

Inquiries are frequently received by the Mines Branch for information relating to methods of treatment of phosphate rock—chiefly for the manufacture of acid phosphate. In view of the comparatively negligible amount of acid phosphate manufactured in Canada, and the limited resources of the country in raw phosphate, a description of the commercial methods of treatment has been omitted from this report. The following publications, however, contain detailed information relating to the subject and may be consulted by those interested:—

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Waggaman and Wagner, Analysis of Experimental Work with Ground Raw Rock Phosphate as a Fertilizer, Bull. No. 699, Bureau of Soils, U.S. Dept. Agriculture, 1918.

The publications of the U. S. Department of Agriculture listed above may be obtained at a nominal cost from the Superintendent of Documents, Washington, D.C.

CHAPTER III.

APATITE MINES AND OCCURRENCES.

Province of Ontario.

Probably the greatest development of phosphate so far discovered in Ontario, is in the township of North Burgess, county of Lanark, between the fifth and ninth concessions. The principal exploitation of this apatite belt has taken place around lot 10 in the sixth, and between lots 1 and 6 in the eighth concession; the development of the phosphate leads in the latter district being extensive, and the mineral zone well defined.

The apatite veins in Bedford township, Frontenac county, though numerous, are of smaller extent, and occur rather as scattered individuals than in the form of vein zones.

In Loughborough township, Frontenac county, a few large bodies of phosphate have been discovered in the ninth and tenth concessions, the Foxton mine, on lot 13 of the latter concession, constituting the principal opening in the district.

Although numerous showings of apatite have been located in this part of the Province, and somewhat extensive deposits in some cases encountered, the development of the phosphate bodies in this region falls far short of that of the Lièvre River and Templeton districts in the Province of Quebec. The main difference in the mode of occurrence of the mineral in the two provinces, is that, in Ontario, the phosphate bodies possess principally the form of more or less well defined veins—isolated or in vein zones—the leads being confined within walls, and often consisting chiefly of apatite, either massive or disseminated in crystal form through calcite. The veins of massive apatite, though continuous, are seldom of great width for any distance, the average lateral extent being probably less than 3 feet. Such veins have a pronounced tendency to widen out and to pinch without warning. The calcite bodies carrying apatite crystals disseminated through them are often of considerably greater width, but the proportion of pure phosphate to vein matter in such deposits is, as a rule, not large. The cobbing of the apatite crystals from the calcite matrix, in such cases, entails considerable labour, and few deposits of this class prove to be of sufficiently high economic value to warrant any extensive development. In Quebec, on the other hand, the apatite bodies possess more usually the form of large, irregularly shaped pockets, distributed throughout a belt of often considerable width, and, in some cases, joined by small stringers or veinlets of phosphate. Veins of phosphate, enclosed between defined walls, are also encountered; but such deposits are usually of smaller extent, save in a few instances, where a number of leads occur in close proximity to one another. Practically all the large phosphate mines opened up in the

Lièvre River district were concerned with pockety bodies of apatite, rather than with vein bodies.

The majority of apatite veins in the Ontario district being narrow, operators often found it more practical and cheaper to conduct work by hand than with air or steam drills, especially in the deeper workings. As a rule, workings have not been carried to any great depth, the deepest phosphate mine in the Province not exceeding 200 feet; in Quebec, on the other hand, a depth of over 600 feet has been reached, though this, it should be stated, is an extreme case.

The chief mines worked for phosphate in the Province are enumerated in the following pages. A number of the old time apatite producing mines have since been re-developed for the mica which occurs with the phosphate, the latter mineral, in some cases, being saved as a by-product. As a general rule, however, the mica found on leads carrying phosphate as the principal vein-matter, is seldom of high quality, the crystals being often twisted and crushed. The amount of mica found on such leads, also, is usually smaller than that encountered on veins carrying calcite, or on those in which pyroxene forms the chief mineral; consequently, more attention is paid to veins of the latter types, and the production of apatite at any mica mine at the present day is very small. The haulage and freight charges, also, from the mines to Buckingham, Que., where are located the principal domestic consumers, amount, in many cases, to almost as much as the mineral brings, delivered at the mills. Many operators, consequently, do not take the trouble to cob and save the apatite they encounter, but run it with the waste to the rock dump.

As will be seen from Table II, showing the production of phosphate in the Province, the annual output for twelve out of the last twenty-six years (1894-1919) has been nil. The greater part of the total production for the period in question—4,650 tons—probably represents accumulated mineral from one or more mica mines, and may consist of the production during a number of years. At the various mica mines, small piles of phosphate may be seen, the mineral representing the contents of pockets encountered while extracting mica. In many cases these quantities have been accumulating for a number of years, the operators never considering it worth while to ship the mineral away.

There is no mine actually being operated for phosphate alone in the Province at the present time, nor has there been for a number of years.

Frontenac County.

TOWNSHIP OF BEDFORD.

Concession VI, lot 30.—Bobs Lake, or Taggart mine. This property which, at the present time, is an active mica producer, was opened up for phosphate in 1891, by the Montreal Mining Company. About a dozen men were employed, and a depth of 50 feet was reached in the pits. Work appears to have been abandoned in the following year, the amount of apatite found on the veins being small.

Mining has since been carried on by Mr. Taggart, of Westport, from 1897 to 1900, and later by Messrs. Kent Bros. and Stoness, who are the present owners and operators. A number of pits have been opened upon a system of parallel veins, and over two thousand barrels of rough-cobbed mica are reported to have been shipped from the mine. Very little phosphate is encountered, and no shipments have been made since the present owners commenced operations.

References:—
Ont. Bur. Min., I. p. 239; XIII, p. 92; XIV, p. 86; XVI, p. 89; XIX, p. 127; XX, p. 111.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 159.

Concession VII, lots 32, 33, 34.—Mining for phosphate was commenced on these lots in the eighties by Mr. R. C. Adams, who later, in 1888, became manager for the Anglo-Canadian Phosphate Company of Liverpool, England, and continued to work this and other properties for the Company. No very extensive work was carried out, but a number of small pits were opened on pockety deposits of apatite crystals scattered through a soft pyroxene and calcite gangue. The upper portions of these pockets were so soft that the crystals could be extracted with pick and shovel, without the use of explosive. All the pockets and veins are small, but there are a number of them; their general direction is northwest and southeast.

No further work has been conducted on the property.

Reference:—
Rep. Royal Commission, 1890, p. 176.

Concession X, lots 27, 28, 29.—McLaren mine. This property was worked about 1889, by Mr. Edward Watts and the Hon. Peter McLaren, of Perth. Only a small number of men were employed, and the workings consist of merely a few small surface pits. The largest opening measures 25 × 12 feet and is about 30 feet deep. All the pits are located on lot 29.

An output of some 500 tons of phosphate is reported, all of which was hauled to Westport to be shipped to Buckingham, Que. The mine lies on the west side of West Rideau lake, and is about 8 miles by winter road from Westport.

The phosphate is green, compact, and also granular, and contains a large quantity of pyrites. The amount of the latter mineral present, especially in the granular variety, often renders the phosphate practically valueless. A quantity of the apatite hauled to Westport at the time of working is still lying on the wharf.

The apatite occurs on narrow leads in a dark green hornblende-pyroxene rock, the veins having a northeasterly direction.

Reference:—
Ont. Bur. Min., I, p. 239.

Concession XI, lot 28.—Mr. W. J. Webster, of Westport, carried out a little work for phosphate in 1890. A few tons were extracted, but the leads were found to carry more mica than apatite, and operations were conducted principally for the former mineral. The adjoining lot, 21, of the tenth concession of North Crosby township, was also acquired and worked in a small way by Mr. Webster. The workings are situated near the northeast

shore of Wolf or West Rideau lake. No mining has been performed since 1903, for either mica or phosphate.

Reference:—
Ont. Bur. Min., II, p. 250.

Concession XVII, lot 1.—Opinicon Lake mine. Attention was drawn to phosphate occurrences in the vicinity of Opinicon and Devil lakes as far back as 1869, and on the above property a deposit was opened up in 1870, by Mr. Alexander Cowan, of Brockville. The leads are reported to have been from 2 to 4 feet wide. The phosphate was chiefly green in colour, though zones of red mineral were also encountered. About 75 tons were mined in 1870, and by the end of 1871 a total of 550 tons was produced. The whole of this amount was shipped to England, and the cessation of work in 1872 was caused by the high ocean freight charges which rendered export of the mineral unprofitable.

Mining was subsequently renewed in 1892 by a syndicate, which employed about a dozen men for a year, and also installed machinery. A pit 50 feet deep was sunk, and a vein was opened up for a distance of 150 feet.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124; Rep. Prog., 1872-73, p. 177.
Ont. Bur. Min., II, p. 251.

Other localities in Bedford township, where phosphate veins have been discovered, but worked only in a small way, are:—

Concession II. lot 4.
" *IV. lot 6.*
" *VII. lot 7.*
" *IX, lot 29.*
" *XII, lot 3.*

TOWNSHIP OF HINCHINBROOKE.

Concession I, lots 29 and 30.—Eagle Lake mine. This property includes also lots 29 and 30 in the first concession of Bedford, the main workings being situated, however, in Hinchinbrooke. The two sets of workings are separated by the concession road, which divides the two townships.

The owner and operator of this mine was Mr. Boyd Smith, of Washington, D.C., who commenced work in 1887, having a couple of years previously opened the St. George Lake mine, which lies about 3 miles to the north. Mr. Smith employed an average of 25 men, the number rising, occasionally, to over 60; and between 1887 and 1891 took out about 4,000 tons of phosphate, most of which was shipped to England; a small quantity, also, was consigned to Philadelphia. The average grade of the mineral shipped is said to have been about 84 per cent, and the price secured $15 per ton. The mine was shut down in 1891 and has not since been worked.

The apatite is massively crystalline, of a green colour, and occurs on a series of some half dozen veins having a direction of northeast and southwest. These leads are traceable for a distance of over a mile, and the width of the vein zone is about 300 yards. The width of the individual

leads varies from 6 inches to 6 feet, the phosphate usually occurring in pockets and irregular, chimney-like bodies. There are over twenty openings scattered over the property, the main pits lying near the southeast shore of Eagle lake. Here, three openings have been made on a large vein of mineral, the apatite body having been followed to a depth of 175 feet. All the pits were operated open-work.

The deposit is chiefly remarkable for the large development of magnetite, which occurs both in small veins having no definite direction, but traversing the phosphate zone in an irregular manner, and also along with the apatite body on the main phosphate lead. Although numerous veins of the mineral occur, they are all too narrow to admit of exploitation. In one of the main pits the entire vein filling at one point is said to have consisted of magnetite, this mineral completely replacing apatite; and it appears to have been no uncommon occurrence for one mineral suddenly to give place to the other. Calcite, mica, and other vein minerals often present in apatite veins appear to be almost entirely absent at this spot.

About 700 tons of magnetite iron ore have been shipped from this property to the Hamilton Blast Furnace Company, and Mr. Harris, of Tichborne, has worked over the dumps for second grade apatite, which was shipped to the same Company.

The mine, which was also known as the Blessington mine, lies $\frac{1}{4}$ mile from the Kingston and Pembroke branch of the Canadian Pacific railway—a siding having been built for the shipment of mineral—and $1\frac{1}{2}$ mile from Tichborne station.

Although veins carrying magnetite are of widespread occurrence on these lots, they are all narrow, and little beyond surface work has ever been attempted. A number of small openings have been made on the east side of the road, in Bedford township, the deepest pit not exceeding 15 feet. The magnetite is titaniferous, and contains, also, small amounts of nickel and cobalt.

The present owner is Mr. Charles Jenkins, of Petrolia, Ont.

References:—
Ont. Bur. Min., I. p. 240; II, p. 251; VIII, p. 228; IX, p. 194.
Rep. Royal Commission, 1890, pp. 167, 172.
Geol. Surv. Can., Bull. Ap., 1904, p. 30.

TOWNSHIP OF LOUGHBOROUGH.

Concession VI, lot .—Known as the Johnson[1] mine, and worked in 1890 by Messrs. Lohmer, Rohr and Co., of Montreal. Yielded less than a hundred tons of phosphate.

Reference:—
Ont. Bur. Min., I, p. 240; II, p. 251.

Concession VII, lot 11, W.$\frac{1}{2}$.—Known as the Lacey, or General Electric Company's mine, and operated at the present time for mica. This property represents the largest producer of mica in Canada. The deposit was first located in 1882, and was worked for several years for phosphate by Messrs. Smith and Lacey, of Sydenham, who subsequently continued mining

[1]No particulars of the lot number are given in the reference cited.

for mica. The amount of phosphate extracted was not large—probably less than 200 tons— and no attention is paid to the apatite encountered in the workings at the present time, the quantity being too small to be worth saving. The mineral met with is usually of a dark, black-green colour, and occurs, both as small masses, along with the mica, in certain parts of the deposit, and also as small isolated crystals.

The mine lies four miles from the village of Sydenham, and is owned and operated by the General Electric Company, of Schenectady, N.Y.

References:—
Ont. Bur. Min., III, p. 192; X, p. 134; XI, p. 287; XII, p. 126; XIII, p. 91; XIV, p. 84; XV, p. 102; XVI, p. 86; XVII, p. 91; XVIII, p. 140; XIX, p. 127; XX, p. 110.
Rep. Royal Commission, 1890, p. 148.
Geol. Surv. Can., XIV Ann. Rep., 1901, p. 182A.

Concession IX, lot 5, W. ½—Coe mine. This property is situated near Gould lake, and adjoins the Gould Lake mica mine. Opened in the eighties by Mr. Coe, the mine was later worked by Mr. C. Sterling, of Kingston, who employed a small force in extracting phosphate during 1890, and took out about 150 tons of all grades. The property has since been worked by Webster and Company, for mica.

Only one deep pit has been opened, work having been confined principally to surface stripping and quarrying. In some cases, the veins cropped out on the side of a small ridge, or bluff, and the apatite was extracted by cutting back the face, while in others, small pits were made on the level ground at the base of the ridge. All the apatite found at this point is of a brownish-red colour. No very extensive phosphate bodies appear to have been discovered, all the leads being narrow.

Webster and Company, of New York, are the present owners of the mine.

Reference:—
Ont. Bur. Min., II, p. 251.

Concession IX, lot 7.—Apatite crystals occur in some quantity, scattered through a large vein-filling of pink calcite. Little, if any, phosphate has ever been shipped from the property, which has been somewhat extensively worked for mica.

Concession IX, lot 16.—About 100 tons of apatite were taken off this property during 1890 and 1891, by Mr. C. Sterling, of Kingston, the mineral being obtained as a by-product while mining for mica.

Concession X, lots 6 and 7.—Gould Lake mine. This property is being operated at the present time as a mica producer, being owned by the Birch Lake Mining Syndicate, of Ottawa. The Company took over the mine in 1910, and have kept some half dozen men employed, more or less steadily, ever since. A small amount of apatite is found in certain of the pits, but no shipments have ever been made by the present owners.

The mine was first opened by Mr. T. Holland, of Sydenham, about the year 1880, and was later acquired by Messrs. Smith and Lacey, of the same place, who mined both mica and phosphate. Webster and Company, later, carried on about a year's work, for mica, employing an average of thirty men, and obtained, also, a quantity of phosphate.

The general trend of the veins is north and south; and they occur in a light coloured, grey pyroxenite, enclosed in greyish or red gneiss.

The deepest opening on the property is that known as the Holland pit, which is down 115 feet, and is 100 feet long at the bottom, and 12 feet wide. A parallel lead 20 feet to the west of this pit has been worked to a depth of 110 feet, and what is known as the Woodruffe pit has also been carried down to a depth of some 85 feet. This latter opening lies several hundred feet southeast of the two former pits, which are situated on the crest of a ridge close to the shore of Gould lake. A flat dike of diabase was encountered in the Woodruffe pit; this cut off the mica lead, and was found to be about 10 feet thick.

The mica produced by this mine is a high quality golden-amber.

A small camp was erected in 1911, and a 14 horse-power boiler, and steam hoist, installed.

Reference:—

Ont. Bur. Min., X, p. 133.

Concession X, lot 10.—Massive, red phosphate occurs in some quantity, associated with amber mica, on a series of parallel leads in red granite-gneiss.

A quantity of mica has been taken off the property by various parties, including Mr. Sloan, of Perth, and Mr. Mace, of Tamworth. An analysis of the phosphate from this property yielded[1]:—

Tricalcic phosphate.....	89·22 = 40·87	phosphoric acid.
Calcium fluoride.....	7·66 = 3·73	fluorine.
Calcium chloride.....	0·67 = 0·43	chlorine.
Calcium carbonate.....	0·24	
Magnesia.....	0·16	
Alumina.....	0·84	
Ferric oxide.....	0·91	
Insoluble.....	1·15	
Total.....	100·85	

Concession X, lot 13.—Foxton mine. Work on this property, which lies seven miles northeast of Sydenham and about two miles from Perth Road, was commenced by Mr. James Foxton, of the former place, about the year 1886. The apatite body is said to have measured 2½ feet at the surface, widening to 5 feet at a depth of 10 feet, and increasing to 10 feet at 50 feet. From here the vein narrowed for some distance, subsequently widening again, until, at 115 feet, the deposit measured 15 feet. The lead was almost vertical, and the shaft appears to have been sunk on a pocket or widening of the vein, since all the workings are confined to a small area in the immediate vicinity of the main shaft. Large pyroxene crystals are found embedded in the apatite, which is bluish-green in colour, and compact crystalline. The vein occurs in a very coarse-grained, greenish-

[1]Geol. Surv. Can., Rep. Prog., 1877-78, p. 61I.

grey pyroxenite, enclosed in dark gneiss, and has a direction of N.W.-S.E. Some of the smaller veins carry a reddish apatite.

In addition to the main shaft, there exist some half dozen smaller pits. These openings were sunk to a small depth on the vein, or on stringers from the main deposit, short drifts being run along the leads from the shafts. In one of these openings to the east of the main pit, a body of pinkish calcite, carrying phosphate crystals scattered through it, was encountered at a short distance from the surface, while another opening disclosed an apatite lead carrying a very large quantity of massive pyrites. The phosphate from this mine, when cobbed clean of such impurities as pyroxene crystals, scapolite, epidote, mica, etc., was of high grade, and a quantity was shipped to England, via Kingston and Montreal.

As many as 50 men were employed at the mine, and a large camp was erected, a steam plant, comprising drills, hoist, and pumps, also being installed. All the mine buildings are now in a dilapidated condition. The greatest depth reached in the workings was about 175 feet, this being the depth of the main shaft. All the openings are situated on the summit of a ridge, overlooking, and to the south of Long lake, which lies about 100 feet below it.

Work was continued for about six years, and over 5,000 tons of mineral were taken out. The mine was later disposed of to Mr. H. Richardson, of Kingston, who, however, has done no work beyond a little prospecting or mica.

Messrs. Lohmer, Rohr and Company, of Montreal, also mined a small quantity of phosphate in the nineties, under lease.

A pit, opened in 1890 a few hundred feet from the workings described above, was known as the Concession mine, and reached a depth of 60 feet.

References:—

Ont. Bur. Min., I, p. 239; II, p. 251.

Rep. Royal Commission, pp. 53, 168, 171, 177, 439.

TOWNSHIP OF OSO.

Concession 1, lot 6.—St. George Lake mine. This was formerly one of the largest phosphate mines in the district, and was opened in 1885 by Mr. Boyd Smith, of Washington, D.C. Work was continued for six years, and the mine was ultimately closed down in 1891 and has not since been reopened. Although the workings are extensive, the mine did not produce a great amount of mineral, 1,500 tons being reported as a liberal estimate of the quantity of phosphate shipped A force of from 15 to 40 men was employed.

The phosphate found at this spot is uniformly of a brown or reddish colour, and occurs in a well defined vein, between crystalline limestone below and reddish gneiss above, the dip of the deposit approximating 40° S.E., and its strike being N.E.-S.W. Considerable quantities of pyrites occur disseminated through the apatite, which is associated with dark green pyroxene.

There are two openings, both large, open-work pits; the chief of these

measures 200 feet long by 40 feet wide at its broadest part, and is some 50 feet deep. This opening has been made on the northwest side of a ridge, about 150 feet high, and situated 500 yards east of the tracks of the Kingston and Pembroke branch of the Canadian Pacific railway. The distance from Olden station on the same line is about a mile. A little distance to the northeast of the big pit is a smaller opening, made on a continuation of the same lead of phosphate. This pit measures 100 × 25 feet, and is 65 feet deep. The large size of the waste dumps at this mine would indicate that a great deal of dead rock had to be handled in order to extract a relatively small amount of phosphate. The quantity of pyrites in this rock and in the apatite remaining on the stock piles is large, and detracts from the value of the mineral.

No machinery appears to have been employed either at this mine or on the Eagle Lake property, which was also worked by Mr. Boyd Smith.

The present owner of the mine is Mr. H. Walker, of Oconto, Ont.

References:—
Ont. Bur. Min., I, p. 240; II, p. 251; IX, p. 194.
Rep. Royal Commission, 1890, p. 172.
Geol. Surv. Can., Bull. Ap. 1904, p. 30.

Concession V, lot 2.—About the year 1890, a small amount of phosphate was taken off this property, by Messrs. Wilson and McMartin, of Perth. In 1905, the General Electric Company, of Schenectady, N.Y., acquired the mine, and mined for a short time for mica; but no further work has been done.

The mica is a very dark variety, and the crystals are much crushed and twisted, a large percentage being useless. Large bodies of red, compact, phosphate accompany the mica, and have been mined by means of open-cuts and drifts, run into the side of a steep ridge of dark gneiss, with intercalated limestone and dark-coloured pyroxene bands.

The adjoining lots along the same ridge have been worked on a small scale, for phosphate, by the various owners. The general geological conditions here are similar to the above.

The recently constructed short line of the Canadian Pacific railway passes almost over the old phosphate pits.

Concession VI, lot 14.—Silver Lake mine. This property was first opened for phosphate in 1891, by Mr. William Davis, of Perth, and was subsequently acquired by Mr. Boyd Smith, of Washington, D.C., U.S.A., who is the present owner. Mr. Davis had about a dozen men employed for a few months during 1891, and some 250 tons of phosphate were extracted from a few surface pits. The apatite is of a brown colour, and occurs on a series of parallel, narrow veins, enclosed in reddish gneiss.

Reference:—
Ont. Bur. Min., I, p. 240; II, p. 251.

TOWNSHIP OF STORRINGTON.

Concession VI, lot 14.—About 300 tons of apatite were raised about the year 1880 by Mr. W. J. Morris. The lead appears to have been narrow—averaging under 12 inches in width—and carried a reddish phosphate, mixed occasionally with small quantities of mica. An analysis of the apatite gave:—

Tricalcic phosphate.....	88·14	=	40·37 phosphoric acid.
Calcium fluoride.....	6·80	=	3·31 fluorine.
Calcium chloride.....	0·69	=	0·43 chlorine.
Calcium carbonate.....	0·06		
Magnesia.....	0·15		
Alumina.....	0·61		
Ferric oxide.....	0·15		
Insoluble.....	3·89		
Total	100·49		

Reference:—
Geol. Surv. Can., Rep. Prog., 1877-78, p. 2H.

Concession XIV, lots 4 and 5.—Some 500 tons of phosphate are reported to have been raised on these lots about 1885, by Messrs. Bawden and Machar, of Kingston, and by other parties mining under royalty to the above.

The property was later worked for mica by Messrs. Bawden and Gunn, who took out a monthly average of 3 tons of rough-cobbed mineral during part of 1900.

References:—
Ont. Bur. Min., X, p. 133.
Rep. Royal Commission, 1890, p. 170.

Concession XV, lot 21.—Known as the Opinicon, or Rock Lake mine, and worked during 1891 and 1892 by the Kingston Phosphate Company, of Montreal, and by Mr. James Bell, of Arnprior, under royalty to the Canada Company of $2 per ton. Mr. Bell had previously mined on this property during 1888 and 1889, and extracted about 500 tons of mineral. A force of 25 to 30 men was employed, and work was conducted by day and night shifts. Two pits were sunk, the larger reaching a depth of 225 feet on an incline of 45°, and being 75 feet long. The vein is reported to have widened from 2 feet at the surface to 8 feet at the bottom of the main pit. From 4 to 5 tons of phosphate per diem were raised from this opening. The second pit reached a depth of 40 feet, and measured 20 × 30 feet at the surface, widening as it went down. An average of 2 tons of mineral per diem was produced from this opening. Steam was used for drilling and pumping and for hoisting from the large pit.

The phosphate produced was massive crystalline, and of a green colour, changing locally to red. After being cobbed and, in some cases, washed, it was hauled a distance of half a mile to the lake, and loaded into scows of 100-tons capacity, being then taken by water to Kingston, and shipped to London and Hamburg.

The mine was closed down in 1892, and has not since been worked. The total amount of phosphate produced from this property would amount to about 1,500 tons.

References:—
Ont. Bur. Min., I, p. 239; II, p. 251.
Rep. Royal Commission, 1890, p. 173.

Lanark County.

TOWNSHIP OF NORTH BURGESS.

Concession III, lot 16.—A hundred tons of apatite are recorded to have been shipped from this property to the United States, in 1871, by

Mr. M. Philips. The colour of the phosphate was red, and the mineral yielded on analysis:[1]—

Tricalcic phosphate	85·24	=	39·05 phosphoric acid.
Calcium fluoride	7·78	=	3·80 fluorine.
Calcium chloride	0·74	=	0·48 chlorine.
Calcium carbonate	0·22		
Magnesia	0·55		
Alumina	1·20		
Ferric oxide	1·29		
Insoluble	3·49		
Total	100·51		

Concession IV, lot 11.—Worked in 1871 by Mr. G. Clark, of Sherbrooke.

Concession V, lots 3 and 4.—Phosphate was mined on these lots as far back as 1867, when the Rideau Mining Company conducted operations for a short period. Other lots, including 8, 9, and 10, were simultaneously worked by this Company, who opened up a number of shallow pits and shipped a quantity of phosphate to Germany. Many of the openings have since been exploited for mica, which occurs in some quantity on the veins. The principal work for apatite was carried out on lot 4. There, some half-dozen narrow pits have been opened upon parallel leads of phosphate and very dark mica, the openings being some 10 to 15 feet apart, and situated only about 50 feet from the shore of Big Rideau lake. The deepest of these pits is down 70 feet, the remainder being only shallow openings. The average width of the pits does not exceed 5 feet. Considerable phosphate was extracted, also, from lot 10, and the workings here are somewhat extensive.

No machinery was ever employed on this property, which has since been worked by various parties for mica. Lots 4 and 8 belong, at present, to the estate of the late Mr. J. Rogers, of Perth; while lot 3 is owned by Mr. E. Smith, of Perth; and lot 10 by Mr. J. Mahon, of Rideau Ferry.

References:—
Ont. Bur. Min., III, p. 193; XII, p. 130; XIX, p. 127.
Rep. Royal Commission, 1890, p. 175.
Geol Surv. Can., Rep. Prog., 1870–71, p. 316.
Dept. Min. Can., Min. Br., Mon. Mica., 1912, pp. 164-6.

Concession V, lot 13 E. ½.—Silver Queen mine, owned by Mr. Edward Smith, of Perth, Ontario. This property was first worked in 1903, when Mr. R. McConnell, of Ottawa, carried out a few months' work for mica with a small force of men. Two years later the mine was acquired by the present owner, and was worked by Mr. C. Ellsner, under lease, for a year, both mica and phosphate being mined. The owner has worked more or less steadily since 1906, and has taken out a large quantity of mica and considerable phosphate. None of the latter mineral has been mined or shipped during the last five years, as work has not been carried on in the old pit where the principal apatite-bearing lead is exposed. About 100 tons of fine-grained, greenish-white, sugar phosphate were lying at the mine when the property was visited, in 1912.

[1]Geol. Surv. Can., Rep. Prog., 1877–78, p. 41I.

Although several openings have been made while mining for mica, phosphate has been found in quantity at only one point, this being on the side of a small ridge of gneiss rising some 50 feet above the neighbouring crystalline limestone zone. Here, a pit has been sunk vertically, some 35

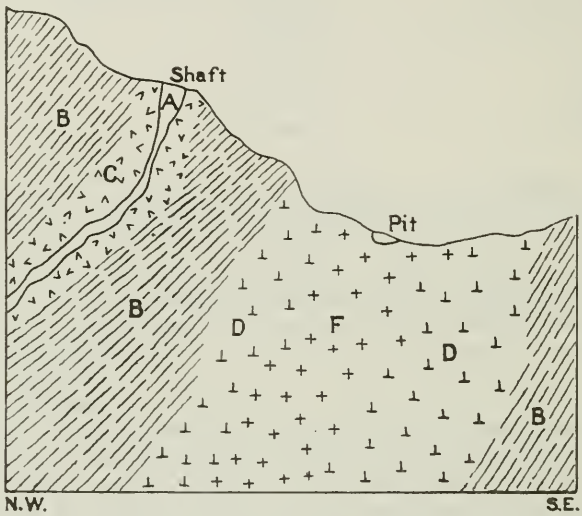

Fig. 6. Section at Silver Queen mine, township of North Burgess, Ont. A, mica-phosphate vein; B, country granite-gneiss; C, pyroxenite; D, fetid crystalline limestone; F, feldspar zone, consisting of bluish microcline mixed with calcite, sphene, diopside, etc. Scale: 1 inch = about 500 feet horizontal and 25 feet vertical.

feet, from which point an inclined stope has been carried a further 65 feet, to N.W., drifts being run along the deposit in a northeasterly direction. The total length of the excavation is about 60 feet. At the north end, a $4' \times 5'$ timbered collar has been built in, through which pass the pipes for drilling and pumping, and through which hoisting is carried on. Pillars of rock have been left at intervals on the stope to support the roof. The mica and phosphate occur in large pockety masses on a zone extending a considerable distance, and the occurrence somewhat resembles, on a smaller scale, the Blackburn deposit in Templeton township, Que.

Much of the mica is crushed and twisted, as is often the case where large quantities of phosphate are present.

The deposit, which occurs along the contact of a pyroxenite belt with crystalline limestone, has a direction of N. 30° E., with a dip to N.W. An interesting feature is the occurrence, on crevices in the sugar phosphate, of sheets of white hornblende-asbestos or "mountain-leather." Long, prismatic crystals of dark green actinolite, penetrating pink calcite, were found on the dump, and small quantities of scapolite were noticed. The pyroxenite varies from a dark green to a light grey rock, the pyroxene often possessing highly developed cleavage in three directions. The crystalline limestone adjacent to the contact with the pyroxenite is remarkable both on account of its colour, which is a light blue, and for its property of liberating sulphuretted hydrogen when crushed or struck with the

hammer. This rock also contains a large amount of phlogopite, in minute crystals, as well as pyrites, diopside, garnet, tremolite, and graphite.

About 500 feet to the southeast of this phosphate lead, a feldspar deposit has been uncovered and worked in a small way. This deposit appears to constitute a feldspathic zone about 100 feet wide, paralleling the phosphate vein, and is probably not a true dike, but, in part, at least, of contact metamorphic origin. The feldspar of this deposit, like the limestone above mentioned, is also characterized by its containing sulphuretted hydrogen.

The mine is equipped with a boarding house for twenty men; boiler house with 15 H.P. vertical boiler; steam hoist; pump, and three drills. Wooden buckets are used for raising the rock, etc., and slide on a wooden skipway, inclined at varying angles at the different depths. An average of half a dozen men is employed.

The distance from Perth by road is 12 miles, but shipment of mineral can be made from Hogg bay on Big Rideau lake, distant about one mile from the workings.

References:—
Ont. Bur. Min., XV, p. 105; XVI, p. 88; XVII, p. 92; XVIII, p. 140; XIX, p. 127; XX, p. 111.
Dept. Min. Can., Min. Br., Mon. Mica., 1912, p. 167.

Concession V, lot 16.—Donnelly mine. Phosphate was mined on this property previous to 1870, and four openings were made, from which about 100 tons of apatite were raised by Messrs. R. Leckie and Company, of Montreal.

The mine, which lies about 9 miles southwest of Perth, has since been exploited for mica, which occurs in some quantity with the apatite.

The deposit is a typical contact between a dark compact pyroxenite on the northeast, and normal gneiss on the southwest, the direction being almost due N.W.-S.E. The vein matter is principally pink calcite, in which mica crystals associated with bunches of phosphate occur embedded. The mica crystals are of more than usual size, and of excellent quality and colour. The lead at the surface was only a few inches wide, but developed into a body over 8 feet across at the bottom of the main pit. The dip is about 80° N.E. Several pits have been opened along the vein, the deepest being down 35 feet, while the largest pit has a length of 35 feet and is 6 feet wide. Towards the south the lead appears to branch off into two portions. The total length of lead worked is about 150 feet. No machinery has been in use on the mine, hoisting being by derrick and horse whim; the only building is a small mica shed.

Reference:—
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 169.

Concession V, lots 18 and 19.—Also lots 18 and 19 in concession VI. A small amount of surface work was conducted on these properties in 1871 by Messrs. Matheson and Bell, and a little phosphate was secured. Two pits, each about 40 feet deep, were sunk, and a production of 200 tons was reported.

Reference:—
Geol. Surv. Can., Rep. Prog., 1870-71, p. 319; 1871-72, p. 127.

Concession VI, lot 1.—McMartin mine. Was worked somewhat extensively in the early phosphate days. No details of production are available.

Concession VI, lots 10 and 21.—These lots were worked in 1871 by Mr. G. Clark, of Sherbrooke, who took out a quantity of phosphate, chiefly of a red colour and often mixed with hematite. Lot 10 is now known as the Old Anthony mine, and has been worked within more recent years for mica. The workings on this property extend to a depth of over 125 feet, and the main pit has been opened on a 4-foot vein, having a direction of N. 35° E., and occurring on the contact of dark green pyroxenite with red granite-gneiss. Mining was continued here for several years, operations being conducted by Floerstein and Company, during 1873 and 1874: this Company acquiring the mine from Mr. Clark.

Lot 21 is now known as the Star Hill mine, and has since been worked for mica by a number of operators. The amount of phosphate found at this point was not large.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124; 1872-73, p. 177; 1874-75, p. 108.
Rep. Royal Commission, 1890, p. 174.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, pp. 170, 174.

Concession VI, lot 12.—A little green granular apatite has been raised on this lot, the mineral chiefly being obtained while mining for mica.

Concession VI, lot 13 E. ½.—Martha mine. Although worked extensively for mica during recent years, this property was originally opened for phosphate, in 1871, by an English company, several hundred tons of mineral being raised. The vein—composed of calcite, mica, and apatite—is reported to have measured over 25 feet in width. In 1892, the mine was acquired by the Lake Girard Mica System, who worked for both mica and phosphate, and subsequent operators include the Mica Manufacturing Company, of London, and Messrs. Sewell and Smith.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124.
Rep. Royal Commission, 1890, p. 174.
Ont. Bur. Min., III, p. 194; X–XV, for more recent details of mining for mica. Also Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 172.

Concession VI, lot 13 W. ½.—Known now as the Munslow mine, this property has been worked during more recent years for mica. Apatite was first mined here in 1871, by Mr. Edward Schultze, who opened, principally, small surface pits, and extracted only a small quantity of mineral.

The workings of this mine adjoin, and form part of those of the Martha mine, on the east half of the same lot.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 173.

Concession VII, lot 9.—Two narrow pits, respectively 35 and 90 feet deep, were opened about the year 1883 on well defined, parallel leads of apatite and mica. Work was continued for a couple of years, and the property has been subsequently worked for mica by Mr. Edward Smith, of Perth. The total amount of phosphate produced on this lot, and on the east half of lot 11, in the same concession, is estimated at over 2,000 tons.

References:—
Rep. Royal Commission, 1890, p. 173.
Ont. Bur. Min., XV, p. 105.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 175.

Concession VII, lot 11 E. ½.—This lot, together with 9 in the same concession, formed what was known as the Otter property. Lot 9 has since been worked for mica, but this mineral does not occur in any quantity on

lot 11, and but little mining for it has been attempted. A number of small pits exist, the largest measuring 45 × 8 feet, and being 35 feet deep. This opening has been made on a lead of mica and brown phosphate having a direction of N. 20° E., and a dip of 80° S.E.

The property, which lies a few hundred yards from the Hanlon mica mine, and worked, about 1891, by Messrs. Cross and Foster, of Smiths Falls, is now owned by Mr. McLaurin, of Perth.

The total amount of phosphate raised on these two lots is estimated at about 2,000 tons: the initial work was commenced in 1870.

References:—
Ont. Bur. Min., II, p. 251.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 175.

Concession VII, lots 11 W. ½, 12 W. ½.—Work has been chiefly confined to lot 12 (Byrnes' mine). Mining was commenced by Mr. A. Cowan, of Brockville, in 1870, and several pits were opened. The largest opening is about 55 feet deep. The apatite is of a red colour, and is frequently much mixed with hematite or pyrites. Mica accompanies the phosphate on most of the leads, and is of a very dark colour, being also hard and brittle. The amount of phosphate taken from the veins on these lots is reported as upwards of 1,500 tons, the whole amount being shipped to the Brockville Chemical Company's works. Mining was continued here from 1870 until 1874; since then, with the exception of some work for mica in 1901 by the General Electric Company, who now own the property, and intermittent work by the former owner, Mr. P. Byrnes, the mine has lain idle.

References:—
Geol. Surv. Can., Rep. Prog., 1870-71, p. 319; 1871-72, p. 124; 1872-73, p. 177.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 176.
Ont. Bur. Min., X, p. 132; XI, p. 290; XII, p. 129, XIII, p. 91.

Concession VIII, lot 1.—Otty Lake mine. Worked in 1871 by Mr. Edward Schultze, and in 1873 by Messrs. Morris and Griffin, of Wolverhampton, England. The latter Company only worked for one year, and raised about 350 tons of phosphate. Mr. R. McConnell, of Ottawa, acquired the mine in 1908, and has conducted a considerable amount of work for mica, employing 35 men, and using steam for drilling, hoisting, etc. The largest opening is 100 feet long, 15 feet wide, and about 40 feet deep.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124; 1873-74, p. 110; 1874-75, p. 109.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 176.

Concession VIII, lot 2.—This property was worked in 1870 by Hon. R. Matheson of Perth, who opened up a pit 60 feet long by 15 feet deep, besides numerous smaller openings, and secured a considerable amount of phosphate. The deposit is reputed to be the first ever worked in Canada, a small amount of mining having been conducted in 1855. For what purpose the apatite was mined is not stated.

The lot was divided into a number of sections, all owned by different parties, these including (besides the above) Messrs. Meighen and Morris, and Messrs. Morris and Wilson, of Perth. The various owners mined small amounts of phosphate between 1870 and 1875.

In 1907 Messrs. Kent Bros., of Kingston, acquired the mine, and worked a couple of seasons for mica. The largest opening on the property is an open pit 60 × 25 feet, and 25 feet deep, situated near the shore of Andrew lake. The deposit at this point consists of pockety accumulations of light, silver-amber mica, associated with white calcite, and small amounts of green apatite.

A number of openings exist on the lot, the old phosphate pits being located, principally, on the southeast end of the property. One of these pits disclosed a flat, pockety lead averaging 3 feet wide, and carrying a vein filling of dark green apatite and mica, under a capping of dark gneiss. Several small openings exist on this lead, which has a general strike of northwest and southeast, and carries large quantities of scapolite and wilsonite, the enclosing rock finally taking on the character of a scapolite-pyroxenite.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124.
Rep. Royal Commission, 1890, p. 174.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 177.

Concession VIII, lot 3.—Apatite was mined on this lot in 1870 from a vein 8 feet in width, the workings being situated near the shore of Otty lake. The operators were Messrs. Ritchie and Jackson, of Belfast. A shaft 30 feet deep was sunk upon a 3-foot vein, and drifts were run in both directions from this opening along the lead. A number of smaller pits, also, were opened, the total production of phosphate falling not far short of 1,000 tons. The apatite is green in colour, and both granular and massively crystalline, occurring associated with amber mica on well defined veins. These veins strike N.W. and S.E., and average about 2 feet in width. The rock adjacent to the leads is a coarsely crystalline, quartz-syenite: narrow bodies of pyroxenite separating the vein filling from the country rock.

The present owner of the property is Mr. R. Cordick, Sr., of Perth, and the mine was worked for a few months in 1908 for mica by Messrs Kent Bros., of Kingston.

References:—
Geol. Surv. Can., Rep. Prog., 1870-71, p. 320; 1871-72, p. 124; 1873-74.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 178.

Concession VIII, lots 4, 5 and 6.—This property is owned by Mr. William MacLaren, of Perth, who is engaged, at the present time, in mining for mica. A little phosphate is extracted simultaneously, but the quantity is small, and no shipment of this mineral has been made since 1908. The apatite found on these lots is usually massive, green, rock-phosphate, but a little of the sugar variety also occurs. Work is carried on intermittently, some half a dozen men being employed; in addition to work at the main pit on lot 4, operations, chiefly of a prospecting nature, are conducted at various points on the property.

A new steam plant was installed at the main pit in 1911, this comprising a 40 H.P. portable, horizontal boiler, and 3-drill compressor. This machinery had not yet been put into operation at the end of 1912. The mine is equipped with boarding house, stables, mica trimming sheds, etc.

Mica and phosphate are extensively developed all over these lots, and numerous openings have been made in the past, chiefly for the latter mineral. The main pit, now being worked for mica, was originally opened for phosphate, and the owner reports that a promising lead of apatite has lately been uncovered in the northwest end. This pit is a narrow open-cut, or trench, 75 feet deep, and averaging some 10 feet wide; it has been excavated by sinking on a vein of approximately the same width, the

course of the lead being followed in sinking, so that a somewhat irregularly shaped opening has resulted. The direction of the deposit is N.W.-S.E., and its dip is nearly vertical.

Mining for phosphate on these and adjoining lots was commenced as early as 1870. In this year, Messrs. Watts Bros., of Perth, leased lot 4 from the owner, Mr. Flaherty, and continued work for a year. Over 200 tons of apatite were extracted, and shipped to Germany, the price paid being $10.50 per ton at the mine.

Lot 5 was also worked during 1870 by the owner, Mr. R. Matheson, of Perth, and numerous openings were made on the property, without, however, resulting in any large production of phosphate. Openings were also made on lot 6 about this time, but the majority of them were unimportant.

Between 1878 and 1883, the above lots, and also lot 5 in concession IX, were worked by Mr. P. C. Adams, of Montreal, and the output of apatite during this period is reported to have been over 5,000 tons.

In 1888 the Anglo-Canadian Phosphate Company, of Liverpool and London, England, acquired the abovementioned properties, and other phosphate lands in the townships of Bedford and North Burgess, and commenced mining with a steam plant. It was found, however, that work by machinery proved more expensive than hand work, and steam was abandoned in favour of hand drilling. The Company put down two main pits, 100 feet and 80 feet deep respectively, besides numerous smaller openings, and extracted some 2,000 tons of apatite, employing, on an average, about 20 men. Practically all of this production was shipped to Germany and England; the former country taking the highest grade mineral. On account of the drop in prices in the early nineties, the Company abandoned operations in 1891. The mine lay idle until 1901, when Hon. Peter MacLaren commenced work for mica and phosphate, and operations have been continued intermittently by him and the present owner up to the present time.

The mine lies 6 miles south of Perth.

References:—
Geol. Surv. Can., Rep. Prog., 1871-72, p. 124; 1873-74, pp. 123-127; 1882-84, p. 7L.
Ont. Bur. Min., XI, p. 287.
Rep. Royal Commission, 1890, pp. 168-175.
Dept. Min Can., Min. Br., Mon. Mica, 1912, p. 178.

Concession IX, lot 4.—Numerous small openings have been made in the past upon this lot, and a small amount of phosphate was raised. The largest pit measures 15 × 6 feet, and is 30 feet deep. This opening discloses a vein of amber mica, pink calcite, and green apatite, between walls of normal pyroxenite, having a direction of N.W. and S.E The width of the lead is about 5 feet.

Messrs. Watts, Adams, and Noble, of Perth, have worked the property for mica and phosphate during recent years, but operations have been entirely confined to the surface.

A vein of barytes occurs on this lot, but has not been exploited.

Reference:—
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 179.

Concession IX, lot 6.—A large number of pits, several of them of considerable extent, exist on this lot, more particularly on the eastern portion. Little information regarding these old workings is available, but a quantity of phosphate would appear to have been raised from them. The veins,

which carry red and green apatite—both massive, and in crystals disseminated through calcite—possess a strike of E. 15° S., and dip nearly vertically.

A small amount of mica has been mined during recent years—in 1904 by Messrs. Montgomery and Adams, of Perth, and in 1910 by Mr. J. H. Mendels, of the same place.

References:—
Ont. Bur. Min., XIV, p. 85.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 180.

TOWNSHIP OF NORTH ELMSLEY.

Concession VIII, lot 25.—A very large body of pink calcite is exposed upon this lot, and has been mined in a small way for the apatite crystals which occur disseminated in large quantities through it. Only one opening has been made, upon a portion of the vein which here measured 10 feet in width; over 100 tons of phosphate are reported to have been raised. All the work done on this property was performed previous to 1870.

Reference:—
Geol. Surv. Can., Rep. Prog., 1870-71, p. 320.

Leeds County.

TOWNSHIP OF SOUTH BURGESS.

Concession IV, lot 1.—Cantin mine. This lot, which has since been extensively worked for mica, was mined in a small way for apatite in the early seventies. Among later operators have been Webster and Company, who extracted a few hundred tons of phosphate, besides a large amount of mica; also the General Electric Company, of Schenectady, N.Y., who are the present owners. No apatite has been shipped from here for many years. The deposit appears to occur at the contact between pyroxenite and granite-gneiss, and the mica and phosphate are disseminated in scattered crystals or in small pockety aggregates through a large body of very hard and compact pinkish-white calcite. Small crystals and streaks of pyrites are a constant accessory in this calcite body—the mica crystals often being stained a blue colour—caused by decomposition of the sulphide.

The main pit on the property has a depth of 110 feet, and measures 85 feet in length, being from 12 to 25 feet in width. It is an open-cut on level ground, and follows the course of the lead, which runs E. 10° N. The vein was found to be cut off at 100 feet by a horse of reddish granite, and it was this obstacle which put an end to mining operations.

References:—
Geol. Surv. Can., Rep. Prog., 1870-71, p. 320.
Ont. Bur. Min., III, p. 195; V, p. 276.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 190.

TOWNSHIP OF SOUTH CROSBY.

Concession VII, lots 14 and 15.—Apatite was mined in small amount on these lots in the seventies, and, more recently, work has been conducted for mica. Lot 14 now comprises the Sand Lake mica mine, which has produced large quantities of mica since 1900. There is one large pit of circular form, 25 feet across and 75 feet deep.

References:—
Geol. Surv. Can., XIV Ann. Rep., 1901, p. 182A.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 187.

ADDITIONAL APATITE OCCURRENCES IN ONTARIO.

Apatite has been discovered, and the veins in some cases stripped and worked in a small way, in a number of townships in Peterborough, Lanark, Renfrew, Hastings, and Haliburton counties. The following is a list of the more important localities in these counties where apatite deposits have been found:—

Haliburton County—
Cardiff, *Concession XIV, lot. 22.*
Hastings County—
Monteagle, *Concession VI, lot 26.*
Lanark County—
Bathurst, *Concession VIII, lot 11.*
Peterborough County—
Dudley, *Concession III, lot 4.*
Dysart, *Concession V, lot 11.*
Harcourt, *Concession XI, lot 21.*
Monmouth, *Concession X, lot 6.*
" *Concession XI, lots 13, 14, 17.*
Renfrew County—
Ross, *Concession 1, lot 7,* (Elliot mine).
" *Concession VI, lot 13,* (Cole mine).
" *Concession VII, lot 1.*
" *Concession IX, lot 7.*
Sebastopol, *Concession X, lot 31,* (Smart mine).
" *Concession XI, lot 31,* (Meany mine).
" *Concession XII, lot 23,* (Parks mine).
" Turner's island, in Clear lake.

In Sebastopol township several large deposits of phosphate were discovered. The veins in this region are remarkable for the large and well-formed crystals of apatite, titanite, and zircon, which they carry, and at the localities mentioned many handsome specimens have been found. On lot 31 of concession X, a mine was opened prior to 1880, and yielded a considerable quantity of phosphate.

At the mine on Turner's island, scapolite in large, semi-translucent crystals, is an important constituent of the vein. Titanite crystals, up to 40 pounds in weight, have also been found here. The mine was operated between 1879 and 1882, and yielded about 200 tons of phosphate.

On lot 31 of concession XI some 300 tons of phosphate were produced in the early eighties, the vein being, in some places, as much as 16 feet wide, and carrying pyroxene, calcite, and apatite.

At the mine on lot 23, concession XII, the apatite occurs chiefly in the form of well-shaped crystals, disseminated through pink calcite.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, pp. 5-7L.
Ont. Bur. Min., IX, p. 194.

NIPISSING DISTRICT.

An occurrence of apatite is recorded from lot 4, concession VI, of the township of Ferris.

Province of Quebec.

The small amount of apatite produced annually in Canada at the present time, is practically all derived from the Province of Quebec, and is a by-product of mica mines.

Although phlogopite mica and phosphate occur in Canada in intimate association, it has been found that, as a general thing, the two minerals seldom are present in large amount in one and the same deposit, and that one tends to give way to the other. Where a large development of apatite has taken place, mica is often conspicuously absent, and *vice versa*. There are, it is true, notable exceptions to this rule, many of the mines in the Templeton district having produced large quantities of both minerals. Along the Lièvre river, however, the formation of apatite has been seldom accompanied by any important development of mica, at any rate within the main body of the phosphate. The mica found at the mines in this region usually occurs either in the outer zone of the pyroxene belt or in small veins adjacent to the phosphate body, and carrying only small amounts of apatite. Such veins naturally received little attention at the hands of the phosphate miners in the early days, and a vein carrying mica was seldom followed unless showing an exceptional amount of apatite. The waste dumps of the old phosphate mines in this district, therefore, cannot be expected to contain any great quantities of mica, although some of them probably would yield sufficient mineral to repay working over.

The total recorded production of phosphate in the Province of Quebec since the commencement of mining, or rather since 1878, the first year for which returns of production are available, amounts to 300,000 tons, or just about nine-tenths of the total output of the two provinces, Ontario having a record of only 33,469 tons. (See Tables II and III). Roughly nine-tenths of this total represents production previous to 1893.

The richest phosphate bodies discovered in the Province were those in ranges XI and XII of the township of Buckingham and in the township of Portland West, west of the Lièvre river. Scattered deposits of more than average richness were worked at various points in the Templeton district and towards the Gatineau river, but the total tonnage taken from these mines was not large. Although scattered mica deposits are found all through the country between and adjacent to the Lièvre and Gatineau rivers for a considerable distance to the north of Ottawa, apatite as a vein mineral accompanying mica seems to become less abundant with increasing distance from the main bodies to the south, and in several of the most northerly located mica mines it is almost entirely absent.

Although there is, at the present time, no prospect that any serious mining for phosphate can be undertaken in the near future the Lièvre river apatite area certainly still holds large bodies of mineral, and would be the most favourable region for operations in the case of any eventual revival of mining.

Labelle County.

township of bowman.

Range IV, lots A, 1, 2, 3, 4.—High Falls mine. Opened in 1890 by the General Phosphate Corporation, Ltd., of London, England, who worked the Ross Mountain mine (range VI, lots 5 and 6, and range VII, lots 1 and 2 of Portland West), at the same time.

The Company worked for only one year, employing as high as 80 men. The total production from the High Falls mine is estimated at about 1,000 tons. The workings lie only about half a mile from the High Falls on the Lièvre river, but rapids made it impracticable to ship the mineral from this point, and it had to be hauled to a wharf some miles below. When the dam at the Little Rapids—some eleven miles below—was constructed, the river became navigable up to the foot of the High Falls.

The pits lie on the southeast side of a ridge, which rises steeply from Barbutte or Bowman lake. There are six important openings, the largest being a flat drift 100 feet long, 25 feet high, and carried 75 feet into the hill. Pillars were left at intervals to support the roof of this opening which still contains extensive showings of phosphate. The mineral is massive and compact, and is of a blue-green colour, occurring on shoots and pockets in a light, grey-green pyroxene. The remainder of the pits are all open-cuts into the ridge, the deepest of such openings not exceeding 75 feet, and 20 × 15 feet.

Much of the rock at this point is a brown-green pyroxene, containing crystals of dark, almost black, hornblende. Stringers and small pockets of pink and white, fine-grained calcite traverse this rock, and carry crystals of apatite, pyrites, and sphene.

A good bush road still connects the mine with the village of High Falls, but all the buildings have long since disappeared. The mine was equipped with a large camp, and a steam plant was installed. No work has been done upon the property since 1892.

An analysis of apatite from this mine, conducted by M. F. Connor, of the Mines Branch, yielded the following:—

Phosphoric acid	39.24 = 85·74	tricalcic phosphate.
Lime	55·70	
Magnesia	0·20	
Soda, Potash	0·80	
Water	0·28	
Chlorine	0·65	
Fluorine	3·10	
Ferric oxide, Alumina	0·72	
Insol. and silica	0·06	
	100·75	
Less oxygen = chlorine, fluorine	1·37	
	99·42	

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 16; XII, Ann. Rep., 1899, p. 99.
Que. Bur. Min., 1891, p. 87, 1892, p. 82.

Range V, lots 27 and 28.—Brazeau mine. Owned by Messrs. Watts and Noble, of Toronto and Perth, who purchased the mine in 1907. The property lies about five miles from High Falls, and is the most northerly

situated phosphate deposit which has so far been worked in this region; the phosphate bearing belt, which extends in a northwesterly direction from the Ross Mountain mine, on the sixth range of West Portland, appearing to have its northerly limit at or near this locality. This belt possesses a length of about ten miles. The owners have worked intermittently during the past twenty years, operations usually being conducted in winter. The last operations were conducted in 1910. A maximum force of 12 men was employed, and the total production of the mine is estimated at 1,500 tons.

There are several small openings, the largest measuring 35 × 30 feet, and being about 40 feet deep. This pit has been excavated open-cut in the southwest side of a ridge, upon a sort of chimney deposit of dark, yellowish-green apatite—the pocket being followed down by sinking on the floor of the cut. The bottom of this pit is said to show a body of apatite over 20 feet wide. No calcite was noticed, the walls of the opening appearing to consist of massive apatite, mixed with dark coloured pyroxene and hornblende. The phosphate contains a considerable amount of pyrrhotite disseminated through it in fine grains.

There are a few buildings, including cobbing house, bunk house, etc., at the mine, but no machinery has ever been used.

A noticeable feature is the conspicuous absence of waste rock, the amount of dead rock extracted being very small. The material taken from the pit appears to have been almost entirely phosphate. Scarcely any mica occurs on the property.

The output was hauled to the foot of the High Falls, and taken down by scow to Buckingham.

TOWNSHIP OF BUCKINGHAM.

Range X, lot 25.—Apatite was discovered on this lot in 1876 by Mr. G. C. Brown, but no development of the property has ever taken place. The distance of this lot from the Emerald phosphate belt is about 2½ miles, the valley of the Lièvre river separating the two.

South of the tenth range, no important deposits of apatite have ever been located in the township of Buckingham, though the mineral is sometimes found associated with calcite in the graphite mines.

Reference:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 306.

Range XI, lot 19.—Washington or Lansdowne mine. This property comprises a portion of the phosphate belt upon which is situated the Emerald mine—the workings of the two properties being contiguous. Mr. G. C. Brown, in 1876, was the first to carry out any work on this and the adjoining lot (18), and operations were later conducted, in 1882, by the Dominion Phosphate Company, of New York, who ceased work in the following year, and transferred their working force to the North Star mine, which they continued to operate until 1891. No extensive bodies of phosphate were discovered, and no further development of the property has taken place.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 14.
Que. Bur. Min., Mines and Minerals of the Province of Quebec, 1889-90, p. 122.

Range XI, lots 25 S. ½, 26.—Kendall mine. About 100 tons of apatite were mined on this lot about the year 1880, the mineral being taken from an open-cut in the side of a ridge. The vein measured 18 feet in

width, and carried a hard, compact phosphate, rather stained by iron. In 1892, the property was again worked by Mr. W. C. Kendall, of Buckingham, who mined for mica—this mineral being found in a band of serpentine limestone which traverses the property. No further work has taken place.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 19J; VI Ann. Rep., 1892-93, p. 39A; XII Ann. Rep., 1899, p. 113J.
Que. Bur. Min., 1892, p. 87.

Range XII, lot 17 N. $\frac{1}{2}$.—Aetna mine. This mine includes the most easterly openings which have been made upon the great phosphate bearing belt exposed on lots 17, 18, and 19, of the twelfth range of Buckingham, and exploited, in addition, at the Squaw Hill and Emerald mines.

In 1873, H. G. Vennor alluded to the presence of large masses of apatite on these lots, and predicted their importance. In 1875, the above lot, together with 18 N. $\frac{1}{2}$ and 19, was acquired by the Buckingham Mining Company, who did considerable prospecting and development work. In 1889, lots 17 N. $\frac{1}{2}$ and 18 S. $\frac{1}{2}$ were taken over by the Anglo-Continental Guano Company, Ltd., of London, England, who named the property "The Squaw Hill and Aetna Phosphate Mines." This syndicate worked for only three years, the mine being purchased in 1892 by the British Phosphate Company, of London, who confined most of their work to the Aetna property. Shortly after the last named Company took over the mine, phosphate mining in the Lièvre district came to an end, and the property has lain idle ever since.

The Aetna mine is situated about one mile east of the Emerald workings, and is separated from these by a valley, in which runs the Tamo lake road. The pits are located on the top of a steep ridge, into the base of which an adit was driven for some distance, in an attempt to locate new phosphate leads. Mining, however, came to an end before the two sets of workings connected.

References:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 304; Rep. Prog., 1873-74; p. 145; Bull. Ap., 1904, p. 14; XII Ann. Rep., 1899, p. 102.
Que. Bur. Min., Mines and Minerals of the Province of Quebec, 1889-90, p. 125.
Que. Bur. Min., 1892, p. 82.

Range XII, lot 18 S. $\frac{1}{2}$.—Squaw Hill mine. Known also as the Grant mine, and worked about 1876, in a small way by Dr. J. A. Grant, of Ottawa. In 1889, this property, together with the Aetna mine, was taken over by the Anglo-Continental Guano Company, of London. In this year, Obalski reports a pit 70 feet deep, from which over 3,000 tons of phosphate were said to have been taken. In 1892, the British Phosphate Company, of London, worked the mine, and produced large quantities of mineral. The main pit consisted of an inclined opening 140 feet deep. The workings were lit by electricity, and the mine was equipped with a large steam plant. The following year, however, saw the closing down of this and practically all the other phosphate mines in the Lièvre River district; this result being brought about by the largely increased production of the Southern States.

An analysis of a pale greenish-grey apatite from this mine, made by G. C. Hoffmann in 1878, gave:—

Tricalcic phosphate	89·68
Calcium fluoride	7·13
Calcium chloride	0·41
Calcium carbonate	0·84
Alumina	0·71
Magnesia, ferric oxide	0·28
Insoluble	0·37
Total	99·42

Specific gravity = 3·1493.

Massive, sea-green apatite from another pit on the same property gave:—

Tricalcic phosphate		74·30	
Calcium fluoride		5·86	
Calcium chloride		0·16	
Calcium carbonate		6·47	
Alumina		1·98	
Iron sulphide	S	3·51	Pyrrhotite.
	Fe	5·37	
Magnesia, ferric oxide		0·54	
Insoluble		2·05	
Total		100·24	

References:—
Geol. Surv. Can., Rep. Prog., 1877-78: pp. 3H and 7H (analyses of apatite); Rep. Prog., 1882-84, p. 12J; IV Ann. Rep., 1888-89, p. 108K; XII Ann. Rep., 1899, pp. 102, 116J; Bull. Ap., 1904, p. 14.
Que. Bur. Min. 1899, p. 90; 1802, p. 82; 1893, p. 105.
Mines and Minerals of the Province of Quebec, 1889-90, p. 125.

Range XII, lot 19.—Emerald mine. This property is situated at the western extremity of the phosphate bearing belt on which are also located the Aetna and Squaw Hill mines. The workings lie a few hundred yards off the main Lièvre River road, about 300 feet above the river, and some 500 yards distant from it. The mine was formerly one of the largest and most important phosphate producers in the district, and was exploited originally by the Buckingham Mining Company, about the year 1875. Subsequently Messrs. Murray and Allan carried out some work on the property, and later Mr. W. A. Allan worked a short while. In 1884, the Ottawa Phosphate Mining Company took over the mine, and continued to work until 1892, when the mine was shut down. No further work has taken place. In 1889 there was a reported output of 3,500 tons of phosphate—the force employed numbering 60.

Numerous openings exist on the property, the largest pit being situated on the north side of the hill. From the character of the workings, it would appear that the phosphate occurred in large, irregularly shaped pockets, which were joined up by narrow veins or necks. These pockets have been followed by tortuous workings, the intervening rock being left standing in pillars and benches. Most of the pits are open-work, and the present state of many of the workings is so bad that it would entail a large expenditure to render them anything like safe, should a new exploitation of the property ever be contemplated.

In one of the pits a vein of massive phosphate over 90 feet wide is reported to have been encountered. The apatite contains a considerable amount of iron pyrites, which occurs both in the form of small grains scattered through the phosphate and in nodules, the latter attaining a diameter of as much as six inches. The deposit is cut at one point by a dike of diabase, having a width of 35 feet, and an easterly direction. Calcite would appear to be relatively absent in this deposit, and very little mica has ever been found. A small amount of somewhat 'ruled' amber mica occurs on the north end of the lot; this mineral appears to be confined to small veins on the border of apatite and country rock. Machinery was never employed to any extent on the property. An adit was commenced at the foot of the hill, for the purpose of unwatering the upper pits, and also to serve as a means of running the phosphate to the river; this work, however, was not completed before the mine was closed down. The average output of this mine, during the middle eighties, was 5,000 tons of phosphate per annum—about 50 men being employed. A total production from the mine of about 35,000 tons is estimated up to the year 1890—this including all grades.

The accompanying plan shows the various rock types present in the immediate vicinity of this mine and of the adjoining Squaw Hill property, and is taken from Guide Book No. 3, International Geological Congress, 1913. The geology was worked out in 1912 by M. E. Wilson and J. Stansfield, of the Geological Survey, and the new rock types determined for this area are shown. The plan shows the close and involved association of the various widely divergent rock types that is characteristic of the mica-apatite regions of Quebec and Ontario.

References:—
Geol. Surv. Can., Rep. Prog., 1873-74, p. 145; IV Ann. Rep., 1888-89, p. 108K; Bull. Ap., 1904, p. 14. Summary Rep., 1911, p. 284.
Mines and Minerals of the Province of Quebec, 1889-90, p. 123.
Guide Book No. 3, International Geological Congress, pp. 89-93, 1913.

Range XII, lot 26.—Was worked for apatite in the early eighties. Two pits were sunk, one 10 × 12 feet and 22 feet deep, and the other 9 × 6 feet and 14 feet deep. No work appears to have been done upon the property since 1882. The mine was known as the "Vennor" lot.

Reference:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 20J.

Range XII, lot 27.—Several openings were made on this lot as far back as 1872. H. G. Vennor records six abandoned pits in 1873. Beyond some prospecting conducted by the Buckingham Mining Company in 1875, no further development would seem to have taken place.

References:—
Geol. Surv. Can., Rep. Prog., 1873-74, p. 145; Rep. Prog., 1876-77, p. 303.

TOWNSHIP OF DERRY.

Range II, lots 2 and 3.—A little work was done upon these properties in the eighties, and they were acquired later by the Du Lièvre Milling and Manufacturing Company, of Buckingham, Que., a concern which afterwards changed its name to the Du Lièvre Phosphate Mills. In 1899, the Glen Almond Mica and Mining Company mined in a small way for mica; but this mineral occurs here in too crushed a condition to render its extrac-

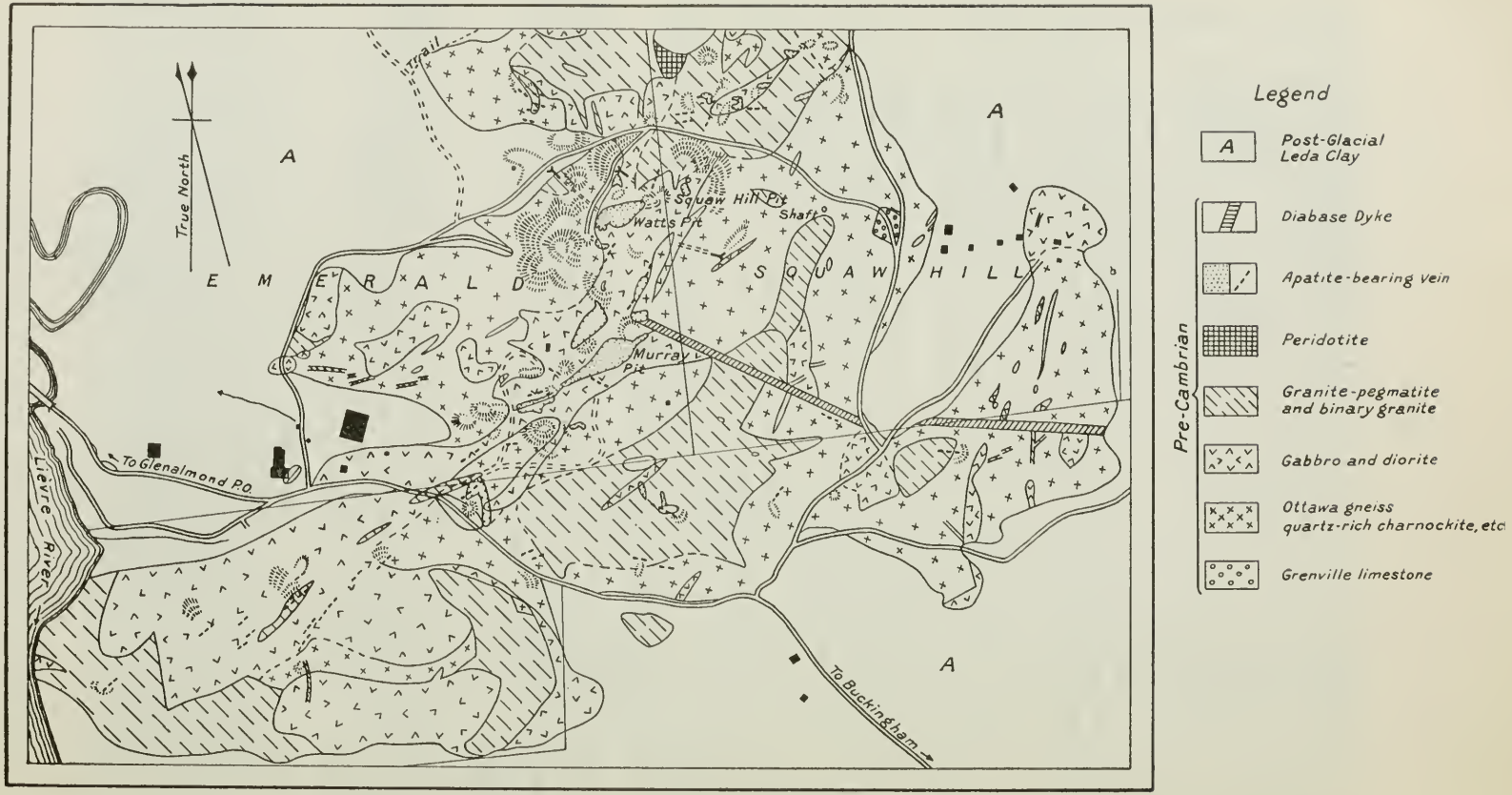

Fig. 7. Emerald mine, Buckingham township, Que. (After Stansfield.)

tion profitable. The phosphate bodies on these lots do not appear to be extensive, the mineral occurring more in the form of pockets and mixed with mica and calcite, than as veins of massive, crystalline apatite. This property is referred to incorrectly in various reports as range II, lot 23.

References:—

Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Que. Bur. Min., 1900, p. 21.
Geol. Surv. Can., XII, Ann. Rep., 1899, p. 133J.

Range VI, lots 8 and 9.—These lots were worked for a few months during 1910 by Mr. John Gorman, of Buckingham. Only surface work was done, and about 30 tons of phosphate were taken out of two small pits situated at the foot of a small bluff. The locality lies 20 miles from Buckingham, and is very inaccessible. The phosphate is dark green and massive, and occurs on the hanging contact of a narrow dike of granite striking N.W.-S.E. and dipping 42° S.W. into the side of a small ridge. The phosphate body is 5 feet wide where exposed. All the mineral taken out was hauled to Buckingham, to the Electric Reduction Company's works.

TOWNSHIP OF PORTLAND EAST.

Range I, lot 3.—Fowler and Bacon mine. A small amount of phosphate is reported to have been extracted in the early eighties by Messrs. Fowler and Bacon, who opened a few pits and worked a short while. None of the openings exceed 10 feet in depth.

Reference:—

Geol. Surv. Can., Rep. Prog., 1882-84, p. 13J; Bull. Ap., 1904, p. 14.

Range I, lot 6.—Little Rapids mine. This property was opened for phosphate, about 1876, by the Buckingham Mining Company, who extracted a few hundred tons of mineral, a considerable proportion of which was shipped to England. The property was known at this time as the Watts mine.

In 1883, Mr. W. A. Allan, of Ottawa, acquired the mine, and from this time until 1894 did considerable work on the veins by means of a number of narrow pits and trenches—a large quantity of mica being mined during the later years. The deepest workings consisted of two pits, 210 feet and 220 feet deep, respectively, sunk on leads averaging 5-6 feet in width. The mine was equipped with a large plant, comprising steam drills, pumps and hoists, and two 80 horse-power boilers, with compressor. A tramway was constructed along the side of the ridge, towards the river, being continued across the low ground at the base of the hill upon trestle work. The cars were drawn by a small locomotive. The phosphate was stored at a wharf on the river, and was taken in scows down to Buckingham, twelve miles below, where it was put on board cars. The mine is located on the northwest side of a ridge having a northeasterly direction, and lies 285 feet above the Lièvre river, and about half a mile distant from it. (See Plate IX.)

The phosphate and mica leads, of which a large number have been located, possess an approximate strike of north and south, and have been exploited by means of numerous small and narrow pits, all of which are open-cast.

The mine lay idle from 1895 until 1911, in which latter year the present owner, Mr. M. J. O'Brien, acquired the property, and commenced to work for mica. Operations were begun on the east side of the hill, and a

quantity of mica was taken from a small open pit. Later, these workings were abandoned, and at the present time (1912) one of the old phosphate pits is being deepened. While operations are being conducted primarily for mica, a considerable quantity of phosphate, also, was produced during the past year (1912). When the property was visited in the summer of 1912, the ore dump contained some 200 tons of high grade 80 per cent phosphate, while a considerable quantity of "seconds", or screenings, averaging 60 per cent, had also been saved. The phosphate is of the massively crystalline, green variety, in which pockets of white "sugar" phosphate sometimes occur.

The pit is being worked open-cast, and is 130 feet deep, 35 feet along the vein, and 10 feet wide. Hoisting is performed by a small steam winch operating an ordinary derrick, and drilling is done by steam, supplied by a 40 horse-power portable boiler. An average force of a dozen men is employed.

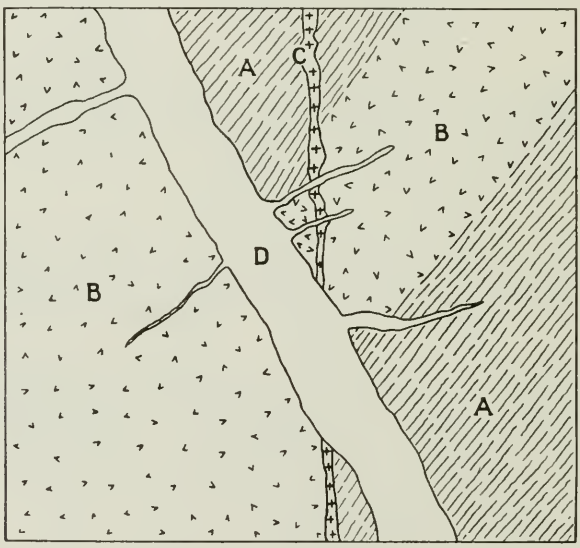

Fig. 8. Diabase dike D cutting pyroxenite B, country gneiss A and pegmatite C. Little Rapids mine, township of Portland East, Que. Scale: 1 inch=500 feet.

The enclosing rock is the normal type of pyroxenite, intruded by numerous stringers of acid rock, consisting principally of feldspar. The mica present is a dark amber; and a curious feature is that in certain pits the mica crystals were found enclosed almost solely in the feldspar stringers, instead of, as is more usually the case, in the pryoxenite proper.

The occurrence of a massive diabase dike on the property may be mentioned. This dike of hard, fine-grained and almost black rock, is a notable feature of this locality. Its width at this particular spot is 240 feet; its direction is W. 30° N. and its dip 80° W. The main body of the dike forms the wall of one of the pits on the east of the property, and has

cut the mica and phosphate body in two. In spite of the size of the intrusive, little alteration seems to have been produced in the country rock, even along the direct contact. The usual selvage is present, and the dike itself is fissile and fractured along the contact; but the pyroxenite appears to have suffered no contact metamorphism. Numerous small veins, or apophyses, run out at right angles from the main dike body; and small stringers are frequently met with in the phosphate pits—the intrusion of the main mass having caused considerable dislocation of the pyroxenite-gneiss. Plate X shows two such apophyses from the main dike. The light-coloured rock is pegmatite, which is later than the pyroxenites and the mica and phosphate bodies, and strikes N. 8° W. The stringers shown cut this pegmatite almost at right angles, and are respectively 17 and 5 inches wide. The country gneiss has the usual strike of N.E.-S.W., with a dip to N.W. Fig. 8 shows a diagrammatic plan of the occurrence. The dike can be followed for a distance of many miles across country, and is of a rusty brown colour, when weathered. An occurrence of similar rock can be seen at the Daisy mine in the adjoining township of Derry, some 4 miles distant; at Perkins Mills, also, nine miles southwest of the Little Rapids mine, the intrusive is seen cutting gneiss.

Range I, lot 7 and range II, lot 6 have also been acquired by Mr. O'Brien. There are said to be over 200 openings on the property.

An analysis of the phosphate from this mine, made in 1878 by G. C. Hoffmann, gave:—

Tricalcic phosphate	88·46	=	40·51 phosphoric acid.
Calcium fluoride	6·93		
Calcium chloride	0·13		
Calcium carbonate	1·94		
Magnesia	0·21		
Alumina	0·27		
Ferric oxide	0·83		
Insoluble	1·63		
Total	100·40		

Indications of phosphate are numerous all over this and adjacent properties; and it should prove possible to extract considerable quantities, were the market value of the mineral sufficient to render mining operations profitable.

References:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 302; Rep. Prog., 1877-78, p. 6H; Rep. Prog., 1882-84, pp. 17, 18J; VI Ann. Rep., 1892-93, p. 39A; XII Ann. Rep., 1899, pp. 101, 102J; Bull. Ap., 1904, p. 14.
Mines and Minerals of the Province of Quebec, 1889-90, p. 123.
Que. Bur. Min., 1892, p. 87.
Ont. Bur. Min., Royal Comm., 1890, p. 179.
Dept. Min. Br., Can., Mon. Mica, 1912, p. 60.

Range I, lot 7.—Forms part of the O'Brien property, and is said to have produced over a thousand tons of high grade apatite during the early eighties. The main opening measures 32 by 63 feet, and is about 45 feet deep.

Reference:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 15J

Range II, lot 6.—Was worked in 1876 by Mr. Edward Watts, of North Burgess. The occurrence is similar to that at the Little Rapids mine. Very little work appears to have been done on the property.

Reference:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 303.

Range I, lot 8, and range II, lots 7, 8.—London mine. This property is at present owned by Mr. A. McMillan, of Poupore, and is separated from the Little Rapids mine by a valley. The mine has lain idle since 1890. It was formerly owned by the Dominion Phosphate Company, of London, England, who installed a large steam plant, and employed about 30 men. Operations do not appear to have proved very successful, and the amount of phosphate produced is said to have been small. Work was continued only for a couple of years, and no further exploitation of the property has taken place. Several openings exist on the property, the deepest pit being down about 100 feet. An estimated total of some 700 tons of phosphate of all grades was produced.

References:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 303; IV Ann. Rep., 1888-89, p. 108K; Bull. Ap., 1904, p. 14; XII, Ann. Rep., 1899, p. 101J.
Mines and Minerals of the Province of Quebec, 1889-90, p. 124.
Que. Bur. Min., 1889, p. 90; 1890, p. 80.

Range III, lots 1 and 2.—On these two lots are situated the main workings of the Société Française des Phosphates du Canada, or, as it was more generally called, the French Company. This syndicate was organized in Paris in 1881, and acquired a large number of properties in the Quebec phosphate bearing region, more particularly in the township of Portland East. The following is a list of these properties, which comprised an area of 4,795 acres:—

TOWNSHIP OF PORTLAND EAST.

Range I, lot 13.
" *II, lots 2 E. ½, 3 N. ½.*
" *III, lots 1, 2.*
" *IV, lots 1 S. ½, 2 E. ½, 3 N. ½.*
" *V, lot 9 E ½.*
" *VI, lots 7, 8, 9, 10, 22, 24.*
" *VII, lots 7, 8, 9, 10, 21, 27, 28.*
" *VIII, lots 6, 9, 10, 11, 12, 16, 17, 30.*
" *IX lots 4, 5, 9, 16 S. ½, 17, 18, 19, 20, 30, 31.*

TOWNSHIP OF PORTLAND WEST.

Range IV, lot 20.
" *lot 3.*

TOWNSHIP OF TEMPLETON.

Range XIII, lot 3.

The operations of the Company were confined almost entirely to lots 1 and 2 of range III; lot 1 S. ½ of range IV; and lots 16 and 17 of range VIII, township of Portland East; the remaining properties receiving little attention beyond a small amount of prospecting work. The entire output from the various workings appears not to have exceeded 2,000 tons of phosphate.

The Company, formed in 1881, and highly capitalized, continued operations for only two years, and had already ceased work in 1883.

The workings on range III, lots 1 and 2, consist of numerous narrow pits and trenches, opened on a series of more or less parallel leads. (See Plate XI.) Lot I was the more extensively developed, and yielded the greater portion of the total amount of phosphate mined. The deepest pit probably does not exceed 50 feet. J. F. Torrance, in 1882, reported some 15 openings on the two lots.

A considerable amount of high grade, silver-amber mica occurs associated with the apatite, which is both massive and of the powdery variety known as "sugar" phosphate—the latter perhaps predominating. In 1910, Mr. M. J. O'Brien acquired the above lots; also lots 16 and 17 of range VIII, and lot 9 of range IX, and carried out a small amount of work during 1910–13.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, pp. 13, 17J; Bull. Ap., 1904, p. 15.
Mines and Minerals of the Province of Quebec, 1889-90, p. 127.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 61.

Range III, lot 3.—Worked in 1911 for a few months by Mr. M. J. O'Brien. A few small pits were opened, the deepest being 30 feet. The veins are narrow, and carry powdery green apatite, and a somewhat dark, crushed mica; their strike is N. 20° E, with a dip to SE. The phosphate-bearing rock is a mixture of greyish pyroxene, feldspar, and scapolite, the latter mineral probably being a result of alteration of the feldspar. This scapolite is seldom fresh and lustrous, but possesses a grey or pink colour, and is largely altered to wilsonite.

The augite-scapolite rock seldom contains any mica, but pockets of apatite frequently occur in it. Small aggregates of medium sized, black tourmaline crystals were observed at one spot, and an unusual occurrence, in a bed of sugar phosphate on lot 1, was a drusy mass of small purple and green fluorite crystals of octahedral habit, intimately associated with small dark phlogopite crystals and faujasite.[1]

Range IV, lots 1 N. $\frac{1}{2}$, 2 E. $\frac{1}{2}$.—Known as the Glasgow mine, and opened in 1884 by the Glasgow-Canadian Phosphate Company. Operations were conducted for only two years, and no further development has since taken place.

The workings are situated on the northeast end of the ridge of phosphate bearing rock which extends from this point to the Lièvre river, and upon the southwest end of which is located the Little Rapids mine. No extensive work appears to have taken place, and the openings consist of a few small surface pits. The Company owned also lot 1 in range III of the township of Derry—this lot adjoining the above property to the east—but no work appears to have been undertaken here.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 15.
Mines and Minerals of the Province of Quebec, 1889-90, p. 127.

Range VI, lot 2.—Known as the Salette mine, and was worked in a small way by Hayes and Company in 1891. Little work appears to have been carried out on the property, and no extensive veins of phosphate were encountered.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 15.
Que. Bur. Min.,1891, p. 88.

[1]In a specimen of this material Dr. W. F. Ferrier has identified the rare mineral yttrocerite.

Range VI, lots 15, 16, 17 and 18.—Chapleau mine. These lots were acquired in 1883 by Chapleau and Company, who opened up some small pits on lot 17. The largest opening was 126 feet long and 10 feet deep. The phosphate is massive and green; little mica or pyrites is present. Work was abandoned by the owners in 1884, and nothing further appears to have been done upon the property. The Company also worked lots 5 and 6 in the eighth range of Portland West.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 16J; IV, Ann. Rep., 1888-89, p. 108K; Bull. Ap., 1904, p. 15.
Mines and Minerals of the Province of Quebec, 1889-90, p. 127.

Range VII, lot 18.—North Star or Haycock mine. This property possesses numerous extensive openings, amongst them being what is probably the deepest pit in the country sunk in search of phosphate. This opening is an inclined shaft 620 feet deep, sunk on an open cut having a total length of about 125 feet. The workings are situated on the crest of a ridge about 600 feet above the Lièvre river, and lie four miles northeast of the village of Notre Dame de la Salette—the nearest shipping point on the river, to which the mineral was hauled by teams.

The property was worked in the first instance about the year 1879, by Mr. Haycock, of Ottawa, who later disposed of it to the Dominion Phosphate Company, of New York. This syndicate carried out a large amount of work between the years 1882 and 1891, in which latter year the mine was shut down; it has not since been reopened. The following account of the work done is given by J. Obalski in "Mines and Minerals of the Province of Quebec", 1889:—

> An inclined shaft has been sunk to a depth of 605 feet along the phosphate lead and at an angle of about 20°. At 200 feet the phosphate body was found to be 20 feet wide and 60 feet long. This shaft is now abandoned, and a new one has been sunk to a depth of 250 feet, at an angle of 45°. Large apatite bodies have already been encountered in this opening, and a third shaft is being put down on the same lead.
>
> This is the only mine where the workings extend to such a great depth and possess such regularity, this latter feature being made possible by the regular and persistent nature of the vein. There is an extensive plant comprising steam hoists and pumps and air drills. The average force employed is 50-60 men, and the yearly production reaches 8,000 tons. The total amount of mineral so far (1890) raised is about 25,000 tons. This is the first mine on the Lièvre river to be equipped with an air compressor.

The phosphate is green and massively crystalline, and good quality brown-amber mica in crystals of large size, is locally present in the apatite. The amount of phosphate in sight when the mine was closed down is said to have been considerable, and the veins are reported to have shown no signs of narrowing in depth. This is important, as tending to refute a not uncommon belief in the district that mica and phosphate deposits are confined to the surface. The evidence on which such a belief is based is largely of a negative character; and the fact that pockets of these minerals often do not carry paying quantities of either mica or apatite in their lower portions is no support whatever for the contention that the deposits are only to be found at or near the surface. The essentially pockety nature

of the phosphate bodies renders it both difficult and expensive to mine them; but the proved existence of large veins of apatite with associated mica at a depth of over 600 feet at this mine is sufficient evidence that the many shallow workings scattered throughout the district have by no means necessarily exhausted the deposits upon which they have been opened.

All buildings upon this property have long since been demolished. The mine is at the present time owned by Mr. W. H. Nichols, of New York and Capelton.

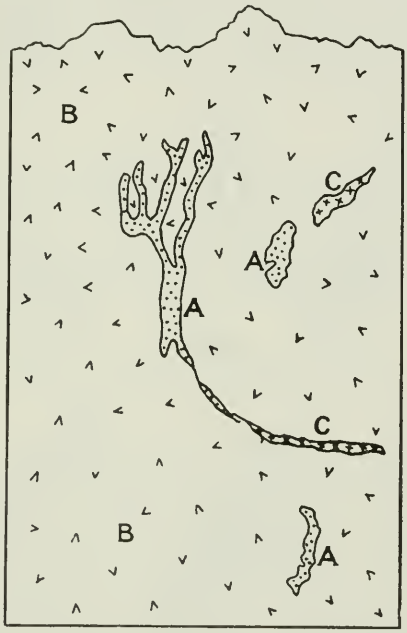

Fig. 9. Section in northeast side of pit at North Star mine, township of Portland East, Que., showing apatite stringers. (After Penrose.) A, apatite; B, pyroxene; C, feldspar. Scale: 1 inch = 10 feet.

The country rock at this point is normal, rusty gneiss, dipping about 60° to the east. Both the gneiss and the pyroxenite are extensively cut by grey pegmatite dikes and stringers; and a variety of rock types, from an almost pure felsite to normal pyroxenite, may be observed on the dumps —the different types ranging from very fine-grained to very coarse-grained. Epidote occurs in some quantity, associated with pyrites and pyroxene.

The adjoining lots, 16 and 17, known as the Sweetland property, have also been worked on a small scale for phosphate, but the openings are unimportant.

The sections through the apatite leads at this mine, shown in Figs. 9 and 10, are taken from R. A. Penrose's bulletin on phosphate (Bull. No. 46), issued in 1888 by the United States Geological Survey. All the deeper workings are now inaccessible.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 16J; IV Ann. Rep., 1888-89, p. 108K; Bull. Ap., 1904, p. 15; XII Ann. Rep., 1899, pp. 100-101.
Mines and Minerals of the Province of Quebec, 1889-90, p. 122.
Que. Bur. Min., 1890, p. 80.
Ont. Bur. Min., Royal Commission, 1890, p. 179.

Range VII, lot 24.—Craft mine. Situated about two miles north of Notre Dame de la Salette. A few small openings exist on this property, the largest being a pit 50 × 25 feet and about 40 feet deep. The apatite vein strikes N. 25° E., and has a course approximately parallel with the ridge on which the mine is located. The country gneiss dips here N. 50° W.

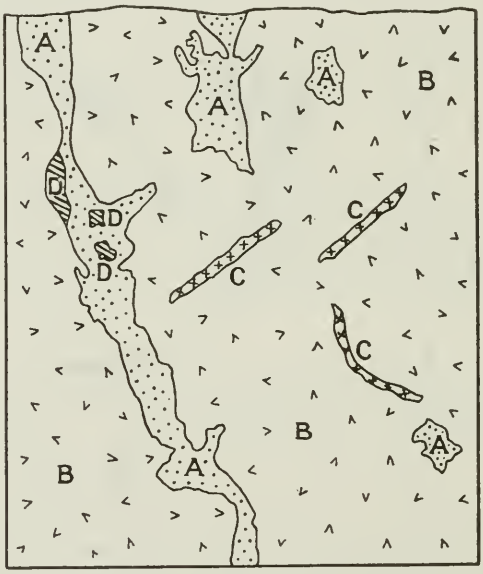

Fig. 10. Section in southeast side of pit at North Star mine, township of Portland East, Que., showing vein of apatite and mica and feldspar stringers. (After Penrose.) A, apatite; B, pyroxenite; C, feldspar; D, mica. Scale: 1 inch=10 feet.

The phosphate is of both the red and green varieties, and occurs in pockety fashion. The mine was worked about the year 1880, and has lain idle ever since.

Reference:—
Geol. Surv. Can., Rep. Prog., 1882, p. 19J; Bull. Ap., 1904, p. 15.

Range VIII, lots 16, 17.—Formerly worked by the Compagnie Française des Phosphates du Canada, who opened four pits on the property. The largest of these openings measured 13 × 45 feet and was 25 feet deep. The mine was later (in 1910), acquired by Mr. M. J. O'Brien, who conducted operations in a small way for a month or two. (See under Range III, lots 1 and 2, page 70).

Reference:—
Dept. Min. Can. Min. Br., Mon. Mica, 1912, p. 62.

Range VIII, lot 26.—Philadelphia mine. This property was first worked about 1880, by Mr. C. Brown, of Lachute, who subsequently sold out to the Philadelphia and Canada Phosphate Mining Company. This Company worked for about six months during 1884, employing 10 men. Results did not prove satisfactory, hence the mine was shut down, and has lain idle ever since.

The main opening is 40 × 15 feet and some 90 feet deep. The pit is sunk on an incline to S.E., and follows a well defined N.E.-S.W. lead of red and green apatite. There is little mica or calcite associated with the phosphate. The property lies 3 miles north of Notre Dame de la Salette. The output which is said to have totalled about 2,000 tons, was hauled in winter to Buckingham, 22 miles distant. Both this and the succeeding lot (27) are now owned by Mr. A. Wells, of Buckingham.

Reference:—
Geol. Surv. Can., Bull. Ap., 1904, p. 15.

Range VIII, lot 27.—Cameron or McLaren mine. Adjoins the Philadelphia mine and has produced about 200 tons of phosphate. The main pit is 15 × 10 feet and 25 feet deep; besides which there are several small openings. The only work done on the property was carried out by Mr. John McLaren, of Buckingham, in 1882 and 1883; a small gang being engaged in intermittent mining during these years. Now owned by Mr. A. Wells, of Buckingham.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 18J; Bull. Ap., 1904, p. 15.
Mines and Minerals of the Province of Quebec, 1889-90, p. 127.

Range IX, lot 27.—Worked intermittently during 1882 and 1883, by Mr. Bradley of Pennsylvania; since then, no further exploitation has taken place. Only small pits exist on the property, the largest measuring 15 × 15 feet and 10 feet deep. The workings are reached by a mine track of 2½ miles, connecting with the La Salette road. The phosphate is green and massive. Little mica or calcite was noticed. This property is sometimes known, and is alluded to in various reports, as the Crown Hill mine. The more important Crown Hill mine is situated in the seventh range of Portland West, on the west side of the Lièvre river.

TOWNSHIP OF PORTLAND WEST.

Range III, lot 15.—A number of shallow openings exist on this and adjoining lots, the property having been prospected for phosphate a number of years ago. None of the workings are important. Apatite occurs in massive form, and also in large crystals, on small pockety veins in a light-coloured pyroxenite. These veins are remarkable for the large amount of scapolite that they carry. This mineral occurs in well formed crystals—often of large size, and up to 50 pounds in weight—which line the walls of the leads, and are associated with small well formed crystals of pyroxene. Zircon was noticed in one of the pits—the crystal being prismatic, about an inch in length, and of a light cinnamon colour; it penetrated the base of a crystal of scapolite.

Silver-amber mica is found on certain of the veins, but is not present in any quantity on the above lot. About six tons are reported to have been taken off the adjoining property—lot 14 S½.

References:—
Geol. Surv. Can., XII, Ann. Rep., 1899, p. 133J.
Que. Bur. Min., 1899, p. 35.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 105.

Range III, lot 24 N. ½.—A few openings for phosphate were made on this property in the early nineties, and these workings were later extended when mica came into prominence. The latter mineral exists in some quantity on this and the adjoining lot, but phosphate does not occur very plentifully.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 133J.
Que. Bur. Min., 1899, p. 34.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 105.

Range IV, lots 27 and 28.—Fleming and Allan mine. Messrs. Fleming and Allan, of Ottawa, carried out extensive work on these lots in 1889 and 1890. The phosphate is usually of a red colour, though massive green apatite also occurs. The veins are reported to have been as much as 20 feet wide, and to have carried considerable quantities of excellent amber mica. When the price of phosphate rendered mining for this mineral no longer profitable, operations were still continued for mica; and considerable quantities are said to have been secured from the old phosphate pits and from new workings. With the exception of some surface work carried out in 1908, under lease, no active exploitation of the property has taken place since 1893, in which year Mr. H. McRae, who had operated steadily for two years with an average force of 35 men, shut down the mine. The two principal openings are 75 feet long, 12 feet wide, and about 45 feet deep. They follow parallel fissure leads of phosphate and mica, associated with large bodies of pink calcite, in a greyish pyroxenite enclosed in dark gneiss. Numerous smaller pits exist, and are distributed along a high ridge, which is traversed by a number of dikes of pink and white aplite. These latter consist essentially of orthoclase feldspar, with a little quartz, and exhibit a considerable development of black tourmaline along their contacts with the gneiss and pyroxenite. Large masses of grey, coarsely crystalline feldspar were noticed on the dumps, and carry small crystals of brown titanite scattered through them.

Lot 27 at the present time is owned by Mr. Farley, of Ottawa, while lot 28 is the property of Mr. W. A. Allan, also of Ottawa.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, pp. 120, 133J.
Mines and Minerals of the Province of Quebec, 1889-90, p. 124.
Que. Bur. Min., 1890, p. 80; 1893, p. 105; 1894, p. 97.
Dept. Min Can., Min. Br., Mon. Mica, 1912, p. 106.

Range VI, lots 5 and 6; range VII, lots 1 and 2.—Ross Mountain mine. This property comprises four river front lots—that is, lots running east and west instead of north and south—situated at the southern extremity of the great phosphate bearing belt lying directly west of the Lièvre river, and approximately paralleling it. This phosphate belt represents one of three great areas of development of apatite in the Province of Quebec, the others being in the townships of Buckingham and Templeton, respectively. The belt in question yielded an important quantity of phosphate

during the late eighties and early nineties—the mines located upon it including such great producers as the Crown Hill; High Rock; Star Hill; Central Lake; and High Falls mines. These properties, at the time of the phosphate "boom", represented the centre of greatest activity in the mining of this mineral in Canada, and the amount of capital expended upon them was very large.

Good showings of apatite had been located on this property during the early eighties by Messrs. Ross Bros., of Buckingham, but it was not until the end of 1890 that active mining was commenced. In this year the above lots were acquired by the General Phosphate Corporation, Ltd., of London, who also worked the High Falls mine, in the township of Bowman, at the same period.

This Company had 60 men employed during 1891, and produced 700 tons of phosphate. Unfortunately, the succeeding year saw the fall in the price of the mineral, and the mine was shut down. Adits had been driven into the base of the high ridge, upon which the workings are situated, during the latter part of 1891, and it was intended to carry the upper pits down to meet these, but the work was never completed.

The largest opening is a pit 60 by 20 feet and said to be 80 feet deep, situated on the southeasterly spur of the ridge, which falls away steeply to the river at this point. There are two other fair sized pits on the property, besides numerous small surface openings and the adits already mentioned. The phosphate is massive, and of a dark green colour. It occurs associated with pink and white calcite, and considerable pyrites, in pockety form, in a hard, dark grey pyroxene. A little mica also occurs at some spots, but this mineral is not common at any of the mines situated on this belt of apatite.

The principal openings are located on range VI, lot 5, the distance to the shipping point on the Lièvre river being about half a mile.

Lots 1 and 2 in range VII, abut on the Crown Hill or Little Union mine, which lies immediately to the north of this property.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 19J; Bull. Ap., 1904, pp. 15, 17; XII Ann. Rep., 1899, pp. 96, 97.
Que. Bur. Min., 1891, p. 87; 1892, p. 82.

Range VII, lots 3 and 4.—Crown Hill or Little Union mine. This property, together with the Star Hill mine, was actively worked from 1882 to 1888 by the Union Phosphate Mining and Land Company, of New York. In the latter year both these mines were taken over by the Canadian Phosphate Company, Ltd., of London, who continued operations until 1892, in which year both mines were shut down. Work was carried on by means of three principal openings (pits 11, 15 and 18), the deepest of which reached a depth of 120 feet. This last pit is located on a small flat, near the edge of a pond or swamp, while the other workings are all situated on the side of the ridge above. The three pits were all connected by inclined tramways—the cars being hauled by horse, or by cable—while a gravity skip was employed to convey the mineral to the Company's wharf on the Lièvre river—about three-fourths of a mile distant, and lying some 600 feet below the crest of the ridge upon which the workings are situated. The Canadian Phosphate Company employed an average of 150 men, and the mine was equipped with a large steam plant. All machinery, etc., has long since been removed, and most of the buildings demolished.

The Company produced 4,000 tons of phosphate during 1888, and 6,500 tons in 1889—about one-third of these quantities in each case representing first grade mineral; one-third "seconds", and one-third, third or lowest grade. From the inception of work upon the property, up to 1891, it is estimated that a total of about 35,000 tons of phosphate was produced.

The output was shipped in 75-100 ton scows down the Lièvre river to Buckingham, where a portion was ground at a mill owned and operated by the Company, the remainder being shipped crude to England and the United States. The mill was a small building, having a capacity of only 8 tons per diem, and the treatment of the phosphate consisted in drying, crushing, grinding, and screening. Only the inferior grades were thus treated, the final product averaging about 65 per cent. In 1889, 1,300 tons of ground phosphate was produced.

About 1905, the property was bought in by Mr. R. Ross, of Holland Mills, who secured about 500 tons of apatite from surface workings. Mr. Ross disposed of the mine in 1907 to Mr. J. F. Higginson, of Buckingham, who is the present owner. Mr. Watts, of Perth, had a couple of men on the property for a few months during 1910, and took out about 50 tons of phosphate.

The property lies between the Ross Mountain mine, to the south, and the High Rock mine, to the north, and is about 3 miles distant from the village of Notre Dame de la Salette, which is situated on the opposite bank of the river.

The apatite veins have a more or less definite N.W.–S.E. direction throughout the entire extent of this phosphate belt—conforming to the direction of the ridge itself. At this mine, however, the strike of the leads is not so apparent, and they appear to pursue a somewhat irregular course. The apatite is massive and of a green colour, the veins traversing a normal, grey-green pyroxenite. Both pyrites and pyrrhotite are present in considerable amount, and large cleavage pieces of pink and white calcite, together with well crystallized scapolite, were noticed on the dumps. Brown amber mica of good quality occurs in some amount on certain of the leads. The surface gneiss is often very rusty, and exhibits a burnt appearance, due to the decomposition of large quantities of iron sulphides—the principal development of pyrites having taken place adjacent to the phosphate bodies. The rock known as "leopard granite", consisting of a ground mass of brownish-grey feldspar interveined with minute stringers of dark green pyroxene, occurs somewhat plentifully in the pit near the crest of the ridge.

References:—
Geol. Surv. Can., Bull. Ap., 1904, pp. 15,16; XII Ann. Rep., 1899, pp. 97, 98.
Mines and Minerals of the Province of Quebec, 1889-90, p. 122.
Que. Bur. Min., 1890, p. 80.

Range VII, lots 5, 6, 7, 8; range VIII, lots 1 and 2.—High Rock mine. Probably the most extensively developed of all Canadian phosphate properties. The initial work done upon these lots was carried out by Messrs. McParland of Kingston, in 1879. In 1881 the property was acquired by the Phosphate of Lime Company, Ltd., of London, England, who continued operations until 1894. Active mining was discontinued in 1892, when the drop in phosphate prices occurred, but about 25 men were kept on for a couple of years longer, and were engaged in extracting the mineral

in sight. This mine was thus the last active operator in the district. Mr. R. Ross of Holland Mills, and Mr. Edward Watts of Perth, have both done a small amount of work on the property during recent years, under royalty; operations were confined to surface pits and the amount of phosphate secured was small. The Company employed a force of 130-150 men, the majority of whom—together with their families—resided at the mine, in houses built by the Company. The buildings, stores, etc., formed a small village, which was systematically planned and erected in blocks, being located on the summit of a ridge 600 feet above the river. (See Plate XII.)

The plant included 13 boilers and 2 compressors—air drills, steam hoists and pumps being employed. The mine was connected with the Company's wharf on the river by a tramway two miles long. The cars took a load of 3 tons and descended by gravity, being hauled up again by horses. The various pits were all connected by tramways centering at the cobbing sheds, the cars being hauled by horses, or by gravity system on the steeper grades. The workings consist of some half dozen very large pits, measuring as much as 200 × 50 feet, opened along the crest of the ridge and extending, in some cases, to a depth of 200 feet. These are all open excavations, made at intervals along the veins which have a N.W.–S.E. direction, and crop out on the summit of the hill, drifts being run, in some instances, from one pit to another, following shoots and pockets of phosphate. The largest opening on the property was what was known as No. 11 pit. This opening was the principal centre of mining for several years, and is reported to have yielded over 11,000 tons of mineral during the two years 1887 and 1888. The entrance to this excavation is on the southwest flank of the ridge, and is 160 feet below the crest. A vein of apatite, which attained a maximum width of 30 feet, has been followed into the hill by means of a large and irregularly shaped drift, having a general northeasterly direction. This drift has been carried in for a distance of over 350 feet, the height varying greatly. From this main opening a number of short raises and stopes have been carried in different directions along shoots and pockets of phosphate, which extend without any definite course from the main lead. A pit also was sunk in the floor of the drift, and carried down to a depth of 70 feet. Pillars were left at intervals to support the workings. The largest opening made for phosphate in the entire district, which is accessible at the present time, is represented by this excavation.

The mineral taken out was graded by screening, washing, and hand cobbing, into two standard qualities: No. 1, rock and sand, and No. 2, sand. The annual output of the mine was about 8,000 tons, of which 6,000 tons were No. 1 grade, and 2,000 tons seconds. The approximate total of No. 1 grade phosphate (75–80 per cent) produced during the life of the mine was 65,000 tons.

In 1890 the Company installed additional machinery, including a 12-drill compressor with four boilers. This plant was located on the bank of the river, the air being led to the mine through a 5″ pipe line. New machinery, also, was erected at the mine itself, and a number of additional drills were employed.

All vestiges of buildings, etc., have long since disappeared.

The phosphate is of a uniform green colour, and massive. Small amounts of light amber mica occur on certain of the veins. The country rock is for the most part a rusty gneiss, having a strike of N. 65°W. and a southwest dip.

The altitude of the ridge at the post-office, which was situated almost on the crest, is 986 feet. What are known as the Duguay workings, comprise three pits on lot 7, range VIII. The major portion of this lot was the property of the Canadian Phosphate Company; but the pits referred to, together with 3 acres in the centre of the lot, belong to the High Rock mine. The workings are small, and disclosed no extensive body of mineral. The present owners of the High Rock mine are a Montreal syndicate, and are represented by Mr. G. Bonner, of 1060 Notre Dame Street West, Montreal.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, pp. 5, 9J; Bull. Ap., 1904, pp. 15, 19; XII Ann. Rep., 1899, pp. 98, 99.
Mines and Minerals of the Province of Quebec, 1889-90, p. 121.
Que. Bur. Min., 1890, p. 80.

Range VIII, lots 3, 4, 7, 8, 9; range IX, lots 5, 6, 7, 8, 9.—Star Hill or Old Union mine. Situated about two miles northwest of the Crown Hill mine, and, like it, owned and operated from 1882 until 1888 by the Union Phosphate Mining and Land Company, of New York. In the following years both these properties were acquired by the Canadian Phosphate Company, Ltd., of London, who worked steadily until 1892, in which year the two mines were closed down.

The Star Hill workings lie about one mile northwest of the High Rock mine, and comprise a series of long, narrow pits opened along the southwest slope of a high ridge, and paralleling the ridge itself in their longest direction. The phosphate occurs here in bunches or pockety aggregates scattered through a dark, medium-grained pyroxenite containing a considerable proportion of feldspar. These pockets are disposed in more or less defined horizons, the trend of the series being N. 40°W., this being the direction of the ridge itself. The pits are located a little distance below the crest of the hill, and the apatite bodies appear to dip into the ridge towards the northeast.

The phosphate is a dark to medium green, compact apatite, and is associated with considerable quantities of brown amber mica. This latter mineral was discarded as valueless at this period, and the dumps are said to contain considerable quantities of large sized and good quality sheets.

While the majority of dumps of old phosphate mines have been searched over during recent years in order to recover the mica, those of the mines in this district have not as yet been turned. Situated, as most of them are, on the flanks of steep ridges, they are well located for working with a minimum of expense and labour.

Both calcite and pyrites are conspicuously absent in these openings, the largest of which measures 200 × 60 feet and is said to be about 200 feet deep; while an adjoining pit is 100 × 50 feet and 150 feet deep. At certain of the openings a red, massive apatite was encountered, but this variety is not common.

A large steam plant was employed, and a number of the mine buildings are still standing, though in a dilapidated condition. An average force of 125 men was engaged.

Mr. Edward Watts, of Perth, did a little surface work, under royalty, in 1908, securing a few tons of phosphate. The mine is now owned by Messrs. Higginson, Webster, and Aylen, of Buckingham. A mine road of $3\frac{1}{2}$ miles connects the mine with the wharves on the Lièvre river, and the phosphate was hauled winter and summer. The workings are chiefly confined to lots 8 and 9 of range VIII, and lot 7 of range IX.

References:—
Geol. Surv. Can., Rep. Prog,, 1882-84, p. 10J; Bull. Ap, 1904 pp. 15, 18; XII Ann. Rep., 1899, p. 99.
Mines and Minerals of the Province of Quebec, 1889-90. p. 122.
Que. Bur. Min., 1890, p. 80.

Range VIII, lots 5 and 6.—Chapleau mine. A few small openings were made on these lots, in 1885, by Messrs. Chapleau and Company. Results do not appear to have proved encouraging, and no further work has been carried on. Lots 15, 16, 17, and 18 in the sixth range of Portland East were also worked by this Company, in 1883.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 15.
Mines and Minerals of the Province of Quebec, 1889-90, p. 127.

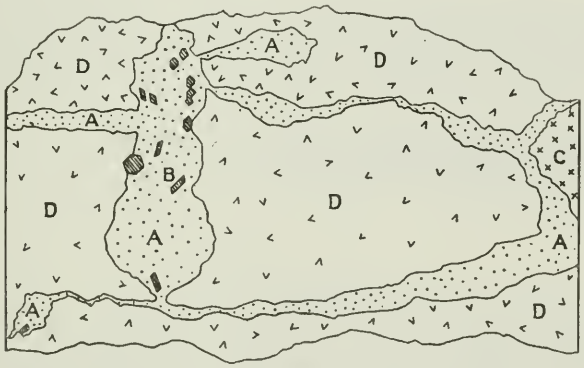

Fig. 11. Section in the Bonanza pit, Union mine, township of Portland West, Que., showing pockety occurrences of the apatite. (After Penrose.) A, apatite; B, mica; C, feldspar; D, feldspar, mica, and pyroxene rock. Scale: 1 inch=16 feet.

Range IX, lots 5 and 6.—These lots have yielded about 100 tons of apatite, which was secured mainly as a by-product during mining for mica. The property was worked in 1893 by Mr. W. McIntosh, and, in 1899 and 1900, by Mr. A. Cameron, of Buckingham. Nothing further appears to have been done. These lots originally formed part of the Star Hill property, but were not actively worked.

References:—
Geol. Surv. Can., XII, Ann. Rep., 1899, p. 133J.
Que. Bur. Min., 1892, p. 87; 1899, p. 35; 1900, p. 22.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 107.

Range X, lots 7 and 8.—Central Lake mine. The main workings lie on the slope at the south end of the lake, and are the least extensive of any of the larger mines in the district. The property was first worked about 1880 by Mr. McNaughton, of Buckingham, and was taken over in 1887 by S. P. Franchot and Company, of the same place (later the Central Lake Mining Company). The Company employed an average force of from 20 to 30 men, and in the year 1889 produced about 1,000 tons of phosphate. The mine was closed down in 1892, and has not since been worked. At the time of operation, the locks and dam at the Little Rapids on the Lièvre river, about ten miles below, had not been constructed, and although the workings lay only about one mile from the river, the presence of rapids necessitated it being hauled several miles.

The apatite is of the normal green colour, and massive. Little of the powdery variety known as "sugar" phosphate occurs at the mines in this district. Mica is rather plentiful on certain of the leads at this mine, and a small quantity was taken out in 1910 by Mr. Watts, of Perth, who, however, worked only surface pits.

Most of the pits lie at the south end of Central lake, the boarding house and mine offices being situated at the north end, about half a mile distant.

There are some twenty openings on the property, the deepest, it is said, extending down about 120 feet. Steam drills, pumps, etc., were in use, and some of the buildings are still standing. The mine is the property of the estate of the late Mr. S. P. Franchot, one of the owners being Mr. Richard Franchot, of Niagara Falls, N.Y.

References:—
Geol. Surv. Can., IV Ann. Rep., 1888-89, p. 108K; XII Ann. Rep., 1899, p. 99.
Mines and Minerals of the Province of Quebec, 1889-90, p. 124.
Que. Bur. Min., 1888, p. 89; 1889, p. p 89-91, 1890, p. 80.

Hull County.

TOWNSHIP OF HULL.

Range IX, lots 14 N. ½ and 15 N. ½.—Scott mine. Opened by Mr. Michael Scott, of Old Chelsea, some thirty-five years ago. Only surface work was done—none of the pits exceeding 10 feet in depth—and not more than a few tons of phosphate were taken out. Several tons of rough mica were mined in 1908 by Mr. M. G. Robertson, who had a dozen men employed for a few months. Nothing further has ever been done upon the property.

The phosphate is dark brownish-red in colour, and is massively crystalline. The leads occur on the east side of a small ridge of gneiss and crystalline limestone, which is traversed by narrow belts of pyroxenite, the whole series being cut by later pegmatite veins.

Several veins of red jasper are found upon contacts of these pegmatites with crystalline limestone. The jasper is of a dark red colour and is associated with specularite and calcite. One vein of this mineral is over 3 feet in width. Red ochre is reported to occur on this property but has never been worked.

The property lies two miles from Chelsea station on the Gatineau Valley branch of the Canadian Pacific railway.

An analysis of a phosphate sample from this property, made by M. F. Connor, of the Mines Branch, yielded:—

Phosphoric acid	40·15 = 87·73	tricalcic phosphate.
Lime	53·30	
Ferric oxide, Alumina	1·30	
Magnesia	0·28	
Soda, Potash	0·64	
Water	0·36	
Chlorine	0·40	
Fluorine	3·20	
Silica and insol	1·80	
	101·43	
Less oxygen = chlorine, fluorine.	1·38	
	100·05	

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 16L; XII Ann. Rep., 1899, pp. 124J and 131J; Bull. Ap., 1904, p. 26.
Que. Bur. Min., 1892, p. 84.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 110.

Range IX, lot 15 S. ½.—Belongs to Mr. John Sweeney, of Old Chelsea. The property was opened for phosphate some thirty years ago, and has since been worked for mica by Messrs. Kent Bros., of Kingston.

The phosphate is massively crystalline and of a brown colour. It occurs in small quantity, associated with pink calcite and crushed amber mica, on pocket and fissure leads in a darkish pyroxenite. The veins have suffered extensive dislocation as the result of pegmatite intrusions, dikes of the latter rock being of frequent occurrence all over the property.

Reference:—
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 110.

Range X, lot 4 S. ½.—Owned by Mr. Thomas Barrett, of Cantley. The mine was first worked in 1875 by Mr. H. Darby, of Templeton, and subsequently by Mr. Andrew Mayne, of Ottawa, who took out considerable quantities of phosphate from a few surface pits. Messrs. Gemmill and Nellis, of Ottawa, mined for a few months during 1881, and are reported to have secured about 150 tons of mineral.

The openings are all small surface pits, the largest being an open-cut, with a drift at the north end; the total length of this pit is 32 feet.

The phosphate is dark red in colour, locally mottled with green, and is of the massively crystalline variety. It occurs with a dark amber mica, on pockets in a normal grey pyroxenite, cutting a gneiss and crystalline limestone country, the whole being extensively intruded by pegmatite dikes. An uncommon characteristic of the apatite is the rough, matt surface of the broken rock, which thus differs in a marked manner in appearance from normal, glossy apatite.

Range XI, lot 11.—Featherstone mine. Owned by the estate of Mr. T. F. Nellis, of Ottawa. The lot was worked a number of years ago by Mr. Thomas Featherstone, of Cantley, for phosphate and mica, and at intervals from 1907 to 1910 by the late owner, for mica. The phosphate occurs

both in the massive form and as well formed crystals scattered through the calcite filling of the veins. There are three openings, all on the same

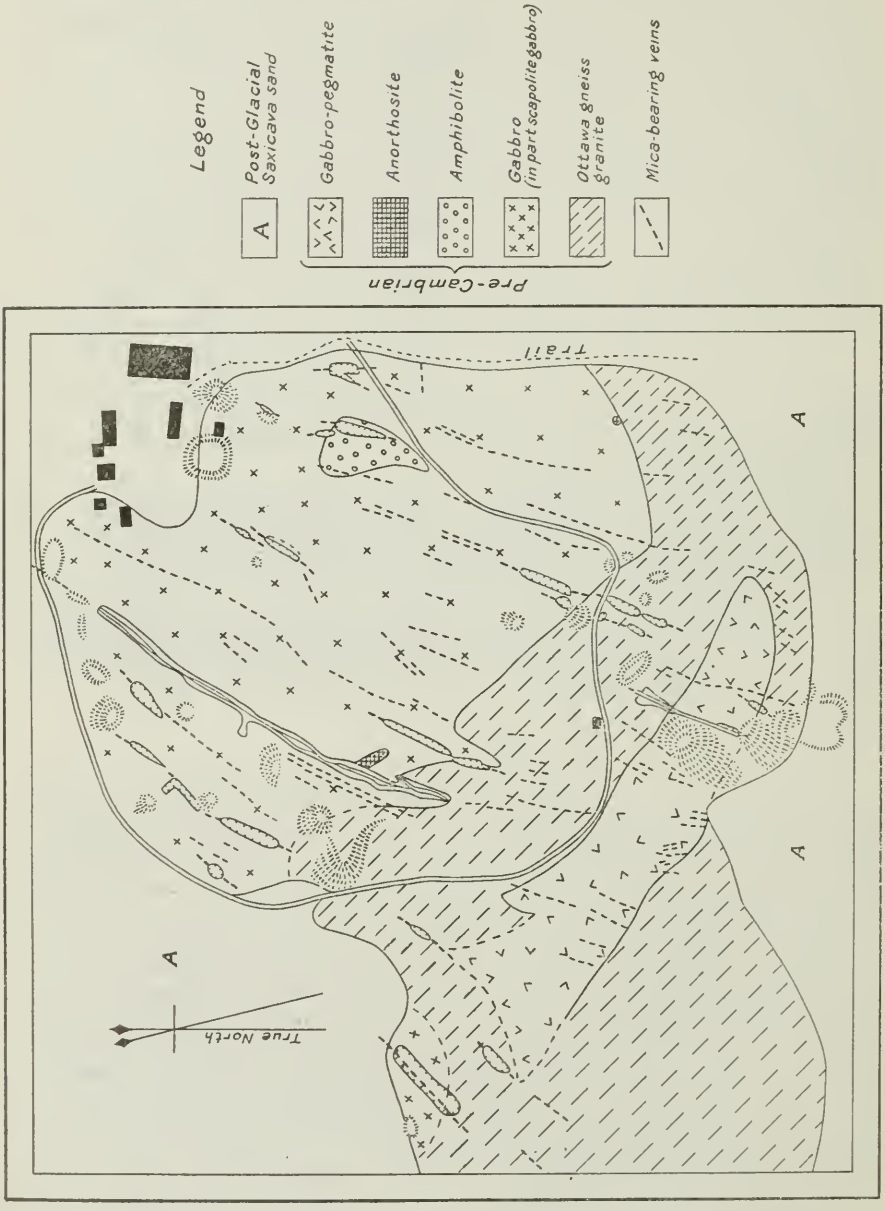

Fig. 12. Nellis mine, Hull township, Que. (After Stansfield.)

lead, the deepest being down 45 feet, 60 feet long, and 15 feet wide. The strike of the phosphate lead is N. 30° E.

The workings lie on the crest of a small ridge, about half a mile from the Gatineau river.

Range XII, lot 10.—This mine is variously known as the Gemmill, Nellis, or Vavasour mine, and was originally opened for phosphate in 1878, by Mr. Donald Gow, of Cantley, who worked continuously for six years, and took out about 3,000 tons of high grade apatite.

Subsequently, Messrs. Nellis and Gemmill took over the property, and operated, for a few years, for both phosphate and mica, under the name of the Vavasour Mining Association.

The mine is now owned by the estate of Mr. T. F. Nellis, of Ottawa. The late owner kept an average staff of ten men more or less continuously employed up to a few years ago, practically all work done being for mica. The property lies about two miles east of Kirk Ferry station, on the Gatineau Valley branch of the Canadian Pacific railway, and 13 miles north of Ottawa, and connects with the Cantley-Ottawa road by a field track.

The workings are situated on a small hill, or knoll, measuring about one-third of a mile across, and composed principally of a grey-green pyroxenite, enclosed in biotite gneiss. The veins, of which there are a number, strike in a northeasterly direction, and have a maximum width of 15 feet, while the length of the principal lead has been estimated at 1,200 feet. The aggregate length of the veins exceeds 2,100 feet; and practically this entire length has been worked, though the openings are chiefly confined to five principal and parallel leads. This deposit exhibits probably the greatest development of parallel leads within a narrow zone to be found throughout the whole phosphate area.

The principal filling of the veins consists of pink calcite, containing well formed crystals and compact aggregates of green apatite, with mica crystals, often of large size, scattered through the mass. The mica is a first class silver-amber, yielding a large percentage of $5'' \times 8''$ sheets, and over 300 tons of marketable mineral are said to have been produced from the mine.

No machinery is, or has been, employed at the mine, with the exception of small steam pumps in the deeper workings. Hoisting is done by means of horse derricks and hand winches operating boom derricks.

The workings consist of numerous pits, trenches, and drifts, following the line of the leads, the greatest depth reached being about 180 feet. The veins are not, as a rule, vertical, the general dip being some 60° southeast.

The pyroxenite varies from a coarse-grained normal type to a finely crystalline mixture of pyroxene and small spangle mica. It is cut by several narrow pegmatite veins. Some exploratory work has been carried out to the southwest of the main workings, but without much success.

Fig. 12 is a general plan of the workings, showing the geology.

Although large quantities of phosphate were formerly encountered, and the mine was worked solely for this mineral, little apatite has been taken out during recent years.

Excellent contacts between pyroxene and gneiss are to be seen on the south side of the hill. Here, several narrow veins have been followed by drifts for some distance into the hill, the vein filling consisting of pink calcite, in which occur scattered mica and apatite crystals. The walls of the veins are formed of narrow bands of pyroxene only a few inches thick, enclosed in a quartzose gneiss. The pyroxene walls exhibit well defined

comb structure. At certain spots, more especially on the southwest of the property, pockets lined with large and well formed crystals of pyroxene are met with in the pyroxenite.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 17L; XII Ann. Rep., 1899, pp. 115, 121J; Bull. Ap., 1904, pp. 26, 27; Summary Report, 1911, pp. 280, 282.
Mines and Minerals of the Province of Quebec, 1899-90, p. 128.
Que. Bur. Min., 1892, p. 85; 1894, p. 98; 1895, p. 60; 1898, p., 31; 1899, p. 20; 1900, p. 20.
Dept. Min. Cao Min., Br., Mon. Mica,1912, p. 97.
Guide Book. No, Internatinal Geological Congress 1913, pp. 111-113.

Range XII, lot 14.—This property was first worked by Mr. Irish, of Aylmer, about thirty years ago, and subsequently by Mr. Snow, of Ottawa, and by Messrs. Gemmill and Co., also of Ottawa. The last named took out about 200 tons of high grade phosphate, mostly secured from one pocket located near the railway. The opening here is 35 feet deep, and has been formed by quarrying the north side of a small knoll of pyroxenite cut by a coarse pegmatite. The pegmatite has intruded a large pocket of mottled green and red phosphate, and has caused the formation in the phosphate of considerable quantities of black tourmaline, which traverses the massive apatite in small veins and stringers.

There is very little mica present at this spot, and calcite is relatively scarce throughout the deposit, which is associated with a dark green pyroxenite.

References:—
Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 114.

Range XIII, lot 1 S. $\frac{1}{2}$.—Burke mine. This property was originally worked as a phosphate mine, and yielded considerable quantities of apatite. It has been worked for mica at intervals since 1894, by several parties, and the dumps, also, have been turned over to recover the mica discarded in the earlier days.

The openings consist of two pits, one a shaft 8 × 8 feet, and 25 feet deep, and a second drift or inclined trench a short distance from the first, and about 20 feet deep, from the bottom of which a further drift has been carried to the northwest, the total depth being about 50 feet.

The rock is a vuggy, green pyroxenite, carrying much pink calcite and silver-amber mica on fissure leads and pockets, the walls of which are lined with well formed pyroxene crystals. The mica crystals are rather contorted and inclined to split up into ribbon mica.

A large amount of iron pyrites is present throughout the deposit, the rock being, in places, stained a deep red.

The bottom of the main pit showed a large mass of pink calcite following a more or less horizontal lead, and carrying mica and brown apatite crystals disseminated through it.

Some of the massive pyroxene is of a very dark green colour, yielding perfect cleavage fragments in three directions.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, pp. 115, 123, 132J; Bull. Ap., 1904, p. 27.
Que. Bur. Min., 1894, p. 96.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 97.

Range XIII, lot 10 N. $\frac{1}{2}$.—McLelland mine. The property of Mr. R. McConnell, of Toronto, who acquired the mine in 1911, and has had a few men employed during the past year in mining mica. The crystals found at this mine, however, are of very poor quality; the sheets are hard and brittle and almost black in colour, besides which a large proportion of the mineral is so crushed as to be worthless.

The mine was opened in 1878 by Mr. Wilkinson, of Ottawa, and about 1,000 tons of phosphate are said to have been extracted between this year and 1883. Previous to taking over this property, Mr. McConnell had worked under lease for several years for mica; no phosphate was mined, however, this mineral appearing to become less plentiful in depth, and what little was found was thrown on the waste dump.

The veins, of which there are three, have a strike of N. 10°E. and dip about 65°E. Upon the largest of these leads an inclined shaft 100 feet deep was sunk, the vein-body being subsequently stoped out from below. Pillars were left to support the walls of this opening, which now consists of an open stope 100 feet deep, 8–12 feet high and some 50 feet long. A cribbed ladderway is built in at the north end.

The veins are remarkably regular and have well defined walls. The latter, especially the hanging wall, are thickly lined in places with large mica crystals, which, being arranged for the most part with their basal planes parallel to the vein wall, give to the latter a remarkable tessellated appearance.

The veins occur in a mass of pyroxenite, with a strike of north and south, enclosed in biotite gneiss, the whole formation being traversed extensively by later pegmatite dikes. On the west contact of pyroxenite and gneiss, a large body of pink calcite and phosphate, the latter chiefly of a reddish-brown colour, has been formed, and carries considerable quantities of mica.

The workings are situated on a small knoll about two miles north of the village of Cantley. Although the veins possess such well defined walls and regular direction, they do not appear to extend the whole width of this knoll; they are confined rather, to a small zone on the east side and extending midway across its breadth.

The following analysis of a sample of grey-brown apatite from this mine was made by M. F. Connor, of the Mines Branch:—

Phosphoric acid	39·60	= 86·53 tricalcic phosphate.
Lime	54·20	
Magnesia	0·35	
Soda, Potash	0·77	
Water	0·32	
Chlorine	0·44	
Fluorine	3·30	
Carbon dioxide	0·66	
Insol. and silica	0·48	
Ferric oxide, Alumina	1·00	
	101·12	
Less oxygen = chlorine, fluorine	1·44	
	99·68	

References:—
Geol. Surv. Can., Rep. Prog., 1882-84; p. 17L; Bull. Ap., 1904, p. 26.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 101.

Range XIII, lot 12.—Worked by Messrs. Gemmill and Company about 1885. About 300 tons of phosphate are reported to have been taken out. The mine has later been exploited for mica by Webster and Com-

pany, and by Messrs. Winning, Church, and Co., of Ottawa, who worked for several months during 1910.

References:—
Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 100.

Range XVI, lot 13 S. $\frac{1}{2}$.—Wilson mine. This property was first opened in 1891 by Messrs. J. A. Wilson, of Cantley, and Neil Stewart, of Ottawa. Work was continued for two years, both phosphate and mica being mined. Mr. J. H. Connor leased the mine during the winters of 1905 and 1906, and took out 250 tons of phosphate. In the two following years Mr. Wilson continued operations, and shipped about 400 tons of first-grade apatite. No further work has been carried on since 1909. A stock of some 800 tons of second-grade phosphate, stated to average 60 per cent, is still lying at the mine.

A great number of phosphate veins have been located on this property, the majority being narrow, but carrying good indications of mineral. A number of small openings have been made at various points, but most of the phosphate referred to above, has been taken from one pit. This excavation is an open-cut and sink 80 feet deep, 20 feet wide, and 30 feet long, and has been opened on a lead of green, massive apatite containing very little mica or calcite. The bottom of the pit is said to show an 8-foot vein of apatite. This vein has a direction of W.20°N. and dips 80°S., all the leads on the propery having approximately a similar strike and dip. The workings lie on the southwest side of a gneiss ridge, and the phosphate veins cut across this ridge almost at right angles.

The mine is the property of Messrs. Wilson and Stewart, and lies three miles from Cascades station, on the Gatineau Valley branch of the Canadian Pacific railway, this being the nearest shipping point. No machinery has ever been used at the mine, and the only buildings are a small bunk-house and a cobbing shed.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 122J; Bull. Ap., 1904, p. 27.
Que. Bur. Min., 1892, p. 85.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 103.

Range XVI, lot 14 S. $\frac{1}{2}$.—This lot also is the property of Messrs. Wilson and Stewart, and has been worked on a small scale. The veins here carry considerable quantities of pink calcite, in which occur small crystals of blue apatite and mica, and the deposit is of a more pockety nature than that on the adjoining lot.

A small pit has been opened on one such vein, and has been worked as an irregular drift 15 feet high carried about 35 feet into a small bluff.

The last work done was performed in 1910 by Mr. M. Dubois, of Wakefield, under contract with the owner.

Range XVI, lot 16.—Known as the Barber mine. A pockety lead of phosphate and pink calcite was worked in 1882 to a depth of 35 feet, the pit being 40 feet long. About 120 tons of phosphate are said to have been taken from this pocket.

References:—
Geol. Surv. Can., Rep. Prog., 1882-84, p. 17L; Bull. Ap., 1904, p. 26.

Phosphate has also been mined in small quantities at various other spots in the township of Hull, chief among which are the following. None

of these properties have yielded any great quantity of the mineral, but a number of them have been worked since 1890 for mica:—

Range X, lot 16.
" *X, lot 17.*—Haycock mine.
" *XI, lots 5, 6, S. ½.*—Kearney mine.
" *XI, lot 9.*
" *XI, lot 10.*—Nellie and Blanche mine.
" *XII, lot 6 S. ½.*
" *XII, lot 9.*
" *XIII, lot 3.*
" *XV, lot 12a.*—Dacey mine.
" *XV, lot 12b.*—McAllister mine. About 50 tons of phosphate were taken out by Mr. R. J. McGlashan, of Wilson's Corners, in 1910, while mining for mica.
Range XV, lot 13.—Connor mine.
" *XVI, lot 12.*—Moore or McLelland mine.
" *XVI, lot 15 S. ½.*—Cassidy mine.
" *XVI, lots 15 N. ½, 16 and 17.*—Horseshoe mine.

TOWNSHIP OF TEMPLETON.

Range V, lots 9, 10 and 11.—Known as the McRae mine, and opened in 1891 by H. McRae and Company. The workings are inconsiderable, and the property was worked for less than a year. The pits are situated about one mile east of the Blanche river, and four miles from East Templeton station. The Company installed an electric plant, utilizing water power on the Blanche river, and this was one of the earliest mines in the Province to employ electricity.

Diamond drilling was resorted to, and the existence of considerable bodies of phosphate was proved. However, before the property could receive more extensive development, the price of phosphate fell, and the mine was closed down. About 30 men were employed, and some 500 tons of apatite was taken out. (See Plate XIII.)

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 103J.
Que. Bur. Min., 1891, p. 88.

Range VII, lot 7.—Known as the Grier mine. A few small openings were made here about the year 1880, and 100 tons of phosphate were extracted. The apatite is said to have been mixed with considerable pyrites.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 10GG; Bull. Ap., 1904, p. 25.

Range VIII, lot 15 E. ½.—Rainville or Dugas mine. This property lies one and one-half mile southwest of Perkins Mills, and 10 miles from East Templeton station, on the southeast slope of the same hill upon which are situated the Phosphate King and Wallingford mines.

The property was originally opened up by Mr. W. Miller, of Montreal, in 1875, and was later worked by the Templeton and North Ottawa Mining Company. In 1891, the mine was worked for mica and phosphate by the Hon. C. A. Dugas, who also took out a small quantity of asbestos from a small deposit on the northern part of the lot. In 1896-7, Messrs.

Baumgarten and Manchester worked for mica, under lease; and in 1897, Webster and Co. had twenty men engaged in extracting this mineral. The present owners are Messrs. Wallingford Bros., Ltd., who acquired the property in 1906, and reopened the mine for mica in 1918.

It is estimated that over 2,000 tons of phosphate and $200,000 worth of mica have been taken off this property since the commencement of mining.

Each operator, in turn, equipped the mine with machinery; including steam pumps, drills, hoists, etc.; and a depth of 70 feet was reached in the main pit.

There are half a dozen openings, consisting of long, narrow trenches, excavated on parallel leads of phosphate and mica. The general direction of these leads is N.W.–S.E., with a slight dip to S.W.

The largest pit is 85 feet long, 15 feet wide, and 70 feet deep. There are, also, numerous small prospect pits scattered over the property. The pyroxenite varies in character considerably, ranging from a coarsely crystalline, normal rock of a dark green colour, to a finely crystalline and almost black mica-pyroxenite. The vein matter is largely pink calcite and apatite of a deep sea-green colour, mica occurring chiefly on the walls, but also, to some extent, disseminated through the vein-body. One lead carries a light coloured, yellow, massive phosphate, in which deep green fluorite and amethyst crystals are found. Considerable quantities of pyrites are present at certain spots and the pyroxene surrounding the pyrites possesses an unusual, blue colour. The mica is a good quality, brown amber.

References:—
Geol. Surv. Can., Rep. Prog., 1876-77, p. 303; XII Ann. Rep., 1899, p. 129J.
Que. Bur. Min., 1891, p. 86; 1892, p. 86; 1897, p. 97; 1905, p. 10.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 68.

Range VIII, lot 15 W. ½.—Phosphate King mine. Lies about one-fourth of a mile from the Rainville, or Dugas mine, and on the western slope of the same hill. Formerly owned by Mr. A. W. Stevenson, the property was worked in 1892 and 1893 by Mr. J. Wallingford, who employed half a dozen men in mining for mica and phosphate. In 1894, the Lake Girard Mica System took over the mine and installed machinery, continuing work for two years, employing some 20 men, and mining both mica and phosphate. In 1894, this Company took out 35 tons of mica and about 500 tons of phosphate from a vein averaging 9 feet wide. In 1896–7, Messrs. Webster and Company mined here for mica; but in the latter year the property was acquired by the Mica Mining and Manufacturing Company, of London, who continued operations until 1899. The last named syndicate was formed to take over all the mines of the Lake Girard System, and work was conducted both in the Province of Quebec and in Ontario. The Company had as many as 50 men engaged at this mine, and considerable quantities of both mica and phosphate were produced. With the exception of a few months' work carried on in 1906 by Mr. T. J. Waters, no further mining has been done since 1899.

The mica and phosphate occur on pockety leads having a strike of S. 70°E. and a dip of 60°S. An inclined drift 50 feet high has been carried 100 feet into the hill to the east, on the main lead. From here a shaft was sunk 70 feet, and a further drift run 280 feet.

There are, in addition, numerous other minor openings, the largest being 50 feet deep, and lying a short distance to the east of the main pit.

The mica is of good colour, but a large percentage is crushed, and inclined to split up into ribbon mica.

About 8,000 tons of high grade phosphate are said to have been taken from the mine.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 129J.
Que. Bur. Min., 1892, p. 86; 1894, p. 95; 1895, p. 60; 1896, p. 97; 1899, p. 30.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 69.

Range VIII, lot 16.—Wallingford mine. Owned by the Wallingford Mica and Mining Company, of Ottawa. The mine adjoins the Phosphate King property, and lies about one-fourth of a mile to the northwest of it. The distance from Perkins Mills is $1\frac{1}{2}$ mile, and from East Templeton station 12 miles. Originally opened for phosphate in 1882, by Mr. G. H. Beacon, and worked by him for a couple of years; the property was then acquired by the Pacific Guano and Phosphate Company, of Boston, who continued operations until 1891, with a force of from ten to twenty men.

Upon the last named ceasing work, Messrs. Wallingford Bros. and Company took over the mine, and continued to work, for mica, until 1902. In the following year, this Company was reorganized under the title of the Wallingford Mica and Mining Company, and, as such, has continued to work the property, intermittently, ever since. Though now to be considered an important mica property, this mine formerly yielded considerable quantities of phosphate. The last important production of this latter mineral was in 1898 and 1899: 1,000 tons being taken out in the former and 200 tons in the latter year. Little attention has been paid of late years to the apatite encountered while extracting mica, the low price offered for the mineral not rendering mining profitable; and it is only saved when met with in large quantities.

A large plant exists at the present time at the mine: including an 80 horse-power boiler; six steam drills; four steam hoists; three pumps; and six derricks, besides the usual mine buildings.

Large reserves of excellent mica are said to be in sight in the pits. A total of about 3,600 tons of trimmed mica is estimated to have been produced from this mine. One crystal was met with, which is stated to have yielded $33,000 worth of marketable mica.

The entire phosphate production is estimated at 4,000 tons.

The workings consist of numerous minor openings, prospect pits, etc., and two main excavations, the larger being 170 feet long, 30 feet wide, and 200 feet deep. This opening has a direction of S.70°E.

The deposit is of the fissure and pocket type, and carries large quantities of pink calcite, in which occur finely formed mica crystals and large bodies of green phosphate. No detailed examination of the workings was practicable when the mine was visited, the pits being full of water.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, pp. 128, 129J.
Que. Bur. Min., 1895, p. 60; 1896, p. 96; 1898, p. 34; 1899, p. 30; 1900, p. 19; 1901, p. 32; 1902, p. 16; 1903, p. 58; 1904, p. 36; 1905, p. 10; 1907, p. 24.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 70.

Range IX, lot 14 S. $\frac{1}{2}$.—Opened about 1878, by Mr. Wellington, this mine has since been worked for mica by a number of parties: including Webster and Co.; Jurkowski and Co.; and the Laurentide Mica Company. The latest work was performed by Messrs. Loyer, of West Templeton, in 1909, when about 50 tons of phosphate was taken out; and by Messrs.

Loyer and Charette, in 1910; the latter working for a few months with half a dozen men, and producing about 70 tons of high grade apatite, and a little mica.

The workings consist of five pits, the largest of which is 60 feet deep, 80 feet long, and 20 feet wide. All these openings are open-cuts run into the south and east slopes of a ridge 200 feet high, and lying about a mile from Perkins Mills.

The phosphate is massive, of a light green colour, and occurs associated with large quantities of pink calcite and small sized amber mica, on leads in a dark green pyroxenite. These fissure-leads have a general trend of east and west, and dip at varying angles to the south. Their walls are often covered with a compact mass of small mica crystals. The leads are very irregular, and vary much in width; in a distance of 20 feet, one vein narrows from 15 feet to 3 feet. "Leopard-granite" is a conspicuous rock type on the dumps.

References:—
Geol. Surv. Can., XII, Ann. Rep., 1899, p. 130J.
Que. Bur. Min., 1896, p. 98; 1898, p. 34; 1899, p. 30.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 73.

Range IX, lots 17 and 18 N. $\frac{1}{2}$.—Known as the Goldring mine, and was an important phosphate producer in the late seventies, when Mr. John McLaurin, of East Templeton, worked for two years with a force of 50 men. The Goldring Phosphate Company subsequently acquired the property, and mined for about twelve months with a large force; being succeeded by Messrs. Hebert and Ouimette of Montreal, who worked one year, and took out a large quantity of mineral. The mine then lay idle for a number of years, being taken over, in 1904, by the Papineauville Lumber Company. The last named Company confined their operations to lot 17, where an old phosphate pit was re-opened, and sunk to a depth of 70 feet. Work was commenced early in 1910, and continued for a few months, half a dozen men being employed. About 100 tons of first grade, and 40 tons of second grade phosphate were produced, in addition to a small amount of mica. No further work has been performed since October, 1910.

The old phosphate pits are located on lot 18, the principal opening being a narrow open-cut, carried into the south side of a high ridge lying 3 miles northwest of the village of Perkins Mills. This open-cut is 50 feet long, and from the inner end a drift has been run into the hill for a distance of nearly 100 feet. This opening has been made upon a well defined lead, carrying massive, green apatite and pink calcite, with some mica. The country rock is dark gneiss, cut by quartz bands or dikes; and the vein which has here been followed, occurs on the contact of pyroxenite with such a quartz dike. The strike of the lead is NW–SE., with a dip of 30° NE. The main filling of the vein consists of massive, green apatite, containing pockets of calcite, in which latter occur the mica crystals. Mica is also found embedded in the phosphate, but far more rarely.

An unusual feature of the vein worked on lot 17 by the Papineauville Lumber Company, is the occurrence in the phosphate of small druses carrying a well crystallized smoky quartz, calcite, dolomite, chalcopyrite, and sphalerite.

Reference:—
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 73.

Range X, lot 8.—Marsolais mine. Situated about two miles northeast of the village of Perkins Mills. This mine was worked somewhat extensively by the Templeton and North Ottawa Mining Company, of Montreal. Two pits or drifts were sunk to depths of 90 and 70 feet respectively, and a considerable quantity of phosphate was taken out. The mine and dumps have since been exploited for mica by various parties, and the property was acquired a few years ago by Mr. M. J. O'Brien, who, however, has carried out no work upon it.

References:—
Geol. Surv. Can., XII, Ann. Rep., 1899, p. 130J.
Que. Bur. Min., 1896; p. 98; 1900, p. 19.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 75.

Range X, lot 9 E. $\frac{1}{2}$.—Post mine. Opened by Mr. Post, in 1878, this property was operated between 1889 and 1893 by the Canada Industrial Company, who installed machinery, errected a large number of buildings, and took out a quantity of high grade phosphate. In 1895, the mine was worked for mica by Mr. White, of New York, who employed 15 men. Mr. M. J. O'Brien took over the mine in 1897, and commenced work for mica and phosphate with half a dozen men. The property was newly equipped with a horizontal boiler; steam hoist; boom derricks, two steam drills; and two steam pumps, and considerable work was carried out during 1907-8. Some new pits were sunk, but work was also continued in the old phosphate pit, which is an opening 125 feet deep, and about 100 x 100 feet, and a considerable quantity of mica was extracted. The last work was done in 1909.

The phosphate and mica occur on veins in a grey-green pyroxenite, enclosed in dark biotite gneiss, which is in places highly garnetiferous, and is traversed by a system of granite dikes. The basic rock varies from a normal, compact variety, to a mica-pyroxenite, often mixed with considerable apatite.

Some of the veins carry large bodies of pink calcite, while on others this mineral is almost totally absent. The same applies to both pyrites and pyrrhotite, which are met with chiefly in the openings on the ridge above the main pit. The phosphate is present both in the form of sugar-phosphate and of isolated crystals, embedded in calcite.

Openings exist over almost the whole of the property, which lies $2\frac{1}{2}$ miles northeast of Perkins Mills.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 10GG; IV Ann. Rep., 1888-89, p. 109K; V Ann. Rep., 1890-91, p. 157S; XII Ann. Rep., 1899, p. 130J.
Mines and Minerals of the Province of Quebec, 1889-90, p. 126.
Que. Bur. Min., 1890, p. 80; 1892, p. 86; 1895, p. 59.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 75.

Range X, lot 9 W. $\frac{1}{2}$.—Jackson Rae mine. This property was one of the most extensively worked in the Templeton district, and was actively operated between the years 1878 and 1890 by the Jackson Rae Phosphate Company, of London, which extracted several thousand tons of mineral. Numerous openings, some of them of large extent, exist on the property, the larger pits being located on the south end of the lot and about half a mile nearer Perkins Mills than those more recently worked for mica. The most important excavation is a large open-cut several hundred feet in length which has been opened on a deposit of phosphate lying between pyroxenite and gneiss. The dump material exhibits many varieties of rock,

varying from a normal dark pyroxenite to a mixture of blue-grey microline feldspar and brown titanite, the latter mineral in crystals often from two to three inches in length.

On the north end of the lot a number of small pits exist, the deepest being about 90 feet deep. These workings were exploited from 1908 to 1910 by Mr. M. J. O'Brien, who now owns the mine and who worked for mica. The mica, however, though occurring in considerable quantity, is too much crushed to be of much value, and operations were suspended for this reason. Mr. O'Brien employed an average of 8 men, and installed a steam plant. Most of this installation has since been removed, and only the boarding-house, stables, etc., remain. About 35 tons of mica are reported to have been recovered from the old phosphate dumps.

The deposit is of pockety type, irregular leads of mica and phosphate occurring in a somewhat dislocated and crushed grey pyroxenite. This dislocation appears to be due to intrusion by acid dikes, which have introduced considerable quantities of black tourmaline into the phosphate leads. The tourmaline occurs in groups of radiating columns and stout needles, associated with secondary actinolite, brown titanite, calcite, and mica. A body of such acid rock was met in the main pit, and cut off the mica lead at a depth of some 70 feet.

The phosphate is both of the powdery "sugar" and massive varieties. and is uniformly of a green colour.

The mine lies 14 miles from East Templeton station, on the Canadian Pacific north shore line from Ottawa to Montreal.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 11GG; IV Ann. Rep., 1888-89, p. 108K; XII Ann. Rep., 1899, p. 130J.
Bull. Ap., 1904, p. 25.
Mines and Minerals of the Province of Quebec, 1889-90, p. 126.
Que. Bur. Min., 1892, p. 86.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 75.

Range X, lot 10 N. $\frac{1}{2}$.—Known as the Jubilee or Smith mine, and now owned by the Routhier Mining Company, of Angers, Que. This property was originally opened up about the year 1888 by the McLaurin Phosphate Mining Syndicate, which took over the mines formerly owned by Mr. L. McLaurin, of Templeton. A small camp was erected, and about a dozen men were employed The workings are not very extensive, comprising three small pits, the deepest of which is said to be down about 40 feet. This mine produces an excellent grade of light-coloured, silver-amber mica often in sheets of large size, and when mining for phosphate became unprofitable, the McLaurin Syndicate continued operations for mica. With the exception of a few weeks' work by the present owners, in 1909, the last mining was carried on in 1900.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 130J.
Que. Bur. Min., 1896, p. 98; 1900, p. 19.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 76.

Range X, lot 10 S. $\frac{1}{2}$.—Murphy mine, opened in 1878. The mine was only operated for a couple of years, and does not appear to have yielded much phosphate; but later it was extensively worked by various parties for mica. The Lake Girard Mica System acquired the property in 1892, and worked for some months in 1894. In 1899, Mr. Arthur Murphy shipped 75 tons of phosphate, which was extracted while mining for mica;

and in the following year the Sills-Eddy Company leased the mine and worked a few months. No further development has taken place.

The only important opening is a pit 65 feet deep which has been excavated open-work on a proxenite belt carrying irregular leads and pockets of phosphate and mica. This pyroxenite has been intruded along its strike and midway across its width, by a light grey pegmatite, having a direction of east and west. The mica leads have been worked by means of open-cuts on each side of this acid dike.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 11GG; XII Ann. Rep., 1899, p. 130J.
Que. Bur. Min., 1892, p. 86; 1894, p. 95; 1899, p. 30; 1900, p. 21.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 77.

Range X, lots 15 W. ½, 16 N. ½.—Victoria mine. Opened in 1899 by Messrs. McLaurin and McLaren, and has yielded a large quantity of mica and a small tonnage of phosphate. The present owner is Mr. T. G. McLaurin, of Montreal, who worked from 1907 to 1910 for mica and phosphate. The mine is idle at the present time.

The workings lie 2½ miles northwest of the village of Perkins Mills, and a mile off the road from that place to McGregor lake. They comprise some half dozen pits, of which the largest measures 130 by 45 feet, and is 187 feet deep. This opening has been made on a deposit of phosphate and mica lying between pyroxenite and gneiss, and having a strike of N. 55° W., with a dip of 75° S.W. From the bottom of the pit a drift has been carried 60 feet to the southwest, following leads of phosphate and mica accompanied by large quantities of pink calcite. The north side of the pit exhibits a well defined vein wall.

The mica is a good quality, light amber, and is found disseminated through the body of calcite and phosphate.

The pyroxenite is a light grey-green rock, containing numerous pockets, which are often lined with large and well formed pyroxene crystals, and carry both "sugar" and massive phosphate. Unusually dark coloured apatite is sometimes met with; well formed crystals, almost black in colour, being noticed in one of the smaller openings.

Three well defined leads of high grade phosphate are reported to occur on the property, but have been little worked.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, p. 130J.
Que. Bur. Min., 1899, p. 30; 1900, p. 19.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 78.

Range XI, lot 6.—Mining for phosphate was carried out during the year 1886 by the Templeton and Blanche River Mining Company, who were succeeded in 1891 by the Netherlands Phosphate Company, of Amsterdam. The last named were only in existence a short while, and did not produce more than a few tons of mineral.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 25.
Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Que. Bur. Min., 1891, p. 88.

Range XI, lots 7 N. ½; 8, 9, 10 and 11.—Blackburn mine. The principal workings are situated on lots 9 and 10. This is the largest mica and phosphate mine in the township of Templeton, and lies 13 miles north of the station at East Templeton, and 4 miles from Perkins Mills. It is owned by Messrs. Blackburn Bros., of Ottawa. Originally opened for

phosphate in the eighties by Messrs. Blackburn and McLaren, and being later (in 1888) operated by the East Templeton District Phosphate Mining Syndicate, Limited,who in 1895 gave place to the present owners, the mine has become one of the largest mica producers in the district.

With the exception of a short period—about sixteen years ago, when the mine was closed down for three years—operations have been continued without intermission since 1888. A large force of men has been constantly employed, the number reaching a maximum of 120, some years ago. The large pit on lot 10 was shut down in 1910, and mining at present is confined to the new shaft on lot 9.

The total area of the property comprises about 900 acres, but mining is confined to lots 9 and 10. Numerous openings exist on both these lots, the whole area having been extensively prospected for both phosphate and mica.

Lot 10.—The principal excavation is an open pit over 300 feet long, 180 feet wide at it southeast end, and 120 feet deep. From the southeast end further underground workings have been carried in an easterly direction. These consist of three galleries, 300 to 500 feet long, on the 180, 240, and 280 ft. levels, respectively, and communicating by means of a shaft 160 feet deep. These galleries have been stoped out in places to a height of over 25 feet. Drifts have been carried from them to the north and south, following irregular pockety accumulations of mica and phosphate, enclosed in soft green pyroxenite.

The mica is a first class, light amber, and the crystals usually occur as individuals or in small aggregates embedded in the phosphate. Calcite is relatively absent.

The proportion of commercially valuable mica to the total amount mined is high, about 50 per cent being marketable sheets.

Phosphate was extracted simultaneously with the mica, and some 200 to 500 tons of high grade apatite was produced annually. The mineral was hauled to East Templeton station during the winter months, and shipped thence by rail to Buckingham.

The output of mica formerly kept forty persons employed in the trimming works.

The deposit is associated with a pyroxenite belt of unascertained width and extent, having a strike of northwest and southeast, and enclosed in dark biotite gneiss. Both pyroxenite and gneiss are extensively cut by pegmatite dikes.

No limit, in depth, has as yet, been found for the deposit: considerable reserves of both mica and apatite being still present in the lower workings.

The mine is equipped with a large plant: including a boiler house with one 40 H.P. and one 50 H.P. boiler; an Ingersoll-Sargent compressor, with a capacity of 440 cubic feet free air per minute; and a 4 K.W. dynamo used in generating current for lighting purposes.

There are two steam hoists capable of being operated either by steam or air, and a small reciprocating pump lifting 200 feet, with a capacity of 100 gallons per minute. The mine is supplied with power from a power house situated $2\frac{1}{2}$ miles away, near the outlet of Dam lake. This plant is equipped with a turbine operating a 115 K.W. dynamo, generating (A.C.) at 2,400 volts, transmission being by three-phase line to the mine. The

current is used to run a 75 H.P. motor at 2,200 volts, belted to an Allis-Chalmers compressor supplying air for drilling, and also for pumping and hoisting, if necessary. In addition, the current is run to a 40 H.P. motor operating a hoist. Transformed to 550 volts, it may be used to work a 7½ H.P. pump in the pit, and at 110 volts it is used for lighting, for driving small motors attached to saws, etc., and for running a small centrifugal pump circulating cooling water through the compressor. From the receiver of the latter, a 3″ pipe line is run half a mile to the new pit on lot 9, to supply two air drills.

A tramway connects the pit with the waste dump, and rock was moved in 6-ton, wooden tip cars, drawn by horses. The pit is equipped with two cable hoists, the towers being 60 feet high.

In the old phosphate mining days, large quantities of mica went to the waste dumps; and later, these dumps were turned over; a force of some twenty to thirty men being employed during 1894 and 1895 in recovering the mineral.

The present camp consists of a large boarding house, capable of accommodating over a hundred men; a stable for fifteen teams of horses; store house; weigh house; and manager's quarters; offices, etc.

Lot 9.—About half a mile northeast of the above old workings, an inclined shaft has been sunk on a well defined vein deposit of mica and apatite. This vein has an average thickness of 8 feet. The shaft is down 200 feet, and is 7 × 10 feet square, timbered for a distance of 40 feet from the surface.

A shaft house has been erected, and the pit equipped with an inclined skipway taking cars of one ton capacity. A 30 H.P. horizontal boiler is used for running a steam hoist; and air is piped from the neighbouring mine to work drills and a small reciprocating pump. The method of working is in marked contrast to the quarry methods so generally employed in phosphate and mica mining, and is an example of how a deposit of this nature may be developed to the best advantage.

The mica is a light silver amber, and occurs with massive green apatite, disseminated through a large body of pink calcite.

The strike of the deposit is N. 60°E, with a dip to S.E. Three levels have been run at 60, 100, and 147 feet, and extend about 100 feet from the shaft in a westerly direction, raises being put in, and the vein stoped out, without timbering. This pit has been in active operation since May 1911, with the exception of an interval during which lack of water prevented the power plant from being operated. About a dozen men are employed. About twenty feet from the shaft, in an easterly direction, the deposit appears to be cut off by a body of hard trap rock, which intercepts it almost at right angles. No attempt to cut through this dike has as yet been made. About 200 tons of apatite have been taken from these workings.

The annual production of phosphate during the period that the property was operated solely for this mineral (1885-92) was some 3,000 tons. The total output from the commencement of operations to the present time will probably not fall far short of 35,000 tons.

References:—

Geol. Surv. Can., IV Ann. Rep., 1888-89, p. 108K; XII Ann. Rep., 1899, p. 130J; Bull. Ap., 1904, p. 25.
Mines and Minerals of the Province of Quebec, 1889-90, p. 125.
Que. Bur. Min., 1890, p. 80; 1892, p. 86; 1894, p. 91; 1895, p. 59; 1896, p. 97; 1898, p. 34; 1899, p. 30; 1900, p. 19; 1901, p. 32; 1902, p. 16; 1903, p. 58; 1904, p. 36; 1906, p. 41; 1907, p. 23.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 78.

Range XIII, lots 4 and 5.—Battle Lake mine. Owned and operated by the Wallingford Mica and Mining Company, (formerly the Ottawa Mica and Mining Company), of Ottawa, who acquired the property in 1900, and have worked more or less steadily up to the present time, operations being conducted almost solely for mica.

The main mica workings are located on the north shore of Battle lake, while the old phosphate pits lie nearer the south shore of Rheaume lake, a neck of land about one-sixth of a mile wide separating the two lakes. These old phosphate workings consist of a number of small openings on several more or less parallel leads of massive green apatite, which carry also a little dark mica. Considerable quantities of high grade apatite were produced from these pits during 1886-87 by the Anglo-Canadian Phosphate Company, of London; the mineral being hauled to the Lièvre river, $2\frac{1}{2}$ miles distant, and shipped to Buckingham.

Of late years operations have been mostly confined to several new pits on the steep slope forming the north shore of Rheaume lake, these workings being situated on lot 5. At this point the veins carry only small amounts of apatite, mining being conducted entirely for mica, which occurs in large crystals, and is associated with quantities of mauve and purple wilsonite.

The mine has produced considerable quantities of mica, and important bodies of high grade phosphate exist at various points.

The Anglo-Canadian Phosphate Company also owned lots 6 and 7 of the same range, and carried out considerable work there during 1886 and 1887, installing a steam plant.

Other properties owned by this Company included the following:—

Portland West: *Range X, lots 2, 4, 5.*

Portland East: *Range I, lot 4; Range II, lots 1 W.* $\frac{1}{2}$, *2 E.* $\frac{1}{2}$; *Range V, lots 13, 14.*

Templeton: *Gore, lots 9, 41, 42, 43, 44, 45, 46.*

Bowman: *Range VII, lots 26, 27.*

Wakefield: *Range II, lots 20 E.* $\frac{1}{2}$, *21 N.* $\frac{1}{2}$, *22.*

In 1887, the Company (which previously had borne the name of the Du Lièvre River Land and Phosphate Company) abandoned all work in the Province of Quebec, and commenced operations at the Otty Lake and Bobs Lake mines, in the townships of North Burgess and Bedford, Ont.

References:—
Que. Bur. Min., 1900, p. 19; 1901, p. 32.
Geol. Surv. Can., Bull. Ap., 1904, p. 25.
Mines and Minerals of the Province of Quebec, 1889-90, pp. 124, 127.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 83.

Range XIII, lots 22 and 23.—Breckin mine. This property lies on the crest and upper slopes of a ridge situated about one mile west of McGregor lake. The chief opening is a shallow cut 400 feet long and 12 feet wide, and having a maximum depth of 30 feet. This trench has been opened on a well defined lead of green, massive phosphate, having a NE.–SW. direction, and carrying a little mica. The phosphate bearing rock is a dark-green pyroxenite, enclosed in reddish gneiss. Scapolite and brown sphene are plentiful along the vein, and fine crystals of zircon are reported to have been found here.

The mine is owned at the present time by Mr. H. Grattan, of St. Pierre de Wakefield. It was first opened about the year 1880, by Mr.

Breckin, who employed an average of 50 men for two years, and took out a large quantity of high grade apatite. No further work has been done upon the property, although considerable showings of phosphate exist at various points.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 12GG; IV Ann. Rep., 1888-89, p. 109K.

Gore, lot 6.—A few small openings were made in the eighties by Mr. Murphy, and in 1904 Messrs. Watts and Noble, of Perth, worked for a few months with a couple of men. The amount of phosphate produced was inconsiderable.

References:—
Geol. Surv. Can., Bull. Ap., 1904, p. 25.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 85.

Gore, lot 8.—Rheaume Lake or King Edward mine. The property of Messrs. Wallingford Bros., Ltd., who, however, have never performed much work here.

There is a large development of phosphate at this spot, and considerable work was carried out in 1886, by the Anglo-Canadian Phosphate Company.

The veins have a NE.–SW. direction, and carry massive green apatite and a light silver-amber mica. Pockets in the pyroxenite usually have a filling of pink calcite, in which large and well formed apatite crystals occur disseminated. The faces of these crystals commonly exhibit a glazed and resorbed appearance. (See Plate XIV.)

There are three main openings, reaching a depth of 25 feet, situated 300 yards from the north shore of Rheaume lake.

References:—
Que. Bur. Min., 1905, p. 10.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 85.

Gore, lot 39.—Briggs or Stewart mine. Opened in the late eighties by Mr. Stewart, of Ottawa. In 1907 Messrs. Kent Bros. of Kingston, worked a few months, for mica.

The mine is situated 4 miles northeast of St. Pierre de Wakefield, and connects with the Wakefield road by a good bush track. The workings, which comprise half a dozen surface pits, have been opened on the northwest side of a hill about 500 feet high, in a dark green pyroxenite.

The largest opening is an open-cut, following a lead of phosphate and mica, having a strike of northwest and southeast, dipping northeast, and having a width of 12 feet. The cut has been carried 60 feet into the hill, is 15 feet wide, and 80 feet deep at its inner end.

The mica is hard, brittle, and very dark, and is generally much crushed and of little value, the deposit being of more importance for the phosphate it contains. Large amounts of mauve coloured wilsonite occur, associated with massive phosphate.

No machinery has been employed on the mine.

References:—
Que. Bur. Min., 1896-97, p. 98.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 86.

Other localities in the township of Templeton which have yielded small quantities of phosphate are listed below. The amount taken off any individual property was small, and the localities are given only as an indication of where the mineral has been found. Many of the mines noted have been worked since for mica:—

Locality.	Name of operator.
Range IV, lot 21	McTiernan.
" *IV, lot 22*	McVeity.
" *VI, lot 4*	McIntosh.
" *VI, lot 15*	Brady.
" *VI, lot 17*	Canada Industrial Company.
" *VII, lots 4, 5, and 6*	McLaren.
" *IX, lot 9*	Coursolles and Belcourt.
" *IX, lot 16*	Canada Industrial Company.
" *X, lot 7*	Greer.
" *X, lot 14*	Pearson.
" *X, lot 27*	Thompson.
" *X, lot 28*	Greer.
" *XI, lot 12*	Stewart.
" *XII, lot 2 S.* $\frac{1}{2}$	Miller.
" *XII, lots 8 S.* $\frac{1}{2}$, *9 S.* $\frac{1}{2}$	McLaurin.
" *XII, lot 12*	Templeton and North Ottawa Mining Company.
" *XII. lot 13*	
" *XII, lot 20*	Laurin.
" *XII, lot 21*	Templeton and North Ottawa Mining Company.
" *XIII, lot 11.*	
Gore, lots 16, 17, 18	Blackburn.
" *lot 35*	Allan and Fleming.
" *lot 38*	Murphy.

TOWNSHIP OF WAKEFIELD.

Range I, lot 6 N. $\frac{1}{2}$.—Known as the McBride mine, and owned by Mr. J. Grimes, of Ottawa. The property was worked about ten years ago by Mr. Edward Watts, of Perth, and has since been worked in a small way for mica by the owner.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 12GG.
Que. Bur. Min., 1892, p. 85.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 87.

Range I, lot 12.—Haldane or Hughes mine. This mine was opened in 1878 by Messrs. Haldane and Sons, of Aylmer, and was actively exploited by them until the year 1890. About 4,500 tons of phosphate are said to have been shipped during this period. In 1892, Messrs. Hughes and Robitaille worked for both mica and phosphate. The mine has lain idle since 1893.

The workings, which lie about 15 miles north of the nearest shipping point on the Ottawa river, comprise over twenty pits. The largest vein of apatite encountered had a width of over 10 feet, the mineral being of a reddish colour, and rather mixed with pyrites. This latter mineral is common on the majority of the leads, and occurs often in masses of considerable size. The prevailing colour of the phosphate is pale to dark green, the mineral generally being massive. The deepest pit is an open-cut and drift over 125 feet deep, which has been carried along a lead of phosphate occurring at the contact of pyroxenite and gneiss. Mica

occurs upon pockety leads adjacent to the phosphate body. Minerals associated with the phosphate include epidote, scapolite, chabazite, and natrolite. The phosphate was hauled to the Ottawa river and loaded onto barges for shipment to Montreal.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, pp. 8, 13GG; Rep. Prog., 1882-84, p. 18L; XII Ann. Rep., 1899, p. 117J; Bull. Ap., 1904, p. 26.
Que. Bur. Min., 1892, p. 85.
Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 88.

Range I, lot 14.—Mullins mine. Worked in 1876, and again in 1881, by Mr. G. Clark, of Ottawa. No information as to production is available, but the pits consist of only a few shallow surface openings.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 13GG; Rep. Prog., 1876-77, p. 308.

Range I, lot 15 S. ½.—Known as the Comet mine. The property has been worked by a number of parties, the first operators being Messrs. Chitty and Loken, of Chelsea. Subsequently Mr. J. A. Wilson extracted a few tons of phosphate, and later worked for mica together with Mr. Chubbuck. In 1898, Messrs. Hurdman and Arnoldi, under the name of the Comet Mica Company, mined for mica, and Mr. J. K. Paisley, of Ottawa, took out a little phosphate in 1910.

There are several openings on the property, mostly open-cuts and drifts, run into the side of a small ridge of dark gneiss enclosing a series of pyroxenite bands. Mica and large bodies of "sugar" phosphate, together with some calcite, occur on fissure leads of irregular shape and direction in a grey pyroxenite. The leads are in some instances almost horizontal, and have been mined by means of flat drifts. The first shipment of phosphate ever produced in the Province of Quebec, if not in Canada, is reported to have come from this mine.

Reference:—
Dept. Min. Can., Min. Br., Mon. -Mica, 1912, p. 88.

Range II, lot 16.—Kodak mine. Was worked in the eighties by Mr. J. A. Wilson, and yielded a small amount of phosphate. The mine is a mica, rather than a phosphate producer, and has been worked since 1894 by a number of parties for the former mineral. The operators included the Wakefield Mica Company; Webster and Company; Messrs. Wilson and Chubbuck; and Mr. J. S. King, of Toronto. No work has been done since 1908.

References:—
Geol. Surv. Can., XII Ann. Rep., 1899, pp. 118, 132J.
Que. Bur. Min., 1894, p. 96; 1898, p. 35; 1899, p. 34; 1900, p. 22; 1903, p. 59.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 88.

Range II, lot 17.—This property is known variously as the Wilson, Morris and Kitty Lynch mine. It was opened in 1880 by Mr. J. A. Wilson, who continued work for two years, and took out some 300 tons of phosphate. The present owners, Mr. M. Morris and Mr. H. Flynn of Hull, have since worked for mica; the former in 1892, and the latter in 1907. No mining has taken place since the last named year.

The phosphate is both massive and granular, and varies in colour from dull red to dark green. Large sized mica crystals occur with the phosphate. The strike of the deposit is east and west, and two pits have

been sunk upon it. The westerly opening is 100 feet long, and 35 feet deep, and follows the leads in a zigzag manner.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 9GG; Rep. Prog., 1882-84, p. 18L; XII Ann. Rep. 1899, p. 132J; Bull. A., 1904, p. 26.
Que. Bur. Min., 1894, p. 96; 1895, p. 60.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 90.

Range II, lot 18.—Seybold or Moore mine. The property was first worked by Mr. Isaac Moore, of Ottawa, in 1880. Work was continued for a couple of years, and 500 tons of phosphate were taken out. Later, in 1889, Messrs. Seybold and Gibson mined for mica and phosphate, and, in 1903, the present owner, Mr. McLean, of Ottawa, worked for mica. The property has since lain idle.

Much of the apatite is of a reddish shade, and the mica is uniformly very dark in colour. The pyroxenite itself is a very dark-coloured rock, as is also the enclosing gneiss. Large pockets were encountered in the pyroxenite during the earlier operations: these often being lined with large and well formed crystals of pyroxene. The pockets usually carried a filling of pink calcite, having crystals of apatite and mica scattered through it. The strike of the veins is north and south, with a dip of 75° to the west. The deposit has been extensively intruded by pegmatite dikes, and, in one case, faulting of a phosphate lead by a pegmatite dike has occurred.

The openings are not very extensive, and comprise several surface pits, the largest of which is a narrow open-cut, 50 feet long and 10 feet wide.

References:—
Geol. Surv. Can., Rep. Prog., 1880-82, p. 9GG; Rep. Prog., 1882-84, p. 18L; IV Ann. Rep., 1888-89; p. 108K; XII Ann. Rep., 1899, p. 118J; Bull. Ap., 1904, p. 26.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 90.

Range III, lot 16.—Thompson mine. Belongs to Mr. Thompson, of Cantley. The property has yielded small amounts of both phosphate and mica, which have been extracted by means of a flat drift carried 50 feet into the side of a low ridge.

Reference:—
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 94.

Range IV, lot 24; range V, lots 22, 23, 24, S. ½'s.—Gemmill mine. This property was worked, in 1879, by Messrs. Nellis and Gemmill, of Ottawa, and operations were continued until 1886, when the mine was shut down on account of the low price of phosphate. The total amount of apatite produced is estimated at about 1,000 tons.

The phosphate found on this property is usually of a reddish colour, but is said to be of good quality, and to average from 78–82 per cent, B.P.L. It occurs on more or less regular, horizontal veins or beds, in a hornblende-pyroxene rock, enclosed in an epidotic gneiss. Scapolite is frequent in both pyroxenite and gneiss, while tourmaline and well crystallized zircon also are reported from this locality.

On lot 23, range V, a pockety deposit of pink calcite occurs in the pyroxene, and from this a quantity of apatite crystals was mined. The crystals were well formed individuals, usually doubly terminated: and often with the prism faces almost entirely absent, thus giving the appearance of a double-six-sided pyramid.

A small steam plant was intalled at the mine, which employed about a dozen men. The phosphate was shipped out both by way of Ironsides,

on the Gatineau Valley railroad, this route being used in winter, and by East Templeton in summer. In the latter case, the mineral was taken down McGregor lake in barges, and hauled from Perkins Mills.

Most of the work done was carried out on the south half of lot 24, range IV. Here, an almost horizontal vein of reddish phosphate crops out on the side of a small ravine, and has been worked by means of an adit carried some 150 feet into the hillside. Practically all the phosphate shipped from the mine was obtained from this pit.

No work has been done on the property since 1886. The mine is at present owned by the estate of Mr. T. F. Nellis, of Ottawa.

References:—
Mines and Minerals of the Province of Quebec, 1889-90, p. 128.
Que. Bur. Min., 1899, p. 34.
Geol. Surv. Can., Rep. Prog., 1882-84, p. 19L; Bull. Ap., 1904, p. 26.

Range VI, lot 27.—Belongs to Mr. R. J. McGlashan, of Wilson Corners. The mine is located 3 miles north of St. Pierre de Wakefield, and near the west arm of Wakefield lake, upon a ridge rising 300 feet above the lake. The property was first worked by Mr. R. W. Eady, in 1905, and was taken over by the present owner in 1907. Work has been continued more or less steadily up to the present time, mica being the main objective. Phosphate is saved as a by-product, and the present owner shipped about 185 tons of high grade mineral to Buckingham, between 1908 and 1910.

The workings consist of a number of pits opened on the southeast side of the hill, from which drifts have been carried in a northerly direction. The main pit is 60 feet deep, 15 feet wide, and 75 feet long, opened on a pocket deposit of darkish amber mica, green compact and "sugar" phosphate, associated with pink calcite. The leads and pockets occur in a light grey-green rock, consisting of pyroxene, scapolite, feldspar, and dark quartz. The variety of scapolite known as wilsonite occurs in some quantity in certain of the pits.

The mica is often well crystallized, and a quantity of large sized crystals have been raised. Large crystals of apatite occur, also, embedded in calcite and "sugar" phosphate. The occurrence of large pockets, lined with well shaped crystals of pyroxene, is characteristic of this property.

In the pit on the northeast of the property, a well defined flat lead is exposed, the vein matter being pink calcite and massive phosphate, and the walls are lined for some distance with well formed apatite crystals. Brown titanite, in crystals measuring up to one inch in length, is a common accessory mineral in the wall rock.

The mica is roughly cobbed at the mine, and hauled to the trimming shops at Wilson Corners, 6 miles away.

References:—
Que. Bur. Min., 1898, p. 35.
Dept. Min. Can., Min. Br., Mon. Mica, 1912, p. 94.

Range IX, lot 30.—This property was worked by Mr. Harris from 1879 to 1883. Five men were employed, and about 400 tons of phosphate are reported to have been taken out. The workings, with the exception of one pit 35 feet deep, are all small surface openings.

References:
Geol. Surv. Can., Rep. Prog., 1882-84, p. 19L; Bull. Ap., 1904, p. 26.

CHAPTER IV.

SEDIMENTARY PHOSPHATE.

No discovery of earthy phosphate, of sedimentary origin, which can be regarded as of present economic importance, has, as yet, been made in Canada, and the phosphate reserves of the country are thus confined to the apatite deposits of the Archæan, crystalline rocks in eastern Ontario and Quebec.

While of little significance, owing to their low phosphoric acid content, brief mention may be made of certain low-grade, sedimentary phosphates, which occur at several points.

Alberta.

In 1915, announcement was made of a discovery of phosphate rock in the neighbourhood of Banff, Alberta. Particulars of this discovery first appeared in a report entitled, "Discovery of Phosphate of Lime in the Rocky Mountains," by F. D. Adams and J. W. Dick, issued by the Conservation Commission. The writer was instructed to investigate the extent of this phosphate deposit, and in 1915 made a preliminary examination of the phosphate-bearing series in the Banff district. The results of this examination were published in Mines Branch Bulletin No. 12, "Investigation of a Reported Occurrence of Phosphate in Alberta", 1916. Although the results of this investigation were not encouraging as far as indicating the existence of any appreciable quantity of high grade phosphate in the region, it was considered possible that the phosphatic series might represent a northerly extension of the important Phosphoria formation of Montana, Idaho, and Wyoming, in which States, immense quantities of valuable phosphate rock have been found, at approximately the same geologic horizon as that in which the phosphate of the Banff district occurs. Accordingly, in 1916, an extended reconnaissance for phosphate was undertaken in that part of the Rocky Mountains to the south of the area of original discovery, and lying between Banff and the Montana boundary. The field work did not indicate the existence of phosphate of commercial grade in the region, and, indeed, showed that the phosphate series of the Banff district thins out to the southward. The results of this reconnaissance appeared in Mines Branch Summary Report for 1916, from which the following extracts are quoted:—

> The phosphate bed discovered last year near Banff, was traced south as far as Tent mountain, just north of Corbin, B.C., and about six miles south of Crowsnest. At none of the outcrops found did the bed prove to be as thick as at the best outcrops in the Banff district. Analyses of samples demonstrated that the phosphoric acid content in every case is considerably below the highest obtained from samples taken in the Banff area. The highest P_2O_5 content of samples taken in the southerly portion of the area examined, was 20·70 per cent, while the best rock from Banff ran 27·63 per cent P_2O_5.
>
> The field work indicates, contrary to what might have been expected, that the phosphate bed in question thins out in a southeasterly direction from Banff, and at the same time carries a diminishing percentage of phosphoric acid. At Tent mountain, the most southerly outcrop found, the bed is represented by a thin layer of small phosphatic nodules in a quartzite matrix. The thickness of this horizon is only about 3 inches, and the nodules range in size from 1 to 3 inches diameter. An analysis of the nodular material, freed from

the matrix, showed 21·56 per cent P_2O_5 or 7·14 per cent less than similarly selected nodular phosphate from the Sundance canyon outcrop at Banff. (See Plates XV and XVI.)

No outcrops of phosphate were found south of Tent mountain, either in the Livingstone or Macdonald ranges.

Before the close of the season, the limestones and shales of Turtle mountain, Blairmore, and of the range immediately east of Lille, were examined, with, however, negative results as far as phosphate was concerned. Turtle mountain offers an ideal section of the Carboniferous rocks, but the very uppermost beds of the Rocky Mountain quartzite, and the actual quartzite-shale contact, are obscured by talus. The same condition exists in the range east of Lille, due to the low angle of dip of the beds; but a small ledge of quartzite was found here containng a stratum that strongly resembles the nodular phosphatic bed at Tent mountain; this stratum is only an inch or so thick.

An interesting and significant point is, that in the easterly section of the region examined (in the Banff area, as well as farther to the south) the phosphate bed, in addition to being thinner and poorer in phosphoric acid than in the more westerly-lying ranges, assumes a brecciated, or conglomeratic character. At the Kananaskis lakes, for example, the bed is made up of both rounded and semi-angular fragments of phosphate, sandstone, and quartzite, in a matrix of sandy phosphate.

In the east, also, the bed occupies a decidedly higher position in the quartzite series than in the western section, a fact that would seem to be accounted for by the erosion of a considerable thickness of quartzite, prior to deposition of the overlying Triassic shales. At the Kananaskis lakes, for example, the 2-6 inch phosphate bed occurs only some 2 feet below the quartzite-shale contact; at Tent mountain, near Corbin, the nodular phosphate bed is 3 feet below the contact. At the outcrops on Mount Norquay, northwest of Banff, on the other hand, the 2-foot phosphate bed is overlain by nearly 100 feet of quartzite beds.

The thinning out of the phosphate bed from west to east, its decidedly brecciated or conglomeratic character in the easterly portion of the area, and the fact that a considerably lesser thickness of quartzite beds overlies the phosphate in the east than in the west, taken in conjunction with one another, points to a pronounced unconformity between the Pennsylvanian and the Triassic in the easterly section, with local erosion of the phosphate horizon and subsequent re-deposition as a breccia or conglomerate of the material of the broken-up bed.

The character of the topography indicates that probably the greater part of the phosphate originally deposited in a continuous sheet over this area has been removed by erosion. This is apparent when one considers that the phosphate bed is seldom to be found persisting above the lower mountain slopes; though, in some instances, owing to exceptionally complicated structural conditions, portions of the bed may be found infolded at high altitudes.

In addition to tracing the phosphate bed referred to above, a careful search was made for possible phosphatic beds in the shales that overlie the Rocky Mountain quartzite. The presence of oolitic phosphate in these shales had previously been reported to the writer; but despite careful search at a number of exposures, no phosphate horizons were found in them. A number of beds in the shale succession were sampled, but in almost every case the phosphoric acid content was found to be under 3·5 per cent. The only exception was a 3-inch bed composed practically entirely of small Lingula shells; this yielded 15·79 per cent phosphoric acid, and was found about 700 feet above the quartzite-shale contact in the Highwood pass, Kananaskis lakes. However, practically all of these shales yield a slight reaction for phosphoric acid when tested with nitric acid and ammonium molybdate as do, also, in many cases, the Fernie shales (Jurassic) and the Kootenay sandstone (Cretaceous) of the same area.

The fact that, in the Montana field, the phosphate bed occupies a position at the very base of the shales assigned to the Phosphoria formation, in the upper succession of which no phosphate occurs, would suggest that, in Canada, also, phosphate is not to be looked for in the shales overlying the phosphatic horizon already found.

Manitoba.

J. B. Tyrell[1] records the occurrence on Wilson river, west of Lake Dauphin, section 18, township 25, range XX, of a small deposit of phosphatic shale. This bed consists of minute fragments of the bones and teeth

[1]Geol. Surv. Can., V Ann. Rep., 1890-91, pp. 26A, 91E, 229E; VI Ann. Rep., 1892-93, p. 92R.,

of fishes, embedded in a grey calcareous cement, and crops out in the bank of the river; its thickness and extent have not been ascertained, but the former appears to be small. The tricalcic phosphate content of this shale is 37·70 per cent—equivalent to 17·27 per cent of phosphoric acid. The shale belongs to the Niobrara beds of the Cretaceous formation.

Nova Scotia.

Phosphatic nodules, consisting of coprolites containing shell fragments, have been found in limestone beds of Potsdam age on MacIntosh brook, East Bay, Cape Breton.[1] The nodules are small, and are regarded as being, possibly, the coprolites of a large species of trilobite. Similar nodules exist, also, at Arisaig, in Antigonish county. While of geological interest, the above occurrences are of no possible economic importance.

Quebec.

At Rivière Ouelle[2], on the lower St. Lawrence, similar coprolites to those found at East Bay, N.S., occur in lower Postdam beds. The nodules are black and range up to about the size of a small bean; they have a specific gravity of 3·15, occur in a compact grey or buff-coloured limestone, and yield on analysis:—

$Ca_3P_2O_8$	40·34
$CaCO_3$	5·14
$MgCO_3$	9·70
Fe_2O_3, Al_2O_3	12·62
Volatile	2·13
Insoluble	25·44
Total	95·37

Associated with the coprolites are found tubes of serpulites, up to two inches in length, composed largely of phosphate of lime. A specimen of a hollow serpulites tube gave on analysis:—

$Ca_3P_2O_8$	67·53
$CaCO_3$	4·35
MgO	1·65
Fe_2O_3	2·95
Volatile	2·15
Adhering sand	21·10
	99·73

The amount of such phosphatic material present in the limestone at this point is too small to permit of commercial extraction.

At Allumette rapids[1], Upper Ottawa river, sandstone of Chazy age contains dark brown, phosphatic nodules in some quantity, associated with fossils of brachiopods. Some of the nodules are two inches long, and one inch in diameter, and there is little doubt that they are coprolites. The shells of the brachiopods (*Lingulæ*) are themselves highly phosphatic,

[1]Geol. Surv. Can., Rep. Prog., 1876-77, p. 432.
[2]Geol. Surv. Can., Rep. Prog., 1876-77, p. 434.

and probably account for the high phosphate of lime content of the nodules, *Lingulæ* having formed the food of the animal from which the coprolites were derived. At Grenville, also, on the Lower Ottawa, similar nodules are found in sandstone of the same age, while at Hawkesbury and Lochiel they occur in limestone, and are dirty-brown in colour. A specimen from Allumette island, having a specific gravity of 2·87 yielded on analysis:—

$Ca_3P_2O_8$	36·38
$CaCO_3$ (CaF_2)	5 00
MgO,Fe_2O_3	7·02
Volatile	1·70
Insoluble	49·90
	100·00

The insoluble matter consisted of siliceous sand.

A nodule from the Hawkesbury limestone gave:—

$Ca_3P_2O_8$	44·70
$CaCO_3$	6·60
$MgCO_3$	4·76
Fe_2O_3,Al_2O_3	8·60
Volatile	5·00
Insoluble	27·90
	97·56

[1]Geol. Surv. Can., Geology of Canada, 1863, pp. 125, 462. See also Amer. Jour. Sci., XVII, 1854, p. 235.

CHAPTER V.

GEOLOGY OF THE APATITE BEARING DISTRICTS.

INTRODUCTORY.

Province of Quebec.

The Quebec apatite region includes some eight townships, lying between or adjacent to, the Lièvre and Gatineau rivers, and situated immediately northeast of Ottawa. The greatest development of phosphate is found in the five townships of East and West Portland, Buckingham, Templeton, and Wakefield; while the mineral occurs to a lesser extent, also, in the townships of Derry, Hull, and Bowman. The apatite-bearing district may be said generally to include that section of country lying immediately north of the Ottawa river for a distance of some 16 miles, and between the Gatineau and Lièvre rivers. North of this area, as well as to the east and west, the deposits become smaller and more scattered, the most northerly occurrences of any consequence being in the neighbourhood of High Falls, on the Lièvre river, 30 miles north of its junction with the Ottawa. (See Plate XVII.) As an accessory mineral in mica deposits, apatite is found to the west, north, and east of the already outlined region; small amounts of phosphate being found, almost invariably, associated with the mica at those mines of the latter mineral which lie scattered through the country north of the Ottawa river from the township of Calumet, in the west, to Buckingham in the east. None of these occurrences, however, have proved to be of any economic importance, and the cost of getting the mineral to rail, even where it occurs in sufficient amount to be worth saving as a by-product, leaves hardly any margin of profit.

Besides being traversed by the above-mentioned rivers, the phosphate region is dotted with numerous lakes. The Lièvre river is navigable as far north as High Falls, to which point navigation was made possible by the building of locks at the time of the phosphate "boom". The Gatineau river is not navigable, owing to numerous rapids and cascades which occur at frequent intervals along its course. The chains of lakes render access to the interior sections, away from the rivers, comparatively easy in summer, portages being usually comparatively short; while, in winter, their level surfaces provide short winter roads across country, whereby haulage costs are materially lessened. At many of the more remote mines, shipping of the phosphate was carried out only in the winter on this account.

Settlements are scattered over practically the whole of the area, though the hilly nature of the country keeps the settlers to the valleys and hollows and occasional stretches of more or less level ground. Road communication is fairly good throughout the district.

The generally rugged character of the country encountered immediately to the north of the narrow strip of low-lying land which follows the left bank of the Ottawa river, disappears to some extent to the northward, so that though there is a general increase of elevation, a greater preponderance of level country is encountered in the more northerly districts. Much of this area is occupied by deposits of sand, which often overlie deposits of a stiff, post-glacial clay, resembling in character the marine clays of the Ottawa basin.

Throughout the greater portion of the region in which the apatite deposits occur, however, crystalline rocks predominate. These are continuous with those appearing to the south of the Ottawa river, but over a considerable area to the south of the city of Ottawa, the crystalline series is overlain by the broad area of Palæozoic sediments of the lower Ottawa basin. These sediments consist mainly of bedded blue and grey limestones, shales, sandstones, and conglomerates, and are of Upper Cambrian and Ordovician age. They form a series which, in ascending order has the following sequence,—

	Group.	Rock types.
Ordovician	Utica	Shales and limestone.
	Trenton	Limestones.
	Black River	Limestones and sandstones.
	Chazy	Limestones, shales and sandstones.
	Beekmantown	Limestones and sandstones.
Upper Cambrian	Potsdam	Sandstones.

These sediments conceal the continuity of the older crystalline rocks from Ottawa southward to the St. Lawrence river.

Province of Ontario.

While not traversed by any large streams, as is the Quebec district, the Ontario phosphate area is even more extensively covered by large expanses of water than the former. Long chains of lakes, usually narrow, and having a general parallel direction, extend over the townships of Bedford, Loughborough, and Burgess. The general elevation of the country is similar to that of the Quebec district, though its character is not nearly so rugged nor so well timbered as the latter. Large expanses of excellent farming land are scattered throughout the area, and the country is, on the whole, of a comparatively level character. What is known as the "Mountain," north of Westport, on Upper Rideau lake—a large mass of reddish granite-gneiss rising to a height of some 700 feet—is the most conspicuous, if not actually the highest eminence in the district.

From the western fringe of the Palæozoic belt, tongues of sandstones and limestones extend westward in the neighbourhood of Micaville, and the Rideau lakes. From the southerly sediments bordering on the St. Lawrence, relatively few extensions run northward, the limit of the Palæozoic being represented by a line, which, though indented, has an approximately east and west direction through the village of Hartington, in Portland township.

The chains of lakes follow to a marked degree the trend of the gneiss foliation, of which rock the greater part of the area is composed. The gneiss bands possess a general N.E.—S.W. direction; many of the exposures forming part of eroded, anticlinal folds. Long bosses, or "hogs-backs," of red granite-gneiss are characteristic of the country, while white, crystalline limestone belts cover large areas. (See Plates XVIII and XIX.) In general, it may be said that the gneiss presents a more foliated appearance than in the Quebec region, though local modifications show extremes of both foliated and normal granitic types. The limestone is similar in both

districts, the rock containing inclusions of accessory silicates in greater or lesser degree, consequent upon its degree of metamorphism and distance from intrusive contacts.

The apatite-bearing rocks, or pyroxenites, present similar features in both areas, many modifications of the normal, granular type being met with in each region.

ORIGIN OF THE MICA-APATITE DEPOSITS AND ASSOCIATED ROCKS.

It is beyond the scope of this report to enter into a detailed discussion of the geology of the districts in which the apatite deposits occur. Since Sir William Logan, in the fifties, first attempted a classification of the various types of rocks to be found throughout the area in question, several geologic investigations of the district have been undertaken, and various theories have been advanced to explain the complex features presented. Although, since the earliest years of geological study of the district, the widest differences of opinion have existed respecting the origin of the various rocks, contradictory views being both held and expressed in a long series of papers and reports, the diversity of the rock types encountered within even a very restricted section of the area under consideration; their intimate commingling; and their apparent gradual gradation one into the other, present a correlation problem, phases of which yet remain to be solved satisfactorily. One of the many problems involved, and one which has been a matter of much controversy, is that of the origin of the basic rocks (pyroxenites) with which the apatite and mica bodies are associated. These rocks have been regarded, on the one hand, as metamorphic products of pre-existent sediments, formed by the agency of injected acid masses, while, on the other hand, they have been classed as true dikes of later origin than the rocks enclosing them. Logan, in 1863, went so far as to class the entire Laurentian system—limestones, gneisses, pyroxenites, etc.—as altered sediments. It is now generally conceded that the gneisses of this section are of two types—para-gneisses and ortho-gneisses—the former of sedimentary origin and the latter representing granite injections or batholitic masses to which a schistose or foliated structure has been subsequently imparted. The foliation in the last case is attributed to movements in the rock complex, which would, under a heavy load of superincumbent strata, be in a sufficiently plastic state to assume schistose structures. Those banded gneisses occurring bedded in the crystalline limestones are generally held to be of sedimentary origin. They are supposed to represent argillaceous portions of the original calcareous deposits, corresponding to the clay-stones found in less highly altered sediments, and to have been changed to their present condition by the same processes which have metamorphosed the limestone to its present highly crystalline state. These gneisses are often characterized by the presence in them of abnormal amounts of quartz, either in the form of a siliceous cement, or as small autoclastic lenses. In some cases, also, the quartz occurs as massive bands several feet in thickness. Garnets, also, frequently in considerable quantity, and sillimanite, characterize this type of gneisses, but are not always conspicuously present. (See Plate XXI).

In giving a brief outline of the geology of the Canadian apatite deposits as a whole, it is difficult to consider the Quebec and Ontario districts separately, without going into overmuch detail. From the Lièvre river, in Quebec, in the east, to Haliburton and Peterborough counties, in Ontario, in the west (in which latter region, small deposits of apatite have been worked in the past), more or less similar geological conditions are found. The chief differences are the following. In the easterly portion of this region, the basic rocks, with which the phosphate occurs, are pyroxenites, while in the westerly section they are chiefly represented by amphibolites; the limestones of the westerly section have suffered a lesser degree of metamorphism than those in the east; the ortho-gneisses of the easterly region gradually give way towards the west to alkali syenites. No detailed, geological study of the phosphate-bearing region, as a whole, has ever been made, but a report on the Quebec apatite district was made by Osann[1] in 1899; while the memoir of Adams and Barlow[2] on the rocks of the Haliburton and Bancroft area, represents the most recent publication concerned with detailed work on any section of the apatite-bearing rocks. The area described in this last report, is really outside and considerably to the west of the Ontario phosphate region proper, but the district contains a few small deposits of apatite; hence the interpretation of its geology, as set forth by the writers, has an important bearing on the problems encountered farther to the east.

Osann[3], who in 1899, carried out a geological investigation of a portion of the Quebec phosphate region more particularly of that area bordering on the Lièvre river—found that there were two types of gneisses present, one of which, from analyses, he was inclined to regard as sedimentary and the other as plutonic. The pyroxenites, he was inclined to consider as of two types: (1) intrusive rocks of plutonic origin, belonging to the family of the diorites and basic syenites, and (2), "altered gabbros and secondary vein fillings connected with the formation of the apatite." He is, therefore, disposed to consider the pyroxenites as of true, igneous origin, and the mica and apatite deposits associated with them as of secondary formation along crevices and fissures formed in the dike rock. He remarks in this connexion: "All these peculiarities, and the similarity in mineral content of all the deposits of apatite in the province of Quebec known to me, led to the belief that they are all of the same origin, and younger than the associated gneisses. They are, accordingly, true veins which have been formed in the same way as all other ore veins."

Sterry Hunt,[4] in mentioning the apatite deposits of the Laurentian rocks, refers to them as "irregular beds running with the stratification, and composed of nearly pure, crystalline phosphate of lime," and also as "parallel beds interstratified with the gneiss."

Later,[5] he regards the deposits as of two kinds, and remarks that they "are, in part, bedded or interstratified in the pyroxenic rock of the region, and, in part, true veins of posterior origin." The bedded deposits conformable with the strike and dip of the Laurentian rocks, he regarded as

[1] "Archæan Rocks of the Ottawa Valley", Geol. Surv. Can., Ann. Rep., Vol. XII, 1899, Part O.
[2] "Geology of the Haliburton and Bancroft Areas, Ontario", Memoir No. 6, Geol. Surv. Can., 1910.
[3] Op. cit.
[4] Geol. Surv. Can., Rep. Prog., 1863-6.
[5] Trans. Amer. Inst. Min. Engin., 1884.

"true beds, deposited at the same time as the enclosing rocks. The veins, on the contrary, cut across all these strata, except in rare instances, when, what appear from their structure and composition to be veins, are found coinciding in dip and strike with the enclosing strata."

In 1885, the following further statement is made[1]: ". . . . . show that the crystalline phosphate of lime, or apatite, belongs to lodes of great size, which traverse the ancient gneiss of the region . . . . . All these lodes show a banded structure, not unlike that of the gneiss, to which they are evidently posterior and of which they often contain fragments."

H. G. Vennor,[2] in his account of the apatite mines, makes the somewhat sweeping statement that "there can be no manner of doubt that these deposits of apatite are of a comparatively superficial nature," and goes on to refer to them as "bedded deposits brought to the surface by undulations of the strata." This view is, of course, totally opposed to the real facts; since phosphate bodies of considerable size were still in sight when such mines as the High Rock, North Star, Emerald, etc., on the Lièvre river, were abandoned, the depths reached by some of the shafts exceeding 600 feet.

J. W. Dawson[3] is of similar opinion to Sterry Hunt, observing further that "it also appears that the principal beds are confined to certain horizons in the upper part of the lower Laurentian . . . . . though some less important deposits occur in lower positions." He was inclined to regard the apatite deposits "as a secondary formation, dependent on the original deposition of apatite in the series, which must belong to the time when the gneisses and limestones were laid down as sediments and organic accumulations."

B. J. Harrington[4] regarded the pyroxenites as altered strata originally containing phosphate of lime, and the apatite veins as of subsequent formation, deriving their mineral content from the pyroxenites.

J. F. Torrence[5] was of the opinion that the apatite deposits were irregular segregations from the country rock, which contains zonal impregnations of apatite.

W. B. Dawkins[6] considered the apatite to occur in veins in massive, bedded schists, the veins and schists having obtained their mineral content "from some common, deep-seated source of hydro-thermal action."

G. H. Kinahan[7] supported, in part, the theory of Adams and Barlow, and regards the apatites, and possibly the pyroxenites as originally limestones or allied rocks, which have been altered by paramorphosis.

G. M. Dawson[8] regarded the bedded apatite as organic in origin, and the gneisses, etc., which enclose them as altered sediments—the apatite veins having resulted from a segregation process. This idea was also expressed by J. F. Falding,[9] while R. Bell[10] inclined to the view that the apatite has its source in the pyroxenite, which is possibly an igneous intrusion.

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[1]Trans. Amer. Inst. Min. Engin., 1885.
[2]Rep. Prog. Geol. Surv. Can., 1874-5, p. 108, et seq.
[3]Quart. Journ. Geol. Soc. 32, 1876.
[4]Geol. Surv. Can., Rep. Prog., 1877-8.
[5]Geol. Surv. Can., Rep. Prog., 1882-4.
[6]Trans. Manchester Geol. Soc., 18, 1885.
[7]Trans. Manchester Geol. Soc., 18, 1885.
[8]Trans. Ottawa Field Club, 1884.
[9]Eng. and Min. Journal, 1886.
[10]Ibid.

E. Coste[1] considered the apatite to be of eruptive origin and to be connected with igneous rocks, sometimes pyroxenite, and sometimes pegmatite, mica syenite, or pyroxene syenite, which cut the Archæan series. He also assigns a similar origin to many of the iron ore deposits of the same area, and concludes that "the iron ores and phosphate to be found in our Archæan rocks are the result of emanations which have accompanied or immediately followed the intrusions through these rocks of many varied kinds of igneous rocks, which are, no doubt, the equivalent of the volcanic rocks of to-day. These deposits, then, are of deep-seated origin, and consequently the fears, entertained principally by our phosphate miners, that these deposits are mere surface pockets, are not well-founded."

R. A. Penrose[2] regards the occasional, parallel bands in some pyroxenites as probable joint planes, and mentions the frequent absence of any sharp contact between gneiss and pyroxenite, the border zone being a gradual transition from one to the other with the formation of a pyroxene gneiss.

A. R. Selwyn[3] considers there is no evidence to support the organic origin of apatite or the sedimentary origin of the pyroxenites, which latter he regards as basic eruptions of Archæan age.

W. Davidson[4] believed that the phosphate deposits originated in beds in a Laurentian sea, and attained their present character through subsequent metamorphism, the enclosing gneiss having a similar origin.

R. W. Ells[5] came to the conclusion that the mica and apatite deposits were intimately connected with basic dikes of igneous origin, which have ascended along the bedding planes of the gneiss, though, sometimes, also cutting across this rock. The solutions carrying phosphoric acid, etc., would incline to follow the contacts of the dikes with the gneiss, and as a result of chemical action upon the calcareous portion of the latter, phosphate of lime was produced. This would seem to be intended to account for the class of occurrences known as "contact deposits," as opposed to "pocket deposits." He also emphasizes the cutting of the gneiss by the so-called dikes at various angles, and the frequent distortion of the foliation in their vicinity.[6]

With regard, more particularly, to the mica deposits associated with the pyroxenites, four distinct modes of occurrence were instanced[7]:—

(1) In pyroxene rock near the contact with the gneiss.

(2) On fissures in the mass of the pyroxene dike.

(3) Along the contacts of later pegmatite or diabase dikes cutting the pyroxenite.

(4) In pyroxenite dikes cutting crystalline limestone and which have been intruded by later pegmatites or diabase dikes.

F. Adams and A. Barlow[8] considered that the pyroxenites of the Haliburton-Bancroft area represent altered limestones, and that the apatite and mica which they contain have been formed during the metamor-

[1]Ann. Rep. Geol. Surv. Can., Vol. III, 1887-8.
[2]Bull. U.S. Geol. Surv. No. 46, 1888.
[3]Ann. Rep. Geol. Surv. Can., Vol. IV, 1888-9.
[4]Trans. Am. Inst. Min. Eng., 1892.
[5]Can. Min. Review, XII, 1893.
[6]Geol. Surv. Can., Ann. Rep. 1901, Vol. XII, Part J, p. 96.
[7]Geol. Surv. Can., Min. Res. Bull. Mica, 1904, p. 9.
[8]Geol. Surv. Can., Mem. 6, 1910.

phic process. The pyroxenites of the apatite region proper, were not examined in detail, but they are recognized as being identical in character with the rocks described in the Memoir mentioned; and the tentative suggestion is advanced[1] that, Osann's theory of pneumatolytic action connected with the intrusion of basic igneous rocks, may be the correct theory of their origin.

From the foregoing, it will be apparent that the origin of the pyroxenites, with their associated apatite and mica deposits, has for long been obscure. Unfortunately, no great depths have been reached in the exploitation of mica or apatite deposits, and the deepest workings that do exist are those of abandoned phosphate mines, which have been idle for many years, and are now inaccessible. It is probable that the greatest depth reached in such mines does not exceed 700 feet. These mines, when closed down, owing to the competition of American phosphate producers, were said to still show considerable deposits of both apatite and mica, in depth; hence we have no means of estimating, even approximately, the depth to which these mineral bodies may extend.

As will have been noted, not only do the conclusions arrived at by the above-quoted writers as to the nature of the rocks examined and their mode of origin vary considerably, but even the actual field observations are found, in many cases, to show important discrepancies.

Coste's view, that the apatite is wholly of igneous origin, and that it has been brought in by magmatic material injected into the Archæan series, the mineral tending to segregate in masses along the contacts, is more or less the accepted theory to-day; though his opinion, shared, as noted above, by Selwyn and Bell, that the pyroxenites, as such, might, in some cases, constitute the injected masses in question, is not generally favoured.

The frequent references in the earlier reports to what are variously termed "bedded" and "vein" deposits of apatite and mica, would seem to have been prompted by the fact that there are, at first sight, apparently dissimilar features between the massive and more or less continuous bodies of apatite disclosed in certain of the mines and the smaller, pockety deposits, which have neither continuity nor definite direction. The latter are usually characterized by a greater abundance of accessory minerals, such as calcite, mica, scapolite, etc., the apatite being present frequently in quite subordinate amount. The differences between the two types of deposit are, however, more apparent than actual, and the one class is often found in close proximity to, and merging into, the other. There is no reason for pre-supposing any material difference in the mode of formation of the two types, nor any difference in age, though the formation of the apatite bodies must have taken place over a long period, as evidenced often by the large size of the crystals of apatite, scapolite, pyroxene, mica, and other minerals. The dissimilarity is, indeed, what might be expected if we accept the metasomatic, pneumatolytic theory, and take into consideration the extremely dissimilar types of rocks that constituted the complex into and through which the phosphoric acid-bearing emanations diffused.

As a general thing, in a vein zone where the leads are of moderate width, the entire series of veins has approximately a similar direction,

[1]Ibid, p. 93.

though sometimes one or more cross-leads are found to cut across the series. This is not so evident in a zone comprising a number of small, narrow veinlets; in such case, the leads often pursue a very irregular course, and there is no rule by which they can be followed with any degree of certainty.

As already remarked, although continuous bodies of apatite of considerable width are occasionally found, by far the most common class of deposit met with is the pocket and fissure type. In such a deposit, as the name indicates, the apatite occurs in bunches or pockets of irregular shape and size, these bodies usually being connected by narrow stringers or necks. Often, these connecting stringers are the merest streaks, and in mining hardly appear worth following; yet they frequently connect large masses of phosphate, either laterally or more or less vertically.

Canadian apatite is invariably fluor-apatite, and is thus distinct from the Norwegian mineral, which is chlor-apatite.

The Canadian and Norwegian apatite deposits have been often likened to each other; there being a number of points of similarity, the chief ones being the association of the apatite in both cases with basic rocks of the pyroxenite and gabbro type, and with such minerals as hornblende, mica, scapolite, pyrrhotite, etc. The Norwegian apatite occurs on veins in a complex of mica schists, amphibolites, pyroxenites, and scapolite-or cordierite-gneisses, which has been invaded by a dark gabbro (dipyrdiorite) massif. The scapolite (wernerite) is regarded as an alteration product of feldspar, and the source of the apatite is referred to the pneumatolytic agencies which accompanied the gabbro intrusion. While the Canadian phosphate bodies are found in a somewhat similar series of rocks, the number of types is greater, and they are more difficult to correlate, since the complex appears to have been subjected, in a greater degree, and on a larger scale to repeated metamorphism: the original rocks now representing isolated bodies separated by large areas of the intrusives, which latter, are often difficult to distinguish from the metamorphosed sediments.

As far back as 1884, F. D. Adams[1] noted the close similarity between the amphibole-scapolite rock (so-called "apatitbringer") in which the Norwegian apatite veins occur and a hornblende-scapolite rock from the neighbourhood of Mazinaw lake, Ontario. No extensive bodies of apatite are found in this region, but the noted similarity of the two rocks is of interest.

During the past six years, a new geological survey of the area comprising the principal apatite deposits in the Province of Quebec has been completed by M. E. Wilson of the Geological Survey. A brief synopsis of the conclusions arrived at as to the general geology of the district is contained in the Summary Report of the Geological Survey for 1913, pages 196-207. A greatly extended classification of the intrusive rock types hitherto noted in the area, with the correlation of certain of them as a related series—Buckingham series—and the recognition of certain of the gneissic rocks as probably altered sediments, are the main features of this recent

[1]Adams, F. D., "The Occurrence of Apatitbringer in Canada", Rep. Brit. Assoc., Montreal Meeting, 1884, p. 717.

work. Briefly, Wilson's arrangement of the Pre-Cambrian rocks is as follows:—

Late Pre-Cambrian	Lamprophyr. Diabase.
Igneous Contact.	
Early Pre-Cambrian (Basal Complex)	7. Pegmatite, probably related to— 6. Biotite-hornblende-soda granite and syenite. 5. Pyroxenite. 4. Buckingham series: charnockite (pyroxene-granite), shonkinite (biotite-pyroxene-granite), diorite (pyroxene-syenite and biotite pyroxene-syenite), gabbro and biotite-gabbro, peridotite and pyroxenite. (All the above types possess locally a gneissose character.
Igneous Contact.	
Grenville (Sedimentary) Series	3. Crystalline limestone. 2. Sillimanite-garnet-gneiss. 1. Quartz rock.

The Buckingham series is thus seen, according to the above classification, to comprise a genetically-related, gradational group, the members of which range from a pyroxene-granite to peridotite. Members of this series are found injected into the crystalline limestones, sillimanite-garnet-gneiss and quartz rock, all of which occur in irregular masses of relatively limited areal extent, but occurrent throughout wide zones, having an approximately N.E.-S.W. trend.

The above interpretation differentiates between two types of pyroxenites, in the same manner as Coste's theory; the one type being a dark-coloured and fine-grained intrusive rock, while the other is a lighter and more coarsely crystalline, metamorphic product. It is the latter type with which the mica and apatite are usually associated; and these minerals are thus regarded as having been formed more or less contemporaneously with the intrusion of the limestones and other sedimentaries by the Buckingham series, and in and around the former. (See Plate XX.)

This, briefly, is Wilson's interpretation of the general geology of the Quebec apatite region. In view of the fact that the investigation represents the first detailed study of the district made within recent years, and includes the first complete petrographic classification of the various rock types encountered, the final results of the work will be awaited with much interest.

The intense degree of deformation, coupled with dynamic and contact metamorphism, which the rocks of this region have suffered in early Pre-Cambrian times, has resulted in greatly obscuring their original relationships. Great sections of the original sedimentaries would appear to

have been wholly engulfed, buried or floated off into new positions by the immense batholithic masses that welled up amongst them and understoped them. Practically the sole, present, uniform feature exhibited all over the area is the strike (N.E.-S.W.) and dip (30°-50°) of the gneisses. The younger pegmatites have approximately the same direction, but their strike is by no means constant.

A great degree of the deformation evidently took place prior to the intrusion of these pegmatites, for the latter are not faulted or jointed to any extent, nor do they exhibit any parallel arrangement of the mica, tourmaline, etc., that they sometimes carry.

TYPES OF APATITE DEPOSITS.

As already outlined, the apatite bodies are usually of irregular form, and consist, generally, of a number of irregularly-shaped pockets, joined up by small stringers or veinlets. In some cases, as in some of the Lièvre River deposits, the individual pockets may assume very large dimensions and a more or less regular form, and thus approximate to veins.

Although certain essential differences are claimed to have been noted between various of the apatite deposits, and while attempts have been made to classify the bodies under the headings of several distinct types, such classification is based merely on local variations in form; association of constituent minerals; nature of enclosing rocks, etc., and does not imply any genetic dissimilarity.

Reference is often found to the phosphate "veins" of the Lièvre River district; but, strictly speaking, the term vein applied to the bodies of phosphate in either the Ontario or Quebec areas is misleading; for the bodies are seldom continuous enough along their strike to be termed veins. On the one hand, we find a series of large surface pockets simulating a vein-zone, while a similar arrangement of smaller pockets appears as a pocket and fissure deposit. Any sharp distinction along the lines of the old classification between (1), true fissure deposits; (2), pocket and fissure deposits; and (3), contact deposits, hardly appears possible, in view of the fact that the deposits are all of similar age and origin, and that one type not infrequently merges into another.

Another objection to the term vein as applied to apatite bodies is, that the deposits have no defined walls. In true veins there is a distinct break between the filling and the walls, the break being usually in the nature of a narrow band of selvage or decomposed country rock. Such a break between ore and country is never apparent in the case of apatite deposits, the apatite bodies usually having the appearance of having segregated in place from the enclosing rock, or of being a metasomatic replacement of the latter.

As a general rule the mineral association of the mica-apatite bodies is as follows:—

(1) pure apatite (Plate XXII).
(2) apatite at the centre, and mica at the walls (Plate XXIII).
(3) apatite, mica, and calcite in irregular association, the first-named minerals preponderating.
(4) calcite, with mica and apatite crystals, scattered through it (Plate XXIV).

A classification strictly along the above lines, however, is not feasible, since a sharp distinction between the different types of deposits is not always evident, and a filling of apatite sometimes gives way to one of calcite. A lack of uniformity in the nature of the mineral association is, in fact, characteristic of the deposits, and renders any classification into distinct types, at best, merely conjectural.

On pages 17, 18, 52, 73, 74, and 81 are given several diagrammatic sketches of Canadian mica-apatite bodies. These show the chief characteristics exhibited, and indicate, to some extent, the difficulty of exploiting such erratic deposits.

Those deposits to which the designation of true fissure veins has been applied, are the simplest to exploit, and the easiest to follow. Bodies of this type generally form a group of several narrow and approximately parallel leads, separated by bands of pyroxenite or gneiss. The length of such leads along the strike is seldom more than a few hundred feet, and is, usually, much less. Good examples of such leads are to be found at the Vavasour mine, range XII, lot 10, in the township of Hull, Que., and at the Bobs Lake mine, concession VI, lot 30, of the township of Bedford, Ont. In deposits of this type, apatite is not, usually, present in any large amount, the leads being more prone to carry mica, and it is for this latter mineral that the majority of such bodies have been worked. Calcite of a pink shade often forms a considerable portion of the fissure-filling, and the walls are sometimes lined with large, well-formed crystals of pyroxene. In such deposits, the main mica bodies are usually found near one or both of the walls, and the latter are often lined with a mass of small, intergrown mica crystals. Bunches of such crystals, as well as isolated individuals, also occur distributed throughout the mass of the calcite.

White calcite is characteristic of some deposits, and the mineral is then nearly always of more coarsely crystalline habit than the pink variety.

The leads of this type vary greatly in width, being sometimes over 25 feet across, but the majority are relatively narrow. As a rule, they are approximately vertical. The walls of such deposits are usually of dark-coloured pyroxenite, which, however, frequently forms merely a narrow band bordering the lead on both sides and separating it from rock of a gneissic type.

What have been styled contact deposits, are probably merely deposits of the foregoing type, on a larger scale. That is, in place of a number of parallel leads, only one main body has been formed, and this is then sometimes of considerable width—25 to 50 feet. As a rule, such a deposit carries an even greater proportion of calcite than the narrower bodies, and this calcite filling usually contains numerous small phlogopite and apatite crystals scattered porphyritically through it. If apatite is present in any amount, it is generally found in bunches at or near the walls, rather than in the calcite.

Neither of the above-described types of mica-apatite deposits represents the most usual form in which the large, economic apatite bodies occur, and they are merely mentioned as types. At almost all the large phosphate mines, both in Quebec and in Ontario, but more especially in the Lièvre River district in the former Province, the apatite occurs in irregular pockets, chimneys, or shoots, in a rock composed of pyroxene, feldspar, and quartz.

A regular, well-defined phosphate lead is seldom met with in this area; and it was found, in the deeper workings, that the tendency of the pockets or shoots to pinch out or narrow suddenly, was just as pronounced as in the upper levels. Sometimes, masses of this kind are joined together by a narrow veinlet of phosphate; while in other cases, the bodies appear to be completely disconnected. Although apatite is generally the preponderating mineral in such deposits, a considerable amount of mica is not infrequently present, and at certain mines, pink calcite occurs in large amount. This calcite then usually contains numerous small crystals of mica and apatite. Where much calcite is present, the mica-apatite-calcite bodies are usually enclosed in pyroxenite, containing little or no feldspar or quartz, and the apatite is present in only subordinate amount. Generally, a deposit containing much calcite, or one having walls lined with well-crystallized pyroxene, carries only a minor amount of phosphate. Very often, the calcite filling of surface pockets is found to have been dissolved out by meteoric waters, the resulting cavity containing loose mica and apatite crystals mixed with earthy residue. Such pockets sometimes yield well-formed crystals of pyroxene, which are found lining the walls in the same manner as vein minerals lines the wall of a druse or vug. (See Plate XXV.)

The apatite occurs in three forms. The commonest of these is the massive, crystalline apatite that forms the bulk of the filling of the large pockets exploited in the Lièvre River district. (See Plate I.) It is usually of a dark green colour, but is also found in red, brown, yellowish, and blue shades. A somewhat less common form is that known as "sugar-phosphate." This material consists of small, rounded grains, aggregated into coherent masses, but which may be readily rubbed into a coarse sand between the fingers. The colour is almost invariably a greenish-white. Sugar phosphate is characteristic of certain individual deposits, as, for instance, of the Little Rapids mine in East Portland township, Que., and of the McGlashan mine, in Wakefield, Que., but it is also found in small amount at many mines, usually on the smaller leads, or in bunches in the massive variety. The third type is the crystal form, the habit being usually the prism terminated by the pyramid. Crystals of apatite are found at practically all the mines, but are especially common in those deposits carrying mica and calcite. The finest crystals are obtained from pockets in pyroxenite, where they occur both lining the walls, in close association with pyroxene crystals, and porphyritically enclosed in the calcite filling.

Though often yielding considerable quantities of phosphate, the pockety apatite bodies present many difficulties to the miner. The erratic course and irregular distribution of the leads and pockets render them extremely difficult to follow, and the abrupt pinching out of an apparently extensive and promising pocket of mineral is a frequent occurrence, and characteristic of such a deposit.

The pyroxenites are formed principally of monoclinic pyroxene, salite for the most part, though occasionally orthorhombic varieties occur, such as hypersthene and diallage. In colour, the rock ranges from dark green to light grey. In some instances, a large proportion of black hornblende is present, and the rock is then correspondingly darker in colour.

Where cut by large pegmatite dikes, an alteration of the pyroxene to a soft, greenish actinolite, is frequently observed. At the Lake Girard mine, lot 24, range II, township of Wakefield, Que., large crystals of pyroxene, altered internally to a soft, powdery mineral, are common, the outer portion being formed of lustrous, blue, actinolite fibres, arranged with the long axes normal to the faces of the pyroxene crystal. (See Plate XXVI.)

Irregular masses of grey-brown feldspar, principally orthoclase and microcline, are frequent throughout the pyroxenite bodies. These feldspar masses exhibit a pronounced uniformity in character and appearance throughout the apatite-bearing region, although the pyroxenites with which they occur differ considerably in colour, grain, and general character. The generally constant occurrence of such feldspar masses in the pyroxenites is an important and noteworthy feature. In many cases, this acid-rock has been regarded as representing later pegmatitic intrusions into the pyroxenite, the occurrence of "granite dikes" being frequently noted by earlier writers in their descriptions of phosphate and mica deposits. These irregular masses ("schlieren") of feldspar or feldspar-quartz rock, are considered by Wilson to represent late pegmatitic phases of his Buckingham series, that is, of the intrusives (batholiths) that invaded and altered the crystalline limestones to pyroxenite. The successive batholithic masses would have found many shrinkage or fracture channels in the partly metamorphosed, invaded rocks, into and along which apophyses were injected. These apophyses helped to complete the metamorphism, and upon the eventual cooling of the complex as a whole, formed an integral part of the invaded series. Often, this acid rock contains a considerable proportion of pyroxene, being in fact a pyroxene granite; and it always merges without any sign of a true contact into the surrounding pyroxenite. (See Plate XXVII.)

An almost constant accessory mineral to be found disseminated through such feldspar masses is titanite. This mineral, indeed, is seldom absent in the pyroxenites, and is not infrequently found included in large pyroxene crystals. In colour, it is a dark brown, and the crystals are usually well formed, possessing the ordinary tabular shape, and often attaining a length of 2 inches.

The occurrence of minerals of the zeolite group accompanying the apatite, is of interest. The most frequent varieties are the lime-soda members, chabazite and faujasite; while heulandite has also been found; datolite, as well, is a not infrequent accessory mineral, its variety botryolite occurring somewhat plentifully at the Daisy mine, in the township of Derry, Que., while in powdery form it has been found in large masses at the Bobs Lake mine, in Bedford township, Ont.

The apatite of the Canadian phosphate deposits is, as shown repeatedly by analyses of the mineral from widely separated localities, essentially a fluor-apatite. A number of analyses are given in the Report of Progress of the Canadian Geological Survey, 1877-78, Part H. Of the total number of specimens examined, none possess a chlorine content of over 0·5 per cent; the percentage of fluorine ranging from 3·3 to 3·8. The fluorine content of the phlogopite also, is often considerable, samples of the mica from the Lacey mine, Loughborough, Ont., having yielded as high as 2·24 per cent. The two most abundant of the accessory minerals found in the pyroxenites

have thus a considerable percentage of fluorine in their composition. It is a noteworthy feature of the deposits, that fluorite is a remarkably scarce mineral. It occurs in small purple crystals at the Daisy mine, township of Derry, Que., and druses containing small, green octahedra, associated with faujasite and yttrocerite, have been found on lot 7, range III, of East Portland, Que. The amount of fluorite at both of these localities is, however, insignificant; and the only locality at which fluorite was observed in any quantity, was range IV, lots 20 and 22, in the township of Huddersfield, Que. Here, massive, plum-coloured fluorite occurs in a yellowish coarsely-crystalline calcite, forming the vein matter of leads carrying mica. Apatite is almost completely absent at this spot.

Titanic acid is generally present in the mica-apatite bodies, both in the form of minute rutile needles included in the mica crystals, and combined with lime and silica as titanite, a mineral which may be regarded as typical of the pyroxenites.

Scapolite is another important mineral to be met with in the apatite deposits and occurs in considerable quantities at many points. It has been often regarded as an alteration product of feldspar; and feldspar crystals are often found partially altered to a mineral strongly resembling scapolite. At the Horseshoe mine, range XVI, lot 16, in the township of Hull, Que., large masses of fresh scapolite possessing a high, vitreous lustre are met with, and small apatite crystals frequently occur embedded in these masses. (Plate XXVIII.)

The mineral wilsonite, regarded as an alteration product of scapolite, and often possessing a handsome, pink or mauve colour, is of frequent occurrence, and well developed crystals of scapolite in various stages of alteration are common.

The metallic minerals associated with apatite are chiefly iron pyrites and pyrrhotite. These minerals are often present in considerable quantities, and, as a rule, where pyrites is abundant, pyrrhotite is relatively absent, and *vice versa*.

A peculiar and characteristic feature of the apatite occurring in the form of free crystals, is the conspicuous rounding of the angles. Crystals seldom possess a sharp outline, and the faces are frequently pitted and exhibit a glazed surface, as if they had been subjected to some resorbent action. (See Plates XIV and XXIX.)

Sterry Hunt[1] mentions the occurrence of such resorbed apatite in his report on the crystalline limestones of the Laurentian system, in the course of which he states his opinion that the pyroxenites are merely "beds of passage between the gneisses and the limestones." The "calcareous veins", by which he means the pink calcite deposits occurring with the phosphate in the pyroxenites, he regarded as formed "by gradual deposition or accretion"; in support of which he cites the frequently banded arrangement of the minerals parallel to the walls, inclusion of apatite prisms in mica crystals and of mica crystals in massive apatite, and finally the rounding of the crystal angles of the apatite, while the pyroxene, feldspar, scapolite, sphene, etc., all possess sharp outlines. The rounding of the crystal edges he attributed to "the solvent action of heated, watery

[1]Rep. Prog., Geol. Surv. Can., 1863-66, p. 181.

solutions from which the minerals were deposited, the crystals just formed being subsequently partially re-dissolved as a result of a change in temperature or of chemical constitution of the solution." This implies that apatite was one of the first formed minerals in the veins, and also that the calcite was first introduced after the formation of the apatite, since the solutions which dissolved the latter would, according to the solubility ratio of the minerals, first attack the calcite.

Emmons considered the rounding of the apatite crystals due to a "partial fusion", and observed the same feature on apatite crystals in the limestones of Rossie, New York.

Apatite is not, however, the only mineral of the deposits whose crystals appear to have been subjected to a solvent action. The same characteristic is exhibited by the crystals of sphene that occur with the apatite, and even the pyroxene and phlogopite crystals are more usually etched and pitted than smooth, though the crystal edges of these minerals are not rounded to the same degree. The pyrites and pyrrhotite, too, are often found in indented or corrugated masses, having a pitted surface, similar to that exhibited by meteoric bodies.

SUMMARY.

The mica-apatite deposits possess the form of irregular, pockety masses enclosed in pyroxenite. No limit has been found or can be assigned for the depth to which the deposits extend, but there is no reason for assuming that they are confined to the more or less immediate surface, as has sometimes been surmised.

The pyroxenites represent metamorphosed limestones, which have been invaded, disrupted, and engulfed, by immense batholithic masses of granite, to which latter rock a gneissic character has been imparted by subsequent dynamic movements.

The origin of the mica-apatite-calcite bodies is probably to be attributed to the agency of late pegmatitic phases of this granite and of the aqueous solutions accompanying the pegmatites. These solutions were charged with phosphoric acid, and the apatite is, therefore, to be considered of igneous origin, rather than to have been derived from the original limestones. The calcite probably represents calcium carbonate dissolved from the limestones by heated waters, and redeposited in cavities in the pyroxenites, while the mica is of contact-metamorphic origin.

While certain of the deposits carry apatite as the principal mineral, the majority are composed of calcite, mica, and apatite, in varying amount.

ECONOMIC MINERALS OF THE REGION.

Outside of the deposits of apatite, the region under consideration contains deposits of several other economic minerals—mainly non-metallics.

Asbestos.—Deposits of chrysotile asbestos are not infrequent in certain of the crystalline limestone areas. Development of several such asbestos bodies has been attempted in the townships of Templeton and West Portland, in Quebec, but with little success; the fibre being too short to be particularly valuable and the deposits small.

Barytes.—Narrow veins of barytes occur in both Ontario and Quebec, and in some cases have been exploited in a small way. The chief deposits

in Quebec occur in Hull, Templeton, and Buckingham townships; and in Ontario, in Kingston, Portland, Oso, and North Burgess. The barytes is fairly pure in most cases, the most usual impurity being fluorite, but the colour, as a general rule, is not good, being either a grey, or reddish-brown.

Celestite.—Celestite is known to occur at two localities, both in Ontario; one being in the township of Landsdowne, Leeds county, and the other—which is the more important of the two—in the township of Bagot, Renfrew county. Both occurrences have been worked in a small way, and the Bagot deposit is being exploited at the present time (April 1920). The celestite of this deposit occurs in the form of masses of white columnar crystals, and it is suggested that it may be possible to utilize it to replace barytes in the paint and other industries.

Feldspar.—Feldspar has been mined at a number of points within the area stretching from the Lièvre river, in Quebec, westward to the Muskoka lakes, in Ontario, and southward nearly to the St. Lawrence river. Mining is still in force in the southerly portion of this area, along the line of the Kingston and Pembroke railway, and about 20,000 tons of feldspar are extracted annually The feldspar is usually of a pinkish cast, and is of the orthoclase, or potash, variety. It occurs in dikes, sometimes of considerable width, and is usually mixed intimately with varying proportions of quartz. Certain of the dikes carry a greyish or almost white feldspar. The latter are relatively rare in the southern and western portions of the area (*i.e.* in Ontario), being found mainly north of the Ottawa river, in the Province of Quebec, while the red feldspar dikes are chiefly developed in the Kingston and Muskoka districts of Ontario. All of the pegmatite dikes found throughout the area under consideration are of Pre-Cambrian age, and are among the youngest members of the basal complex series, being probably pegmatitic phases of the youngest granite intrusion.

For data relating to the feldspar resources of the region, see Mines Branch Report No. 401.

Galena.—Several small deposits of galena exist in the region, and have been worked at various times. The most important occurrences are in the township of Fitzroy, Carleton county, and Loughborough township, Frontenac county, Ont. Other deposits occur in Hastings, Lanark, and Leeds counties, in Ontario, and in Hull and Labelle counties, in Quebec.

Data relating to lead deposits in the region are contained in Part II of the twenty-fifth Annual Report of the Ontario Bureau of Mines, 1916

Graphite[1].—The Buckingham district, in Quebec, is one of the important graphite bearing areas of Canada, deposits of this mineral having been worked there for many years. The graphite occurs mainly in the form of disseminated flake, in narrow belts in gneiss, closely associated with crystalline limestones. In addition, narrow veins of massive plumbago occur in proximity to many of the flake graphite deposits, but are not of sufficient extent to be worked profitably. Flake graphite is also mined in the neighbourhood of Perth, Westport, Bancroft and Calabogie, in Ontario, the Black Donald mine at Whitefish lake, near Calabogie, exploiting what is one of the largest, if not actually the largest, graphite deposit known.

[1]A special report on Graphite has lately been issued by the Mines Branch, and copies may be obtained by application to the Director, Mines Branch, Department of Mines, Ottawa.

Magnetite.—Deposits of magnetite exist at a number of localities in the counties of Renfrew, Frontenac, Lanark, and Leeds, in Ontario, as well as in Hull and Pontiac counties, in Quebec. A number of these deposits have been worked at various times. The magnetite bodies are associated with crystalline limestones, amphibolites and other metamorphic rocks of the Archæan series. At the Eagle Lake phosphate mine, in the township of Hinchinbrooke, Ont., magnetite and apatite occur in close association on the same leads. (See pages 44-5).

The magetite deposits are described in detail in Mines Branch Report No. 217: "Iron Ore Occurrences in Canada", by E. Lindeman and L. L. Bolton, 1917.

Mica.—As already stated in preceding pages, the apatite-bearing pyroxenites often carry considerable quantities of phlogopite or amber mica, and many of the old apatite mines have, in recent years, been worked for their mica content.

Muscovite mica also occurs in the region, in granite-pegmatite dikes. These pegmatites are chiefly confined to the northern part of the region (Quebec), and are distinct from the aplitic, feldspar dikes referred to above, usually carrying a white microcline feldspar, sometimes mixed with albite, or soda-feldspar. Certain of these pegmatites yield a very high grade of feldspar, that is much in demand for dental pruposes.

Lepidolite, or lithia mica, occurs in some quantity in a pegmatite dike in the township of Wakefield, Que. The crystals are of fair size, and are associated with lithia tourmaline.

Mines Branch Report No. 118, describes the mica deposits of the region in detail.

Molybdenite.—Molybdenite is not infrequently met with in small amount in the mica-apatite bodies. The mineral occurs in local aggregates along the contacts of pegmatitic intrusions into the pyroxenites; it has never been found in economic quantity in such association. The important molybdenite deposit at Quyon, in Pontiac county, Quebec, lies just west of the Quebec apatite region, and numerous occurrences of the mineral are known and have been worked, in Renfrew, Haliburton, and Frontenac counties, in Ontario.

Pyrites.—While pyrites and pyrrhotite are common accessory minerals in the mica-apatite deposits, they do not occur in sufficient amount to be of economic importance. Important bodies of pyrites are operated in Hastings and Renfrew counties, in Ontario, slightly to the west of the apatite region proper.

Mines Branch Report No. 167, describes the pyrites deposits of Canada.

Strontianite.—A narrow vein of strontianite occurs in Nepean township, near Ottawa, but does not possess economic importance.

Zinc blende.—Zinc blende occurs in some quantity on Calumet island, about fifty miles west of Ottawa, in the Province of Quebec; also in the township of Olden, Frontenac county, Ont. Both these deposits have been worked somewhat extensively.

Data relating to zinc deposits in the region are contained in Part II of the twenty-fifth Annual Report of the Ontario Bureau of Mines, 1916.

CHAPTER VI.

MINERALS OF THE MICA-APATITE DEPOSITS.

The following alphabetical list of minerals from the mica-apatite deposits includes the various species observed by the writer during an examination of the various mines. In addition, several minerals are included, which, though not personally observed, are recorded[1] as having been found in mica or apatite deposits. While many of the species enumerated occur directly on the mica and apatite leads, and closely associated with these minerals, a number of them are found principally in the lean and barren portions of the pyroxenites.

It will be noted that the list includes the minerals recorded from the "mica-apatite deposits." Certain of the minerals were found in mica deposits carrying little or no phosphate, while, conversely, others are reported from phosphate mines yielding only small amounts of mica. As, genetically, there is no sharp distinction to be drawn between the two extremes, the minerals recorded from both mica and phosphate mines are included here.

Albite.

Small crystals of albite were observed lining a cavity in a coarse-grained, felsitic zone in pyroxenite, on lot 3, of the Gore of Templeton, Que. This variety of feldspar is by no means common in crystal form in mica-phosphate deposits, and has been recorded from only a few localities.

Anhydrite.

A specimen of a mauve-coloured mineral that, upon analysis, proved to be anhydrite, was obtained from the MacLaren mine, concession VIII, lots 4, 5, and 6, township of North Burgess, Ont. The mineral was in massive form, and was permeated by white gypsum, which filled the cleavage spaces, and which appeared to have formed a sort of matrix for the anhydrite.

The specimen obtained was about 6 inches across, and was said to have been taken from a mass of several hundred pounds weight that was found on one of the apatite leads some years ago.

Anthraxolite.

This mineral is a hydrocarbon compound of varying composition, and is recorded from several localities in the Provinces of Ontario and Quebec.[2] It appears to be an alteration product of liquid bitumen or asphalt, and is found as vein-filling or as isolated inclusions in both sedimentary and igneous rocks. Specimens have been obtained from the chert beds of the

[1]See Rep. Prog., Geol. Surv. Can., 1877-78, pp. 13-37G.
[2]Ann. Rep., Geol. Surv. Can., 1888-89, Vol. IV, Pt. T, p. 19.

Lake Superior copper region, where the mineral occurs on small fissures, and also from certain trap rocks. The specimens obtained by the writer were from mica deposits, and consist of small, rounded fragments or nodules, the largest of which does not exceed 2″ diameter. These specimens were secured at the Baby mine, lot 1, concession X, of the township of Loughborough, Ont., and occurred as isolated masses of approximately circular shape in the grey, altered, mica-bearing pyroxenite. The mineral is hard and brittle, possesses conchoidal fracture, and somewhat resembles bituminous coal. Its streak is black; but the substance is too hard to mark paper.

Apatite.

As will be already clear from the descriptions of the various mines, etc., many of what are now mica mines were originally opened up as phosphate producers, and both minerals are now won simultaneously at several mines. At certain mines, apatite is almost, if not entirely, absent from the mica leads, but such instances are comparatively rare.

In character, the mineral ranges from massive, compact crystalline to what is known as "sugar-phosphate." (See Plate I). The latter consists of a friable, powdery mass of small, rounded apatite grains, and is often found in large deposits, throughout which well-crystallized apatite individuals and mica crystals occur disseminated. When crystallized, the mineral invariably adopts the prismatic habit with the pyram dal termination. Occasionally the crystals are terminated at both ends, but this is unusual. In size, they range from minute individuals, which often occur scattered through the pink calcite of the veins, to enormous forms several feet in length and a foot or more in diameter. Attention has already been drawn to the frequently rounded crystal edges, and to the often resorbed appearance exhibited by the individuals, a feature which is as common to the large as to the most minute crystals. The colour of the mineral varies greatly, even in one and the same deposit, and massive, compact apatite, also, is sometimes found to merge gradually into the sugar variety. The most usual colour is green, but brown, red, blue, grey, and even white, are also met with. The sugar phosphate is almost invariably of a greenish-white shade.

The best and most perfect crystals of apatite are usually found embedded in calcite. Well-formed individuals, also, often occur included in mica crystals, in which case the prisms almost always lie with their long axes approximately parallel to the basal plane of the mica crystal. Inclusions of other minerals, such as calcite, pyroxene, phlogopite, pyrite, fluorite, in the apatite crystals are not uncommon.

From numerous analyses, it has been found that Canadian apatite is always fluor-apatite, the fluorine content ranging as high as 3·8 per cent. A number of results of analyses of Canadian apatite are given in Part H of the Report of Progress of the Canadian Geological Survey for the year 1877-8. The samples for examination were taken from both Ontario and Quebec deposits, and included the "sugar" as well as the compact varieties of the mineral. A mean of eight analyses given in the above report, and conducted by G. C. Hoffmann, showing the chief constituents, is appended:—

Phosphoric acid	39·733
Fluorine	3·494
Chlorine	0·257
Carbonic acid	0·630
Lime	47·933
Calcium	3·823
Insoluble	1·658
Magnesia	0·305
Alumina	0·840
Ferric oxide	0·361
	99·034
Equivalent to tricalcic phosphate	86·742
" " calcium fluoride	7·172
" " carbonate of lime	1·432

The mean specific gravity was found to be 3·17.

Additional, and more complete analyses of samples of Canadian apatite have recently been conducted by M. F. Connor, of the Mines Branch, the following results being obtained. It will be noted that the chlorine content is in each case considerably in excess of the mean shown by the preceding analyses, and that the percentage of fluorine is very constant:—

	1	2	3	4	5
Tricalcic phosphate	86·53	87·73	81·94	85·74	86·07
Phosphoric acid	39·60	40·15	37·50	39·24	39·39
Lime	54·20	53·30	54·40	55·70	55·64
Magnesia	0·35	0·28	0·31	0·20	0·33
Ferric oxide, Alumina	1·00	1·30	1·30	0·72	0·72
Soda, Potash	0·77	0·64	0·88	0·80	0·72
Chlorine	0·44	0·40	0·67	0·65	0·50
Fluorine	3·30	3·20	3·30	3·10	3·05
Carbon dioxide	0·66	..	1·75	..	....
Water	0·32	0·36	0·12	0·28	0·20
Insoluble Silica	0·48	1·80	0·64	0·06	0·36
Sum	101·12	101·43	100·87	100·75	100·94
Less oxygen=chlorine, fluorine	1·44	1·38	1·46	1·37	1·33
Total	99·68	100·05	99·41	99·32	99·61

1. Massive, reddish-grey apatite, McClelland mine, north half lot 10, range XIV, township of Hull, Que.

2. Dark, reddish-brown, massive apatite, Scott mine, lot 14, range IX, township of Hull, Que.

3. Light grey-green sugar apatite, Rainville mine, east half lot 15, range VIII, township of Templeton, Que.

4. Massive, blue-green apatite, High Falls mine, lot 3, range IV, township of Bowman, Que.

5. Green apatite nodule embedded in sugar phosphate, Blackburn mine, lot 9, range XI, township of Templeton, Que.

Barytes.

This mineral was observed at one spot only, concession VIII, lot 2, of North Burgess, Ont. Masses of small, tabular crystals were found encrusting the walls of druses in white calcite, near the surface of the lead exposed in the S.E. pits, and associated with quantities of small calcite scalenohedrons.

Calcite.

Calcite may be said to be invariably present in the pyroxenites, though the amount is subject to considerable range. In certain pyroxenites the mineral forms large bodies, chiefly as the filling of pockets in the rock, while in others it occurs in small quantities only throughout the mass of the rock. It is frequently present in the form of layers or films between the laminæ of mica crystals, considerably impairing their splitting quality. In character, the calcite is usually more or less coarsely crystalline, the individuals ranging from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch across. Occasionally they are much larger, attaining a length of some 3 to 4 inches. In such cases, the colour of the mineral is nearly always white or yellowish, in contrast to the prevailing flesh or salmon coloured tint of the more finely crystalline variety. The individuals are always twinned polysynthetically, and, save for the colour, masses of the mineral much resemble an ordinary, coarse-grained crystalline limestone.

The pockets, so frequent in the pyroxenites, are almost invariably filled with calcite, mixed with which both mica and apatite occur. Where empty pockets are met with, the calcite has generally been removed by surface waters. It is noteworthy that druses in the calcite are of very infrequent occurrence, and that the usual types of calcite crystals so commonly met with on mineral lodes or lining fissures in sedimentary limestones are exceedingly scarce. Those observed, were generally of scalenohedral habit, and of small size. Crystals of this type occur near the surface of a mica lead on concession VII, lot 2, of North Burgess, Ont.

At one spot—concession VIII, lot 13, of Loughborough, Ont.—a very compact, finely crystalline, dark-red calcite was observed, in which occur, porphyritically, rounded crystals of apatite. Small druses lined with white calcite scalenohedrons occur plentifully in the mass of this red calcite.

Other colours possessed by the mineral are blue, white, cream, and greenish, and it is noteworthy that when such colours prevail either pyrite, or, more commonly, pyrrhotite, is to be found in considerable amount in the deposit. Small, circular lumps of calcite, resembling marbles, and possessing a highly glazed surface, are sometimes found enclosed in crystals of apatite.

Chabazite.

Has been found on range XII, lot 21, of Templeton, Que., where it occurs in small, colourless crystals in scapolite and pyroxene. The crystals have rhombohedral habit, and penetration twins are common. Harrington considers the chabazite from the above locality, as well as the prehnite from mica deposits, to be of secondary origin, and possibly derived from the scapolite[1]. Another locality from which chabazite and other zeolites, including natrolite, have been obtained, is range XII, lot 21, of East

[1]Rep. Prog., Geol. Surv. Can., 1877-78, p. 35G.

Portland, Que. Small, clear, rhombohedral crystals of chabazite were seen coating large, decomposed scapolite crystals at the Rheaume Lake mine, lot 3, of the Gore of Templeton; and minute crystals of what appears to be chabazite, were found associated with green fluorite on range III, lot 1, of East Portland.

Chalcopyrite.

Small grains or irregular fragments of chalcopyrite are sometimes seen embedded in the granular calcite of the pyroxenites, associated with pyrites.

Chlorite.

Chlorite, having approximately the composition of ripidolite, has been found on range IX, lot 18, of Templeton township, Que., and at various other mines in the same district. The following[1] is an analysis of the above specimen:—

SiO_2	35·80
Al_2O_3	13·18
Fe_2O_3	4·28
FeO	10·18
MgO	22·80
H_2O	12·64
	98·88

Aggregates of small, green, chlorite-like scales, were observed at the Baby mica mine, concession X, lot 1, of the township of Loughborough, Ont., usually upon joints and slide-planes in the altered pyroxenite.

Datolite.

This mineral was observed at two localities, namely, range I, lot 9, of Derry, Que., where considerable quantities of white, compact, massive datolite, showing characteristic, Wedgewood-porcelainic fracture, occur in pyroxene and apatite, associated with dark, purple fluorite, and at the Bobs Lake mine, concession VI, lot 30, of Bedford, Ont. At the latter place, the mineral occurs in finely divided, granular form, has a white colour, and can be rubbed to a fine powder between the fingers. The specimens formed part of a mass several pounds in weight, taken from the hanging wall of one of a series of parallel mica leads. This lead also carries scapolite in aggregates of large and well formed crystals. Datolite is recorded also from several other mica deposits, including the Lacey mine, concession VII, lot 11, of Loughborough, Ont.

Epidote.

Epidote is occasionally met with, and is recorded, amongst other localities, from range XIII, lot 23, and range X, lot 9, of the township of Templeton, Que. The mineral is, in both cases, of a yellowish-green

[1]Rep. Prog., Geol. Surv. Can., 1877-78, p. 34G.

colour, and occurs with dark pyroxene and pyrite. A further locality where epidote was found in considerable quantity is range I, lot 12, of Wakefield, Que.

Faujasite.

This mineral has been found in good sized, white octahedrons, associated with green fluorite, at the Daisy mine, range I, lot 9, of Derry, Que. It is also reported to occur at various localities in the township of East Portland.

Fluorite.

Fluorite is a somewhat scarce associate of the mica and apatite. Considering the high fluorine content of both these minerals (up to 2·5 and 3·8 respectively), it is remarkable that the fluoride of calcium should be so rarely encountered. When present, it is often associated with members of the zeolite family, and seems to be a result of alteration of apatite. Only small crystals (up to $\frac{1}{2}$ inch in diameter) have been found, and these are usually of octahedral or cubic habit. Combinations of the two forms also sometimes occur. The mineral is generally of a green or purple colour.

An unusual amount of fluorite was observed at the mine owned by the Calumet Mica Company, range IV, lot 22, of the township of Huddersfield, Que. Here, small masses of fluorite, of a purple-brown colour, occur scattered through cream coloured calcite, and small purple octahedrons were also observed lining cracks and fissures, as well as forming inclusions in the mica crystals (see Orthite).

Galena.

Recorded from range XIII, lot 12, of Templeton, Que., in minute quantities, associated with smoky quartz, in cavities in pink calcite.

Garnet.

The occurrence of garnet, associated with apatite, is recorded by Harrington,[1] who mentions the varieties almandite and hessonite as having been found in Templeton and Wakefield townships, Que., respectively. No specimens of garnet were observed at any spot by the writer, associated with phlogopite mica or apatite. Both the above-mentioned varieties are frequent in the gneisses of the phosphate area, and are also occasionally met with in crystalline limestone, near intrusive contacts of pegmatite or similar rock.

Spessartite occurs plentifully, embedded in the feldspar and mica crystals of the large pegmatite dike opened up at the Villeneuve mine, Que. Uwarowite, or chrome-garnet, has been found in the township of Wakefield, Que., associated with apatite, tourmaline, and pyroxene.

Goethite.

This hydrated iron oxide was observed in some quantity, lining the walls of small cavities in marcasite and pyrite, at the McNally mica mine,

[1]Loc. cit., p. 26.

concession V, lot 21, of North Burgess, Ont. The mineral is of the variety known as przibramite, and is associated with small quartz crystals.

Graphite.

Reported to occur at various localities in the phosphate area, associated with apatite, calcite, and pyroxene. It is common in the form of small flakes in the white crystalline limestone often found adjacent to the pyroxenites, and also in small quantities in the pyroxenite rock itself. In the latter case, the mineral usually occurs as a selvage filling upon joints and slips, and is often associated with crushed mica and pyroxene. Instances of this mode of occurrence are common at the Lacey mine, lot 11, concession VII, of the township of Loughborough, Ont. Though economic bodies of graphite are found in the gneisses and limestones of the phosphate-bearing area, the mineral is not known to occur in any quantity along with apatite deposits.

Hematite.

A large pocket of scaly hematite was encountered on concession V, lot 9, of North Burgess, Ont., while sinking on a mica lead. The iron ore occurs in a sort of lenticular chimney, and contains fair sized mica scattered through it.

On concession IX, lot 1, of Loughborough, Ont., pockets of massive, fine-grained specularite occur in close proximity to the mica lead.

Hornblende.

Primary hornblende, that is, non-pseudomorphous mineral resulting from the alteration of pyroxene, is of not uncommon occurrence along the borders of pyroxenite belts with crystalline limestones. Notable localities are the Parker mica mine, range V, lot 52, of the township of Bigelow; the Father Guay mica mine, range D, lot 15, of Wright, and range III, lot 23, of Hincks, all in the province of Quebec. At the above spots large quantities of normal, black and lustrous hornblende have been formed along the contacts of the pyroxenites with crystalline limestone. The mineral forms compact masses, with individuals up to $\frac{1}{3}$ inch diameter, and is quite fresh and unaltered.

Actinolite in stout prisms of a greenish colour was observed at various points, notably at the Fortin and Gravelle mine, range VII, lot 18, of Hull, Que., and at the Silver Queen mine, concession V, lot 13, of North Burgess, Ont. At the latter place, sheets of the white, fibrous variety of hornblende known as "mountain leather" were also obtained. This mineral also occurs at the Lake Girard mine, and at several localities in the township of Derry, Que. The hornblende varieties of asbestos, known as amianthus and byssolite, were noticed at several points, notably on range VI, lot 19, of Hull, Que. Here, the former mineral occurs in masses with fibres up to nearly a foot in length, and is of a bluish colour. It is found on the contact of a pink aplite with pyroxenite, and is probably an alteration product of pyroxene, caused by pneumatolytic emanations accompanying the aplite intrusion. (Plate XXX.)

What is probably edenite, a clear, reddish variety of hornblende, was observed associated with grey tremolite on concession X, lot 1, of Loughborough, Ont.

Magnetite.

Magnetite is not a common mineral in mica-apatite bodies, but it occurs in large quantities at one particular phosphate mine—the Eagle Lake mine, lots 29 and 30, concession I, township of Hinchinbrooke, Ont. This property is reported to have yielded 700 tons of commercial iron ore. The magnetite is of the ordinary massive variety, and occurs both directly with the apatite and on narrow leads in the more or less immediate vicinity of the phosphate bodies. Magnetite deposits—not associated with phosphate—have been worked at Ironsides, in the Gatineau district, in Quebec province, and at a number of points along the Kingston and Pembroke railway, in Ontario.

Microcline.

This variety of feldspar is common in many pyroxenites, and its association with quartz and pyroxene in varying amounts gives rise to many rock-types throughout the bodies. The mineral is seldom met with in well-developed crystals of free growth. In colour it ranges from white, grey, or bluish, to brown, pink, and red, a greyish-blue or greyish-brown shade being the commonest. The usual mode of occurrence is in massive, coarsely crystalline form, the individuals ranging from $\frac{1}{4}$ inch to 1 inch in length and being frequently intermixed with quartz or titanite. The frequent association of one or more of the following minerals, in varying amounts, with microcline, constitutes rock types which are characteristic of the pyroxenites:—

Microcline: ± titanite, ± pyroxene, ± apatite, ± phlogopite, ± quartz

Though often, apparently, forming an integral part of the pyroxenites, much of the microcline possibly represents pegmatitic material related to late granite batholithic intrusions into the series. Pink microcline is, in addition, the chief constituent of the numerous pegmatite veins which are found cutting the mica and phosphate deposits.

Molybdenite.

This mineral is frequently found in the pyroxenites, sometimes in large masses several pounds in weight, but more frequently in the form of small flakes and scales disseminated through pyroxene. The molybdenite occurs always in more or less immediate proximity to pegmatite or aplite dikes cutting the mica-apatite deposits, and has been brought in by these later intrusions.

Natrolite.

A white, fibrous mineral, resembling natrolite, was observed coating small calcite crystals in vugs at the Moore and Marks mica mine, range II, lot 4, of Alleyn, Que. The individuals were too small and altered to admit of accurate determination, and the mineral may possibly be stilbite or some other member of the zeolite family.

Olivine.

Olivine occurs in large and well formed crystals at the Parker mica mine, range V, lot 52, township of Bigelow, Que. Apatite is conspicuously absent at this mine. The olivine is found associated with pyroxene, and frequently lining the walls of pockets, in a similar manner to the latter mineral. The crystals are of a greyish-green colour, usually tabular in form, and possess sub-vitreous lustre. The largest individuals observed possessed a length of some 4 inches. On the east of the property, a small mica lead has been opened up, the vein yielding numerous black spinel crystals, both disseminated through the coarsely crystalline, white calcite of the vein-filling and in clusters on the olivine crystals which line the walls. At the surface, the olivine crystals are mostly decomposed and friable, possessing a brown or yellow colour, and often display a high degree of iridescence upon their faces.

Although so abundant at this particular point, no other occurrence of olivine associated with phlogopite was observed. Wilson has, however, detected its presence in some amount in certain rock-types of his Buckingham series, the quantity being large enough in some cases to class the rock as a peridotite.

The serpentine of the serpentine-limestones (ophicalcite) of the mica-apatite district is probably an alteration product of pyroxene, rather than of olivine.

Orthite or Allanite.

Tabular crystals, over 1″ diameter, and possessing the character and appearance of orthite, were observed disseminated through massive calcite on range IV, lot 22 of Huddersfield, Que. The mineral is black, and possesses metallic lustre on its crystal faces, though often coated with the brown alteration substance characteristic of orthite. The fracture is conchoidal, the resulting surfaces possessing vitreous to resinous lustre.

It is noteworthy that the fluorite, which at this spot occurs in unusual quantity, often forming large masses embedded in the calcite, in close proximity to the orthite crystals invariably possesses a dark, violet colour. This violet shade gives way, with increasing distance from the orthite, to the normal plum colour possessed by the mineral at this mine.

Orthoclase.

Orthoclase feldspar is probably not a common constituent of the pyroxenites, the feldspar of these rocks usually being of the microcline variety. Orthoclase is, however, occasionally found in well-developed crystals, associated with the crystals of pyroxene lining the walls of pockets or fissures. The crystals observed were white or grey in colour, of simple habit, and were usually of small size. Specimens were obtained from a surface crevice in pyroxenite, on range X, lot 13, of Hull, Que., and from the Gore of Templeton.

Phlogopite.

Phlogopite mica is, at the present time, a far more valuable constituent of the mica-apatite bodies than the phosphate, and many of the old apatite

mines have in recent years been reopened for mica. Although many of the deposits carrying mica in quantity show only small amounts of phosphate, it is seldom that a large apatite body carries no mica.

The mica occurs in crystals, sometimes of very large size (up to 3 and 4 feet diameter, and weighing the larger part of a ton). The crystals occur both scattered irregularly through the calcite or phosphate filling of the pockets and fissures in the pyroxenites, and also lining the walls of such cavities. The latter individuals are, as a rule, of small size and relatively little value commercially. Inclusions of calcite and apatite in mica crystals are common, and these minerals often form layers between the laminæ. The faces of the crystals are seldom smooth and lustrous, but are generally rough and pitted[1].

Prehnite.

Harrington records the occurrence of this mineral from range XII, lot 16, and also from range XIII, lot 23, of Templeton, Que. No specimens came to the writer's notice while examining the deposits. The above-mentioned sample was translucent, of a yellowish-white colour with a greenish tinge. It is stated to have occurred in a cavity, and showed rounded surfaces made up of an aggregation of crystals. The hardness was above 6, and specific gravity 2·891.

Pyrite.

Though not usually abundant in he pyroxenites, pyrite is nevertheless of frequent occurrence, and, in certain deposits, indeed, proves a rather unwelcome accessory, from the miner's point of view, as any large iron content in the phosphate effectually precludes the use of the latter for superphosphate manufacture. To the mica miner, also, pyrites is a deleterious mineral, owing to its liability to decompose, the resulting acid attacking the mica and often rendering the crystals near the surface worthless. Large quantities of so-called "rusty" mica have, thus, often to be discarded when exploiting the upper portions of deposits, the sheets being stained by oxide of iron and useless for electrical purpose. Mica crystals, too, which are taken from deposits carrying much pyrite, are usually hard and brittle, and are characterized by what is known as 'wine-amber' colour, due apparently to the presence of the iron sulphide in the pyroxenite.

Though sometimes massive in character, and in this form occasionally to be found forming solid veins several inches across, pyrite is of more general occurrence in the form of isolated, irregularly shaped masses, having often a pitted surface, as if they had been attacked by some dissolving agency. Such masses are usually embedded in calcite or apatite. Crystals are not uncommon, the usual forms being the octahedron, cube, and pyritohedron, or pentagondodecahedron, either simply or in combination. Large quantities of pyrite crystals, of octahedral habit, but with curved edges and faces, occur embedded in a bluish selvage, on range II, lot 10, of Alleyn, Que. Unusually large quantities of pyrite also occur with the

[1]For additional notes on phlogopite, see "Mica: Its Exploitation, Mining and Uses", Rep. Mines Branch, Department of Mines, Ottawa, 1912.

mica, on range IX, lot 23, of Blake, Que., concession VIII, lot 6, of Loughborough, and concession V, lot 21, of North Burgess, Ont. At the latter place, marcasite occurs with the pyrite, the latter mineral forming a considerable proportion of the vein-filling.

Small crystals of pyrite are not uncommonly found included in phlogopite sheets, and then often give rise to perfect, natural pressure figures.

Pyroxene.

The mica and apatite-bearing pyroxenites are, as their name implies, chiefly made up of one member or another of the pyroxene group. The most common variety, according to Harrington[1], appears to be an aluminous salite, or lime-magnesia-iron pyroxene, but other varieties of diopside, such as malacolite and diallage, are also common.

Orthorhombic varieties, such as hypersthene and enstatite, are sometimes met with, but are not of frequent occurrence. The mode of occurrence of the pyroxene is very variable, and the masses acquire varying characteristics in consequence. Sometimes a body is formed of finely-crystalline, granular pyroxene, mixed with feldspar and quartz, forming a hard, compact rock, in which mica crystals, associated with small amounts of calcite, occur embedded. Again, a mass of pyroxene crystals, often of considerable size, may occur more or less loosely intergrown, with calcite filling the interstices between the partially developed crystals. It is in this type of pyroxenite that pockets, often lined with well crystallized pyroxene individuals, so often occur, the cavities being often connected by irregular fissures. This mode of occurrence has given to mica-apatite deposits associated with pyroxenites of this type the designation of "pocket and fissure" deposits. A third type of pyroxenite is that in which the pyroxene crystals form a relatively compact mass, with few pockets, but with more or less regular mica-apatite leads traversing the body. The walls of such leads also, are sometimes lined with large and well-developed pyroxene crystals (see Plates XXV and XXI).

The habit of the crystals is prismatic, and the more usual combinations are *a*, *b*, *u*, *v*, *m*, *c*, (Dana). The crystals are sometimes striated longitudinally, and are occasionally flattened in the direction of the orthodiagonal. Crystals terminated at both ends are not common, and are usually found embedded in apatite or calcite. Good examples were observed on concession VII, lot 19, of the township of Bedford, Ont.

In colour, the mineral ranges from nearly black to light grey, the commonest shade being a greenish-grey. It is noteworthy that fresh unaltered pyroxene is relatively scarce, even in deep workings. In certain deposits, lustrous, fresh crystals are common, but, as a rule, the mineral is dull throughout its mass, and the crystal faces are usually matt and rough. When fresh and lustrous, pyroxene crystals are sometimes mistaken for apatite, especially when the prism faces are developed to the same extent as those of the pinacoid, giving an hexagonal appearance to the individuals.

Inclusions of mica, pyrite, calcite, and apatite in pyroxene crystals are frequent, the first two named being the most commonly observed. Frac-

[1]Rep. Prog., Geol. Surv. Can. 1877-78, Part G, p. 17.

tured and bent crystals, which have been re-cemented by calcite or apatite, are sometimes met with.

Crystals twinned on *a* are frequent, and prominent parting, or pseudo-cleavage, due to twinning, is often observed on large crystals. Twinned crystals are common at the McGlashan mine, range VI, lot 27, township of Wakefield, Que.

The most interesting and conspicuous feature to be observed in connexion with the pyroxene, is its tendency to become altered to a kind of uralite. This mineral is essentially a pseudomorph of hornblende after pyroxene, which retains the crystal form of the latter mineral while acquiring the composition and cleavage of the former. What were originally pyroxene crystals are frequently found altered to a greenish-blue mineral with fibrous structure, which is probably referable to uralite or traversellite. This transformation of pyroxene to hornblende is especially to be remarked in cases where later pegmatite dikes cut pyroxenites. Localities which may be noted are range XIII, lot 12a, of the township of Hull; range VI, lot 19, of the same township, and range II, lot 24, of Wakefield, all in the province of Quebec. At the latter place (the Lake Girard mine), large pyroxene crystals were noticed, which consisted of an inner core of soft, green, powdery mineral, having an outer covering, some $\frac{1}{2}''$ thick, of blue, fibrous traversellite, the fibres being at right angles to the faces of the original crystal (see Plate XXVI).

Three analyses, by Harrington[1], are appended, the first of which represents the composition of the centre, or unaltered portion, of such a pyroxenite crystal: the second is that of the zone bordering upon the centre and partly altered to a lustreless mineral; and the third represents the most altered or exterior portion of the same crystal. The specific gravities of the samples were, in the first case, 3·181; in the second 3·205, and in the third only 3·003. Although mineralogically different in character, the two inner crystal zones have much the same chemical composition.

Analyses of Pyroxene Crystals.

	Internal, or unaltered, zone	Intermediate, or partly altered, zone	External, or completely altered, zone
SiO_2	50·868	50·898	52·823
Al_2O_3	4·568	4·825	3·215
Fe_2O_3	0·970	1·741	2·067
FeO	1·963	1·358	2·709
MnO_2	0·148	0·152	0·276
CaO	24·438	24·392	15·389
MgO	15·372	15·268	19·042
K_2O	0·497	0·150	0·686
Na_2O	0·218	0·076	0·898
Loss on ignition	1·439	1·200	2·403
	100·481	100·060	99·508

In the last case there is a loss of about 9 per cent of lime, and a gain of 4·5 per cent of magnesia; which loss and gain appear to determine the

[1]Rep. Prog., Geol. Surv. Can., 1877-8, p. 21G.

change from pyroxene to hornblende. The above anaylses very fairly represent the average composition of pyroxene from the Archæan rocks of Ontario and Quebec.

A more recent analysis of pyroxene, conducted by N. L. Turner, of the Mines Branch, is shown below. The material in this case was provided by a small crystal about one inch in diameter, and was lustrous and unaltered. The crystal was obtained at the Daisy mine, township of East Portland, Que.:—

SiO_2	52·42
Al_2O_3	5·35
Fe_2O_3	1·14
FeO	1·53
CaO	21·32
MgO	16·31
Na_2O	0·99
K_2O	0·44
H_2O	0·20
MnO	0·15
TiO_2	0·03
SO_3	0·04
Cl	0·02
	99·94

Pyrrhotite.

Magnetic pyrites is an even more prevalent mineral in the deposits than the ordinary variety, and can usually be observed, if only in subordinate amount, in the majority of mica-apatite leads. As in the case of pyrite, the mineral is generally either massive, or in the form of irregularly-shaped fragments with pitted or indented surfaces, embedded in calcite or apatite. Mica crystals surrounded by massive pyrrhotite were observed at certain mines, and in such cases the laminæ are usually found to be of a reddish-brown shade and relatively hard and brittle. Small plates of pyrrhotite are common in the crystalline limestones which frequently border on the pyroxenites, and these plates sometimes possess obscured crystal outlines. More often, however, the mineral here, also, is in the form of irregular fragments. It is noteworthy that the calcite found in deposits in which pyrrhotite or pyrite occurs at all plentifully is almost invariably light in colour (usually white, cream, or yellow), in contrast to the prevailing salmon tint of the normal mineral. This fact is especially noticeable at the Moose Lake mine, range IV, lot 1, of Villeneuve township, Quebec; at the Cantin mine, concession IV, lot 1, of South Burgess, Ont. (calcite also of a blue shade); on concession XI, lot 10, of Bedford, Ont., and on concession VII, lot 19, of Bedford.

The surface of the pyrrhotite fragments at the first named locality is peculiarly ribbed, resembling the face of a coarse file, the ridges often, however, pursuing a wavy course. The mineral seems to have been squeezed or pressed in amongst the calcite with which it occurs, and to have penetrated along the cleavage planes of the latter mineral, thus acquiring a ridged surface.

Quartz.

Although quartz has often been alluded to by various writers as a common mineral in the mica and apatite deposits, the writer's experience is that it is somewhat of a rarity. Massive, milky quartz is sometimes met with in the mass of the pyroxenites, and the mineral is also present, associated with feldspar, as a rock-forming constituent, in the same manner as it is present in granite or similar rock types. Crystals of quartz, however, were observed remarkably seldom, and then only as small individuals lining the walls of druses in calcite or apatite. It was never seen associated with pyroxene crystals upon the walls of pockets in pyroxenite. At the Goldring mine, range IX, lot 17, of Templeton township, Que., crystals of smoky quartz up to 1″ in length were seen lining cavities in massive apatite, and on range VI, lot 15, of the same township, considerable quantities of pale amethyst crystals occur. Chalcedonic quartz, also, is recorded from the first named locality. Much of what has been described as massive, vitreous quartz is possibly fresh and unaltered scapolite, which sometimes occurs in considerable quantities in the pyroxenites.

Two large and very perfect, pseudomorphic crystals of a dark, earthy mineral after quartz were obtained from concession VII, lot 14, of South Crosby, Ont.

Rensselaerite.

This mineral is a pseudomorph of steatite after pyroxene, and is recorded from mica-apatite deposits, as is also the somewhat similar mineral pyrallolite.

Rutile.

Rutile has been reported to occur in some mica-apatite deposits, one locality being range X, lot 10, of Templeton township, Que. No specimens were observed by the writer in any of the mines, but very large prisms occur in a barytes vein, associated with acicular, green actinolite, on range XIII, lot 13 N. ½, of Templeton. The vein occurs on the contact of amphibolite with crystalline limestone.

Scapolite.

In many mica-apatite deposits scapolite occurs in considerable quantity, and often in the form of large crystals, either as isolated individuals or, more commonly, in crystal aggregates. From a careful examination of the rock matter from the various mines, it is evident that scapolite is present in considerable amount in the majority of pyroxenites. While occasionally fresh and unaltered—and in that case possessing characteristic, vitreous lustre and splintery fracture—the scapolite most commonly encountered has undergone considerable alteration, and is opaque and often earthy, with a silky lustre. Fresh scapolite in massive form occurs somewhat plentifully at the Horsehoe mine, range XVI, lot 6, of the township of Hull, Que., and often encloses crystals of apatite and mica. Notable localities where altered scapolite occurs in quantity are, in Quebec: Chaibee mine, range A, lot 6, of Wright; Nellie and Blanche mine, range XI, lot 10, of Hull; range XII, lot 13, of Templeton (in well-formed square crystals);

range III, lot 15, of Portland West; and in Ontario: Baby mine, concession V, lot 13 W. ½, of North Burgess; concession VIII, lot 1, of the same township; Bobs Lake mine, concession VI, lot 30, of Bedford. (See Plate XXXII).

The usual crystal forms exhibited are combinations of *a*, *m*, *h*, *z*, *r*, *c* (Dana). The cleavage parallel to *a* is prominent. In colour, the scapolite is usually of a grey, white, or yellow shade. A specimen of scapolite from a pyroxenite in Ottawa county, Que., was analysed by F. D. Adams, and found to contain:—

SiO_2	54·68
Al_2O_3	22·45
Fe_2O_3	0·49
CaO	9·09
MgO	trace
K_2O	1·13
Na_2O	8·36
Cl	2·41
SO_3	0·79
H_2O	0·86
	100·44

The presence of chlorine is especially interesting, in view of the small amount (about 0·25 per cent) of that element present in the apatite of the deposits. In order to ascertain whether chlorine is a usual constituent of the scapolite of the pyroxenites, fourteen other samples were examined by Adams, in all of which the presence of chlorine was detected, though mostly in small amount. A locality where scapolite occurs in more than usual amount is concession VIII, lot 6, of Bedford, Ont. Here large quantities of massive, highly altered, soft scapolite form practically the entire vein filling of the mica leads, calcite and apatite being noticeably absent.

Serpentine.

Serpentine is occasionally met with among the pyroxenites, and probably has resulted from the alteration of pyroxene. Serpentine was observed on range XVI, lot 27 of the township of Hull, and on range X, lot 2 of the township of Templeton, Que. At this latter locality, crystals of phlogopite are traversed by minute, irregular cracks filled with serpentine and the crystals are often embedded in a soft, yellow-green serpentine. Stringers of chrysotile asbestos, up to half an inch in width, occur here.

Specularite.

This mineral occurs with red and brown jasper along the contact of a pegmatite dike with crystalline limestone, adjacent to a mica-apatite vein, on range IX, lot 16, of Hull, Que. The specularite is both massive and in the form of small, tabular plates lining fissures in the jasper.

Sphalerite or Zinc Blende.

This is recorded from range IX, lot 17, of Templeton, Que., in smal yellow-brown crystals, associated with quartz and apatite.

Spinel.

Spinel was only observed at one locality, namely, range V, lot 52, of the township of Bigelow, Que. Here, as already described under Olivine, an irregular pocket has been opened up in the mass of the pyroxenite, carrying a greyish olivine mixed with white calcite and dark mica. Scattered through the mass of this rock occur well-crystallized, black spinels (pleonaste) in individuals up to $\frac{3}{4}''$ across. The crystals are sometimes aggregated into small groups, and are usually combinations of *o*, *d* (Dana), while twins are not uncommon. The occurrence would seem to be connected with an intrusion of peridotite.

Steatite or Talc.

A soft, soapy mineral, of greenish-grey colour, and resembling talc, is frequently to be observed on joint planes in the pyroxenites, and appears to be, in many cases, an alteration product of mica. True pseudomorphs of steatite after mica occur on range III, lot 51, of the township of Thorne, Que., and the latter mineral can sometimes be observed passing into talc.

Titanite or Sphene.

One of the accessory minerals most frequently to be observed in the pegmatitic injections into the pyroxenites. As a rule, the titanite tends to occur most plentifully in the more acid portions of such masses. The occurrence in pyroxenite belts of acid zones, consisting of a rock formed essentially of grey, blue, or brownish feldspar and titanite, is very conspicuous. The crystals range from $\frac{1}{4}''$ to $1\frac{1}{2}''$ in length, and are almost always of the typical, tabular, pyramidal habit assumed by this mineral. Twins are common. The colour is almost invariably a dark brown to black, and the crystals are usually more or less opaque.

Titanite individuals are also sometimes found embedded in pyroxene, but this mode of occurrence is infrequent compared with the characteristic association of the mineral with the feldspar. Occasionally, also, titanite crystals are observed embedded in apatite or calcite. Rounded nodules of calcite, similar to those so often found in apatite, also occur enclosed in titanite. Large quantities of titanite crystals occur in a pink aplite cutting pyroxenite, on range XIII, lot 12a, of Hull, Que., and well-formed individuals possessing high lustre were observed on concession VII, lot 19, of Bedford, Ont., associated with apatite crystals and enclosed in a calcite vein filling.

Tourmaline.

Though not infrequently found in pyroxenites, associated with apatite, pyroxene, pyrite, calcite, etc., this mineral has been brought in by later acid intrusions, and is not contemporaneous with the mica-apatite bodies. It is usually found in the more or less immediate vicinity of such acid

dike-masses, and has been deposited pneumatolytically along or adjacent to fissures and joint-planes in the pyroxenite. The mineral is generally referable to the variety schörl, and possesses the ordinary prismatic or rhombohedral habit.

In certain mica deposits, a brown tourmaline resembling dravite or magnesia-tourmaline, is very abundant. Such an occurrence is that on concession IV, lot 17, of Bedford, Ont., where the mineral occurs in aggregates of small, flattened crystals of prismatic habit and also massively crystalline. Large quantities of reddish-brown tourmaline occur associated with a yellowish mica on concession X, lot 1, of Loughborough, and on concession II, lot 5, of Bedford, Ont. The mineral is massive, with occasional small crystals developed throughout its mass, and closely resembles vesuvianite. Such brown tourmaline is, however, uncommon in the apatite deposits.

Tremolite.

This variety of amphibole was occasionally observed as the result of an alteration of pyroxene. The most notable localities where the mineral occurs in large quantities, are on concession X, lot 1, of Loughborough, and concession II, lot 5, of Bedford, Ont. Here the contact metamorphic action of an acid intrusive upon crystalline limestone has resulted in the formation of large quantities of greyish-green tremolite, which occurs in aggregates of inter-penetrating, prismatic crystals adjacent to the intrusive contact. The prisms sometimes attain a length of 6 to 8 inches. In addition, a quantity of brown, acicular tremolite occurs in compact masses in certain portions of these deposits.

Greyish-white, fibrous tremolite occurs also on range II, lot 4, of Alleyn, Que., where it forms large masses in a normal pyroxenite.

Vesuvianite.

Mentioned by Harrington as occurring with apatite in the township of Wakefield, Que. The occurrence seems doubtful, and its mention may, probably, be traced to the presence of well-formed vesuvianite crystals, at various localities in the above township, adjacent to the contact of crystalline limestone with dikes of pegmatite.

Wilsonite.

This mineral was first observed by Dr. Wilson, of Perth, Ont., probably in a pyroxenite. Its colour varies from white to a beautiful, peach-bloom pink, and the mineral usually occurs in massive form, without definite crystal outlines. In character and appearance wilsonite resembles an altered scapolite, and it is very probable that it really is an alteration product of this mineral. Sterry Hunt, however, dissented from this view and considered it to be altered gieseckite. It appears that plagioclase frequently alters to scapolite, and that the latter mineral then undergoes a further change to wilsonite. No specimens showing all three stages were found, but the three minerals were, on several occasions, observed at one and the same mine. Wilsonite is mainly identifiable by means of its conspicuous pink or mauve colour, and the passage of scapolite to wilsonite

is only to be recognized by the gradual change of shade of the mineral. No analysis of wilsonite is available, but it may be noted that Tschermak, Bauer, Naumann-Zirkel, Chapman, and others, regard the mineral as an altered scapolite, whilst Dana considers it to be altered pinite. A notable locality for wilsonite is lot 39, of the Gore of Templeton, Que., where it occurs in large quantities at the Briggs mine, generally in large, irregular masses, surrounded by small, crushed, and very dark mica, and embedded in granular apatite. It was also observed on range III, lot 2, of East Portland; range VI, lot 26, of Wakefield, both in the province of Quebec; and concession VIII, lot 2, of North Burgess, Ont.

Yttrocerite.

This rare mineral has been detected by Dr. W. F. Ferrier associated with fluorite, mica and chabazite, in specimens collected by the writer on range III, lot 1, of East Portland township, Que.

Zircon.

Recorded as an occasional occurrence with apatite at a number of mines in the Quebec phosphate region. The mineral would appear to have occurred particularly frequently on range XII, lots 12 and 21, and range XIII, lots 21 and 23, of the township of Templeton.

Harrington[1] records the occurrence of large crystals (up to 15 inches in length) from the above district. The habit is usually prismatic, a common combination being *m*, *p*, *u*, *x* (Dana), while the simple combination of prism and pyramid *m*, *p*, is also found. Distorted individuals are not infrequent. The colour ranges from hyacinth to cherry-red, brown, to greyish. The crystals are very brittle, and full of flaws, and often contain inclusions of either apatite, calcite, or mica. They usually occur embedded in apatite, calcite, pyroxene, mica, or orthoclase, and in the first case the apatite is generally of the "sugar" variety.

The writer has obtained small crystals of narrow prismatic habit and of a bright hyacinth colour and high lustre, from range III, lot 15, township of West Portland, Que. The crystals were enclosed in scapolite, which latter mineral is particularly abundant at this spot.

[1]Loc. cit., p. 29.

APPENDIX.

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INDEX.

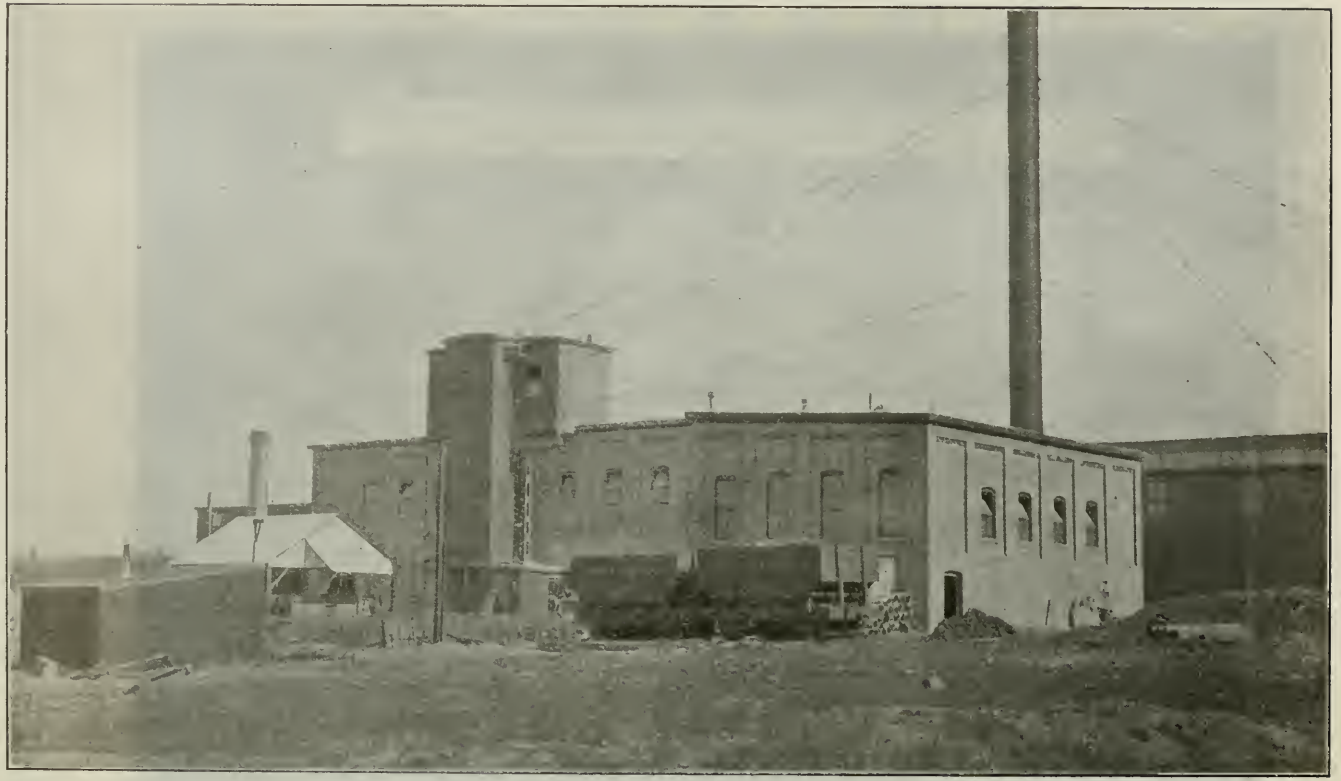
A

B

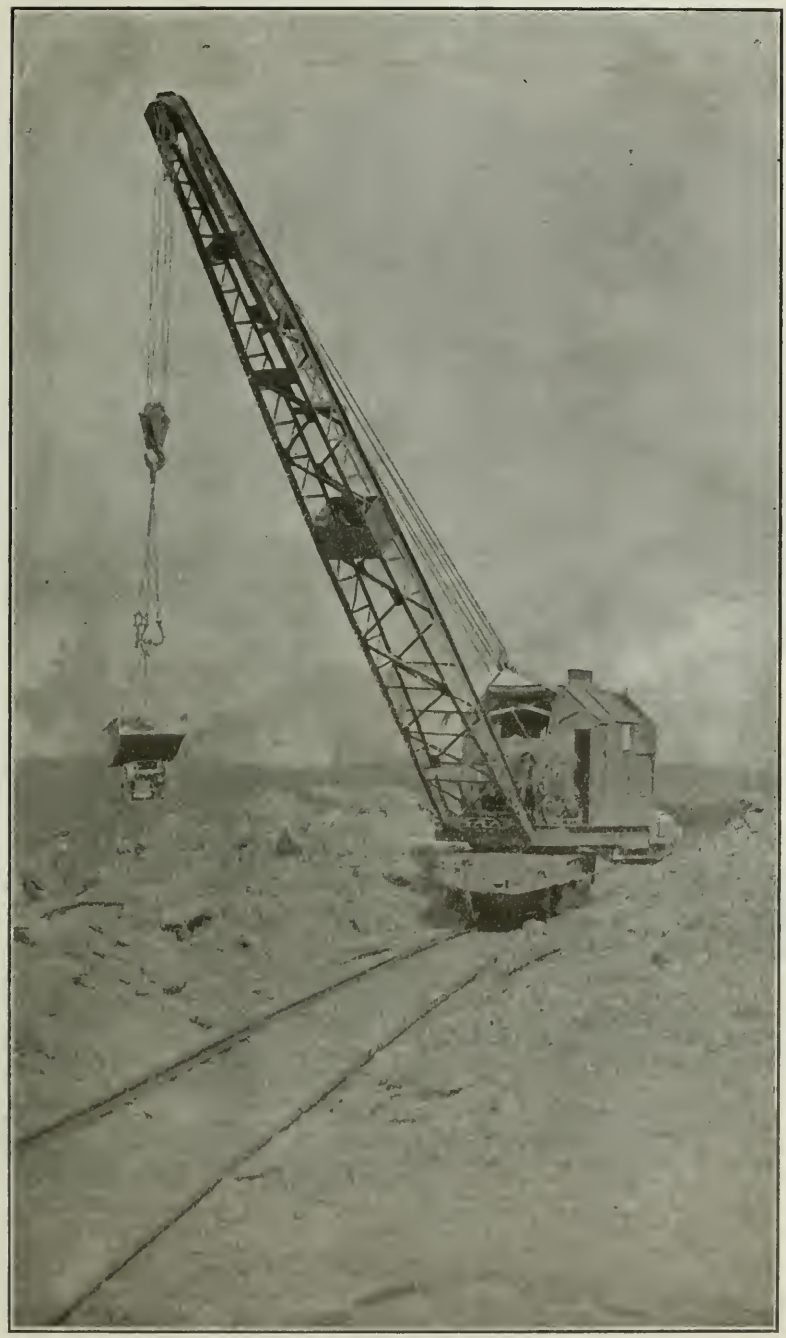
C

T

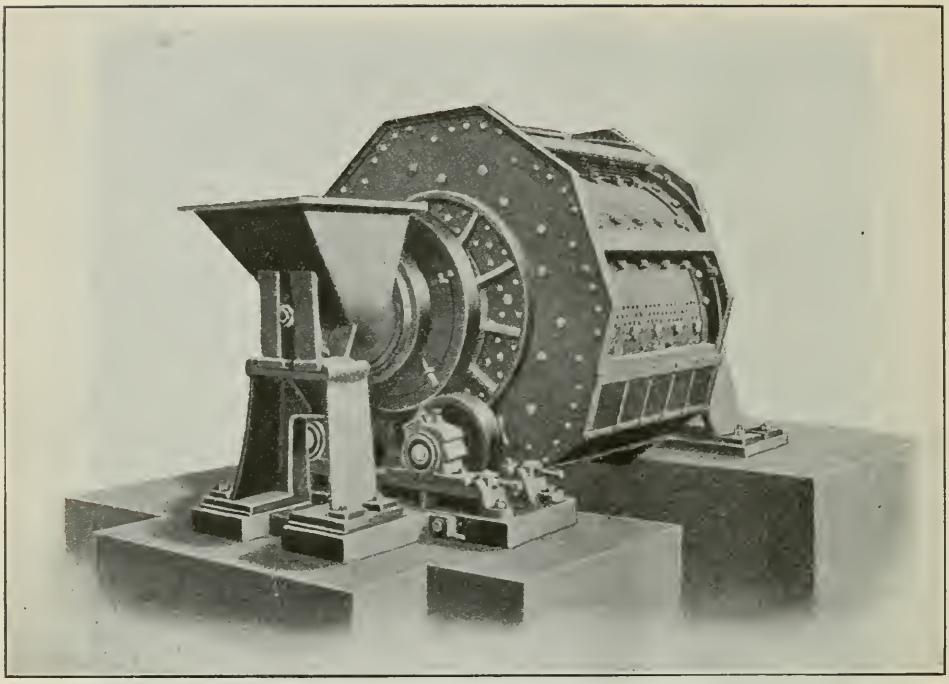
Varieties of Canadian apatite. The pieces marked A on the left are of the normal massively crystalline type; those marked B are coarse to medium grained "sugar" apatite; C is fine grained "sugar" apatite; D rounded nodules of massive apatite enclosed in "sugar" apatite, (the nodules probably represent resorbed apatite crystals); and E massively crystalline apatite traversed by small veins of "sugar" phosphate.



Mill building of the Cross Fertilizer Co., at Sydney, C.B.

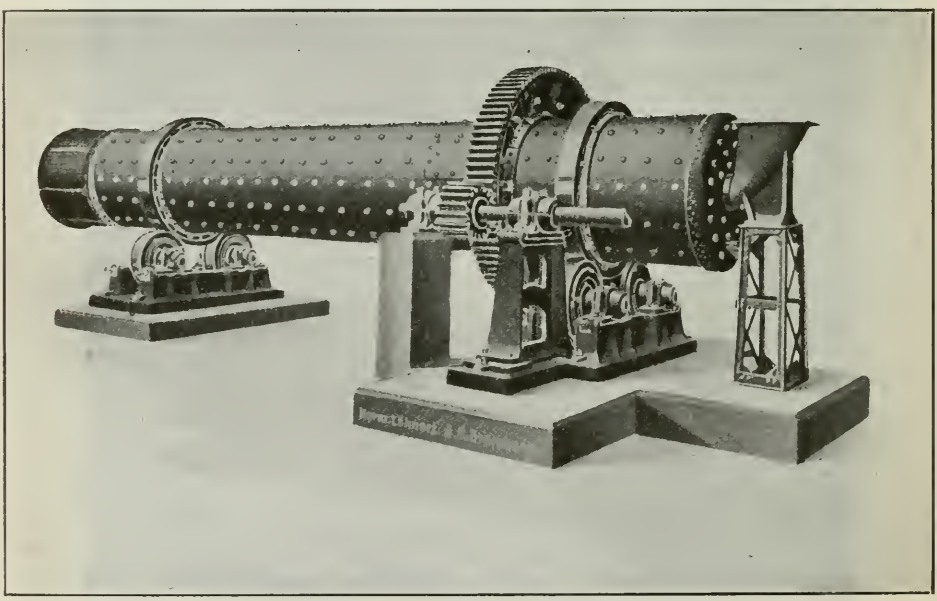


Loading basic slag, Cross Fertilizer Company's Works, Sydney, C.B.



Löhnert axleless ball mill, for grinding basic slag.

PLATE V.



Löhnert steel ball tube mill, for grinding basic slag.

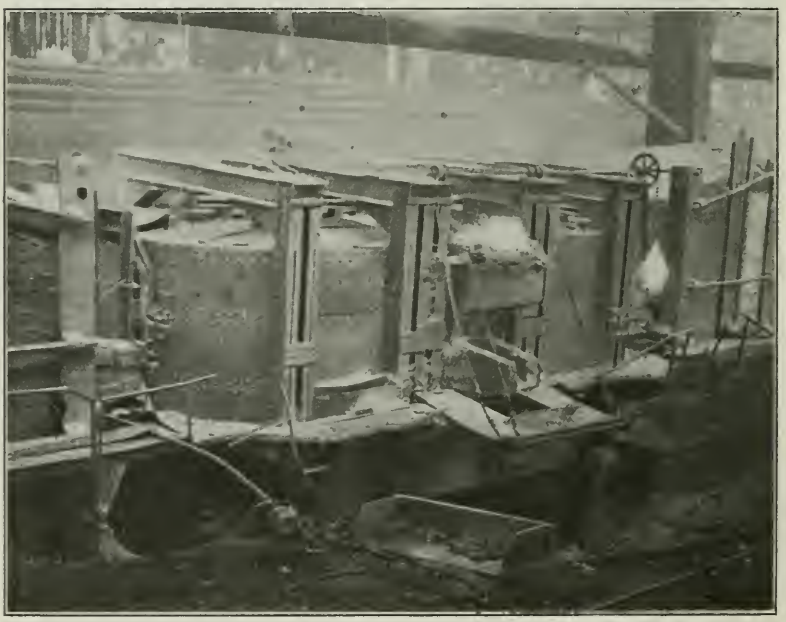
(Photo, F. H. Sexton)

Basic Bessemer converter during blow, at works of Dominion Iron and Steel Co., Sydney, C.B.

(Photo F. H. Sexton)

Basic open-hearth furnace—charging side—at Dominion Iron and Steel Company's works, Sydney, C.B.

PLATE VIII.



(Photo F. H. Sexton)

Fifty-ton basic open-hearth furnace—tapping side—at Dominion Iron and Steel Company's works, Sydney, C.B.

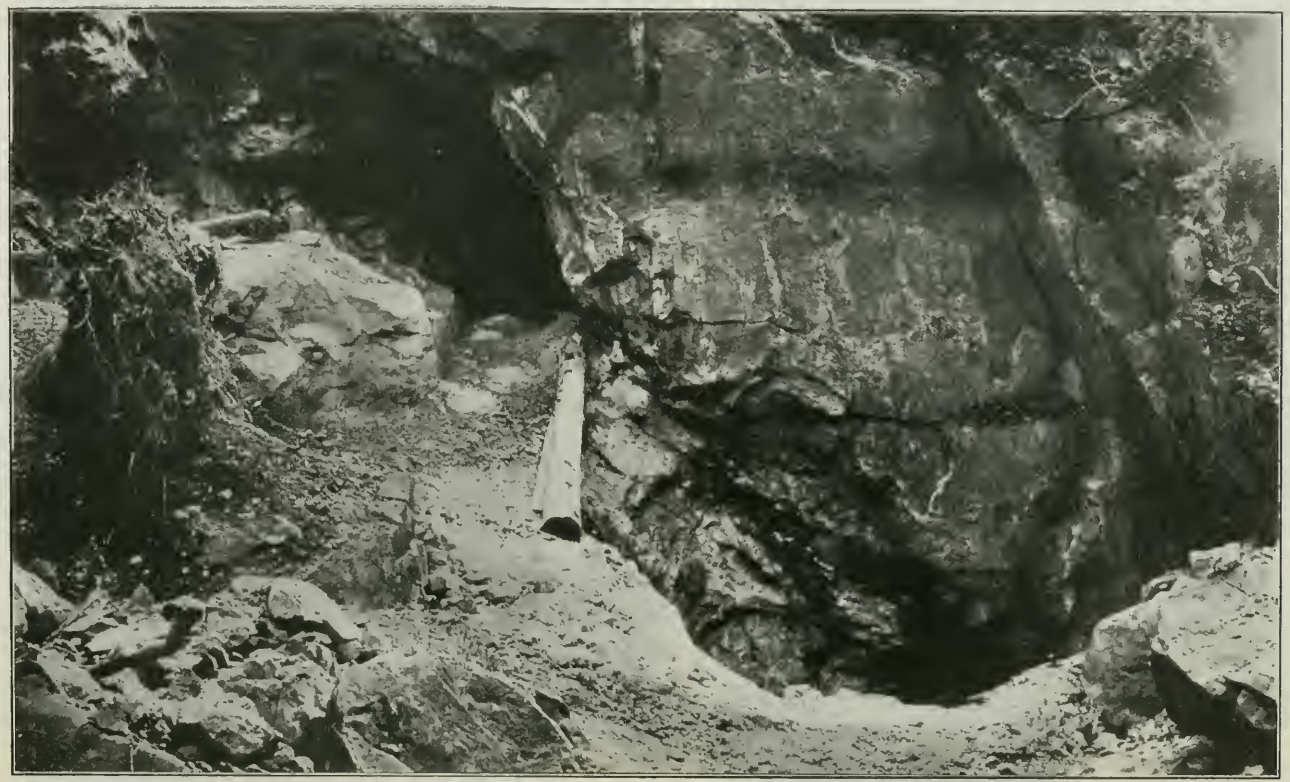
PLATE IX.

(Photo. M. E. Wilson, 1912)

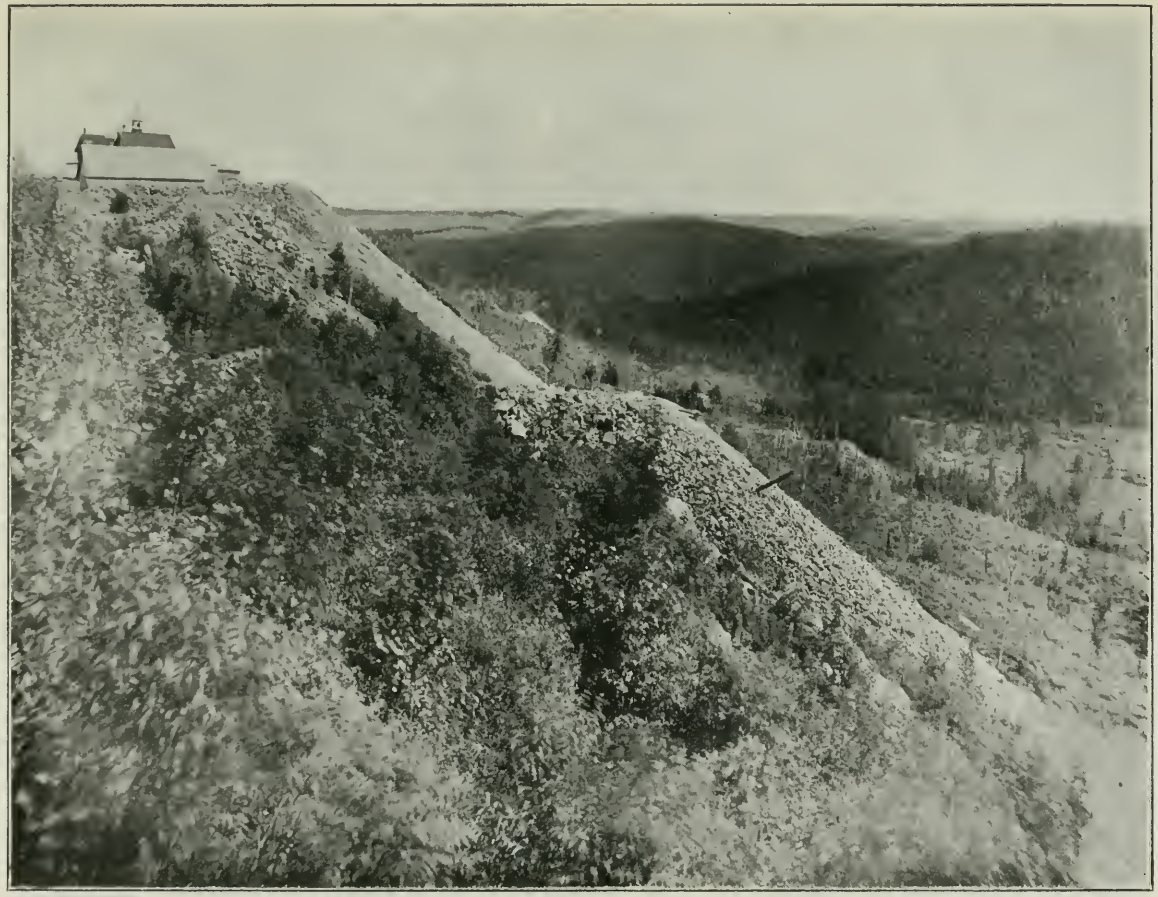
General view of hill at Little Rapids mine, township of Portland East, Que., showing upper and lower workings. The general strike of the mica-apatite leads is indicated by the dotted line. The view illustrates the typical physiographical features of the Quebec mica-apatite region—low ridges of granite-gneiss covered by second growth birch, maple, and poplar.

PLATE X.

Apophyses from main diabase intrusion, cutting pegmatite, Little Rapids mine, township of Portland East, Que.



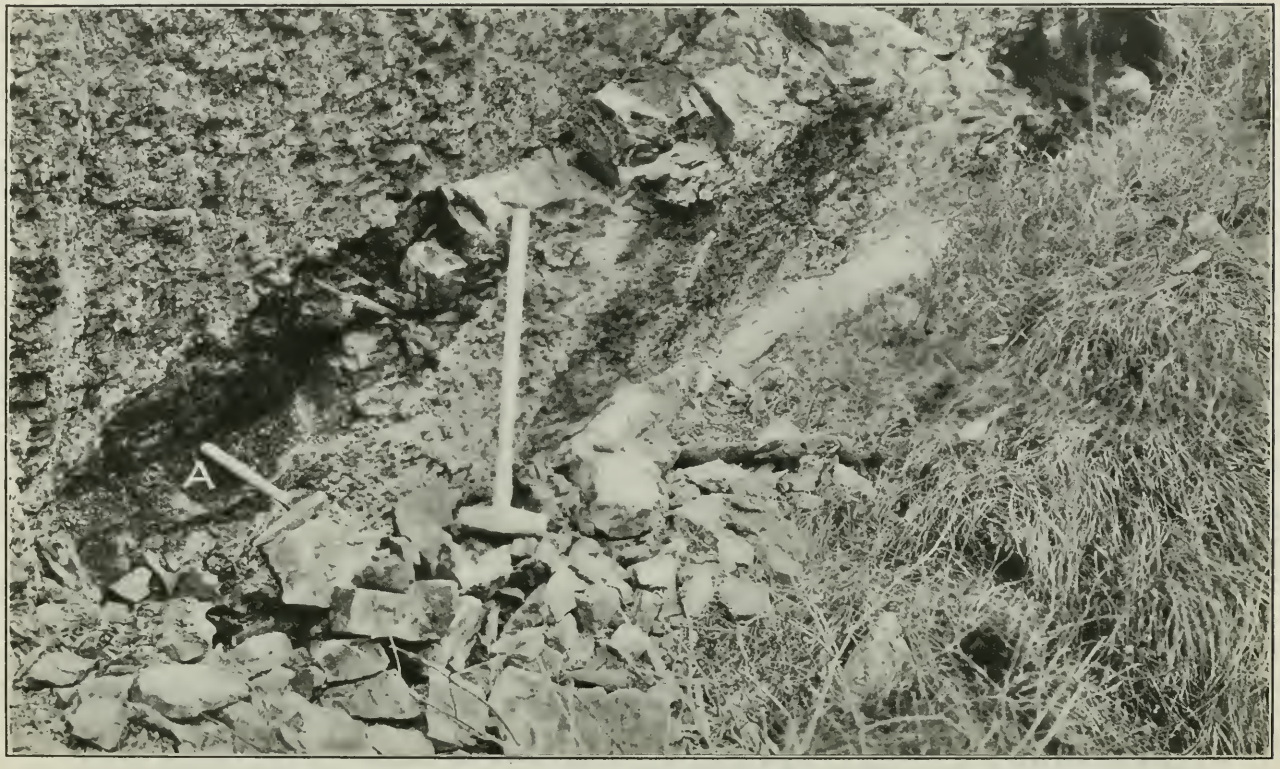
Drift and pit on inclined, pockety mica-apatite lead, range III, lot I, township of East Portland, Que. This illustrates the mode of occurrence and common method of working of the leads.



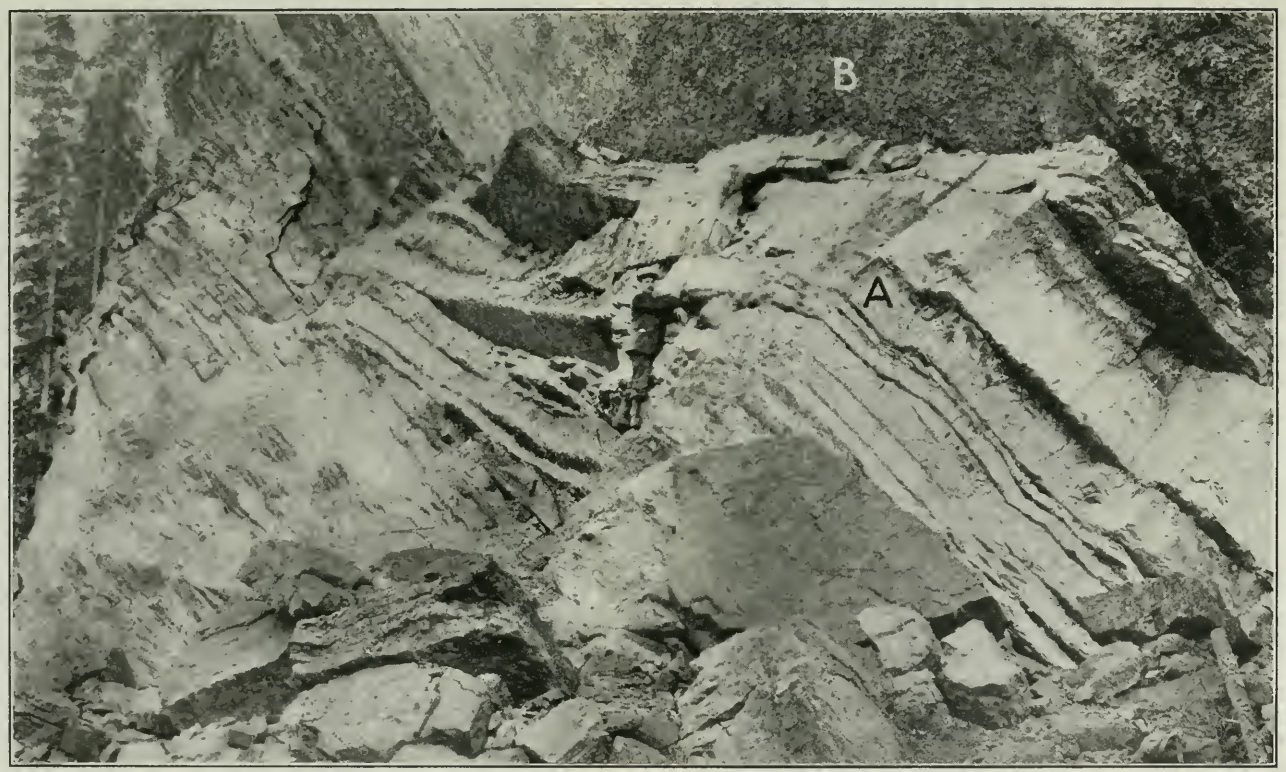
High Rock mine, township of Portland West, Que.; view of southeast side of ridge, showing rock dumps. (Photograph taken when the mine was being worked, about 1890). This view illustrates the general topographic features of the Quebec phosphate area.

Open cut on apatite lead, McCrae mine, township of Templeton, Que. Ordinary method of working surface showings of phosphate and mica on vertical veins.

Apatite crystals with pitted faces, township of Templeton, Que.



Main phosphate bed (A) Sundance canyon, Banff, Alberta. The thickness of the bed here is 11 inches.



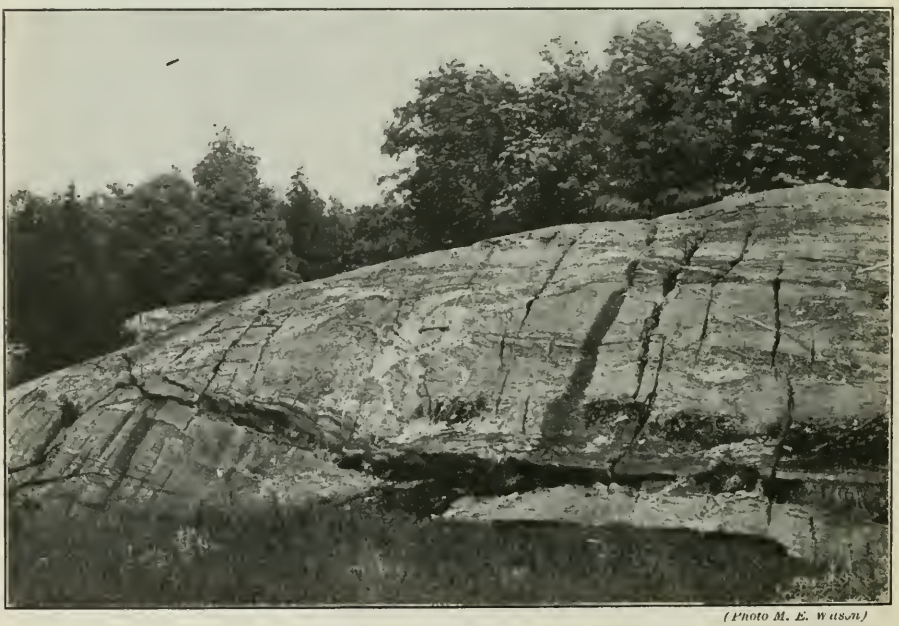
Main phosphate bed (A) and Phosphoria series (phosphatic quartzites and shales), Sundance canyon, Banff, Alberta. The main bed here measures 18 inches.

PLATE XVII.

(Photo M. E. Wilson)

View of the Lièvre River valley, Que., looking southeast from the Ross Mountain phosphate mine, showing the village of La Salette. The spot from which the photograph was taken is the southerly end of the ridge upon which the chief apatite mines of the Province were opened; these included the Crown Hill, High Rock, Star Hill, Ross Mountain, and Central Lake mines. The view illustrates the general nature of the terrain in the Quebec apatite region—low, wooded hills of granite-gneiss, crystalline limestone and pyroxenite, separated by clay flats.

PLATE XVIII.



(Photo M. E. Watson)

Typical exposure of garnet gneiss, township of Templeton, Que., showing pegmatite stringers. Such "hogs-backs" of gneiss are characteristic of the apatite regions of both Quebec and Ontario.

PLATE XIX.

(Photo. M. E. Wilson.)

Characteristic weathering surface of Grenville crystalline limestone, showing inclusions of harder, hornblendic rock, range IX, lot 13, township of Buckingham, Que.

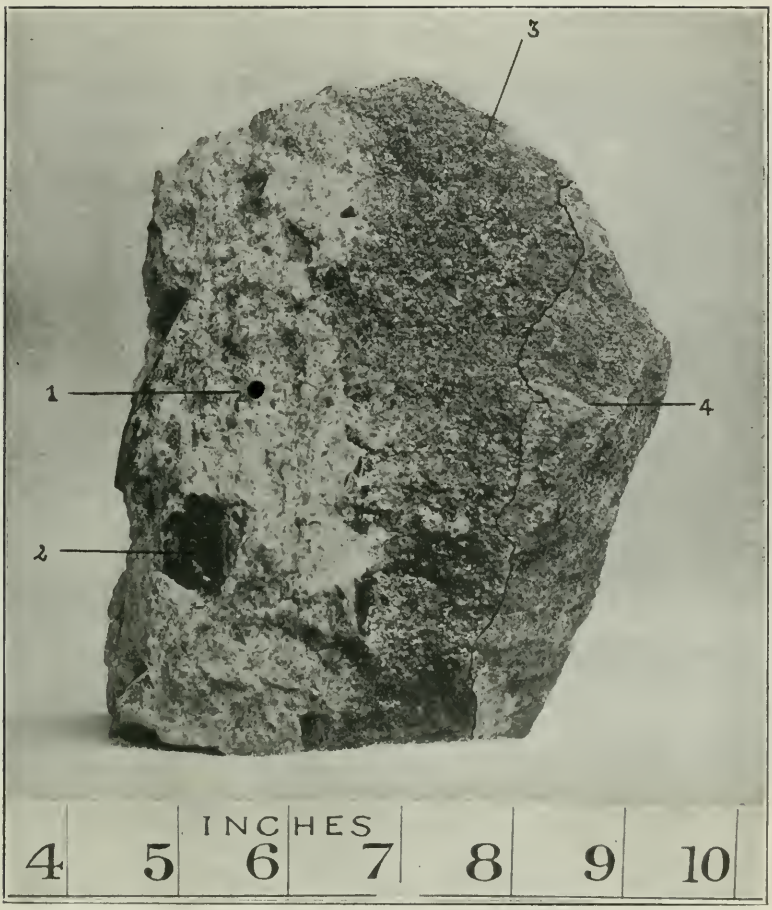
PLATE XX.

(Photo. M. E. Wilson.)

Pyroxenite (dark) invaded by pegmatite (light), Walker mine, township of Buckingham, Que.

(Photo. M. E. Wilson, 1913)

Banded garnet-gneiss, township of Derry, Que. This is the predominant rock type in the Quebec phosphate area.



Piece of vein of green, massively crystalline apatite (1), showing included phlogopite crystal (2), zone of mixed pyroxene-spangle mica (3), and pyroxenite proper (4). From concession VIII, lot 2, township of North Burgess, Ont.

Piece of mica-apatite vein, showing mica crystals along the walls (1); next, a narrow zone of small, spangle mica (2); vein filling of granular "sugar" phosphate (3) with included mica crystals, and, in the centre a narrow strip of pink calcite (4). In the original specimen there is a close approach to development of flow structure, which is lost in the photograph; this structure is probably due to incipient parallel banding of the mica and phosphate particles, caused by squeezing of the vein. Specimen from range I, lot 16, township of Wakefield, Que.

Pink calcite with small apatite crystals disseminated through it. Such material is the characteristic gangue of mica-apatite leads and pockets.

Large crystals of pyroxene (salite) lining the wall of a mica-apatite lead, Connor mine, township of Hull, Que.

Section through crystal of pyroxene altered through the agency of a pegmatitic intrusion to hornblende. A, white calcite; B, outer zone of earthy, structureless mineral; C, inner zone of fibrous hornblende; D, crystal of titanite. From Lake Girard mine, township of Wakefield, Que.

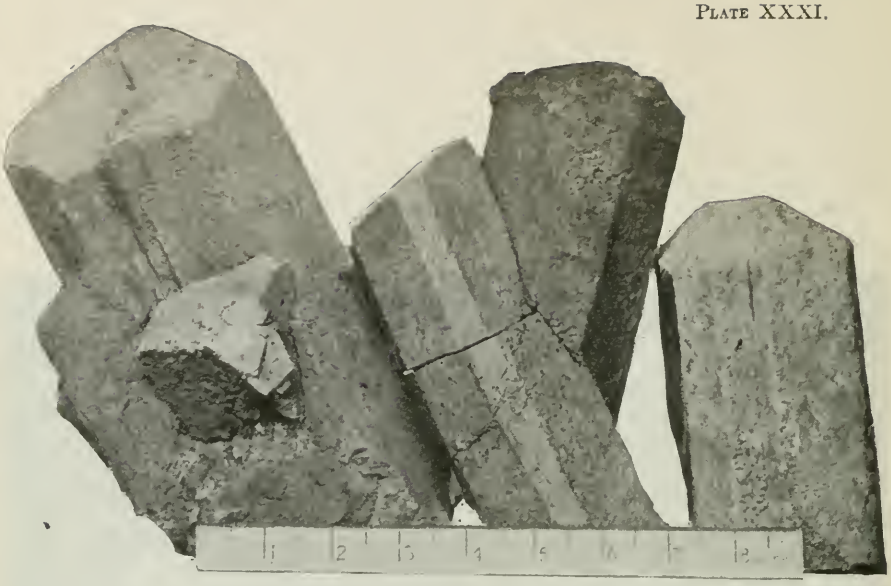
Pyroxenite (P) invaded along shrinkage or fracture channels by pegmatitic material (A), the latter probably representing later acid apophyses from the batholithic granite-gneiss which brought about the formation of the pyroxenites themselves. The pyroxenite along the immediate contacts is slightly darker in colour, but otherwise is unaltered. The dark crystals (S) in the feldspar are titanite. Specimen from Little Rapids mine, township of Portland East, Que.

Specimen showing intimate association of apatite (A), scapolite (S), feldspathic rock (F), pyroxene (P), from the Star Hill mine, township of Portland West, Que.

Group of apatite crystals, showing rounded, pitted and glazed faces. From township of North Burgess, Ont.

Amianthus asbestos, from a contact between aplite and pyroxenite, township of Hull, Que. The mineral is not uncommon in such association, but it is of poor quality, and the narrow stringers possess no economic importance.

PLATE XXXI.



Large crystals of pyroxene, from the township of Hull, Que. (See also Plate XXV.)

PLATE XXXII.

Large crystals of scapolite, from range III, lot 15, township of Portland West, Que.

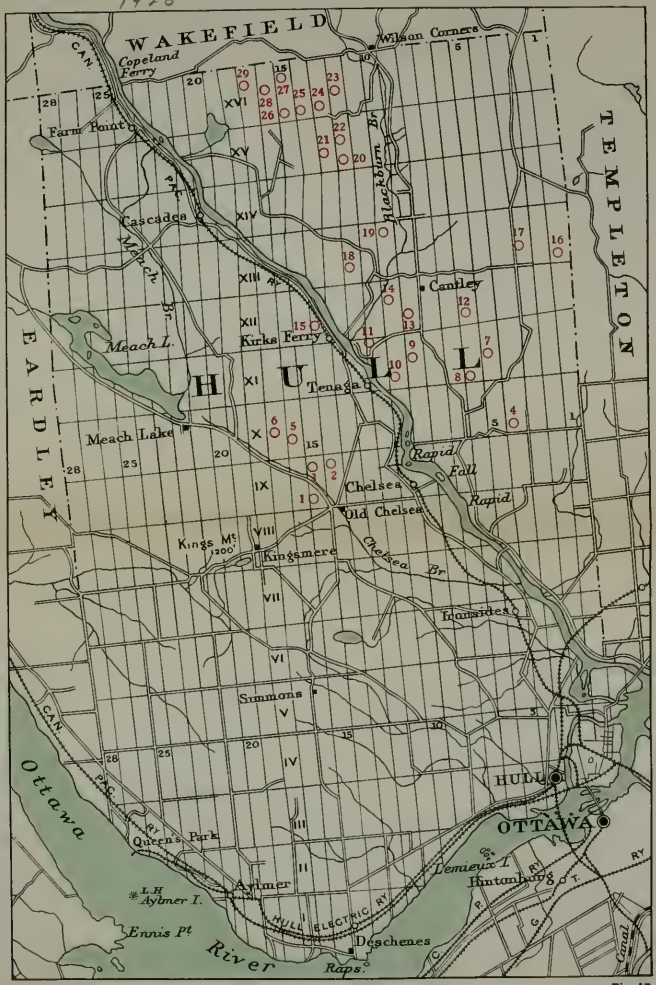
17	Prospect
18	Gemmill
19	McLelland
20	Dacey
21	Connor
22	McAllister
23	Moore
24	Wilson and Stewart
25	Wilson and Stewart
26	Cassidy
27	
28	Horseshoe
29	

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF HULL, QUEBEC
Scale: 2 miles to 1 inch

1 ½ 0 1 2 3 4

Fig. 17

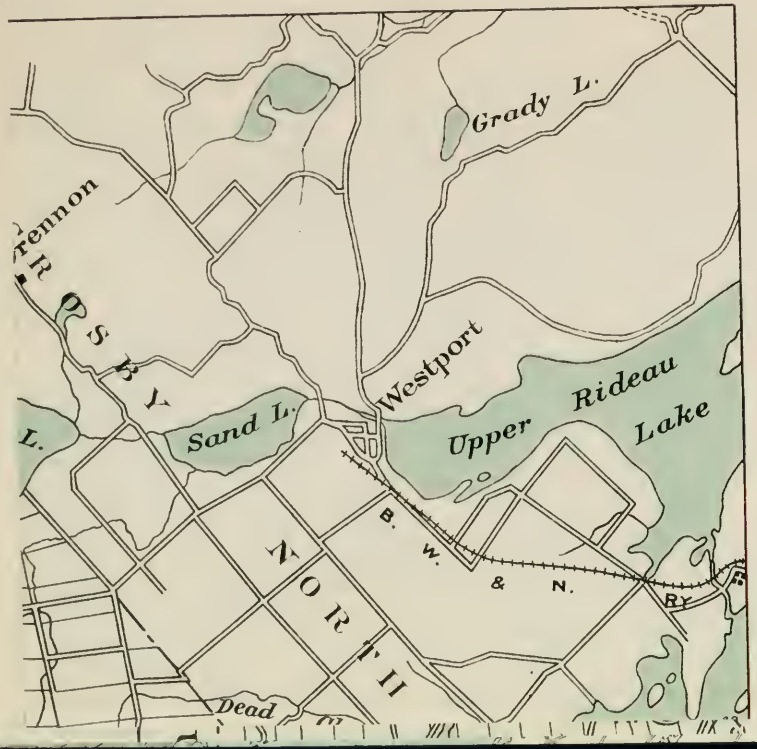


No.	Name of Mine
1	Sweeny
2	Scott
3	
4	Barrett
5	Prospect
6	Haycock
7	Kearney
8	
9	Prospect
10	Nellie and Blanche
11	Featherstone
12	Prospect
13	Prospect
14	Vavasour
15	Gemmill
16	Burke
17	Prospect
18	Gemmill
19	McLelland
20	Dacey
21	Connor
22	McAllister
23	Moore
24	Wilson and Stewart
25	Wilson and Stewart
26	Cassidy
27	
28	Horseshoe
29	

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF HULL, QUEBEC
Scale: 2 miles to 1 inch
1 ½ 0 1 2 3 4

Fig. 17



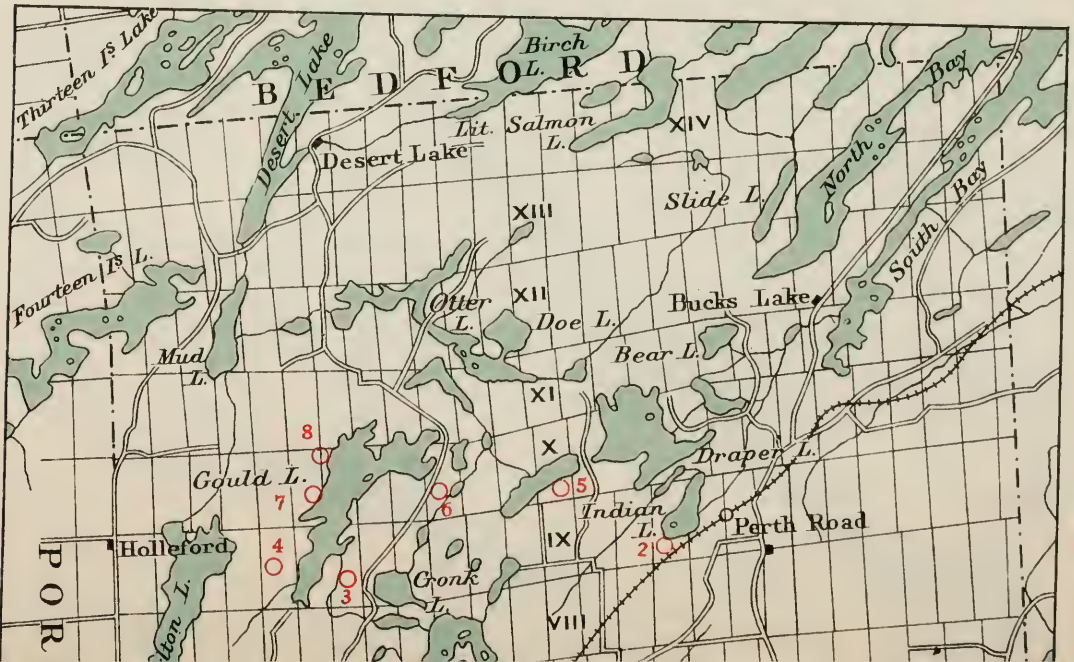
No.	Name of Mine
1	Opinicon Lake
2	Prospect
3	Prospect
4	Prospect
5	Prospect
6	Webster
7	
29	
30	Thompson
31	Grier

No.	Name of Mine
1	Opinicon Lake
2	
3	
4	Prospect
5	
6	Webster
7	
8	McLaren
9	
10	Prospect
11	Bobs Lake
12	
13	Anglo-Canadian Phosphate Co.
14	
15	
16	
17	Eagle Lake
18	

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF BEDFORD, ONTARIO
Scale: 2 miles to 1 inch

Fig. 8



No.	Name of Mine
1	Lacey
2	Sterling
3	Prospect

No.	Name of Mine
1	Lacey
2	Sterling
3	Prospect
4	Coe
5	Foxton
6	Sloan
7, 8	Gould Lake

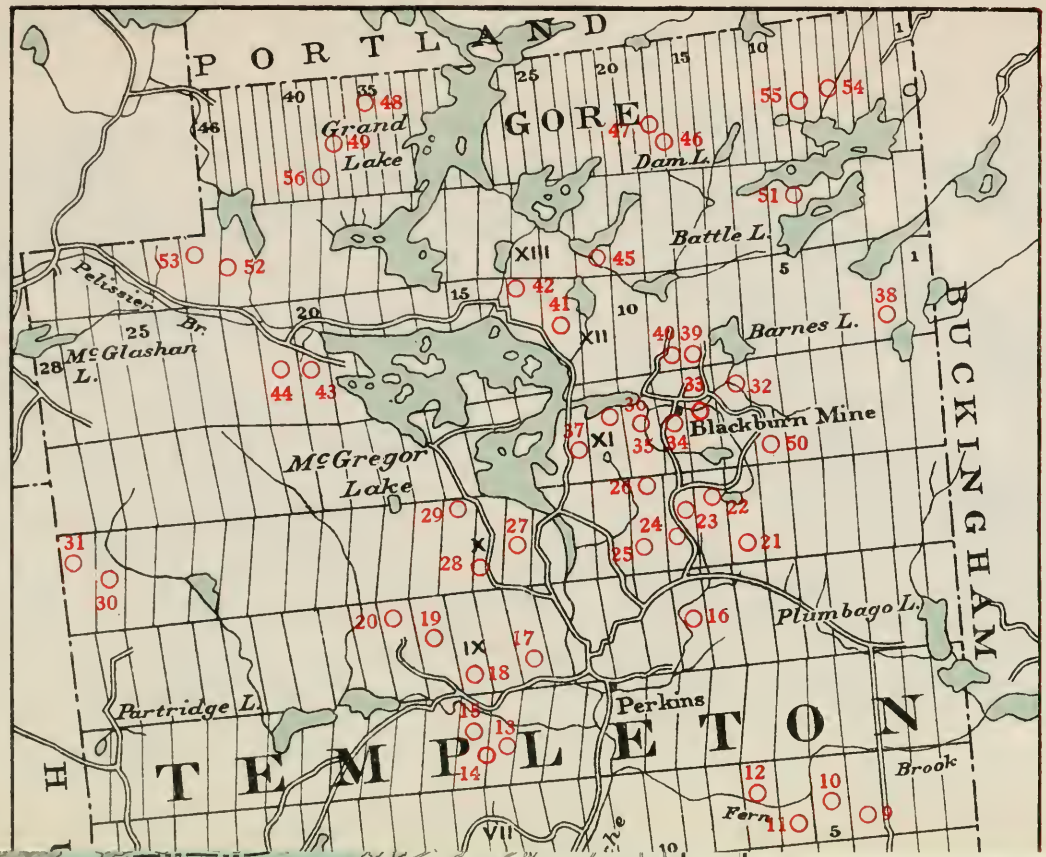
○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF LOUGHBOROUGH, ONTARIO

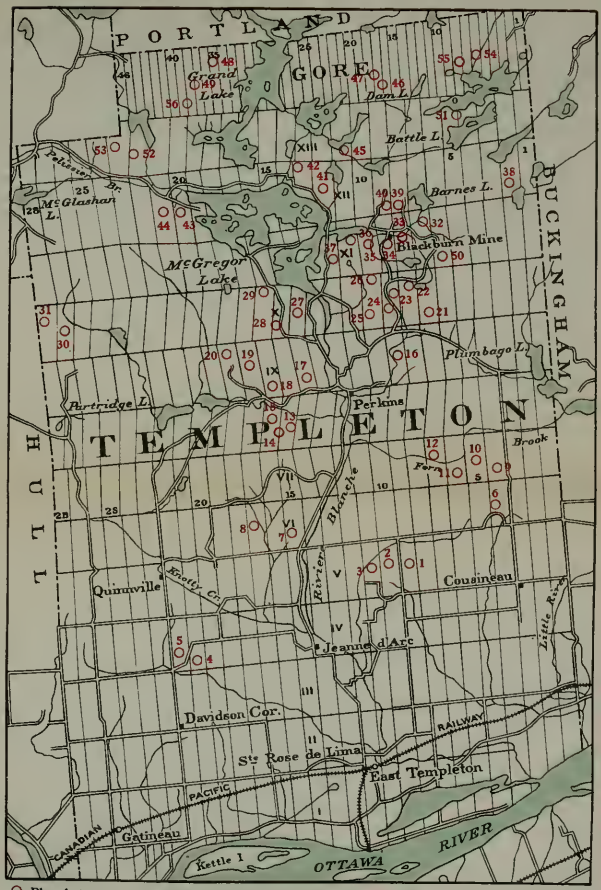
Scale: 2 miles to 1 inch

1 ½ 0 1 2 3 4

Fig. 9



No.	Name of Mine
1	
2	McRae
3	
4	McTiernan
5	McVeity
6	McIntosh
7	Brady
8	Canadian Industrial Company
9	
10	McLaren
11	
12	Grier
13	Rainville or Dugas
14	Phosphate King
15	Wallingford
16	Coursolles and Belcourt
17	Wellington
18	Canada Industrial Company
19	Goldring
20	
21	Grier
22	Marsolais
23	Post
24	Jackson-Rae
25	Murphy
26	Jubilee or Smith
27	Pearson
28	Victoria
29	
30	Thompson
31	Grier



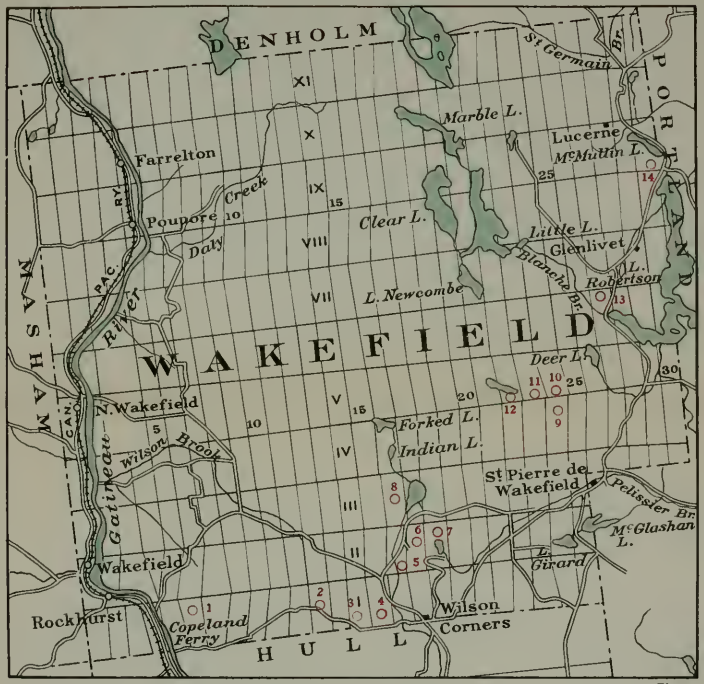
○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF TEMPLETON, QUEBEC
Scale: 2 miles to 1 inch
1 ½ 0 1 2 3 4

Fig. 25

No.	Name of Mine
1	
2	McRae
3	
4	McTiernan
5	McVeity
6	McIntosh
7	Brady
8	Canadian Industrial Company
9	
10	McLaren
11	
12	Grier
13	Rainville or Dugas
14	Phosphate King
15	Wallingford
16	Coursolles and Belcourt
17	Wellington
18	Canada Industrial Company
19	Goldring
20	
21	Grier
22	Marsolais
23	Post
24	Jackson-Rae
25	Murphy
26	Jubilee or Smith
27	Pearson
28	Victoria
29	
30	Thompson
31	Grier
32	
33	
34	Blackburn
35	
36	
37	Stewart
38	Miller
39	McLaurin
40	
41	Templeton and North Ottawa Mining Co.
42	Prospect
43	Laurin
44	Templeton and North Ottawa Mining Co.
45	Prospect
46	Blackburn
47	
48	Allan and Fleming
49	Murphy
50	Prospect
51	Battle Lake
52	Breckin
53	
54	Prospect
55	Rheaume Lake
56	Briggs or Stewart

No.	Name of Mine
1	McBride
2	Haldane
3	Mullins
4	Comet
5	Kodak
6	Kitty Lynch or Morris
7	Seybold or Moore
8	Thompson
9	
10	Gemmill



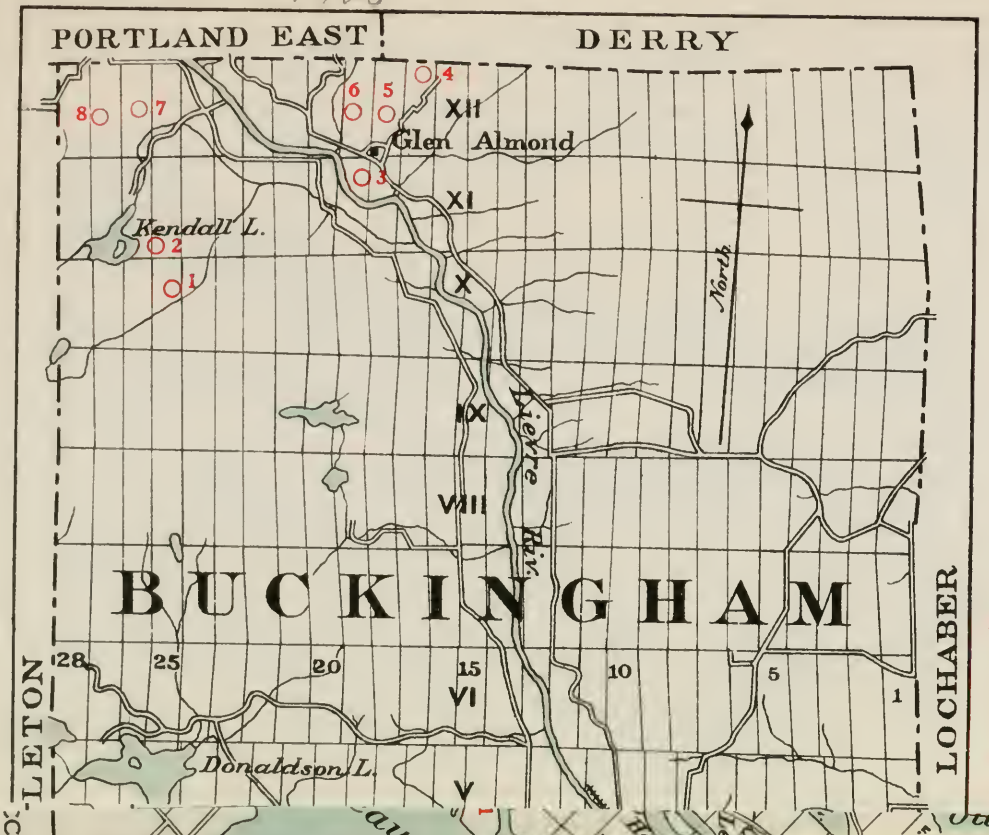
No.	Name of Mine
1	McBride
2	Haldane
3	Mullins
4	Comet
5	Kodak
6	Kitty Lynch or Morris
7	Seybold or Moore
8	Thompson
9	
10	Gemmill
11	
12	
13	McGlashan
14	Harris

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF WAKEFIELD, QUEBEC

Scale: 2 miles to 1 inch
1 ½ 0 1 2 3 4

Fig 27



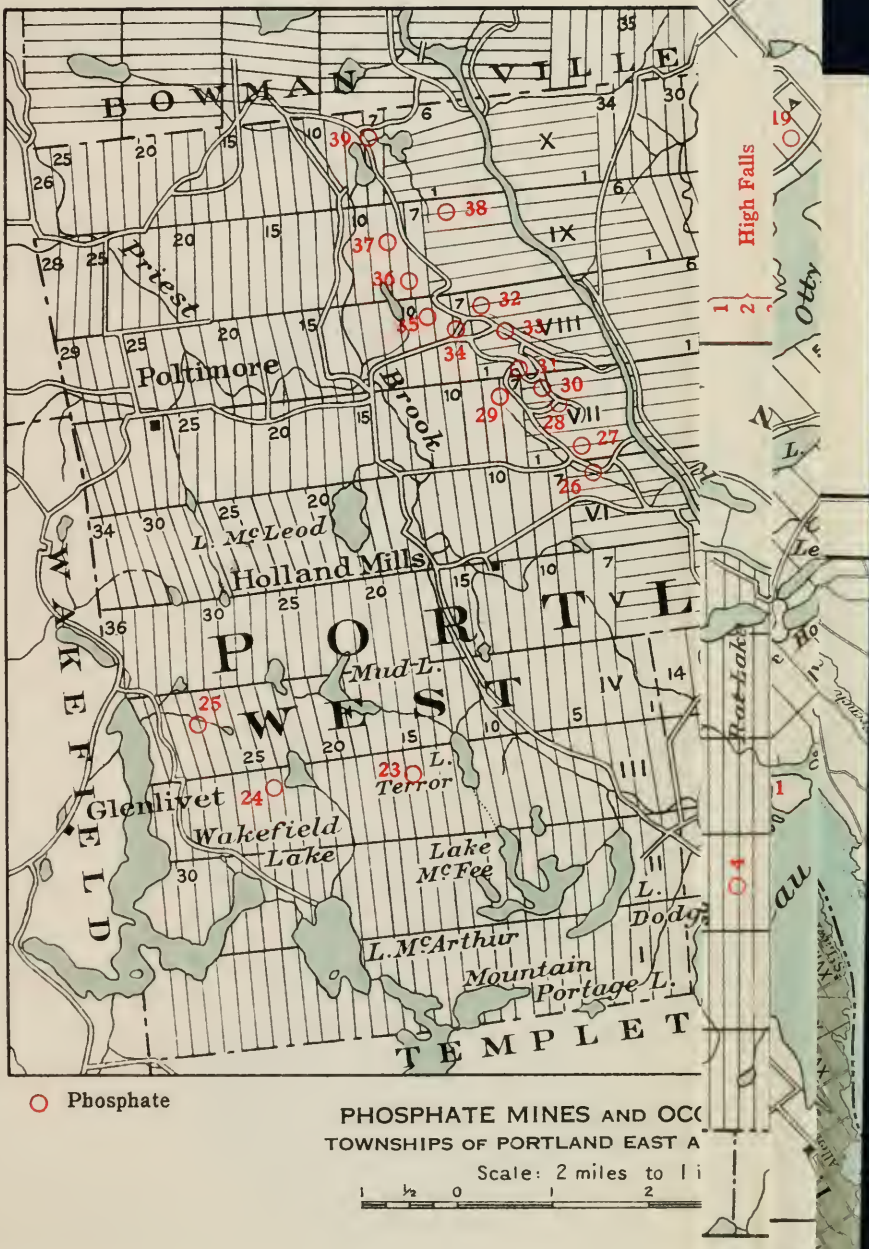
No.	Name of Mine
1	Prospect
2	Kendall
3	Washington or Lansdowne
4	Aetna
5	Squaw Hill
6	Emerald

No.	Name of Mine
1	Prospect
2	Kendall
3	Washington or Lansdowne
4	Aetna
5	Squaw Hill
6	Emerald
7	Vennor
8	Prospect

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF BUCKINGHAM, QUEBEC
Scale: 2 miles to 1 inch

Fig. 15



○ Phosphate

PHOSPHATE MINES AND OCC
TOWNSHIPS OF PORTLAND EAST A

Scale: 2 miles to 1 i

1 ½ 0 1 2

No.	Name of Mine
1	Fowler and Bacon
2	Little Rapids
3	
4	
5	London
6	
7	Watts
8	
9	French Co.
10	
11	O'Brien
12	Glasgow
13	
14	Chapleau
15	
16	Salette
17	North Star or Haycock
18	Craft
19	French Co.
20	Philadelphia
21	Cameron
22	Bradley
23	Prospect
24	Prospect
25	Allan and Fleming
26	Ross Mountain
27	
28	Crown Hill or Little Union
29	
30	High Rock
31	
32	Chapleau
33	
34	
35	Star Hill or Old Unioo
36	
37	
38	
39	Central Lake

○ Phosphate

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIPS OF PORTLAND EAST AND WEST, QUE.

Scale: 2 miles to 1 inch

Fig. 23

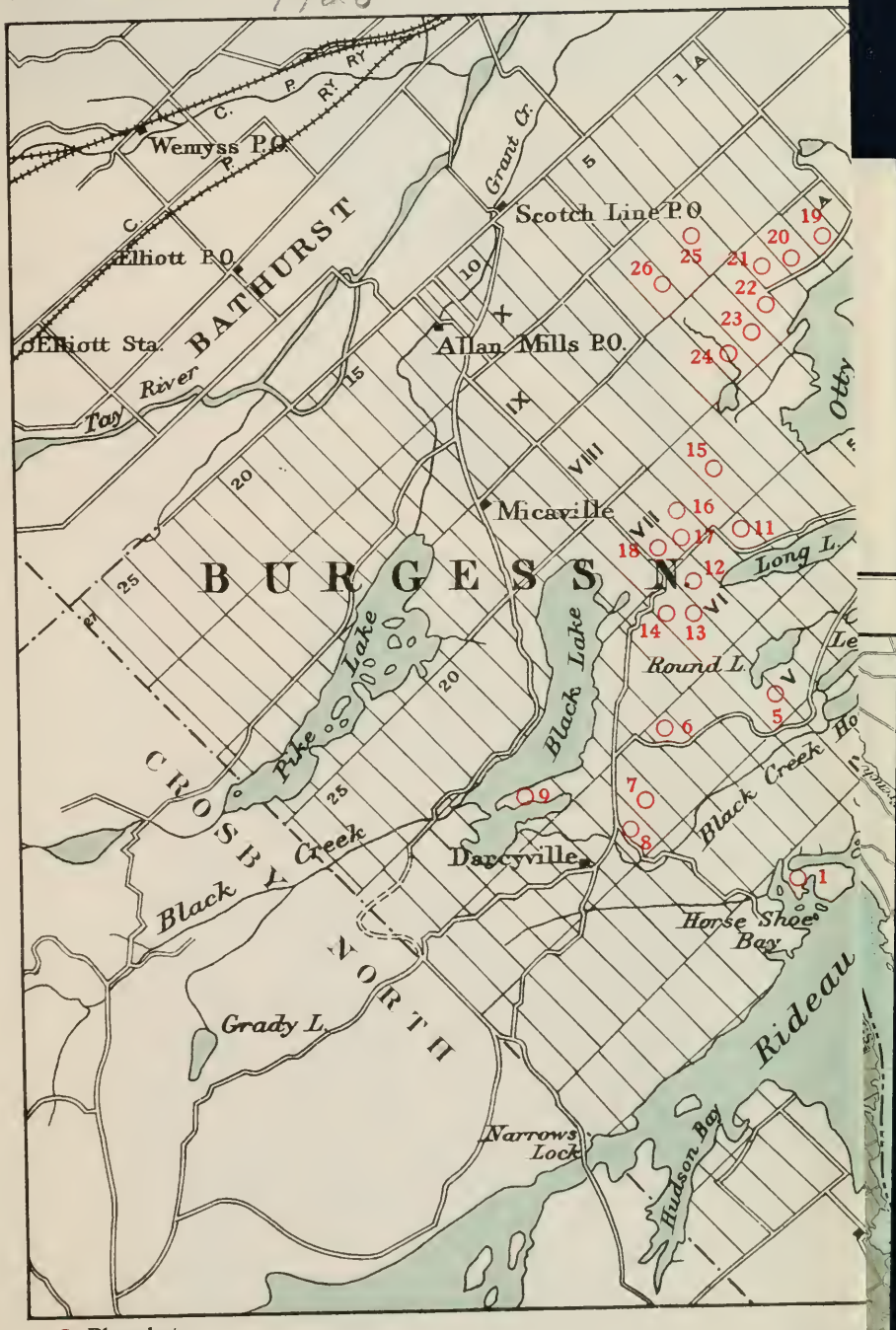
No.	Name of Mine
1	
2	High Falls

○ Phosphate

Fig.14

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF BOWMAN, QUEBEC

Scale. 2 miles to 1 inch

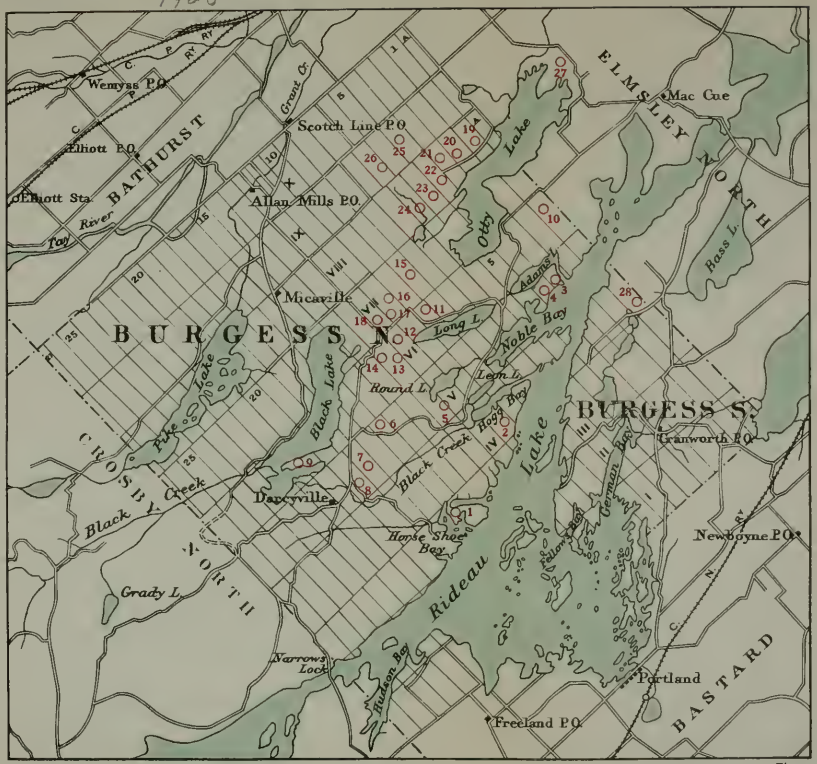


○ Phosphate

PHOSPHATE MINES AND OCCUP
TOWNSHIPS OF BURGESS NORTH AND SO

Scale: 2 miles to 1 inch

1 ½ 0 1 2 3



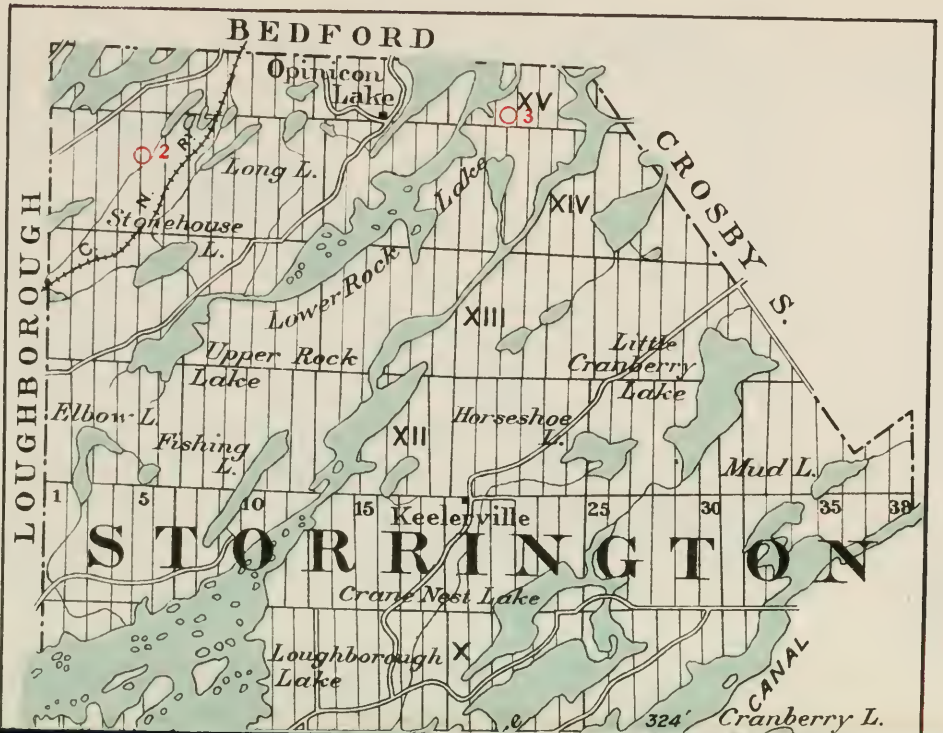
No.	Name of Mine
1	Philips
2	Clark
3, 4	Rideau Mining Co.
5	Silver Queen
6	Donnelly
7, 8	Matheson and Bell
9	Star Hill
10	McMartin
11	Old Anthony
12	Prospect
13	Martha
14	Munslow
15, 16	Otter
17	Cowan
18	Byrnes
19	Otty Lake
20	Matheson
21	Ritchie and Jackson
22, 23, 24	MacLaren
25	Atcheson
26	Anglo-Canadian Phosphate Co.
27	Prospect
28	Cantin

○ Phosphate

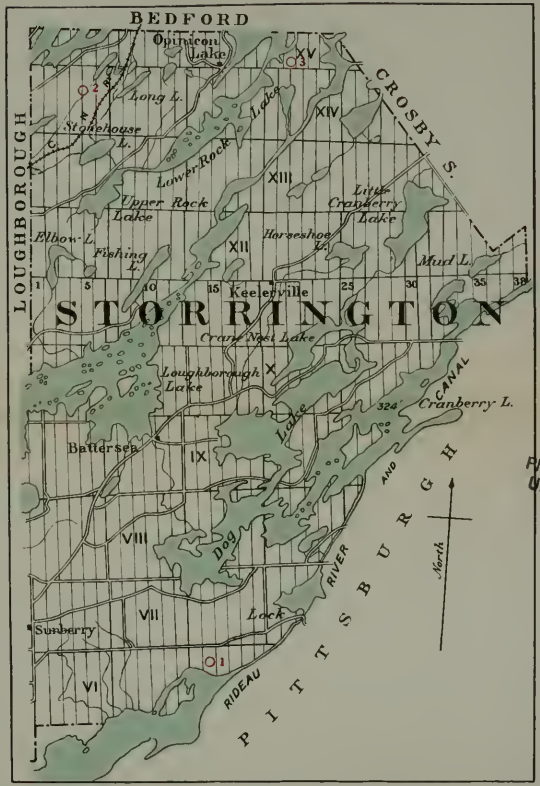
Fig. 12

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIPS OF BURGESS NORTH AND SOUTH, ONTARIO

Scale: 2 miles to 1 inch
1 ½ 0 1 2 3 4



No.	Name of Mine
1	Morris
2	Bawden



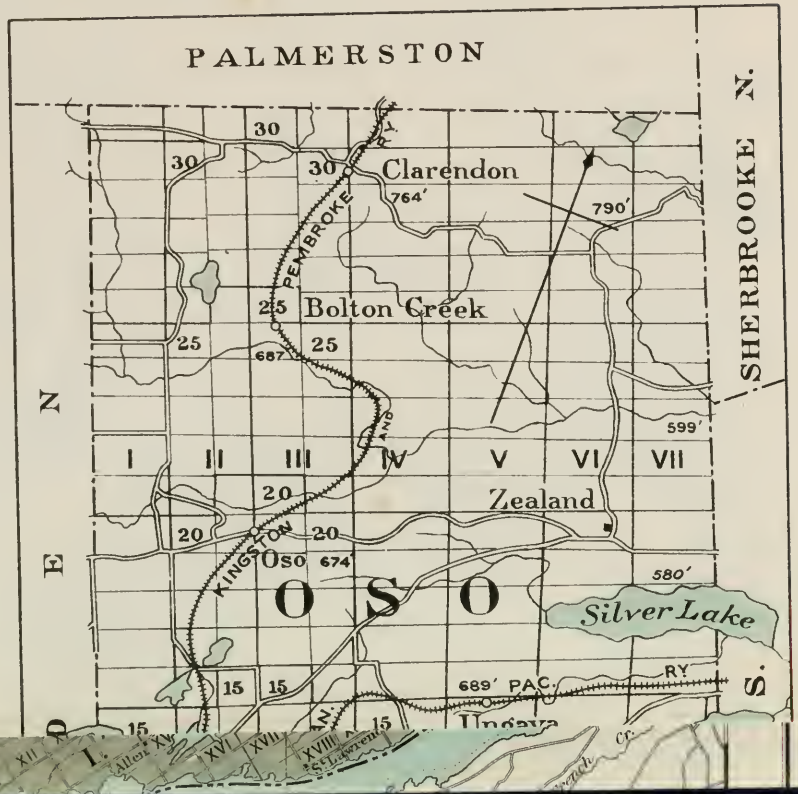
No.	Name of Mine
1	Morris
2	Bawden
3	Opinicon or Rock Lake

O Phosphate

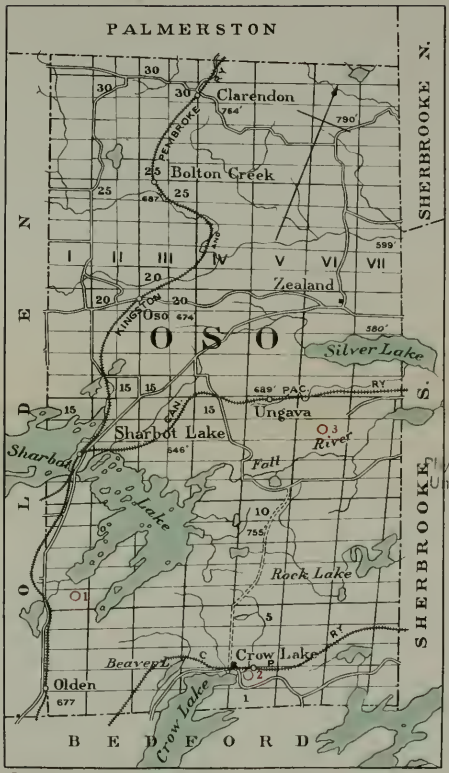
PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF STORRINGTON, ONTARIO

Scale: 2 miles to 1 inch

Fig. 11



No.	Name of Mine
1	St. George Lake
2	Wilson and McMartin
3	Silver Lake



No.	Name of Mine
1	St. George Lake
2	Wilson and McMartin
3	Silver Lake

Phosphate

Fig. 10

PHOSPHATE MINES AND OCCURRENCES
TOWNSHIP OF OSO, ONTARIO
Scale- 2 miles to 1 inch

CANADA

DEPARTMENT OF MINES

MINES BRANCH

HON. T. C. CASGRAIN, Minister — W. [illegible], Deputy Minister

EUGENE HAANEL, Ph.D., Director

1916

Base map from plate Dept. of the Interior

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MAP

SHOWING LOCATION

OF THE

PRINCIPAL MINES AND OCCURRENCES

IN THE

QUEBEC PHOSPHATE AREA

PHOSPHATE

PALÆOZOIC ROCKS (CAMBRO-SILURIAN)

LAURENTIAN

Scale 20chns or 3.95 miles to one inch