SUMMARY REPORT

OF THE

MINES BRANCH

OF THE

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR ENDING DECEMBER 31

1916

PRINTED BY ORDER OF PARLIAMENT

OTTAWA
PRINTED BY J. DE L. TACHÉ, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1917

[No. 26a—1917.] 29417c [No. 454]

To His Excellency The Duke of Devonshire, K.G., P.C., G.C.M.G., G.C.V.O., etc., etc., Governor-General and Commander-in-Chief of the Dominion of Canada.

MAY IT PLEASE YOUR EXCELLENCY,—

The undersigned has the honour to lay before Your Excellency, in compliance with 6–7 Edward VII, chapter 29, section 18, Summary Report of the work of the Mines Branch of the Department of Mines during the Calendar year ending December 31, 1916.

(Signed) **Albert Sévigny,**

Acting Minister of Mines.

HON. ALBERT SÉVIGNY,
Acting Minister of Mines,
Ottawa.

SIR,—I have the honour to submit herewith, the Director's Summary Report of the work of the Mines Branch of the Department of Mines during the calendar year ending December 31, 1916.

I am, Sir, your obedient servant,
(*Signed*) **R. G. McConnell,**
Deputy Minister.

CONTENTS.

PAGE

DIRECTOR'S GENERAL REPORT—

Chemical Division—

Division of Mineral Resources and Statistics—

Draughting Division—

APPENDIX—

ILLUSTRATIONS.

Photographs.

Drawings.

SUMMARY REPORT

OF THE

MINES BRANCH OF THE DEPARTMENT OF MINES

FOR THE CALENDAR YEAR ENDING DECEMBER 31, 1916.

R. G. McConnell, B.A.,
Deputy Minister,
Department of Mines.

Sir,—I have the honour to submit herewith the Summary Report of the Mines Branch of the Department of Mines, for the calendar year ending December 31, 1916.

CHANGES IN STAFF

INSIDE SERVICE.

F. E. Carter, B.Sc., Dr. Ing., resigned his position May 1, 1916, as assistant chemist in the Division of Fuels and Fuel Testing.

L. L. Bolton, M.A., B.Sc., Mining Engineer, Division of Mineral Resources and Statistics, transferred to the administrative staff of the Department of Mines, as Secretary to the Deputy Minister.

Gordon H. Simpson, resigned his position as distribution clerk, September 30, 1916.

OUTSIDE SERVICE.

H. Freeman, resigned his position October 18, 1916, as assistant assayer at the Dominion of Canada Assay Office, Vancouver, B.C.

The following additions to the staff of the Mines Branch were made during 1916:—

INSIDE SERVICE.

V. F. Murray, B.Sc., appointed February 4, 1916, as assistant chemist in the Division of Fuels and Fuel Testing.

R. C. Cantelo, B.Sc., appointed October 17, 1916, as assistant chemist in the Division of Fuels and Fuel Testing.

R. J. Traill, appointed December 18, 1916, as assistant chemist in the Ore Dressing and Metallurgical Division.

OUTSIDE SERVICE.

R. D. McLellan, appointed October 19, 1916, as assistant assayer in the Dominion of Canada Assay Office, Vancouver, B.C.

ORGANIZATION: CLASSIFIED LIST OF STAFF.

The following is a complete list of the technical officers and other employees at present on the staff of the Mines Branch:—

Administration Staff—

M. M. Farnham, B.A., secretary to the Mines Branch.
Miss J. Orme, private secretary.
W. Vincent, filing clerk.

Administration Staff—Continued.
Miss I. L. McLeish, typewriter.
Miss W. Westman, typewriter.
Miss M. E. Young, typewriter.
Mrs. O. P. R. Ogilvie, librarian.
E. O'Leary, messenger (military service).
J. H. Fortune, caretaker.

Division of Mineral Resources and Statistics—
J. McLeish, B.A., chief of the division.
A. Buisson, B.Sc., mining engineer.
J. Casey, clerk.
Mrs. W. Sparks, clerk.
Miss G. C. MacGregor, B.A., clerk.
Miss B. Davidson, stenographer.

Ore Dressing and Metallurgical Division—
G. C. Mackenzie, B.Sc., chief of the division.
W. B. Timm, assistant engineer.
C. S. Parsons, B.Sc., assistant engineer.
H. C. Mabee, B.Sc., chemist.
R. J. Traill, chemist.

Division of Fuels and Fuel Testing—
B. F. Haanel, chief of the division.
J. Blizard, B.Sc., technical engineer.
E. S. Malloch, B.Sc., assistant engineer.
E. Stansfield, M.Sc., chief engineering chemist.
J. H. H. Nicholls, M.Sc., assistant chemist.
V. F. Murray, B.Sc., assistant chemist.
R. C. Cantelo, B.Sc., assistant chemist.
A. Anrep, peat expert.
L. J. MacMartin, clerk.

Division of Chemistry—
F. G. Wait, M.A., chief of the division.
M. F. Connor, B.A.Sc., assistant chemist.
H. A. Leverin, Ch.E., assistant chemist.
N. L. Turner, M.A., assistant chemist.
R. T. Elworthy, B.Sc., assistant chemist.
Miss L. McCann, typewriter.

Division of Metalliferous Deposits—
A. W. G. Wilson, M.A., Ph.D., chief of the division.
A. H. A. Robinson, B.A.Sc., assistant engineer.
Miss D. M. Stewart, M.A., technical typewriter.

Division of Non-Metalliferous Deposits—
H. Fréchette, M.Sc., chief of the division.
H. S. de Schmid, M.E., assistant engineer.
L. H. Cole, B.Sc., assistant engineer.

Division of Ceramics—

J. Keele, M.A., B.A.Sc., chief of the division,
N. B. Davis, M.A., B.Sc., assistant engineer.
S. C. Ells, B.A., B.Sc., assistant engineer.

Division of Explosives—

J. G. S. Hudson.

Draughting Division—

H. E. Baine, chief draughtsman.
L. H. S. Pereira, assistant draughtsman.
A. Pereira, draughtsman (overseas service).
E. Juneau, draughtsman.
D. Westwood, draughtsman (overseas service).
W. Campion, mechanical draughtsman.

Outside Service, Miscellaneous Employment—

A. W. Mantle, mechanical superintendent.
B. M. Derry, millman, ore dressing laboratory.
J. Moran, chemist, fuel testing laboratory.
A. K. Anderson, chemist, ore dressing laboratory.
E. Groves, proof-reader.
C. Langley, glass blower.
T. J. Dunn, machinist.
F. W. Burstow, machinist.
J. G. Williams, machinist.
Emile Chartrand, handy man and machinist.
V. F. Joly, handy man and blacksmith.
August Kritsch, labourer.
Walter Kritsch, laboratory boy, fuel testing laboratory.
A. Gravelle, carpenter.
F. W. Dier, electrician.
R. S. Cassidy, laboratory assistant (Sussex St.).
L. Lutes, laboratory boy (Sussex St.).
E. Lester, laboratory assistant, ceramic division.
L. Wightman, laboratory assistant, structural materials laboratory.
A. H. Saulter, packer.
J. Routhier, packer.
W. Reid, labourer.
A. Mousseau, labourer.

Dominion of Canada Assay Office, Vancouver—

G. Middleton, manager.
J. B. Farquhar, chief assayer.
A. Kaye, assistant assayer.
R. D. McLellan, assistant assayer.
H. E. Warburton, assistant assayer.
D. Robinson, chief melter.
R. Allison, assistant melter.
G. N. Ford, computer and bookkeeper.
T. B. Younger, clerk.
Thos. Campbell, clerk.
E. A. Pritchett, janitor.

INTRODUCTORY.

During the year 1916, the various functions of the Mines Branch have been exercised to a greater extent than ever before. This increased activity was no doubt caused, to a more or less degree, by war conditions. The increased demand for minerals, both metallic and non-metallic, has occasioned those interested in the mining industry to present their problems and make inquiries of the Mines Branch, with a view to procuring expert advice, or information of such character as would guide them in surmounting the difficulties with which they were confronted.

The general scope of the season's work included investigations of metallic and non-metallic deposits, notably the examination of certain iron ore deposits; the exploitation of limestone, sand, and clay areas; the testing of ores, metals, fuels, oil, and gases; the examination of mineral specimens, and the collection and publication of full statistics of the mineral production, and of the mining and metallurgical industries of Canada.

In addition to the general program of activities, mention might be made of several special investigations, conducted under Mines Branch direction.

The field work connected with the investigation of the Building and Ornamental Stones of Canada—confining attention to the Province of British Columbia—was undertaken, and completed.

An investigation of many mineral springs was made, and tests conducted in the vicinity of the same with a view to determining their radioactive properties; while at the same time, additional samples from the respective springs were collected, in order to ascertain their chemical contents, and thus provide a fuller examination of the waters.

The analyses of mine air from non-metalliferous mines—inaugurated in a previous year—has grown in favour among the mine owners and managers; evidenced by the fact that an increased number of samples have been received at our testing laboratory for attention. During the year, an invitation was extended to metalliferous mine owners to have analyses of the air of their workings examined, and already a number from British Columbia have taken advantage of the offer.

During the year, the facilities possessed by the several laboratories of the Mines Branch have been fully taxed to take care of not only our own departmental investigations, but also these demands made by other departments, by private concerns, and by individuals.

The Ceramic, Structural Materials, Chemical, Fuel Testing, and Ore Dressing Laboratories, have conducted investigations in their various spheres of activity, all with a view to assisting in the development of the general mining industry of the country.

There has been organized a Road Materials Division, and a Highway Laboratory has been equipped. This procedure was taken so that expert advice could be given with respect to the best material to use, and where it may be obtained, for road construction. The importance of this subject may be gathered from the large sums of money that are being expended on public highways.

The pressure of work in all divisions of the Branch, can be attributed to increased activity in mining circles, due to the war. In this regard, mention might be made of one or two instances in which the Mines Branch is rendering efficient service, with a view to aid in the furnishing of necessary commodities for war purposes.

The Ore Dressing Laboratory has undertaken, for the Imperial Munitions Board, the concentration of molybdenite ores, this product being in great demand for the manufacture of special steels. And, at the request of the War Purchasing

Commission, samples of certain ferro-silicon shipments, consigned for war purposes, are being analysed in our chemical laboratory.

In succeeding pages, reference will be found relating to the specific work undertaken by the different officers of the staff. Data, issued for public distribution during the year, consisted of the usual statistical reports, together with several special reports, concerning which reference is made in another section of this summary.

ORE DRESSING AND METALLURGICAL DIVISION.

During the first part of the year 1916, the Ore Dressing and Metallurgical Laboratories of the Mines Branch, in view of the increasing demand for molybdenite for war purposes, devoted considerable time to a development of a satisfactory method for the concentration of this ore. Later in the season, there was undertaken on behalf of the Imperial Munitions Board, the milling and assaying of all metallic ores and minerals.

In addition to the above mentioned work, several ores from certain mining companies and individuals were tested, and reported upon. A general progress report of the work of the division, and of the chemical laboratory connected therewith, will be found in a subsequent part of this summary.

FUELS AND FUEL TESTING.

The Division of Fuels and Fuel Testing, during the year 1916, was engaged in the testing and general investigation of coal from the Province of Alberta; the examination of peat bogs, and chemical analyses, etc., in the laboratories of the Division—of samples of oils, gases, coals, peat, and mine air.

Owing to the increased amount of work consigned to the chemical laboratories, both from the several departments of the Dominion and Provincial governments, it was found necessary to make additions to the staff. Added to the above mentioned work, reference might be made to a special investigation relative to the value of peat fuel for the generation of steam. The results of the investigation have been published in pamphlet form, and may be had on application. Moreover, definite steps were taken in connexion with the special investigation of briquetting the lignites of the western provinces.

CHEMICAL LABORATORIES.

One of the agencies through which the Mines Branch renders service to the general mining industry, is that of its Chemical Laboratories. During the present year, the technical work undertaken has not only been greater in volume, but more than usually diverse in character.

Besides the analyses of metalliferous ores and non-metallic minerals, together with the physical examination of numerous mineral specimens, there has been undertaken, at the request of the Admiralty, the sampling and analyses of its purchases of ferro-silicon.

This special work has been continuous since early in the year, and will, most probably, be maintained during the continuance of the war. Furthermore, our laboratories have been called upon to make certain analyses of war materials for the Imperial Munitions Board and several other departments of the Government. The pressure of this important work has occupied the greater part of the time of the present chemical staff, and it is not possible to issue reports upon the regular departmental work as promptly as is desirable. To cope expeditiously with all the work coming to our laboratories, it will be necessary, in the near future, to increase the staff of chemists.

DOMINION OF CANADA ASSAY OFFICE, VANCOUVER, B.C.

During the season of 1916, a very satisfactory year's business was done at the Dominion of Canada Assay Office, Vancouver.

The records of the Assay Office for the year ending December 31, 1916, show that the amount of work completed is in excess of that of the previous year $91,937.31, and is all the more creditable because of the fact that 1915 was the best year that the office had since its establishment.

The several deposits made at the assay office came from British Columbia, Yukon Territory, Alberta, and Alaska.

During the year 1916, the deposits of gold required 2,001 melts, and 2,001 assays in connexion with the purchase and disposal of the bullion. The net value of the gold and silver contained in the deposits was $2,828,239.65.

During the year, there were several changes in the personnel of the staff, full particulars of which will be found on another page. Towards the end of the season, it was found necessary, in order to keep abreast of the work, to engage another assistant assayer.

IRON ORE DEPOSITS.

During the field season of 1916, Mr. A. H. A. Robinson, in charge of a party, was engaged in making an examination of a number of magnetite deposits, which included magnetometric and topographical surveys in the counties of Lanark, Haliburton, and the district of Parry Sound, Ontario.

Further reference to the work undertaken is to be found on page 15.

INVESTIGATION OF LIMESTONES.

Owing to pressure of office work, Mr. Howells Fréchette, who has charge of the limestone investigation, was unable to continue the field work begun during the previous season. A visit was made to the United States Bureau of Mines at Pittsburgh, to examine into methods of testing limes. However, a special investigation was undertaken in connexion with the Grenville magnesites, reference to which is made on page 21.

INVESTIGATION OF CERTAIN NON-METALLIC MINERALS.

In the Summary Report of 1915, reference was made to the investigation carried out by Mr. H. S. deSchmid, in Alberta, in connexion with a reported discovery of phosphate rock.

Based upon the results of this work, it was decided to continue the investigation southward of the area worked the previous year, and accordingly, Mr. deSchmid spent the 1916 field season covering the area southward from Banff to the international boundary. When this work was concluded, an examination was made of a reported graphite occurrence in the vicinity of Cranbrook, B.C. A short summary of this investigation will be found on page 22.

INVESTIGATION OF THE SANDS AND SANDSTONES OF CANADA.

The work in connexion with the investigation of our sand and sandstones was chiefly confined to the laboratory tests of samples collected during the previous season. No general field work was attempted, because the services of Mr. L. H. Cole—who has charge of the investigation—were taken up in installing the necessary laboratory equipment, and making tests of the samples already at hand. During the year, Mr. Cole, with a view to finding out the most modern methods of testing sands and sandstones, visited several of the important testing laboratories in the United States.

INVESTIGATION OF THE BITUMINOUS SANDS OF NORTHERN ALBERTA.

During the summer of 1913, a brief reconnaissance of the deposits of bituminous sand in Northern Alberta was undertaken by Mr. S. C. Ells, of the Mines Branch. Information secured indicated the desirability of further extending the scope of the investigation.

Consequently, during 1914 and 1915, a large number of core samples of bituminous sand were procured and analyzed; extensive detailed topographical maps of the more important areas were completed; and demonstration paving on a commercial scale carried out in the city of Edmonton.

From the information thus secured, it became evident that large developments of the Alberta deposits would depend on securing a commercial process whereby the bitumen could be separated from the crude bituminous sand, and marketed in a more or less pure form. Paving work and mapping of the bituminous sand area have, therefore, been deferred for a time, and the question of separation taken up.

In April, Mr. Ells was appointed an Industrial Fellow at the Mellon Institute of Industrial Research at Pittsburgh, and shortly afterwards his investigation was transferred to the laboratory of that institution. It is expected that definite information regarding the feasibility of a commercial separation process will be available in 1917.

BUILDING AND ORNAMENTAL STONES OF CANADA.

The investigation of the Building and Ornamental Stones of Canada, undertaken by the Mines Branch, was continued during the season of 1916; Dr. W. A. Parks confining his field work to the Province of British Columbia.

There has now been made a careful examination throughout the whole of Canada, of the localities producing different varieties of stones; the character, size, and commercial possibilities of deposits; together with the suitability of the products for various purposes.

In connexion with the investigation, three volumes have already been published, and are now available for public distribution: Vols. I, II, and III, dealing with deposits in the Provinces of Ontario, Maritime Provinces, and Quebec, respectively. Vol. IV, which describes the Building and Ornamental Stones of Manitoba, Saskatchewan, and Alberta, is now in the press.

The manuscript containing the complete information regarding the Building and Ornamental Stones of British Columbia has been received, and is being prepared for publication. It is expected it will be available for distribution early in 1917.

INVESTIGATION OF PEAT BOGS.

During the field season of 1916, Mr. Anrep, Peat Expert, made an examination of several bogs in the Province of Quebec. A short reference to the deposits visited, is to be found in a subsequent part of this Summary. A full report of the work done is being prepared for publication, and may be had as soon as it is available for distribution, by making application to the department.

METALLIFEROUS MINES DIVISION.

During the year, Dr. A. W. G. Wilson prepared two reports for publication. The first of these, on the Electrolytic Refining of Copper in Canada, was published in the Summary Report for 1915 (pp. 13–25). The second, a report on the Production of Spelter in Canada, 1916, was issued in October of this year. This report includes data on the costs of the various raw materials required by the zinc smelter, based on an inquiry into actual conditions at the zinc smelting centres of the United States, and into prospective conditions at a number of localities in British Columbia.

Near the beginning of the year, Dr. Wilson was placed in general charge of the work of preparing a special report on Molybdenum and its industrial applications. Various members of the Mines Branch staff, and others specially qualified, are to contribute to this report. A general review of the molybdenum resources of the world, and a special chapter on the preparation of the metal and its alloys, and its industrial applications, are to be prepared by Dr. Wilson. Much of the preliminary work was completed during the months of February and March; but in April, it became necessary to suspend work on this report, in order to prepare the special report on the Production of Spelter in Canada, to which reference has already been made.

Immediately on the completion of the manuscript of the Report on Spelter in Canada, Dr. Wilson was granted leave of absence, without salary, for a period of one month, which was afterwards extended to three and one-half months, to enable him to assist in the development of a special process of manufacturing certain munitions of war, of which he was the inventor. During this time he kept in touch with the work of his office, read the proofs of three of his reports that were in the press, and made the preliminary preparations needed to enable him to resume his departmental work at the end of December.

Dr. Wilson has been placed in charge of a preliminary investigation of the Chemical Industries of Canada. He is attempting to ascertain what chemical products are made in Canada; what chemical products are required for our various Canadian manufacturing industries; and what raw materials are needed for the production of these chemicals. It is hoped that it will be possible to secure some accurate data as to the possibilities which may occur for the expansion of our chemical manufacturing industries, and for the further utilization of certain of our natural resources. This investigation may also indicate new lines of development to which the attention of this department might profitably be devoted.

DIVISION OF MINERAL RESOURCES AND STATISTICS.

The annual collection, compilation, and publication of statistics of the mining and metallurgical production in Canada, was, as usual, undertaken by this Division. Seven statistical reports for publication were completed during the year, besides various lists of mine and smelter operations.

A considerable portion of the time of Mr. McLeish, Chief of the Division, and of several of his staff, was devoted in connexion with the special committee appointed to investigate the Iron Industry of Canada. A portion of the report of this committee, dealing with descriptions of the principal iron ore mines and iron ore occurrences in Canada was transmitted to the Mines Branch for publication as a departmental report on the Iron Ores of Canada. The report as submitted will be supplemented by a series of maps exhibiting the results of magnetometric examinations of many of the deposits.

An important development initiated in this Division during the year has been the collection of a monthly record of the production of certain products, such as iron and steel, and coal, and the recovery of metals in smelters. On the basis of the month's reports an estimate of the production during 1916 of pig-iron, iron and steel, ingots, and coal, was published just at the close of the year.

Production statistics, closely estimated, and available immediately at the close of the year covered, are much more valuable for most purposes than detailed records that are not completed for six months, or a year. It is hoped that this collection of statistics more frequently than annually, may, with the co-operation of mine operators, be extended to include other important mine products.

CERAMIC DIVISION.

This Division undertakes the investigation of the clay and shale resources of the Dominion, both in the field and in the laboratory. The work was begun several years ago, and a considerable amount of information relating to clay deposits, their distribution and uses in the various branches of the clay working industry, is now available. The reports, so far issued, give a general knowledge of the materials available in each province, but the reports now in preparation are of a more detailed character.

Laboratory Equipment and Operation.

The Ceramic laboratories and their equipment were described and illustrated in the Summary Report for 1915.

During the summer of 1916, when the new Road Materials laboratory was built adjoining the Ceramic Laboratory, some additional space was allotted the latter. This space was used to accommodate a Whitehead tile press, a powerful screw machine for making full size brick, floor, and roofing tile; and a potter's throwing wheel, driven by an electric motor.

The pyrometer equipment was increased by the addition of a Leeds and Northrup Pyrovolter, an instrument operating on the so-called "potentiometer principle," which registers accurate temperatures. The apparatus accompanying this instrument provides means for standardizing any of the pyrometers in the laboratories.

Laboratory work on the investigation of the clay and shale resources of the Dominion is carried on continuously. Most of this work is done on samples collected by the staff of the Ceramic Division during the regular field investigations. Several samples are submitted for examination by the various members of the Mines Branch and the Geological Survey, and a number of samples are sent for testing from sources outside the Department.

During the year 1916, about 90 samples of clays, shales, and other materials from all parts of the Dominion were tested, and reported on. In several of these tests, full sized wares were produced under conditions approximately those in commercial plants.

In addition to the regular work of testing clays, a number of special investigations were undertaken which had a bearing on the utilization of raw material. These investigations included: (1), the use of apatite as a substitute for bone ash in bone china bodies; (2), the use of apatite as an opacifier in enamels; (3), the treatment of stony clays for the manufacture of brick and tile; (4), the use of bentonite or soap clay; (5), the use of local surface clays for manual training work in schools, or for small potteries; (6), experiments in quartz, magnesite, and chromite, for the manufacture of refractory goods; and (7), tests on kaolin products, in connexion with the kaolin deposits at St. Remi d'Amherst, Quebec.

ROAD MATERIALS LABORATORY.

During the year 1916, a laboratory for the testing of road materials was constructed and equipped. The laboratory is now in operation, and is working in co-operation with the Geological Survey. The work of testing is being carried on under the supervision of Mr. K. A. Clark.

Public sentiment in Canada in favour of the good roads movement, for the improvement of the country's principal highways, has steadily increased during the last few years. Throughout the Dominion, Good Roads Associations hold annual meetings to discuss problems of road construction, maintenance, and finance; to educate public opinion on the advantages to be derived from improved highways; and to organize effort toward the building of good roads. In response to the movement, highway commissions have been appointed in nearly all the provinces. The Province of Quebec for some years has had an aggressive road policy, and has financed and supervised the construction of nearly 2,000 miles of improved highways of all types. In Ontario, also, organization and legislation have received much attention in anticipation of an extensive Provincial program of road construction. The Toronto-Hamilton concrete highway has been built, and other main highways have been definitely indicated for construction in the near future. A great deal of road construction has taken place in British Columbia, and the remaining provinces are planning highway improvements of some sort or another.

In 1914, the Department of Mines undertook to aid in the good roads movement. It has chosen for its field the preliminary work of gathering information as to the location, extent, and quality of available road material, along the routes where highway construction is contemplated. Such information is essential before any definite planning of the details of the construction can be done. This work naturally divides itself into two phases, namely, field work, by which the material is located, mapped, and investigated, in regard to quantities and availability, and laboratory work, whereby such materials are tested for their suitability for highway construction, and data obtained to make possible the choice of the best available material. The Geological Survey has carried on the first phase of the work for three years, but has been dependent until now on outside laboratories for all the tests necessary for the interpretation of the work in the field. This unsatisfactory state of affairs has been remedied by the establishing of a fully equipped Road Materials Laboratory in the Mines Branch.

The laboratory is housed in an attractive two-story addition to the rear of the Mines Branch building. A large room on each floor has been devoted to the work of the laboratory. In the lower room are installed a Deval Abrasion machine, a Ball mill, a Dory Hardness machine, and two diamond drills. On the second floor there are installed a hydraulic press, a diamond saw, a grinding lap, a Page Impact machine for testing rock, and a Page Impact machine for testing the cementing value of rock powders. These machines, excepting the drills, were manufactured by the International Instrument Co., now the International Equipment Co. The drills were manufactured by the Washburn Shops of the Worchester Polytechnical Institute. In addition, the equipment includes three electric drying ovens, two weighing balances for careful work, and a balance for ordinary weighing. All the machines are driven by individual electric motors.

The tests conducted are those specified by the American Association for the Testing of Materials[1]. They have been devised to duplicate as nearly as possible, in the laboratory, the conditions imposed on road materials by actual traffic. The resistance to wear of the broken stone fragments and of gravel pebbles on one another in the road bed, is due to the weight of the traffic and to the wear of metal tires. These conditions are approximately indicated by the results of tests in the Abrasion machine. The Impact machine tests the ability of a rock to stand the shattering action of the pounding of traffic on the road bed. The attempt is made to determine the cementing power of rock powders. It is this cementing power which is depended upon in waterbound macadam and gravel roads to hold the material in place. Other tests such as hardness, specific gravity, and amount of water absorbed, are also determined. The composition of gravel

---

[1] Jackson, Frank H., Jr. Methods for the Determination of the Physical Properties of Road Building Rock, U.S. Dept. Agr., Bul. No. 347, Washington, D.C., 1916.

with regard to the sizes of the particles, is determined by mechanical analysis, by means of screens.

The standard tests of samples, collected by the field parties of the Department of Mines engaged in the survey of road materials, will be conducted in the Mines Branch Highway laboratory. The work of this kind on hand at present amounts to about one hundred samples, and the volume will increase each year. It is planned, however, to devote as much time as possible to investigation work. The laboratory is now co-operating with similar laboratories in the United States in an effort to improve the standard methods of testing road materials.

The most urgent and important problem facing the combined laboratory and field staff is the securing of reliable criteria, to enable the field man to report accurately on the merits of materials occurring in the areas where he works. Only a few deposits can be actually tested, although all are visited and examined. The plan is to obtain, by actual test, a knowledge of the average road making qualities of each of the rock species in any district, and then, by microscopic studies and by chemical and physical tests, to discover the reasons for variations in the strength and cementing value of the rock classes. Such a procedure will give clues which will enable the field man to report intelligently on the quality of a deposit of stone or gravel where it is impracticable to make an actual test. It will, moreover, make it possible for him to estimate the percentage of poor or soft material in a boulder or gravel aggregate, and so arrive at some conclusion regarding its durability.

The relation between the toughness of a rock and its mineral composition and structure is a problem that is being kept in mind. It is also planned to further investigate the reasons for the variations in the cementing properties of rock powders. These reasons are at present not very well understood, yet in water bound macadam surfaces the cementing value of the roadstone is of very great importance. A thorough understanding of the factors involved in the process of cementation might lead to useful results.

In the foregoing Summary, I have endeavoured to indicate the needs which have induced the Mines Branch to install a Road Materials Laboratory, to describe briefly the equipment, and to outline the working plan of the laboratory. In succeeding years, it is hoped that substantial progress can be reported.

TECHNICAL LIBRARY.

The Mines Branch maintains a technical library in which are kept publications of value to the several divisions in its organization. During the year, many reference works of importance were added, and care was taken to secure only those of special benefit to work of the Department. The usual exchanges of Mines Branch reports and monographs were made with other technical institutions, both domestic and foreign. The continued rapid growth of our library since its institution, will soon necessitate the providing of additional quarters.

I have the honour to be,
Sir,
Your obedient servant,
(*Signed*) **Eugene Haanel,**
Director of Mines.

INDIVIDUAL SUMMARY REPORTS.

METALLIFEROUS DIVISION.

INVESTIGATION OF IRON ORES.

A. H. A. Robinson.

The field work in connexion with the investigation of Canadian iron ores, carried out during the summer of 1916, consisted in the examination—including magnetometric and topographical surveys—of a number of magnetite deposits located in different parts of Ontario. From the first of June until the early part of July, the party was stationed at Flower, on the Kingston and Pembroke branch of the Canadian Pacific railway, where a detailed survey was made of the magnetite deposits on lot 22, concessions III and IV, township of Lavant, Lanark county, Ontario. The remainder of July and the first two weeks of August were spent in an examination of deposits in Lount township, Parry Sound district, Ontario. The balance of the season was taken up in an investigation of iron deposits in the vicinity of Irondale, on the Irondale, Bancroft, and Ottawa railway, Snowdon township, Haliburton county.

Mr. Gordon G. Vincent acted as student assistant throughout the season, and performed his duties in a very satisfactory manner.

RADENHURST AND CALDWELL MINES.

LAVANT TOWNSHIP, CONS. III AND IV, LOT 22.

These deposits are situated close to Flower station, on the Kingston and Pembroke branch of the Canadian Pacific railway, on lot 22, concessions III and IV, township of Lavant, Lanark county, Ontario, and are, therefore, conveniently situated with reference to a shipping point, if they are ever worked.

The development, done many years ago, consists of seven pits and two small strippings scattered over a length of about 3,000 feet, and lying, roughly, along a line bearing about N. 50° E. (astronomic), parallel to the general strike of the rocks in the vicinity. Of the five pits on the Radenhurst lot—lot 22, concession III—one, the deepest, is said to be 108 feet with a drift to the east about 20 feet in length; two others are each about 80 feet deep; a fourth, 30 feet, and the fifth, 20 feet. Of the two pits on the adjoining Caldwell lot to the west—lot 22, concession IV—one is said to be about 90 feet deep. Near it a diamond drill hole was put down to a depth of 200 feet. No definite information is available as to results obtained in either shafts or drill hole, except what can be gleaned from an examination of piles of rock and ore scattered about in the vicinity of the various pits.

The country in the immediate vicinity of the magnetic belt is almost completely drift covered. The rocks, where exposed, consist of rusty schists and gneisses; the rustiness is due, apparently, to the weathering of iron pyrites contained in them. Their strike, like that of the iron deposits, is about N. 50° E., and both dip 60 to 70 degrees to the southeast. About 300 feet west of the two pits on the Caldwell lot there is a large outcrop of crystalline limestone, and indications are not lacking that bands of limestone will probably be found more or less closely associated with the iron.

All the pits are now filled with water and debris, and natural outcrops are very few and very small. The only guides, therefore, to the quality of the ore, are the material on the old dumps and what can be seen on the two strippings. The latter show at surface a rusty belt of gneiss, and schist, about 20 feet wide, impregnated along some bands with magnetite, either as grains scattered through the rock, or as narrow ribs of relatively pure ore. The ore piles show material of the same general character, that is, partly small veins and ribs of massive, fine-grained, magnetite, enclosed in a rusty, schistose rock, partly grains of magnetite thickly disseminated through gneiss, and schist. Judging from the general rustiness of the belt, and from the evidence of the ore piles, pyrite must be plentiful. A sample of 280 pounds of ore from the Caldwell lot, sent by Mr. T. B. Caldwell of Lanark, the owner, to the Mines Branch Ore Dressing and Metallurgical Laboratory, in 1914, for a concentrating test, gave on analysis:—

Insoluble	10·35	per cent.
Iron	58·60	" "
Phosphorus	0·048	" "
Sulphur	0·248	" "

(See Mines Branch Summary Report for 1914).

This sample was supposed to be an average one, but since it was taken from an old stock pile, it no doubt represents a more or less hand-sorted product; it is also possible that long exposure to the weather had removed some of the sulphur. It is altogether likely that concentration of some kind, to increase the iron content and eliminate some of the sulphur, will be necessary to make the general run of ore marketable.

The magnetometric survey indicates that the areas within which magnetite is likely to be found, occur as an almost continuous series of lenses following the strike of the enclosing rocks. They extend for a distance of about 3,500 feet, and have an average width of 75 feet, approximately. There is some overlapping of the lenses, and a number of smaller lenses occur outside the main areas. Of the total length of the deposits, about 1,200 feet are in concession IV, the remainder, 2,300 feet, in concession III. It is not intended to convey the impression that everything within the above limits is ore; on the contrary, the probability is that a large portion of it is either barren or nearly so, and that the magnetite is more or less concentrated in bands similar to those exposed in the strippings. Nevertheless, and despite the fact that concentration will probably be necessary, the deposits are of such size as would appear to justify further exploration for the purpose of ascertaining more definitely the quantity and quality of the ore they contain.

A magnetometric and topographical map of the locality is now being prepared for publication.

LOUNT TOWNSHIP.

A number of outcrops of iron ore, showing magnetite, occur, scattered over a large part of the township of Lount, Parry Sound district, Ontario, 14 or 15 miles by wagon road from either Sundridge or South River stations on the Grand Trunk railway. Those at the following places were visited and examined: lot 17, con. III; lot 18, con. II; lots 124, 125, 126, 127, 128, 129, 133, and 134, con. A; lots 129 and 136, con. B, and lot 22, con. VIII. Similar outcrops are also reported as occurring on lots 18 and 19, con. I; lot 145, con. A; lot 32, con. VIII, scattered over a considerable area in concessions XII, XIII, and XIV, and elsewhere throughout the township.

Such development work as has been done on the showings consists of a large number of pits, trenches, and shallow shafts; better adapted, in most cases, to fulfil the requirements of the mining act than to afford information as to the nature and extent of the deposits. The largest of these openings is a trench, or open-cut, approximately 50 feet long, 10 to 15 feet wide and 22 feet deep, on lot 17, con. III, from which some 500 tons of ore were taken in 1901 by the Cramp Steel Company of Toronto. A number of shallow drill holes have also been put down at various points, but, so far as can be learned, without encouraging results.

The country rock of the district is gneiss, often hornblendic, interbanded with which, in the neighbourhood of the magnetite deposits, there can usually be found more or less crystalline limestone. On part of lot 128, con. B, and over a large area adjoining to the northeast and southwest, the rock, where exposed, consists almost entirely of a medium-grained, granular, graphitic limestone. Closely associated with the iron, a very coarse-grained, massive basic rock consisting principally of hornblende and feldspar, or of hornblende alone, is often found; also very considerable areas made up entirely of garnet, or garnet and epidote. One small outcrop of this garnet rock, in the clearing on lot 18, con. II, shows, scattered through it, flakes of molybdenite.

The iron occurs partly as a massive magnetite in seams and pockets in the enclosing rock, partly as disseminated grains in gneiss, or garnet. In one case—a sample from lot 144, con. B—it contained considerable titanium.

Following are a number of analyses made in the Mines Branch laboratory:—

TABLE I.

Analyses of Iron Ores from Lount Township, Parry Sound District, Ont.

Sample No.	1	2	3	4	5	6	7	8	9	10
Iron............................per cent.	55·78	45·98	46·46	29·00	28·42	19·60	29·40	48·70	38·80	43·80
Silica.......................... "	14·50	17·46	9·16	28·04	26·12	27·42	35·10	16·70	32·92	12·70
Titanic Acid (TiO_2)................ "	0·42	0·60	11·50	0·15	0·15	0·25	0·33	0·30	0·43	
Sulphur......................... "	0·26	0·20	1·53	0·02	0·02	0·02	0·22	0·08	0·47	0·50
Phosphorus..................... "	0·018	0·128	0·015	0·054	0·089	0·044	0·176	0·045	0·091	0·051

No. 1. An average sample from an outcrop on lot 129, con. B, showing magnetite in, and disseminated through, gneiss. Associated minerals: quartz, epidote, hornblende, and garnet.

No. 2. Sample taken across a band of magnetite about a foot wide near the contact of a coarse-grained diorite, with crystalline limestone, on lot 22, con. VIII.

No. 3. Sample showing magnetite, garnet, and pyrite, from the dump at a pit 20 feet deep, on lot 144, con. B.

No. 4. Sample showing coarse grains of magnetite disseminated through garnetiferous gneiss; an average sample taken across an outcrop 10 feet wide, on lot 125, con. A.

No. 5. A general sample of a granular, friable, garnet-rock, containing disseminated magnetite, from a dump at one of the pits on lot 125, con. A.

No. 6. An average sample taken across an outcrop of black garnet-rock, on lot 125, con. A.

No. 7. General sample of magnetite in gneiss, from dump at pit on lot 126, con. A.

No. 8. Sample of coarse-grained, better looking ore from same pit as No. 7.

No. 9. Average sample from an outcrop alongside pit in swamp on lot 125, con. A, showing magnetite in narrow bands, and disseminated through a rusty gneiss.

No. 10. Sample of massive magnetite with some intermixed hornblende; from old dump at the Cramp Steel Company's pit, on lot 17, con. III.

A magnetometric survey was made of what was considered the most promising area in the township. This included parts of lots 124, 125, 126, and 127, con. A; lots 17 and 18, con. II, and part of lot 17, con. III. Judging by the results of the survey, there are, scattered over the eastern halves of lots 124, 125, 126, and 127, numerous small deposits of magnetite, some idea of the quality of which may be gathered from the analyses given on p. 18; a number of similar small isolated deposits occur at the southern end of lots 17 and 18, con. II. At the Cramp Steel Company's pit on lot 17, con. III, no vertical attraction was found beyond the boundaries of the pit itself, nor was any ore in place seen in the rock surrounding it; apparently the deposit was a very small one. At the other places in the township, mentioned above as having been visited, dip needle readings taken across the outcrops indicate the same pockety mode of occurrence. At no place examined was there anything found that would indicate the presence of a large or continuous body of iron ore.

SNOWDON TOWNSHIP.

A number of magnetite deposits in Snowdon township, Haliburton county, Ontario, along the line of the Irondale, Bancroft, and Ottawa branch of the Canadian Northern railway, were examined, and a magnetometric survey made covering those on lots 25, 26, 28, and 30, in concession IV.

Howland Mine. This mine is situated on lot 26, con. IV, Snowdon, on a hill about 125 feet higher than, and a quarter of a mile to the south of, the Irondale, Bancroft, and Ottawa railway. Irondale, about a mile and a quarter to the northwest, is the nearest station.

The first work done here was in 1880. In 1881 and 1882, 1,500 tons of ore were shipped. By 1890, a shaft 12 feet by 24 feet had been sunk to a depth of 75 feet, and a body of ore 65 feet long, 35 feet wide, and extending from the 25-foot to the 50-foot level, had been removed. At the present time the workings are full of water, and nothing remains of the surface plant but the rotted timbers of the Lead frame.

The deposit occurs at the contact of a hornblendic gneiss, and crystalline-limestone. Judging by the magnetic survey, the ore-body is roughly triangular in outline, and occupies an area of about 1,800 square feet. The country is largely drift covered, and no outcrops showing ore are to be seen; that on the old dump, however, is a fine-grained magnetite, containing a considerable admixture of dark-green ferruginous silicates, and also much pyrite.

A general sample of ore from one of the old dumps, analysed in the Mines Branch laboratory, yielded:—

Iron	48·12	per cent.
Silica	15·24	" "
Titanic Acid (TiO_2)	0·34	" "
Sulphur	1·86	" "
Phosphorus	0·026	" "

The best ore when the mine was being worked, is said to have run from 55 to 60 per cent in iron, 0·005 phosphorus, and 0·06 sulphur.

LOTS 25, 26, 27, AND 30, CON. IV, SNOWDON.

Magnetite also occurs on the above lots, but judging by dip needle readings, only in isolated pockets, too small to be of economic interest.

Victoria Mine. This deposit is located on lot 20, con. I, Snowdon township, about half a mile east of Furnace Falls station, on the Irondale, Bancroft, and Ottawa railway. It was worked years ago, and a considerable amount of ore was shipped from it. In 1882, the erection of a furnace to smelt the iron ores was started on Burnt river; the works, however, were abandoned before completion.

The deposit occurs in crystalline limestone, which has interstratified with it bands of green ferruginous silicates, red garnet rock, and gneiss. Its strike conforms to that of the limestone, and it stands nearly vertical.

The workings consist of a trench about 240 feet long, by 16 feet wide, which is now filled with water. No ore in place was seen, and dip needle readings taken around the pit did not indicate any extension of the ore-body beyond the old workings, except for a few feet at the north end of the trench.

The ore in the old dumps is a fine-grained magnetite, containing a considerable admixture of dark ferruginous silicates, together with considerable pyrite. Its composition, as shown by an analysis made in the Mines Branch laboratory of a general sample taken from one of these dumps, is as follows:—

Iron	54·22	per cent.
Silica	10·64	" "
Titanic Acid (TiO_2)	0·28	" "
Sulphur	3·074	" "
Phosphorus	0·158	" "

NON-METALLIFEROUS DIVISION.

I

SEPARATION OF LIME FROM GRENVILLE MAGNESITE, AND OTHER WORK.

Howells Fréchette.

Chief of Division.

During the greater part of the year 1916, my time was devoted to routine office work and technical correspondence. Memoranda and replies to inquiries were prepared regarding sources of supply and location of markets for many non-metallic minerals. No field work was carried on.

Numerous samples of faulty shell steel were examined metallographically and photographed for the Imperial Munitions Board.

In June, a visit was made to the United States Bureau of Standards at Pittsburgh, U.S.A. Their methods of testing lime and hydrated lime were studied with a view to inaugurating similar work in connexion with the Mines Branch. The Department is under obligations to the officers of the Bureau of Standards for the many courtesies extended; especially to Mr. W. E. Emley, who is directly in charge of the lime investigations, for his generous aid and kindness in explaining and demonstrating the various tests employed. Plans have been prepared for equipping a special laboratory for lime testing in the new annex to the Sussex Street building; but owing to shortage of raw material, and the crowded condition of the departmental machine shop, the necessary apparatus has not yet been made.

MAGNESITE INVESTIGATION.

The magnesite quarried in Grenville township, Quebec, contains too high a percentage of lime to be classed as high grade material for certain uses to which magnesite is put. In some cases the lime is said to be decidedly detrimental, while in others, it may be considered simply as an impurity, lessening the available percentage of magnesia in the rock. An investigation was conducted to devise if possible, some method whereby the lime content could be reduced, or eliminated.

Small blocks of magnesite were heated in an electric furnace to about 1000°C., and the temperatures at which the constituent minerals yielded up their carbon-dioxide, were observed. These temperatures of dissociation indicated that the magnesite rock is composed essentially of the minerals magnesite and dolomite. It contains but small quantities of subsidiary minerals. The magnesite and dolomite have very similar optical properties and cannot readily be differentiated in the uncalcined rock—both being white, or nearly so. On calcination, however, the magnesite darkens to a pink, yellow or green and shows in strong contrast to the calcined dolomite which is pure white. The accompanying photograph (Plate I) of a piece of calcined magnesite rock indicates the contrast developed. (Enlargement four diameters).

The specimen was broken up and the two constituents carefully separated and analysed by Mr. M. F. Connor.

	A (white)	B (pink)
Lime (CaO)	54·82 per cent.	1·85 per cent.
Magnesia (MgO)	44·42 "	96·90 "
Ferric oxide (Fe_2O_3)	0·07 "	0·13 "
Manganic oxide (MnO_2)	0·05 "	0·08 "
Alumina (Al_2O_3)	0·06 "	0·01 "
Insoluble mineral matter	0·60 "	0·86 "

By scanning these analyses, it will be seen that A, the white constituent, approaches calcined dolomite in composition, the excess magnesia probably being due to imperfect separation. The pink constituent, B, contains less than two per cent lime, due, doubtless, to fine particles of dolomite which were not separated from it.

Owing to the physical similarity of magnesite and dolomite, no method suggested itself for separating them in the uncalcined state. It was found, however, that in the calcined rock the properties of the minerals were very different and offered means of attaining the desired result.

On treating the calcined rock with water it slaked; the pink constituent breaking down to a coarse, gritty powder, the grains of which averaged from one to three millimetres in diameter, while the white constituent slaked into a smooth paste which went into a milk when agitated with water. By draining off this milk, the bulk of the dolomite was removed, leaving magnesia in a fairly pure state. The dolomitic lime was saved by allowing it to settle out of suspension.

By means of small and simple laboratory apparatus, the lime content of a sample of calcined magnesite was reduced from 16·5 to 3·66 per cent. The washings analysed 48·49 per cent lime and 45·50 per cent magnesia—true dolomite lime gives 58·2 and 41·8, respectively The foregoing is based on the results of first experiments. There is little doubt that the lime can be reduced considerably below the figure quoted.

The investigation was not completed at the end of the year, but the tests conducted indicated the feasibility of producing caustic magnesia, low in lime, from the high-lime magnesites, and at the same time obtaining, as a by-product, dolomitic lime paste suitable for structural purposes or for utilization in the manufacture of sulphite pulp.

II.

A RECONNAISSANCE FOR PHOSPHATE IN THE ROCKY MOUNTAINS; AND FOR GRAPHITE NEAR CRANBROOK, B.C.

Hugh S. de Schmid.

PURPOSE OF THE INVESTIGATION.

The season of 1916 was devoted to an examination of Carboniferous and Triassic rocks in the Rocky mountains between Banff, Alberta, and the Montana boundary, for the purpose of determining whether phosphate in economic quantities existed in these rocks. A preliminary examination of the limestones and shales of the Banff area was made by the writer in October, 1915, consequent upon the discovery, by officers of the Commission of Conservation, somewhat earlier in the year, of float phosphate in the vicinity of Banff. The results of this examination, together with details relating to the phosphate bed found, appeared in a special bulletin of the Mines Branch, published early in 1916[1].

---

[1] "Investigation of a Reported Discovery of Phosphate in Alberta," by H. S. de Schmid; Bul. No. 12, Mines Branch, 1916.

Although the results of this earlier work did not point to the existence in the Banff area of any phosphate deposits that could be considered thick enough or sufficiently rich in phosphoric acid to be of economic value as a source of phosphate rock for fertilizer manufacture, it was considered possible that the bed found might be a northerly extension of the more important deposits of the Helena district, in Montana, and that in the area to the south of Banff the phosphate might prove to be both thicker and richer. Accordingly, to determine this point, the writer was instructed to proceed to Banff, and to follow the outcrops of the phosphate bed southward towards the international boundary.

In this work, Mr. C. W. Greenland acted as field assistant.

AREA EXAMINED.

The route followed was southward from Banff, by way of the Spray river, Spray lakes, Kananaskis lakes, and Elk river, to Michel, B.C., and thence by way of Crowsnest and Corbin, into the Flathead valley, to the international boundary. A brief examination of the rocks of the Blairmore-Frank area, Alberta, was also made before the close of the season. Wherever practicable, along the route indicated, the mountain ranges to the east and west were examined; and short, "fly" trips were made off the main trail, wherever contingent opportunity offered. The bad state of the side trails, however, and the amount of burnt timber and wind-falls that renders many of the smaller, lateral valleys impassable to a pack train, materially limited the accessible area. Despite this, a sufficiently extensive examination of the limestones and shales was made to allow of fairly definite conclusions being drawn regarding the phosphate possibilities in the area under consideration.

TOPOGRAPHIC AND GEOLOGIC FEATURES OF THE REGION.

The entire region examined consists of a series of lofty mountain ranges having a northwesterly trend, and separated by deep valleys. Narrow, transverse valleys form breaks through these ranges, at fairly frequent intervals, thus dividing each range into a number of component blocks. These transverse valleys have, generally, formed along lines of weakness, or pressure slips[1], and erosion has widened the breaks, so that they now form important drainage channels. The height of the mountains is commonly from 6,000 to 10,000 feet above sea-level, or 2,000 to 5,000 feet above the intervening valley bottoms. The latter, and the lower slopes of the mountains, are often heavily timbered, but a great deal of forest has been destroyed by fire.

As a general thing, the west side of the ranges slopes more or less gradually, contrasted with the east side, which is steep and often precipitous—at any rate in its upper part. Many, if not most of these ranges, represent fault blocks, the fault lines defining the main, intervening, longitudinal valleys. Mountain building, caused by thrust from the southwest, often occasioned overturning of anticlines to the east; while the steep, east side of the ranges represents, at the present time, in many cases, a fault-scarp; the faulted blocks being tilted to the west. The dip of the rocks commonly varies between 30° and 60° S.W.

Erosion has removed a very great thickness of beds from the backs of these mountains (over 7,000 feet of strata in the Cascade-Palliser-Costigan area, according to Malloch[2]); and the Post-Carboniferous sandstones and shales, which have been preserved along the valley bottoms, are not found at the higher altitudes, save as infolded remnants.

---

[1] See D. B. Dowling, Geol. Surv. Canada, Summary Report, 1906, pp. 67–68.

[2] Geol. Surv. Can., Summary Report, 1907, p. 35.

Hence, it is only on the west side of the ranges, and at a fairly low elevation, that outcrops of the phosphate beds with its associated rocks, are now to be found. In the valley bottoms the Phosphoria beds are usually overlain by a considerable thickness of shales and sandstones, coal measures, etc., together with talus and gravels. Occurring as they do, very near the top of the Rocky Mountain Quartzite formation, the beds have generally been removed by weathering at the higher altitudes on the west side, also; while on the lower slopes, talus often effectually conceals them. Outcrops are thus relatively scarce, and difficult to find.

The ground that may reasonably be prospected for phosphate is confined, therefore, to a relatively narrow strip along the lower western slopes of the main ranges, the area to be examined being the strip immediately above the talus slope. Owing to the angle of dip and the difference in resistance to weathering of the quartzites and overlying shales, the talus slope commonly extends upward to the shale-quartzite contact; its material being principally shale. The quartzite itself, is exceedingly resistant to weathering; and even where standing almost vertical, the uppermost beds continue to form prominent ledges or walls to a considerable height above the talus slope. Both quartzite and shales are frequently cut through by narrow canyons, formed by mountain torrents; and the walls of such canyons sometimes provide admirable exposures of the phosphate bed.

RESULTS OF THE FIELD WORK.

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.

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 containing a stratum that strongly resembles the nodular phosphoric 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[1] 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 oölitic 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.

---

[1] By "Triassic shales" is meant the shale succession, measuring over 1,000 feet, that immediately overlies the Rocky Mountain Quartzite (Upper Pennsylvanian). These shales were originally referred to the Permian, but are now considered to be of Triassic age, and merge upward without distinguishable break into the Fernie (Jurassic) shales.

PHOSPHATE OUTCROPS FOUND.

Outcrops of phosphate were found in the following localities—the thickness and phosphoric acid content in each case being as indicated:—

LOCALITIES WHERE PHOSPHATE OUTCROPS WERE FOUND.

Locality.	Thickness of bed.	Percentage of phosphoric acid.	Equivalent to bone phosphate.
	inches.		
1. End of Goat range, Spray lakes, about 20 miles south of Banff..	7	20·7	45·2
2. Kananaskis range, Highwood pass, about 45 miles south of Banff.................................	2	17·51	38·2
3. Brulé creek, about 8 miles above its junction with Elk river, 110 miles south of Banff..............	5	15·79	34·4
4. Crowsnest, B.C., ¼ mile west of railway station.......	2	not analyzed.	....
5. Tent mountain, 7 miles south of Crowsnest, B.C., and 35 miles north of international boundary.........	3	21·6	47·0
6. Livingstone range, 1 mile east of Lille, Alberta........	2	not analyzed.	....

* Nodular phosphate freed of quartzite matrix.

DESCRIPTION OF OCCURRENCES.

1. The bed outcrops just below the summit, and on the west side of the low ridge forming the southerly termination of the Goat range, at a point just west of the south end of the lower Spray lake. The side of the ridge is fairly steep, and is bare of timber, having been recently burned over. The Triassic shales were not seen in place. The phosphate would appear to occur about 50 feet down in the quartzite succession. The freshly-broken rock is very black and dense, but is white on weathered surfaces. This surface whiteness is possibly due to calcination by forest fires. The strike of the bed is N. 70° W. and the dip about 60° S.W. This occurrence is in the same fault-block as that at Sundance canyon, near Banff.

2. This outcrop occurs about 6 miles, by the Highwood trail, east of the lower Kananaskis lake, on the southwest side of the Opal range, and about one mile north of the gap through which the Elbow trail runs. The bed is exposed along this range for a distance of a couple of miles just above the shales and talus that rest against the lower slopes of the range. This locality offers one of the finest sections met with during the season's work, and shows the entire succession from Carboniferous to Cretaceous (see Plate II). The upper part of the range is composed of Devono-Carboniferous limestones, tilted at an angle of about 75° S.W. Lower down, the entire thickness of Rocky Mountain Quartzite is shown, with the phosphate horizon only 3 feet below its topmost member (a chert-quartzite breccia). Against the quartzite rest about 1,000 feet of buff-weathering, sandy, Triassic shales, followed by black shales and thick-bedded limestones of Jurassic age. The latter contain quantities of belemnites. On the Jurassic rest Cretaceous shales, sandstones, and coal measures. There is no apparent break between the Triassic and Jurassic, the sandy shales giving way gradually to dark, calcareous shales and limestones. The Jurassic-Cretaceous contact was not examined particularly. Although this shale-limestone succession was examined very carefully for phosphate, no bed was found, beyond the thin Lingula horizon already mentioned, which ran 15·79 per cent P_2O_5. All the shales and limestones, however, give a sensible reaction for phosphoric acid, as do, also, the Cretaceous sandstones intimately associated with the coal seams.

The greater part of this shale succession is admirably exposed in the walls of several canyons, the one starting at the quartzite, cut through the shales at right angles. All the shales are extremely contorted and broken. The only fossils found in the Triassic beds were the small Lingula, mentioned above, and an ammonite (probably Meekoceras).

The phosphate bed measures only 2 inches, and consists of a conglomeratic mass of pebbles of phosphate, quartzite, and sandstone, in a sandy, phosphate matrix. It undoubtedly represents a bed that has been broken up and re-consolidated in situ as a shore deposit. This horizon forms almost the outermost bed of the quartzite series, just below the shale-quartzite contact, and so is extremely easy to trace along the range.

This occurrence would appear to be in the next fault-block east of the preceding, or in the continuation of the Cascade mountain—Mount Rundle range.

In this connexion, it may be remarked that in the Banff area the phosphate bed in this latter fault-block possesses a somewhat brecciated character at the Spray Falls outcrop. Farther north, however, at the outcrop on Forty-mile creek, the bed is normal. This, together with the decreasing thickness of the quartzite overlying the phosphate, as one proceeds southward and eastward, suggests deposition in a sea becoming shallower toward the south and east, with partial emergence of land areas, and the formation along them of brecciated and conglomeratic deposits; and finally, complete emergence of the land in the southeastern portion of the region, at a time when the sea still covered the northern and western parts.

The phosphate also outcrops about a mile northwest of the above point, in the northwest wall of the second canyon from the south end of the Opal range, fronting on the main Kananaskis valley. Here, the bed consists of about 6 inches of phosphate fragments, mixed with brecciated quartzite and sandstone.

3. This outcrop was found about 8 miles, by trail, up Brulé creek, above its junction with the Elk river, on the range west of the Elk valley. The outcrop is situated unusually high up, being at an altitude of 2,000 feet above the creek bottom. The exposure is not very distinct, the bed itself and the enclosing quartzites having been much shattered by weathering and fire. The outcrop being on almost level ground, is much obscured by talus, and could only be examined in a cursory manner. The bed consists of nodules of phosphate in a sandy matrix, thus resembling that found farther south, near Crowsnest. No shales were observed, and the position of the phosphate in the quartzite succession could not be ascertained.

At a point about half a mile northwest of the above outcrop, a thin broken bed of phosphate resembling an intraformational breccia was found. This consisted of dark-coloured, angular fragments, averaging less than one inch across, and occurring in a succession of thick-bedded, whitish quartzites. This fragmentary phosphate has a distinct oolitic structure, and is the only example of its kind found in the entire region examined. The bed outcrops about halfway up the west side of the range. The total thickness of the quartzite here appears to be very great, and is possibly to be accounted for by doubling over.

4. A low ridge of Rocky Mountain Quartzite occurs a few hundred yards west of Crowsnest station, rising directly above a small lake that lies almost on the interprovincial boundary. On the west side of this ridge is a narrow depression or draw, west of which lies a low ridge of sandy, Triassic shales. An outcrop of phosphate was found on the west side of the quartzite ridge, almost at the top, and at the south end. The phosphate occurs as small nodules, that weather white, in a sandy or quartzitic matrix. The total thickness of the bed is only a couple of inches, the dip, 40° W.

This outcrop is on the line of that found on Tent mountain, near Corbin, and resembles it in every way. The Triassic shales mentioned above yielded some good examples of Lingula.

5. The phosphate bed is well exposed on the west flank of Tent mountain, between Corbin and Crowsnest. Here, it occurs beneath 3 feet of grey, sandy quartzite, and consists of 3 inches of nodular phosphate in a greenish-brown, sandy matrix. The nodules average 1″ × 1″, but are sometimes as large as 3″ × 2″, and are ellipsoidal in shape.

The quartzite here rises in a steep wall from a flat terrace of talus and shales, the dip being about 35° W., and the strike N. 20° W. (see Plate III.).

6. A thin bed of nodular phosphate, in every way similar to that at outcrop 4, was found on the west side of the Livingstone range, about one mile southeast of Lille, near Frank. The bed occurs at the top of a ledge of quartzite that projects out of the talus slope, a few hundred yards above the Frank-Lille road.

CHARACTER OF THE PHOSPHATE.

With the exception of one minor occurrence, all of the phosphate found in the region under examination is of a more or less uniform character. The rock is black, or brownish-black, depending on the amount of silica present, fine-grained and dense, conspicuously heavy, and commonly weathers whitish. The purer rock might often be mistaken at first sight for an igneous, basaltic type. Where the bed has been exposed to the action of forest fires, as is often the case, this surface whiteness is more pronounced than in the case of natural weathering. The black colour and the characteristic odour that the freshly-broken rock emits, are possibly due to organic matter very intimately mixed with the phosphate at the time of its deposition. An extremely intimate association of this hydrocarbon substance with the phosphate is evidenced by the fact that fragments of the phosphate before the blowpipe, as well as finely-crushed rock ignited for several hours in a crucible, show little alteration as regards colour, while the loss of weight amounts to only about 1 per cent, probably representing mechanically-held water. When the rock is dissolved in nitric acid, the insoluble residue consists chiefly of clear quartz grains, and a certain amount of black impalpable matter. After ignition of the whole, this black substance is found to have completely disappeared, leaving a residue of clean quartz.

Fluorite, commonly of a deep purple colour, but sometimes also, of a lighter mauve shade, is an almost constant and quite conspicuous accessory mineral in the phosphate. Analyses of two samples of fairly high grade rock showed, in both cases, 1·5 per cent fluorine, or about 3 per cent of fluorite. Small amounts of iron sulphide are also locally present.

Fossil remains are abundant, but are commonly fragmentary. The most conspicuous of such remains are usually small splinters of bone, probably belonging to some species of shark. These bone fragments are particularly noticeable owing to their white, or light grey colour, which makes them stand out against the dark phosphate. In Sundance canyon, near Banff, a fairly well-preserved jaw of a species of shark, identical with, or allied to Lissoprion Ferrieri, was found at the contact of the phosphate bed with the overlying quartzite. The above species was first found in the Phosphoria beds at Montpelier, Idaho,[1] and its discovery in Canada lends considerable support to the assumption that the beds at the two localities are the equivalent of one another.

Among other fossils found in the phosphate are undetermined species of Lingula, Conularia, and of Bryozoa; but such remains appear to be present in quite subsidiary amount to those of vertebrates.

---

[1] See O. P. Hay, Nos. 1699 (1909), and 1884 (1912), Proceedings of the United States National Museum.

As already stated, the character of the phosphate bed, as found in the north and west of the area examined, differs considerably from that in the more easterly and southerly portions, being decidedly brecciated in the latter area. Even where the bed shows no evidence of having suffered erosion, as in the northwesterly section, its character is seldom homogeneous throughout the entire thickness, and the richer phosphate tends to occur in botryoidal aggregates of rather irregular form in a matrix of phosphatic quartzite. The phosphate, however, is not present as individual nodules, and the character of the deposit may perhaps be best indicated by picturing it as an incomplete phosphatic impregnation of a sandy bed of varying permeability, zones of quartzite containing little or no phosphoric acid occurring throughout the phosphate proper.

Under the microscope, thin sections of the phosphate show sub-angular quartz grains scattered through a brownish paste of amorphous phosphate. In some sections, the quartz grains predominate, while in others the phosphate matrix covers the greater portion of the section. Distributed through this matrix, micro-organisms of various types occur somewhat plentifully, and are usually lighter in colour than the mass of the phosphate. Irregular particles of dark, almost black, phosphate occur scattered through the lighter, brownish body, the colour being due, apparently, to the presence of a greater amount of very finely-divided organic matter. Occasionally, alternating bands of lighter and darker phosphate are seen concentrically arranged around a minute nucleus. These forms are entirely microscopic, however, and the rock exhibits no resemblance to an oolitic structure.

Behaviour with Acids. With cold, dilute, nitric acid, the powdered rock effervesces slightly; with hot acid the action is quite vigorous.

Tests made to ascertain how the degree of fineness affected the solubility of the phosphate rock, yielded the following results:—

Degree of fineness.	Acid used.	
	Dilute nitric.	Dilute sulphuric.
	Per cent soluble.	Per cent soluble.
60-100 mesh	65·0	71·6
100-150 "	67·0	72·0
200 "	75·8	76·4

Sulphuric acid is, thus, slightly more effective in dissolving out the phosphoric acid from the rock than nitric acid.

Origin. The phosphate has evidently originated in the ordinary manner of sedimentary rocks, and deposition would seem to have taken place in an enclosed and rather shallow sea. The calcium phosphate was probably formed in the usual manner under such conditions; that is, by interaction of ammonium phosphate, produced by an abundance of decaying animal life, with calcium carbonate or other lime salts present in solution in the water. More or less littoral conditions are indicated by the large proportion of sand that was deposited with the phosphate, while the presence of hydrocarbons, to which are probably due the black colour of the rock and its fœtid odour, has been shown to be a characteristic feature of sediments deposited in enclosed bodies of water, deficient in oxygen through absence of mechanical circulation.[1]

COMPARISON OF CANADIAN AND MONTANA PHOSPHATE.

The phosphate from the most northerly occurrences in Montana so far examined, and described by officers of the United States Geological Survey,[2]

---

[1] In this connexion, see Blackwelder, E., "The Geologic Rôle of Phosphorus," American Journal of Science, Vol. XLII., No. 250, 1916, p. 293.

[2] See Stone, R. W., and Bonine, C. A., Bul. 580—N., U. S. Geological Survey, 1914, p. 377. The occurrences described are situated about 50 miles northwest of Butte.

differs materially in its general character from that described above. The Montana phosphate is chiefly characterized by more or less pronounced oolitic texture and a bluish-white coating, known as "phosphate bloom," on weathered surfaces. This bloom is occasionally seen on the Canadian rock, but is not at all typical, since a similar coloration is just as commonly found on the black, non-phosphatic chert that abounds in the Carboniferous limestones of the region.

Through the courtesy of Mr. R. W. Stone, of the United States Geological Survey, the writer has been furnished with samples of the phosphate found near Melrose, Montana, and thus was enabled to compare this rock with that from the region here described. A description of the occurrence of this phosphate and analysis of the same appeared in Bulletin No. 470, pp. 440-451, of the United States Geological Survey, in 1911. The Melrose rock is stated by Mr. Stone to be entirely similar to that from Elliston and Garrison, these being the most northerly occurrences of phosphate so far known in the State.

Beyond the blackish colour common to both, the Canadian and Montana phosphate really possess little similarity with one another, the density and extremely black colour of the former contrasting quite strongly with the oölitic character and bluish shade of the latter.

To illustrate the difference in composition, two analyses of typical phosphate from (A) Melrose, Montana, and (B) Sundance canyon, near Banff, are given below:—

	A[1]	B[2]
Insoluble	4·49	39·02
Phosphoric acid	35·09	20·68
Lime	51·15	31·58
Alumina	2·20	0·46
Ferric oxide	0·10	0·71
Equivalent to bone phosphate	76·64	45·19

[1] Analysis quoted from Bul. No. 470, U. S. Geological Survey, p. 442.
[2] Analysis of sample 14, to Mines Branch, Bul. No. 12, p. 18.

The siliceous nature of the Banff phosphate is at once apparent from the large amount of insoluble in B; almost the whole of this may be taken as quartz. A full analysis of phosphate from an outcrop on Forty-mile creek, north of Banff, is appended. This analysis was made by Mr. M. F. Connor, of the Mines Branch, in 1915:

	Per cent.
Silica	38·52
Ferric oxide Alumina	0·56
Lime	33·60
Phosphoric Acid	24·60
Magnesia	0·20
Soda Potash	0·40
Water and organic	1·10
Fluorine	1·50
Sulphur and manganese	Trace
	100·48
Less O=F	0·63
Total	99·85

The fluorine shown in the above analysis is probably all present as fluorite, which is a very conspicuous, accessory mineral in the majority of samples taken. The amount of lime over and above that necessary to form tricalcic phosphate with the phosphoric acid present is 4·5 per cent, of which about 2·25 per cent is required to form calcium fluoride with the 1·5 per cent of fluorine found. In the analysis of the Melrose rock, quoted above, the percentage of fluorine present is not stated, nor is the presence of fluorite, as a conspicuous mineral in the rock, mentioned in the report. Etching experiments with this rock and concentrated sulphuric acid, however, showed that fluorine in appreciable amount is contained in this phosphate also. Assuming 2 per cent as an average of the fluorine present in the Montana rock, to satisfy which about 3 per cent of lime will be required, we have an excess of lime, over and above that necessary to combine with the 35·09 per cent of phosphoric acid, of 6·64 per cent, as against 2·25 per cent in the Banff rock. The greater part of this lime is probably present as carbonate, some samples of the Melrose rock effervescing quite strongly with dilute, cold hydrochloric acid.

Below are shown, for the purpose of comparison, sequences of the rocks associated with the phosphate, (1) in the area examined by the writer, and (2), in the Elliston, Montana, field. The latter table is compiled from data on pp. 374 and 375 of the report by Stone and Bonine, referred to in the preceding footnote. The thicknesses given for the Canadian rocks are according to J. A. Allan, in Guide Book No. 8, Part 2, International Geological Congress, 1913.

The character of the rocks more or less intimately associated with the phosphate is seen to be similar in both areas. In Montana, however, the age of the Phosphoria beds has been given tentatively as Permian, while in Canada, the occurrence of the phosphate in the succession of quartzite beds of the Rocky Mountain Quartzite would indicate Pennsylvanian age.

The position occupied by the phosphate horizon in both of the successions shown above suggests that the bed found in Canada is the formational equivalent of that in Montana; but the assumption that the former represents a gradual thinning-out and impoverishment of the Montana bed in a northwesterly direction does not appear to be altogether warranted. (See page 32). Since there is an interval of about one hundred and fifty miles between the most northerly Montana phosphate outcrops and the most southerly extension of the series of Carboniferous rock as developed in the Canadian Rocky mountains, most of which interval would appear to be occupied by rocks very much older than the Carboniferous, which have been thrust over more recent sediments, it is not practicable to decide definitely at this time whether the phosphate rock of the two areas was laid down in one continuous ocean extending over the entire region, or in separate basins.

The uniformly nodular, conglomeratic or brecciated nature of the phosphate in the east and south of the region examined, together with the fact that the thickness of overlying quartzite appears to become greater in the northwest of the area, suggests conditions approximating littoral in the former region at a time when the latter was still occupied by sea. We may, thus, imagine a narrow gulf extending inland from a northwesterly ocean to a point somewhere about the international boundary, and during the period of deposition of the phosphate, growing constantly shallower in its southern and eastern portions. Such conditions might result in a greater thickness of phosphate and associated quartzites being deposited in the north and west of these waters, as well as in the progressive denudation, along a shore-line receding at a rather rapid rate from southeast to northwest, of a considerable thickness of the rock already laid down in the former area. If we postulate a sea bottom, shelving

CANADA.				MONTANA.			
Triassic.	Upper Banff Shales.	Buff-weathering, sandy shales and sandstones.	Feet. 1,400	Mesozoic.		Thin-bedded, buff-weathering shales, sandstones, and arenaceous limestones.	Feet ?
Pennsylvanian.	Rocky Mountain Quartzite.	Unconformity? 3-100, feet of thick-bedded, cherty quartzite, in part brecciated. Phosphate bed. Thick-bedded, whitish quartzite, with thin, shaly partings, and interbedded dark chert. Lower beds calcareous and grading insensibly into the underlying limestone.	800	Permian (?)	Phosphoria formation.	Soft, greenish-brown shales and sandstones. Phosphate bed: occupies lowest 5 feet, with quartzite below and black chert above.	80
				Pennsylvanian (?)	Quadrant Quartzite.	Thick-bedded, white quartzites (300-500 feet) grading downward into reddish, sandy shale (100-300 feet).	700
	Upper Banff Limestone.	Blue to grey, thick-bedded limestone, fine to medium-grained.	2,300	Mississippian.	Madison Limestone.	Thick-bedded, blue limestone, with chert nodules.	1,000

rapidly in the direction indicated, the uplift might result in the carrying to the deeper part of large amounts of more or less angular, detrital material, such as would form the considerable thickness of quartzitic breccia that is found overlying the phosphate to the northwest of Banff.[1]

The hypothesis that the area under consideration formed part of such a marine gulf as above indicated, and was separated from the Montana field by a land barrier, is illustrated by Schuchert's palæographic map of North America during the Lower Pennsylvanian (see Vol. XX, Geological Society of America, 1909, Plate 83). Although this map relates to Lower Pennsylvanian time, and the waters of this gulf are supposed to have receded almost entirely during the Upper Pennsylvanian (see Plate 84), and Lower Triassic (Plate 86), more recent investigation of the region may suggest a modification of this view. For instance, if the Rocky Mountain Quartzite is to be referred to the Upper Pennsylvanian, we must consider land and water areas during that period over the region in question to be essentially similar (though perhaps modified) to those obtaining during the Lower Pennsylvanian. For the quartzites, similarly to the underlying limestones, (Upper Banff Limestone) of Lower Pennsylvanian age, are marine, though shallow water, deposits.

Schuchert, referring to the map mentioned above, says:[2] "In the Rocky Mountain region, the late Pottsvillian (Lower Pennsylvanian) faunas everywhere appear to have been followed by an erosion or land interval. How long this emergence persisted can not as yet be estimated, but the Mississippian sea, with its well-known Missourian fauna, apparently reëntered the Rocky Mountain area long before the close of the Pennsylvanic, and then, under practically the same physical conditions as those of the Mississippi valley, continued well into the Permo-Carboniferous or Oklahomian epoch."

This question, however, is not of any particular importance from an economic standpoint; since, whether the bed in Canada represents a northerly extension of the Montana deposits, or not, the outcrops examined show that the phosphate rock in the area under consideration is not comparable either in average richness or in thickness of the deposits with that in Montana. It would appear, also, that over much of the more southerly portion of this area (e.g. in the Macdonald range) whatever phosphate may have been deposited has either been removed by erosion, or has been buried by structural movements beneath great thicknesses of earlier Carboniferous rocks.

Summary.

The phosphate bed as represented in the Banff district, Alberta, becomes thinner and poorer in phosphoric acid the farther south it is followed. The character of the bed, also, alters from that of a more or less massive deposit to an agglomeration of small nodules of phosphate in a sandy or quartzitic matrix. The most southerly outcrop found, at Tent Mountain, about 8 miles south of Crowsnest, B.C., showed a 3-inch bed of such nodular phosphate, of which the purest material ran only 47 per cent tricalcic phosphate.

The Montana and Canadian phosphates are not sufficiently alike in their general character, nor does the succession of the Phosphoria beds and associated rocks in the two areas appear to correspond sufficiently closely, to warrant the assumption without further corroborative data that the phosphate horizon described in this report, and in Mines Branch Bulletin No. 12, is a northerly extension of the Montana economic deposits. The question as to whether, at the period of deposition of the phosphate, a single sea covered the entire

---

[1] See H. W. Shimer, Geol. Surv. Can., Summary Report, 1910, p. 146.

[2] Op. cit., p. 565.

Montana-Alberta field, or whether a land barrier existed somewhere in the neighbourhood of the 49th parallel, needs further investigation.

Methods of Testing for Phosphoric Acid.

In the field, only a rough test for phosphoric acid was made. This consisted in placing a small pinch of powdered ammonium molybdate on the sample to be tested and moistening with a few drops of dilute nitric acid, the intensity of shade of the ensuing yellow precipitate of ammonium phosphomolybdate giving an approximate indication of the amount of phosphoric acid present in the rock. All the analyses of samples were subsequently carried out in the laboratory of the Mines Branch by the writer, the comparative bulk method being used. In this, the amount of precipitate of ammonium phosphomolybdate is measured in a graduated glass tube and compared with the bulk of that obtained from samples of known composition. This method has shown itself sufficiently exact for a quantitative determination of phosphoric acid where a contingent error of two or three per cent is of minor importance, and often yields exceedingly correct results. In a series of tests made for the purpose of ascertaining the probable average error, the maximum discrepancy with the composition as shown by a quantitative analysis was found to be 2·17 per cent, and the minimum ·08 per cent, the mean error being ·65 per cent. This method is particularly useful where quick results are desired and many samples have to be tested; while, for use in the field, the fact that weighing may be dispensed with does away with the necessity of carrying a balance.

The method, in detail, consists in boiling about one-twentieth of a gram of rock ground to 100 mesh with 5 c.c. of dilute nitric acid. (In place of weighing, sufficient accuracy may be obtained by measuring in a small ivory spoon, such as is usually found in blowpipe sets, a flat spoonful being taken in every case). The solution is then filtered and rendered slightly alkaline with ammonia. After adding a few drops of nitric acid, 20 c.c. of ammonium molybdate solution are poured in, and the precipitate is allowed to settle. Settling proceeds fairly rapidly, and the solution is then decanted, and the precipitate washed into narrow glass tubes of 10 c.c. capacity, and graduated into tenths of 1 c.c. The narrower the tube used, the greater the accuracy in reading off the amount of precipitate. After complete settling, the bulk of precipitate in each case is ascertained, and referred to that yield by the check samples of known phosphoric acid content. (By using several check samples instead of one only, and taking the mean of the results, the error is correspondingly reduced.)

Graphite, near Cranbrook, B.C.

After conclusion of the examination of the foregoing area for phosphate, the writer visited an occurrence of graphite about 6 miles west of Marysville, and some 16 miles northwest of Cranbrook, B.C.

The occurrence was prospected some years ago by Mr. Benjamin Pew, and the claim is now owned by Mrs. G. C. Beattie, of Cranbrook. The claim is Crown-granted, and is designated Lot 9085, Group 1, Kootenay district.

The graphite occurs in the form of a well-defined vein, which, from an insignificant width at the surface, widens to 2 feet in the floor of the open-cut that has been run in, cutting the lead at right angles. This cut is 10 feet long, 6 feet wide and 15 feet deep at the inner end. The vein strikes northwest, and varies in dip from 45° to 70° N.E.

The occurrence is on the southwest side of Matthew creek, and about ¼ mile above the bridge carrying the road from Marysville to St. Mary's lake. The outcrop lies about 150 feet above the creek bed, in the face of a steep cliff.

The vein consists of amorphous, matte graphite, mixed with silicates, the nature of which was not determined, but which are possibly hornblendic in character, and of the same type as that composing the enclosing rock. A carbon determination made in the Mines Branch laboratory indicated about 25 per cent of carbon in selected vein material. The purity of this graphite is, therefore, not very high. The mineral might possibly prove suitable for paint pigment, or for foundry facings. (See Plate V.)

Sufficient development work has not been done to indicate the size of the deposit, which appears to be of metamorphic origin, in a country rock of mica-schist, intruded by an igneous dike of dioritic type.

III

INVESTIGATION OF THE SANDS AND SANDSTONES OF CANADA.

L. Heber Cole.

The work in connexion with the investigation of the Sands and Sandstones of Canada, for the year 1916, consisted, for the most part, in preparing and equipping a proper testing laboratory, and testing the samples taken during the field seasons of 1914 and 1915. Very little field work was undertaken. This consisted, mainly, in short trips in the neighbourhood of the city of Ottawa. Three days were spent near Brockville, Ontario, examining and sampling a deposit of moulding sand.

On the 22nd of May, I left for Boston, New York, Philadelphia, Washington, and Pittsburgh, to visit the larger and more important testing laboratories, and to confer with the officials in charge, with a view to finding out their methods of testing sand, etc. The gratitude of the Department is here expressed to the gentlemen interviewed for their courtesy and kindness in affording me every facility for gaining valuable information.

Four days in October were spent in Toronto and Hamilton, conferring with the engineers of the Toronto-Hamilton Highway Commission, on their methods of testing sands, and in sampling and examining some of the sands in the vicinity of Hamilton.

The work in Ottawa has consisted, chiefly, in completing the equipment of the sand testing laboratory. The testing of samples of sand collected during the field seasons of 1914 and 1915 was commenced, and got well under way.

Mr. Lyell Wightman was engaged on October 1, 1916, as laboratory assistant, and has proved an efficient and painstaking worker.

Messrs. Lawson Bros., and Messrs. Alex. Fleck & Co., of Ottawa, very kindly permitted me to carry out, under actual working conditions, tests on a number of sands, in order to determine their suitability for use in the foundry. (The results of some of these tests are given in section IV, p. 53, dealing with "The Occurrence and Testing of Foundry Moulding Sands."

Besides regular routine work, numerous samples of sand have been received for determination and testing. This class of work is increasing, and will continue to increase, as the existence of these laboratories becomes better known.

PRELIMINARY REPORT ON THE INVESTIGATION AND TESTING OF SANDS AND SANDSTONES OF CANADA.

The investigation of the sands and sandstones of Canada, commenced in 1914, has been continued through 1915 and 1916. The importance of gaining an exact and comprehensive knowledge of the country's resources along this line is more evident each day; and the number of inquiries received in the office concerning sand and sandstones show the need of the work.

A tentative division of sands, crushed sandstones, and quartzites, into classes, according to their uses, is presented here:—

1. Silica sands, crushed sandstone, quartz or quartzite.
2. Moulding sands.
3. Building sands.
4. Sands for brick making.
5. Sands for miscellaneous uses.

1. *Silica Sand.*

Silica sand is that in which the principal constituent is quartz. The specified percentage of this mineral may vary according to the use for which the sand is required. This sand may be a natural sand, or may be artificially produced by crushing sandstone, quartz, or quartzite.

The uses made of the various grades of silica sand are numerous. Only the more important ones will be mentioned here.

As a Constituent in the Manufacture of Glass.

Silica sand, used in the glass industry, is, in point of bulk, the most important ingredient of all glass; therefore, it must be very pure, as the glass produced from any sand is largely influenced by the properties of the sand itself. The requirements of a good glass sand include both physical and chemical properties, which may be enumerated as follows:—

Texture.—The sand should be very uniform in grain, and 95 per cent should pass through the 20 mesh (·833 mm. opening) and be retained on the 100 mesh (·147 mm. opening). The glass manufacturers, in most cases, call for the grains to be angular or semi-angular in preference to rounded grains, as they state that the latter are more difficult to melt.

Chemical Analysis.—Glass sand, as a general rule, should contain less than 1 per cent of iron oxide (Fe_2O_3), and in the case of the better grades of glass the higher limit is decreased to 0·5 per cent, and less. Lime, alumina, and magnesia may, in some cases, be permissible in small percentages, as for certain glasses these materials have to be added to the batch; but as a general rule it is best to depend on the sand only as a source of pure silica, and to add the other ingredients as required.

Thus a good silica sand for the manufacture of glass is one made up of uniform, angular grains, containing over 99 per cent of silica (SiO_2).

Silica for Use in the Ceramic Industry.

The use of quartz in the ceramic industry, under the name of "potters flint," is quite extensive. For this use, it has to be ground, so that all will pass through a screen with 120 meshes to the inch. Its chemical composition must be similar to the material required for a glass sand, i.e., the ferric oxide (Fe_2O_3) must be under 1 per cent, else a dead white body will not be obtained when fired to the proper temperature.

Silica Sand for Moulds for Steel and Phosphor Bronze Castings.

In steel foundries a high grade of silica sand is required for making the moulds. This sand must have a high percentage of silica, and be free, or nearly so, from lime, magnesia, and the alkalies, since these impurities tend to decrease the refractoriness of the sand. As a rule, silica sand for use in the foundry should have a silica content of at least 95 per cent. A binder will, in most cases have to be added, such as clay, flour, treacle, etc., in order to bond the sand together, and enable it to retain the shape of the pattern, and withstand the pressure of the molten metal. It should also answer the requirements of an ordinary moulding sand, such as given in the bulletin on the "Occurrence and Testing of Moulding Sands", which appears on pp. 38-55, of this report. In size of grain, the sand should all pass through a screen of 20 meshes to the inch (·833 mm. opening), and 90 per cent retained on a 200 mesh screen (·074 mm. opening).

Silica Brick.—In the manufacture of silica brick for lining furnaces, etc., where very high temperatures have to be withstood, pure quartz sands or crushed quartzites free from alkalies, and practically free from iron oxide, are required. It has been proved by laboratory experiments on material deemed suitable for this use, that the best results were obtained from using crushed quartzites, because many of the crushed sandstones and igneous quartz tested for this purpose, failed to meet the requirements. The material for the manufacture of silica brick should be crushed to pass through a screen of 8 mesh (2·362 mm. opening), bonded with 2 per cent of lime, and raised to a temperature of 1500° C., in order to obtain a fused bonding of the particles.

In the Manufacture of Ferro-Silicon.

In the manufacture of ferro-silicon, silica, in the form of quartz or quartzite, is preferred to sand, which is liable to choke the furnace. The material used should be as pure as can be obtained, and in particular should not contain arsenic or phosphorus.

In the Manufacture of Carborundum.

A sand containing over 99 per cent silica is employed in the manufacture of carborundum. One of uniform grain is preferred. This sand comprises over 50 per cent of the raw material which enters into the composition of this product.

As a Dusting Material for Roofing Papers.

Considerable finely-crushed sandstone or white sand is used each year by the roofing companies in dusting the coatings of tar paper to prevent sticking. The grade required is, approximately, 65 mesh, and should be white in colour, and free from dust.

Silex, or Finely-ground Quartz.—"Silex," or finely ground quartz, or sandstone, is employed as a filler for certain paints for outdoor use. It is also employed to a small extent by companies manufacturing chemicals, metal polishes, hand cleaners, etc.

Furnace Lining.—Crushed vein quartz, quartzite, or sandstone, is used where an acid lining is required for furnaces and converters in both copper and steel smelting.

For Flux.—Quartz is used as a flux in the smelting of basic ores. Whenever possible, the smelting companies endeavour to obtain a supply of ore which has a siliceous gangue for fluxing; otherwise it is necessary to use "barren" quartz, quartzite, or sandstone.

A number of other industries employ silica sand, or crushed quartz; such as in the manufacture of white scouring soaps, sandpapers, etc. These several uses will be mentioned at more length in the final report.

2. *Moulding Sands.*

Considerable time was spent in the laboratory throughout the year (1916), in determining the best methods of testing sands for use in foundry work, and in the testing of the samples of moulding sands collected in the field. The results of this work were presented in a paper read before the March meeting of the Canadian Mining Institute, 1917—a copy of which will be found, commencing at the bottom of this page.

In this paper the occurrence and testing of moulding sands are discussed at length.

3. *Building Sands.*

The scientific study of the sands suitable for use in the building trade is of considerable importance. These sands fall naturally under two main heads:

(*a*) Sands for use in concrete.
(*b*) Sands for use in mortar.

As the laboratory work on the collection of samples of sands thought to be suitable for building purposes has not yet been completed, it is not advisable to go fully into this question until more data are obtained. It can be said, however, from the results so far obtained, that there should be little difficulty in obtaining thoroughly satisfactory grades of both concrete and mortar sands within easy reach of the main commercial centres throughout the Province of Quebec and eastern Ontario—the districts so far covered by this investigation.

4. *Sands for Brick Making.*

In the brick making industry, sand is extensively used as an addition to the clay where the latter, when used alone, has a high shrinkage, and is liable to crack during drying or firing. When used for this purpose, the sand must be free from limestone and pebbles.

Parting sands which are used to dust the brick and tile moulds to prevent sticking, and also to give a proper texture and colour to the surface of the brick, should burn to a colour similar to that to which the clay in the brick will burn, or else to a dark red, in order to colour an otherwise weak coloured brick.

5. *Sands for Miscellaneous Uses.*

Many other uses in which the sand resources of a country are applicable will be dealt with at length in a later report. A few of the more common are:

Blast sand.
Sand, for sand-lime brick.
Abrasives and grinding sands.
Sand for sweeping compound.
Sand for water filtration plants.
Friction sands such as are used for gripping wheels on slippery rails.
Sand for mixing with asphalt.

Sands suitable, for all these uses, are to be found in Canada; and the use of the Canadian material in preference to the imported, is now quite common, as the satisfactory qualities of the Canadian sands are fast becoming better known, and more appreciated.

The field work in connexion with this investigation is to be continued during the field season of 1917, and will cover the western portions of the Province of Ontario.

IV

THE OCCURRENCE AND TESTING OF FOUNDRY MOULDING SANDS.

INTRODUCTORY.

The need, in Canada, for foundry moulding sands of different grades, suitable for different classes of castings, has increased greatly in the last few years, and has led the Mines Branch of the Department of Mines to investigate many

Canadian sand deposits, to determine their suitability for this class of work. At the present time, a large part of the sand used in Canadian foundries is imported, and, although, in a number of instances, local deposits furnish small quantities to foundries in the immediate vicinity, no deposits have been opened out on such a scale as to furnish properly graded sand to the general foundry trade of Canada, the supply being drawn mostly from the United States.

In the summer of 1914, investigation of the sand deposits of Quebec was commenced by the Mines Branch, the field work being continued during the seasons of 1915 and 1916, and extended into eastern Ontario. During the season of 1917, field work will be carried on in western and southwestern Ontario.

In the course of the regular field work, several deposits of sand were encountered, which, based on field examination, gave promise of being suitable for moulding sands. Samples of these were taken, and sent to the Mines Branch Laboratories, Ottawa, for examination and testing.

FOUNDRY SANDS IN GENERAL.

Foundry sand may be divided into two main classes:—

(1) Moulding sands: or the sand which is used to make the mould, into which the molten metal is actually poured; and,

(2) Core sands: which are utilized for making the cores that occupy the hollow spaces in the casting.

The material used for foundry sands varies greatly according to the nature of the casting, the metal to be poured, the particular part of the mould, and the foundry where employed. Thus, materials varying from a heavy clayey loam, to a coarse river sand, are used according to the nature of the casting being made. A sand which is suitable for a coarse casting would not be satisfactory for fine work; so, too, a different grade of sand entirely is frequently used for making the cores. Again, in green sand moulding the sand used differs from that used in dry sand moulding—where the moulds and cores are first baked. The practice in various foundries is so diverse, and the sand employed for different grades of castings varies so widely, that it is almost impossible to lay down a hard and fast set of standards to which a sand must conform in order to be called a foundry sand. This is partly due to the manner in which the average foundryman looks on his sand, and partly to the lack of accurate knowledge as to the behaviour and action of certain sands with regard to the castings made in them. The sand used in most cases is employed on the advice of the foundry superintendent, who generally trusts to his practical experience in the handling of sands, as to the suitability of a particular sand for the work in hand. The appearance of the sand to the eye, and whether it will retain the impress of the hand when damp, are generally all the tests to which the sand is subjected. If the moulder does not like the look of the sample submitted, and, especially, if he knows it is a local sand, it is frequently condemned as not suitable without further examination. While this condition of affairs exists, it will be hard to adopt any standards for moulding sands, but it is conceivable that, when the qualities of different sands in relation to the class of castings made in them have been more fully studied, it will most likely be possible to formulate a set of standards with limits within which a sand may be determined to be suitable for a certain class of casting systematic laboratory and foundry tests.

THE OCCURRENCE OF MOULDING SAND

Natural Moulding Sands.

Moulding sands occur in two main types of deposits; but variations of these types may be encountered. These are:—

(a) From flood plain deposits, and
(b) Re-washed ancient beach sands.

(*a*) *Flood plain deposits.*

From the nature of a moulding sand—it being essentially a silica sand with each individual grain coated with a bonding material—one would expect to find it occurring where deposits of sand and clay were constantly being inter, mingled, and worked over by water, and as a matter of fact, moulding sands in flood plain deposits are of quite common occurrence. In these beds the sand and clay have been well and intimately mixed by the river currents, and deposited on the higher levels in flood time; the excess of clay, being more *minute*, is carried off by the water.

One would thus expect to encounter moulding sands of this character along the upper terraces of the large rivers of the country, such as the St. Lawrence; also along the banks of the ancient waterways.

(*b*) *Rewashed, ancient beaches.*

The second class of deposits which are frequently encountered are of secondary origin. The sand bars and beaches of the ancient seas have been worked over by the waves as they recede, when new levels of the lakes and seas are formed. The washed material from these beaches consists of sand and clay, the former being deposited in greater abundance. It is in deposits of this class, which are found at a lower level than the old beaches or water margins, that moulding sand may be expected to occur. These deposits are, therefore, to be looked for in the vicinity of the ancient glacial lake margins; such as the Iroquois and Algonquin, which formerly occupied the Great Lake Basin; and also within the boundaries of the ancient lake Agassiz in Manitoba. Similar ponded water bodies in glacial times—extending as far as the foot-hills of the Rocky mountains in Alberta—may also have deposits of this character within their margins.

Prepared Moulding Sands.

The natural moulding sands referred to above comprise by far the greater part of the sand used in Canadian and United States foundry practice; but there are being employed increasing amounts of what may be termed "prepared moulding sands;" and as the suitability of this class of sand becomes better known there is no doubt that their use will be widely extended. These sands are prepared for use by crushing either sandstones which have a very friable bonding material, decayed granite, or shattered sandstone having the fractures filled with a plastic material (such as kaolin, etc.). These sands have no fillers added to them, but have perhaps to be screened and washed, as well as crushed, before being offered to the trade.

Under this class may also be placed those earthy loams which, by washing—to remove part of the clayey content—may be utilized as a suitable foundry sand.

Synthetic Moulding Sands

Many foundrymen have stated that they feared it is quite possible that the present known deposits of high grade natural moulding sand will become exhausted, and that resort will have to be had to artificial or synthetic moulding sands made by intimately mixing finely crushed quartz, or clean, sharp sand, with clay, so that each grain of quartz would become uniformly coated with the clay. It can readily be seen that sand so prepared will have decided advantages over the sands at present in use, in that it will be possible to manufacture a uniform material for the class of work required, and also that variations in the material can be made at will to meet the requirements of the trade.

THE TESTING OF MOULDING SANDS.

The examination and testing of a moulding sand deposit can be divided into two parts:—

(a) The field examination of the deposit.
(b) Laboratory examination and testing of the sands.

Field Examination of a Sand Deposit.

In undertaking a field examination of a moulding sand deposit, there are several points to be taken into consideration:—

1. Nature and extent of the deposit (area and depth).
2. Uniformity of sand.
3. Transportation facilities.
4. Location, with respect to the larger markets.

The importance of a field examination can readily be seen. A sand may be suitable for foundry work in every way; but, if it is not in sufficient quantity, easily exploited, and is not favourably situated to the larger markets for this class of material, the deposit is of little value as a commercial venture.

The method of field examination employed by the writer is as follows: The area is tested by drilling test holes with a 6″ post auger drill, in a sufficient number of places to determine the extent and depth to which the sand is encountered. These holes are indicated on a map of the area and the boundaries of the sand plotted. The sand encountered in the drill holes is carefully examined with a hand magnifying glass to note any marked difference in its character. Samples are taken from these holes and mixed together to obtain a uniform sample for testing in the laboratory. If more than one grade is noted, separate samples are taken.

Laboratory Examination and Testing of the Sands.

On commencing the laboratory tests of the samples taken in the field, the question arose, "What are the requirements of a good moulding sand?" The literature on moulding sands is very meagre, and any systematic series of laboratory tests to determine a sand's suitability for a foundry sand are confined to work done by several of the State Surveys, the Bureau of Standards, Washington, and the American Foundrymen's Association. The opinions of the investigators appear to differ greatly both as to the series of tests necessary, as well as the method by which they are to be carried out.

From a study of the literature available, and after numerous conversations with practical foundrymen throughout the country, it was found that the qualities to be taken into consideration in the examination of a moulding sand are as follows:—

Texture.

The texture or fineness of grain is one of the most important points of sand. This will necessarily vary, according to the size and kind of casting to be made in it. Hence, it is at once obvious that sands will have to be selected to suit the class of work for which they are required, or, in other words, sand which is suitable for light work would, perhaps, be a failure when used with heavy work, or vice versa.

Refractoriness.

The capability of effectively resisting the destructive action of the heat of molten metal, is of importance. The greater the size of the casting, the longer it will be in cooling, hence the sand in contact with the metal will be subjected

---

[1] The sands referred to are moulding sand proper. Core sands vary widely in different localities, and mostly require bonding material to be added to them. They will be treated separately at a later date.

to the intense heat for a longer period of time. It is obvious, therefore, that for large castings, a more highly refractory sand will be required than for small castings.

Bonding power.

Moulding sands should possess sufficient bonding power, or cohesiveness of their particles to each other to retain firmly the shape and form of the pattern; and also to resist the pressure of the molten metal in the mould. This bonding power depends partly on the clay mixed through the sand particles, and the clay coating on the individual grains, and partly on the nature of the grains, whether they are angular or rounded, coarse or fine. As a rule, the finer and more angular the sand grains, the greater the bonding power.

Permeability.

One of the properties of a moulding sand which helps to determine its suitability for foundry use is that of allowing the escape of gases through it. The molten metal develops gases which exert a pressure on the face of the mould and, unless the spaces between the grains are sufficient to enable the gases so generated to escape freely, there will be serious danger of creating scabs, or causing the castings to blow on this account. Obviously, then, heavy castings will require a more open sand of a coarser grained texture than will fine castings.

Durability.

The durability or life of a sand is of great importance. There are many sands which, when used once or twice, lose some of their desirable qualities, and soon become "dead" or useless. It is manifest that the sand in contact with, and adjacent to, the molten metal will suffer most. The present practice is to screen out the coarse particles, and add fresh sand to the remainder. The greater the durability of a sand, the better it is, as it will last longer, and it will not be necessary to add fresh sand to it so frequently.

In deciding upon the methods to be employed in examining the samples taken—with a view to ascertaining their characteristics regarding the qualities just enumerated, it was decided to proceed as follows:—

The sample for examination is first passed through a 10 mesh screen, and what is retained on this screen is considered the sample for examination; and all tests are conducted with this material.

ACTUAL TESTS.

Texture.

The texture is determined by making a granulometric analysis of a representative sample, generally 100 grams. This is passed through a series of Tyler standard screens, by shaking for a definite length of time on a mechanical shaker; the material retained on each screen being collected, weighed, and noted. If the sample, in the first place, weighs 100 grams, the weight recorded as retained on each screen is the percentage retained on that screen; and the cumulative percentage of all material that would be retained on any given screen, if that screen alone were employed, can readily be determined. The screens used for this test and the form used for tabulating the results are as follows:—

Indicate the screen crushed through and also first retaining screen	SCREEN SCALE RATIO 1·414				WEIGHTS		
	Openings		Mesh	Diameter wire inches	Sample weights	Per cent	Per cent cumulative weights
	Inches	Millimetres					
	·065	1·651	10	·035			
	·046	1·168	14	·025			
	·0328	·833	20	·0172			
	·0232	·589	28	·0125			
	·0164	·417	35	·0122			
	·0116	·295	48	·0092			
	·0082	·208	65	·0072			
	·0058	·147	100	·0042			
	·0041	·104	150	·0026			
	·0029	·074	200	·0021			
Pass	·0029	·074	200	·0021			
				Totals,			

In order to gain some idea of the relative fineness of the sand, and to be able to express this in one figure, a more convenient form than the whole granulometric analysis, the average fineness of the sample is calculated. The average fineness is determined as follows: the material passing through each screen and retained on the next smaller, is multiplied by the mesh of the screen passed through. The results obtained are totalled and divided by 100, the resultant being the average fineness. In other words, if all the grains of the sample were reduced to a uniform size, they would just pass through a screen whose mesh was equal to the average fineness of the sample. For example the granulometric analysis of a sand is:—

	Mesh	%	The calculations for average fineness will be
Retained on	10		
"	14	—	14 × 0·10 = 1·40
"	20	0·10	20 × 0·12 = 2·40
"	28	0·12	28 × 0·23 = 6·44
"	35	0·23	35 × 0·65 = 22·75
"	48	0·65	48 × 0·72 = 34·56
"	65	0·72	65 × 1·50 = 97·50
"	100	1·50	100 × 13·01 = 1301·00
"	150	13·01	150 × 22·30 = 3345·00
"	200	22·30	200 × 61·37 = 12274·00
Through	200	61·37	Total....... 17085·05

$$\frac{17085\cdot05}{100} = 170\cdot85$$

or the average fineness of the sample is 170·85.

Microscopic Examination.

It has been found that the free use of the microscope in examining the sand, both fresh and after being burned, has added valuable data which helps materially in determining a sand's suitability for a moulding sand. Microphotographs of the sand are also valuable for comparison.

Refractoriness.

The refractoriness of a sample is determined by preparing a cone of the sand and heating it to fusion in an electric furnace along with standard Segers cones, and noting at what cone the sand fuses.

Bonding power.

The determination of the bonding power of a moulding sand from tests either in a laboratory or in actual foundry practice presents many difficulties, and the methods so far devised give only relative results, and these are variable according to the skill of the operator in making the tests. The tentative method adopted for these tests is similar to the method employed by the Bureau of Standards, Washington, D.C., with a few slight modifications. By this test the transverse strength of the sand is determined. A known quantity of a particular sand is weighed (generally 500 grams), and mixed with a definite quantity of water, so that the sand will just hold together. From this sand, a test bar is made, one inch square, in section, by 12 inches long. This is moulded in a snap flask on a piece of plate glass.

The sand is packed in the flask as uniformly as possible from end to end with the thumb and forefinger of each hand, and smoothed with a trowel. The flask is removed, and the test bar, is left on the plate. The glass plate and bar are then weighed, the weight of the glass plate having been previously determined, and the weight of the test bar is obtained by difference.

While the test bar still retains its moisture, it is gently and steadily shoved lengthwise over the edge of the glass plate until it breaks off and the length breaking off is noted. Continuing this operation, successive portions are broken off and the average length of the overhang at the breaking moment is determined. The weight of the bar in grams being known, the transverse strength of the specimen can be calculated from the following formula:—

$$S = \frac{\text{Wt. of bar (in grms.)}}{4} \times \frac{L^2 \text{ in inches}}{453{\cdot}6}$$

S = transverse strength;
L = length of overhang in inches.

A series of tests were conducted on each sample, taking 5 c.c. additional water each time until the test bar deforms on attempting to shove it over the edge of the glass. An average of the transverse strength results obtained by using varying quantities of water is taken to represent the transverse strength of the specimen.

Permeability.

The method adopted for the determination of the permeability of a moulding sand is, as far as the writer knows, entirely new. Investigations along this line have consisted in passing either a definite amount of water or air sand, and noting the time required. Both these methods introduced a serious error, since once the first air or water had passed through the sand, channels would be opened through the sand which would greatly facilitate the flow of the remainder of the air or water. To overcome this difficulty the apparatus shown in Fig. 1 was designed, and the results so far obtained have been extremely satisfactory. With this apparatus, ordinary illuminating gas at a definite pressure is passed through the sand, and ignited the instant it reaches the top of the sand tube. The interval of time required from when the gas is turned on, to the moment of ignition, is noted by a stop watch, thus determining the initial passing of the gas, and overcoming the error due to the forming of channels

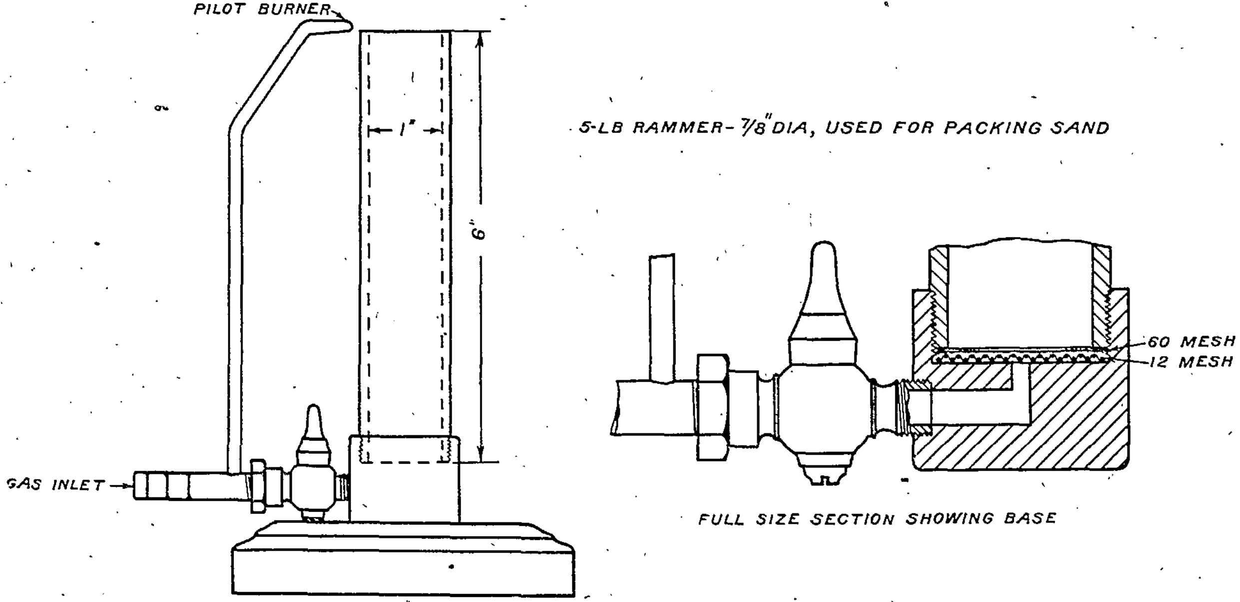


Fig. 1. Apparatus for determining permeability of moulding sands.

through the sand. Three tests are run on each sample, using fresh sand each time. The average time is taken as permeability factor. The sand is packed uniformly in the cylinder by placing in a small quantity at a time (about 1 inch of sand), and pressing it down for 5 seconds, using a 5 lb. weight. When the cylinder is filled it is struck off flush on the top with a straight edge.

Durability.

All the foregoing tests may be regarded as a preliminary inquiry as to whether any sand can be classed as a moulding sand and passed on to the durability test, which must always be regarded as the final one by which a sand from an unworked deposit is accepted or rejected. The durability test is made under actual working conditions, hence definite knowledge of the usefulness of a sand can be determined.

If a sample, when subjected to the previously described tests, has proven satisfactory within certain accepted limits, a large sample is obtained and tested in a commercial foundry, where castings are being made of the class to which the sand is deemed best suited. A pattern is chosen, usually, one which comes in the general run of the foundry, and the sand to be tested is used with this pattern. Care is taken to keep separately the sand in which the casting is made, and another cast from the same pattern is made, using this sand without any fresh added. This operation is repeated until the sand shows signs of becoming "dead." After each cast, the sand is thoroughly mixed and a sample taken. These samples are submitted to all the laboratory tests previously described, and any differences noted. For means of comparison, a duplicate series of castings is made in parallel with the sand being tested, employing some well-known moulding sand.

TEST OF A MOULDING SAND COLLECTED NEAR BROCKVILLE, ONT.

To illustrate the methods employed in the examination and testing of a moulding sand the following report of a test on a deposit of moulding sand from near Brockville, Ont., will serve. This deposit was one encountered in the course of the regular field work, in connexion with the investigation of the sand deposits of Ontario.

Field Examination.

The deposit in question lies 2½ miles to the west of the town of Brockville, Ont., between the G.T. Ry. line (Montreal to Toronto), and the river road, (Brockville to Belleville).

As far as could be determined in the time at the disposal for the field examination the area underlain by moulding sand is of considerable extent, although detailed work, was only carried out on the area shown in the sketch map Fig. 2. No time was available to trace the extension of the deposit to the east or to the west, but this will be done during the field season of 1917.

The topography of the immediate district is decidedly rugged in appearance. The drift with which the district is overlain consists of rolling hills of boulder clay, sand, and gravel, through which numerous "islands" of bare rock protrude. These patches of bare rock consist, to the north and northeast, of Potsdam (?) sandstone, and, to the south and west, of Laurentian granites. All outcrops of rock examined were well glaciated, and rounded, showing clearly defined striæ.

By reference to the sketch map Fig. 2, it will be seen that the area so far known to be underlain by moulding sand lies between and around the rock outcrops already mentioned. A stream passing through the deposit has revealed clay beneath the sand.

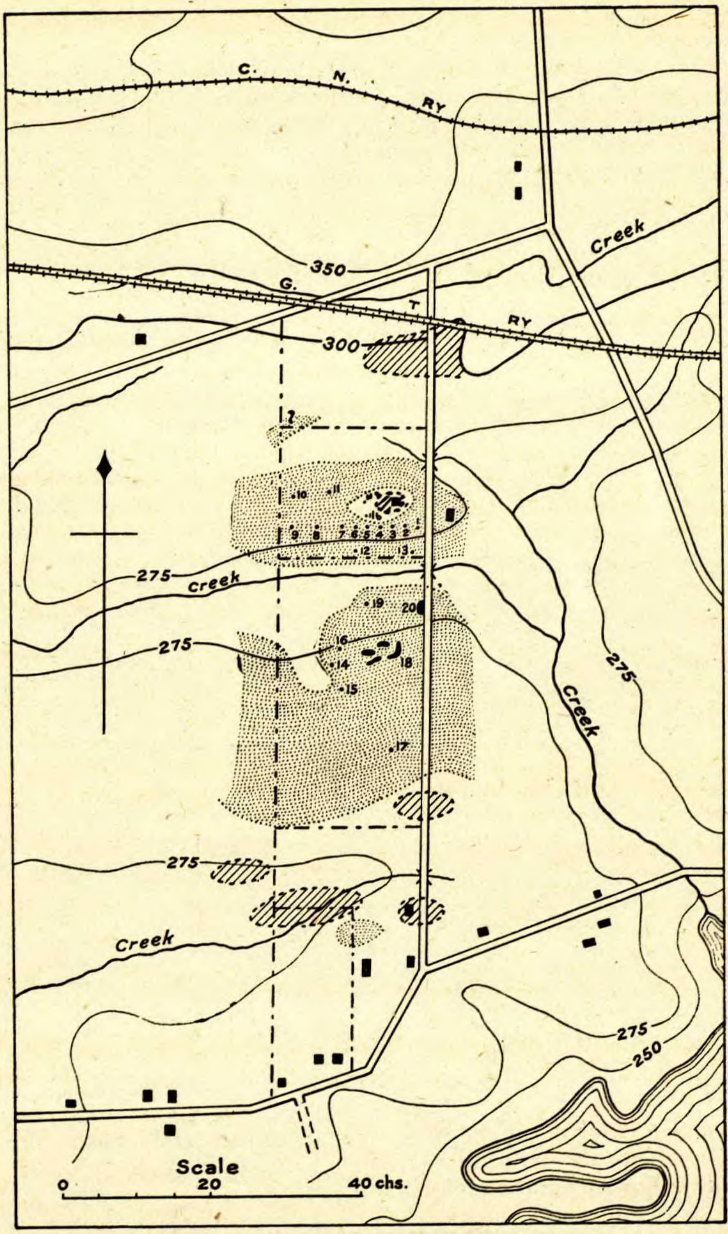


Fig. 2. Sketch map showing areas underlain by moulding sand on the property of T. H. Bresee and others, 2½ miles west of Brockville, Ontario.

The sand lies beneath a thin layer of loam averaging about 6 to 12 inches in thickness. In most places where tested, there was a definite line of demarcation between the loam and the sand.

The sand is fairly uniform over the whole deposit shown in the sketch, and will average 2 ft. 4 ins. thick. In all the test holes and pits, only two boulders were encountered, each about 2½ inches diameter; so that the sand appears to be free from stones in the area examined. To the edges of the deposit, where the sand and boulder clay are in contact, it may be that the boulders are more frequent.

In order to determine the nature and extent of the deposit a number of test pits were examined and drill holes bored as indicated on the sketch map. The results obtained from these pits and holes are as follows:—

Record of Test Pits and Borings on Brockville Sand Deposit.

Hole or pit.	Amount of stripping.	Thickness of moulding sand.		Material below moulding sand.
	Inches.	Feet	Inches.	
1	8	3	8	sand and clay interbanded.
2	8	3	4	do
3	14	1	0	sandy clay.
4	12	1	2	" "
5	10	1	6	" "
6	10	3	10	" "
7	15	1	9	" "
8	8	2	0	" "
9	10	1	10	" "
10	7	2	2	" "
11	10	2	6	" "
11a	stiff clay to a depth of 3 feet.			
11b	" " " "			
	Inches	Feet.	Inches.	
12	6	2	0	sandy clay.
13	10	1	6	" "
14	4	2	6	" "
15	8	2	6	" "
16	6	3	0	" "
17	8	2	0	" "
18 pit.	8	2	6	" "
19	10	2	8	" "
20 pit.	4	3	2	" "

No idea can be given of the total tonnage of sand available, as the complete boundaries were not located, but that there is a considerable quantity there can be no doubt, judging from the area tested.

Preliminary Tests.

A sample of 40 pounds of sand was taken when the deposit was first visited, and this was applied by the Alex. Fleck, Ltd., foundry, Ottawa, to make moulds for three iron castings; one at a time, using the Brockville sand, exclusively, each time. The weight of the casting was about 12 pounds, and all three casts were perfectly satisfactory, having a good smooth surface, free from scabs, and corners showing clean definition.

This preliminary test having proved satisfactory, two lots of 600 pounds each, were dug, and shipped by the writer to Ottawa, without preparation in any way, in order to test the lasting and wearing qualities of the sand. Care was taken to see that the samples collected were representative of the whole deposit as far as could be ascertained. One shipment was taken to the foundry of Alex. Fleck, Ltd., Ottawa, where the first tests were made; and the other 600 pounds was delivered to the brass foundry of Lawson Bros., Ottawa.

At both places the tests carried on were made under the supervision of the writer, who followed closely all the results obtained, and examined the sand and castings after each cast.

TEST OF SAND AT THE FLECK FOUNDRY, OTTAWA.

It was desired to gain an idea of the life of the sand when employed with fairly heavy pieces of casting. In order to obtain comparative results, the same amount of fresh No. 3 Albany Moulding sand—as used in this foundry was taken—and used side by side with the Brockville sand on the same pattern. After each cast, each sand was kept separate, thoroughly mixed, sampled, and used again. The piece cast was an iron flange in the shape of an L, 5-feet long, 10 inches wide, and 1 inch thick; with a 3 inch flange 1 inch thick, on one side. The weight of the casting was approximately 200 pounds.

Five castings were made in each sand under ordinary working conditions, the moulding being done on the two sands by the same moulder throughout, under the direct supervision of the foreman. Care was taken that each sand was thoroughly mixed after each casting. A sample of each sand was taken when fresh, and after each burn, and examined in the Mines Branch Laboratories. No fresh sand was added to either test, and only the sea coal that was absolutely necessary was employed.

The castings were examined after each cast. There was no noticeable difference between those cast in either sand, or from the first and fifth cast in the same sand.

TEST OF SAND AT THE LAWSON BRASS FOUNDRY, OTTAWA.

The sand sent to Lawson Bros. was used in their brass foundry on general run of work, employing whatever pattern they needed each day. The Brockville sand was kept separate throughout, and the cast was varied between brass and iron, all castings being small. The sand was mixed thoroughly after each burn and no fresh sand added to it. Samples after every alternate burn were taken for examination. Seven castings in all were made in the same sand, the weight of castings varying from 12 to 50 pounds. Five were brass, and two iron. All castings showed clear, sharp, well defined edges, and the body free from scabs. No sign of burning appeared on any of the castings. A sample of the fresh Albany sand, No. 0, as used in this foundry, was taken for comparison.

LABORATORY TESTS.

The samples for examination—obtained from the casting tests at the two foundries—were subjected to the following laboratory tests.

GRANULOMETRIC TEST.

The samples as brought from the foundries were each treated as separate samples. Each one was thoroughly mixed and quartered, and 100 grams taken, and put through a set of Tyler Standard Screens, on a mechanical shaker. The results obtained are tabulated in Table I.

TRANSVERSE STRENGTH.

The test for determining the transverse strength or bonding power of the sand was carried out in a similar manner to that employed in the Bureau of Standards, Washington, D.C., U.S.A., with the exception of always taking the same amount of water. A series of tests were run on each sample, varying the amount of water 5 c.c. each time, and taking the average of results obtained as the transverse strength. The results of the tests are given in Table II.

TEST FOR REFRACTORINESS.

A test for the refractoriness of the fresh Brockville sand was made by preparing a cone and fusing it in an electric furnace with Standard Seger cones. The test cone fused at cone 8 which is equivalent to 1290 degrees C. or 2354 degrees F.

MICROSCOPIC EXAMINATION.

The fresh sand, as well as the samples from each burn, were examined under a binocular microscope, and the following notes made:—

No.		
1	No. 3, Albany fresh sand (*Fleck Foundry.*)	Small grains, well rounded. Larger grains, semi-angular. Quartz predominant. Occasional grain of magnetite; all were coated with clay and of uniformly yellowish colour.
2	„ „ 1st. burn.	Quartz grains in some cases have the clay partially burned off. Sintering is seen in a few cases in the smaller grains. In most cases sand grains are unchanged.
3	„ „ 2nd. burn.	Similar to No. 2 with exception that the sand has a darker appearance, due to occasional grains having turned reddish in colour from the oxidation of the ferric iron coating.
4	„ „ 3rd. burn.	Sand has a darker appearance. Sintering more pronounced. Cementing of groups of the smaller grains together. Larger grains losing their clay coating to a small extent.
5	„ „ 4th. burn.	Similar to No. 4 with the grouping together of the smaller grains more pronounced.
6	5th. burn.	Large grains have taken on the appearance of spongy masses due to the adhering of the smaller particles to them. Smaller particles are grouped and cemented together still further. Sintering quite pronounced. Occasionally edges of larger grains are fused.
7	Bockville fresh sand. (*Fleck Foundry*).	Sand consists of fairly clean quartz sharp and angular with only a very thin film of clay coating. Magnetite, hornblende, feldspar, and mica visible. Light yellowish colour.
8	„ „ 1st. burn.	Sintering appearing. Sand assuming a darker colour.

No.			
9	Brockville Sand, *(Fleck foundry)*	2nd. burn.	Sintering quite pronounced. Larger grains have smaller grains cemented to them and the smaller grains commencing to group together in cemented masses.
10	„ „	3rd. burn.	Sintering and cementing together o fsmall particles more pronounced. Sand grains showing decided effect of heat.
11	„ „	4th. burn.	Complete fusion in mass of some of the smaller groups of particles can be seen. The edges of most of the larger grains have become fused and present an appearance of water-worn sand.
12	„ „	5th. burn.	Sintering pronounced in most of the grains. Small grains are grouped together and well fused. Larger grains show fusion of sharp edges. Bonding coating has disappeared from the greater percentage of grains.
13	Brockville fresh sand. *(Lawson foundry)*.		Coating slightly affected. No sign of sintering.
		1st. burn.	Sand similar in appearance to original.
14	„	3rd. burn.	No sign of sintering. Coating only slightly affected. Otherwise similar to original.
15	„	4th. burn.	Same as No. 14.
16	„	5th. burn.	Same as No. 15 with slight signs of sintering.
17	„	7th. burn.	Slight sintering. Smaller particles in some cases cemented together.
18	No. 0 Albany fresh sand.		Highly siliceous sand. Uniformly graded and coated. Sand particles sharp and angular. Light yellow in colour.

Microphotographs of each sample were taken, and are shown in Plates VI, VII, and VIII. (See plates at end.)

Chemical Analysis.

A chemical analysis of the Brockville sand was made, with the following result:—

Ultimate Analysis.

SiO_2	74·35	per cent.
Fe_2O_3	1·10	„ „
FeO	1·48	„ „
Al_2O_3	12·63	„ „
CaO	2·60	„ „
MgO	1·06	„ „
Na_2O	2·73	„ „
K_2O	2·15	„ „
H_2O	1·90	„ „

It is questionable whether much information can be obtained from ultimate analysis, beyond a very general indication of the refractoriness, and is moreover frequently very misleading, hence it is deemed advisable to omit it in future.

Permeability Test

The permeability test shows that the permeability increases the oftener the sand is subjected to the molten metal. Results are given in Table III.

CONCLUSIONS DEDUCED FROM RESULTS OF TESTS.

An examination of the results obtained from the series of tests carried out on this sand brings out some interesting facts regarding the properties of moulding sands, and their behaviour under actual working conditions.

Granulometric Analysis.

By comparing the No. 3 Albany screen analysis with the Brockville sand used at the Fleck foundry, it will be seen that there is in both cases increase in the coarseness of the particles, the oftener the sand is submitted to the heat of the molten metal. In the case of the No. 3 Albany, this increase is uniform and very gradual; whereas with the Brockville sand the changes are abrupt, and not uniform, showing a tendency of the smaller particles to become cemented together. On the other hand, the Brockville sand as used at the Lawson foundry, shows only a slight increase after each burn, and the increase is uniform.

Tests for Transverse Strength.

In examining the results obtained by the tests for transverse strength it is seen that both in the No. 3 Albany and the Brockville sand used at Fleck's, there is a gradual decrease in the amount of water used and also a decided decrease in the transverse strength. In the case of the Brockville sand used at Lawson's the decrease in strength is only slight.

Microscopic Examination.

By microscopic examination of the samples obtained after each burn, and also the fresh sand, some interesting data were secured. The Brockville sand (Fleck's), shows decided sintering and cementing together of the smaller grains to the larger ones, with a consequent decrease in bonding power. This sintering and cemeting together of the particles is shown plainly in the microphotographs, Plate VII. The sand tested at Lawson's shows very little alteration when examined under the microscope.

Chemical Analysis.

The conclusions to be drawn from the chemical analysis are so slight that it can be dispensed with in an examination of this kind, the physical tests being the only ones of value.

SUMMARY OF RESULTS.

Summing up the results obtained in the tests, it appears that the Brockville sand is a suitable moulding sand for stove plate and similar light work in iron, but although the heavier castings made in it were seemingly all right, it would not be advisable to use it on very heavy work, as the possibility of its failure would be greater than the coarse sands in general use, owing to the fineness of its texture with the resultant tendency to sinter when exposed repeatedly to the molten metal.

It appears to answer all requirements for use in the general run of brass foundry work. With a little care in selection and grading at the pit, several grades uniform in texture could be obtained.

TABLE I.

Granulometric Tests.

Cumulative per cent of material retained on given meshes.

		6.	8.	10.	14.	20.	28.	35.	48.	65.	100.	150.	200.	200+	Average Fineness.
Brockville (Flecks).	Green sand..	—	—	—	—	·09	·24	·46	·69	1·63	8·85	49·95	77·21	—	132·9
	1st. burn....	—	—	·27	·80	2·01	4·14	8·83	19·54	28·83	40·27	67·83	82·87	—	102·0
	2nd. „	—	—	·18	·36	·78	2·00	4·88	12·00	16·95	28·80	60·27	80·79	—	114·4
	3rd. „	—	—	·41	·89	2·01	3·91	8·84	20·18	27·70	41·96	68·35	83·00	—	94·7
	4th. „	—	·30	·80	1·26	2·17	4·46	8·68	19·70	29·03	41·23	70·26	85·12	—	99·21
	5th. „	—	·31	·74	1·41	2·46	5·15	10·98	24·60	34·05	48·09	72·46	80·02	—	96·6
No. 3 Albany (Fleck's).	Green sand..	—	—	·40	1·00	1·98	4·65	13·08	34·03	50·65	65·96	78·51	83·77	—	81·3
	1st. burn....	—	—	·69	1·30	2·47	4·74	12·37	32·82	50·66	66·85	79·58	85·55	—	79·7
	2nd. „	—	·36	·91	1·56	2·76	5·55	13·72	36·09	52·11	68·03	79·65	86·01	—	78·2
	3rd. „	—	·40	1·03	1·86	3·52	6·68	16·13	36·52	54·18	69·33	82·22	82·34	—	77·5
	4th. „	·42	·92	1·43	2·13	3·39	6·89	16·53	39·35	54·37	70·24	82·68	87·90	—	73·5
	5th. „	—	·50	·90	1·63	2·89	6·23	15·68	37·71	52·85	68·96	81·30	87·78	—	75·6
Brockville (Lawson's).	Green sand..	—	—	—	—	·09	·24	·46	·69	1·63	8·85	49·95	77·21	—	132·9
	1st. burn....	—	—	—	·05	·18	·46	·75	1·22	2·79	11·56	48·43	74·05	—	134·0
	3rd. „	—	—	—	·13	·26	·44	·81	1·21	10·41	10·41	51·75	77·06	—	131·3
	4th. „	—	—	—	·11	·38	·69	1·05	1·42	2·7	11·44	46·25	72·39	—	134·8
	5th. „	—	—	—	·18	·38	·68	1·16	1·93	3·91	12·83	50·46	72·91	—	132·7
	7th. „	—	—	·20	·40	·62	1·02	1·42	3·37	4·22	11·71	49·06	60·75	—	140·1
	*Green sand.	—	—	·14	·46	·88	1·38	2·03	3·01	5·03	11·27	19·46	26·64	—	171·4

*No. 0 Albany (Lawson's).

TABLE II.

Transverse Strength in Pounds.

(500 grams sand used in all tests; therefore, percentage of water used is double number of c.c. used divided by 10).

	H_2O used.	45 c.c.	50 c.c.	55 c.c.	60 c.c.	65 c.c.	70 c.c.	75 c.c.	80 c.c.	85 c.c.	90 c.c.	95 c.c.	Average.
Brockville (Fleck's)	Green sand...........						0·76	0·85	0·87	0·96	0·97	1·01	0·93
	1st. burn............						0·75	0·84	0·90	0·97	——	——	0·865
	2nd. „						0·86	0·85	0·86	0·81	——	——	0·845
	3rd. „				0·80	0·87	0·89	0·90	——	——	——	——	0·865
	4th. „				0·76	0·75	0·65	·085	——	——	——	——	0·752
	5th. „				0·76	0·78	0·74	0·79	——	——	——	——	0·767
No. 3 Albany (Fleck's)	Green sand..........		0·74	0·73	0·93	1·07	——	——	——	——	——	——	0·867
	1st. burn............		0·62	0·71	0·57	——	——	——	——	——	——	——	0·633
	2nd. „		0·57	0·69	0·65	0·74	——	——	——	——	——	——	0·665
	3rd. „		0·65	0·65	0·80	——	——	——	——	——	——	——	0·700
	4th. „		0·62	0·63	0·62								0·623
	5th. „		0·58	0·59	0·55								0·573
Brockville (Lawson's).	Green sand..........						0·76	0·85	0·87	0·96	0·97	1·01	0·903
	1st. burn............						0·84	0·76	0·84	0·89	0·95		0·856
	3rd. „						0·92	0·97	0·96	0·85	——	——	0·875
	4th. „						0·90	0·92	0·88	0·88	0·85	——	0·886
	5th. „						0·91	0·82	0·97	0·88	——	——	0·895
	7th. „						0·85	0·81	0·84	0·89	——	——	0·847

TABLE III.

Permeability Test.

Time in seconds. Gas pressure = 2·8 inches.

		1st. Trial.	2nd. Trial.	3rd. Trial.	Average.	
No. 3 Albany (Fleck's Foundry).	Fresh	$4^{1}/_{5}$	5	4	$4^{2}/_{5}$	
	1st. burn	4	3	$3^{1}/_{5}$	$3^{2}/_{5}$	60 c.c. water used = 12%.
	2nd. „	$2^{4}/_{5}$	$2^{4}/_{5}$	$2^{4}/_{5}$	$2^{4}/_{5}$	
	3rd. „	$2^{4}/_{5}$	$2^{4}/_{5}$	$2^{4}/_{5}$	$2^{4}/_{5}$	
	4th. „	3	$3^{1}/_{5}$	$2^{1}/_{5}$	$2^{4}/_{5}$	
	5th. „	$2^{3}/_{5}$	$2^{3}/_{5}$	$2^{3}/_{5}$	$2^{3}/_{5}$	
Brockville Sand (Fleck's Foundry).	Fresh	19	$17^{3}/_{5}$	18	$18^{1}/_{5}$	70 c.c. water used = 14%.
	1st. burn	8	$7^{3}/_{5}$	$8^{2}/_{5}$	8	
	2nd. „	8	8	$9^{1}/_{5}$	$8^{2}/_{5}$	
	3rd. „	5	6	7	6	
	4th. „	7	$5^{1}/_{5}$	$5^{1}/_{5}$	$5^{4}/_{5}$	
	5th. „	$5^{1}/_{5}$	6	$6^{3}/_{5}$	$5^{1}/_{5}$	
Brockville Sand (Lawson's Foundry).	Fresh	19	$17^{3}/_{5}$	18	$18^{1}/_{5}$	70 c.c. water used = 14%.
	1st. burn	$10^{2}/_{5}$	10	$10^{2}/_{5}$	$10^{1}/_{5}$	
	3rd. „	$12^{3}/_{5}$	$10^{1}/_{5}$	11	$11^{1}/_{5}$	
	4th. „	$8^{1}/_{5}$	8	$8^{1}/_{5}$	$8^{1}/_{5}$	
	5th. „	11	$11^{4}/_{5}$	$10^{4}/_{5}$	$10^{4}/_{5}$	
	7th. „	$8^{4}/_{5}$	$7^{3}/_{5}$	$6^{4}/_{5}$	$7^{4}/_{5}$	
Albany No. 0	Fresh	23	23	$21^{4}/_{5}$	$22^{3}/_{5}$	70 c.c. water used = 14%.

V

INVESTIGATION OF BITUMINOUS SANDS OF NORTHERN ALBERTA.

S. C. Ells.

Field work during 1915 had comprised:—

(1) Detailed topographical mapping of the more important bituminous sand areas in northern Alberta. Surveys were completed on October 17, 1915, and map sheets of the six principal areas were issued on March 15, 1916; and (2) construction of demonstration pavements illustrating the commercial application of Alberta bituminous sand as a paving material. Reference, in detail, to the above construction, appeared in the Summary Report of 1915. Subsequently, Mr. A. W. Haddan, Acting City Engineer of the city of Edmonton, examined the work, and submitted the following reports:—

"Experimental Pavement with Fort McMurray Tar Sands."

January 15, 1916.

Complying with your request to keep in touch with the piece of experimental paving surface constructed with the bituminous tar sands from Fort McMurray, I made the first inspection yesterday.

For the past week or two, the temperature has ranged from 15° F. to 46° F. below zero, which may be considered as low a temperature as our pavement surfaces are designed to take. The surface was covered with from 2 to 3 inches of snow, with a thin coating of ice next to the surface. The snow was shovelled off from strips of the surface, but in no cases did we find contraction cracks due to low temperature.

As soon as the snow leaves in the spring and before the frost has left the ground, I will make a thorough inspection of the surface to determine the effect of the first wintering.

November 1, 1916.

I have your letter of October 24th, enquiring as to the condition of the experimental pavement, laid in this city, with the native bituminous sands from Fort McMurray and Fort McKay. I examined this pavement again yesterday on receipt of your letter, and find it in perfect condition. The only defect is the transverse crack, which is probably due to contraction of the base and subgrade, and could not be taken in any way as default of the surfacing.

The pavement does not show any markings, due to horse traffic in hot weather. There are no indications of any waving either on the sand mixture or rock mixture. There is no indication of any pitting, which we sometimes find on our suburban roads, due to the clay caking on the surface, and when it flakes off, very often pits the surface by taking a small portion with it.

As a result of the above investigation[1] of the deposits of bituminous sands of northern Alberta, a considerable amount of statistical data and other information is now available. Three outstanding features presented by these deposits may be briefly stated:—

(*a*) In the McMurray district, in the Province of Alberta, there is a large and practically continuous body of bituminous sand, represented at many points by individual outcrops. The area of the deposit is not less than 750 square miles, and is probably much greater.

Upwards of two hundred of the principal outcrops have been accurately measured, and ninety-three core samples procured, and analysed. Measurements indicate that, owing to various and recognized causes, the thickness of the deposit varies from point to point. Although it is thus difficult to state an average vertical dimension, it is probable that, including both high grade and low grade material, the thickness of the bituminous sand over a large area is not less than 130 feet.

Wide variation occurs, from place to place, in the quality of the material, and only after careful exploration by means of adequate equipment can the true

---

[1] Preliminary Report on Bituminous Sands of Northern Alberta, No. 281, and Mines Branch Summaries, 1913, 1914, and 1915.

value of any individual area be affirmed. Nevertheless, owing to heavy overburden, and lack of uniformity in the quality of the bituminous sand, it is probable that quite 80 per cent of the area represented by outcrops may be eliminated from further consideration at the present time. Certain of the outcrops, representing many millions of tons of bituminous sand, should, however, lend themselves to development on a commercial scale.

It must be recognized that the success of such development will largely depend on making no false move in the first place, and in eliminating all "lost motions" during subsequent operation.

(*b*) It has been shown that, by using a properly designed plant, and by observing reasonable care in the manipulation of materials, Alberta bituminous sand can be successfully utilized in the construction of asphaltic wearing surfaces—including both sheet asphalt, and various rock mixes.

(*c*) From a comparative study of detailed cost data, based on the use of Alberta bituminous sand, and of various imported asphalts, it is evident that markets for the former, in its crude state, will be restricted by freight charges within comparatively narrow limits in western Canada. Indeed, it is probable that extensive development of the McMurray deposits will depend largely on the successful commercial application of a separation process whereby the bitumen can be marketed in a more or less pure form. Such a process would doubtless ensure for the McMurray product a considerable market, not only as a paving material, but in meeting various other demands for a high grade bitumen. Indeed, so far as the Alberta deposits are concerned, it is difficult to over-estimate the importance that will attach to a successful separation process.

In view of the above considerations, the writer suggested, early in 1916, that further paving work and topographical mapping of the bituminous sand area be deferred for a time, and that an attempt be made to determine some commercial method for the separation of the bitumen from the crude bituminous sand. This suggestion was accepted and arrangements made to undertake the investigation at the laboratory of the Mellon Institute of Industrial Research at Pittsburgh, Pa. Work at Pittsburgh is now in progress, and a statement of results obtained will be available in 1917.

Before proceeding to Pittsburgh, the writer visited McMurray, and prepared for shipment a quantity of bituminous sand for laboratory purposes. While awaiting an opportunity to return to Edmonton, it was necessary to remain at McMurray six days after the completion of the above work. This interval was spent in considering a number of matters, of which the following may be very briefly mentioned.

For many years past, more or less exaggerated claims have been made by various persons regarding the occurrence of coal seams in the McMurray area. Two of the more important of the reported seams were, therefore, found, and samples procured. Proximate analyses[1], by fast coking, are given below, and are, as far as the writer is aware, the first definite information regarding the character of the coal in this area. The sample from McKay is from an outcrop just above June water level of the Athabaska river, and almost due east from the Roman Catholic Mission House. The other sample is from a point on the Christina river, approximately 5½ miles from the mouth. This outcrop occurs in the north bank and is also just above June water level. Both seams are, therefore, at or near the base of the Dakota sands.

---

[1] Analyses by F. G. Wait, Chief Chemist, Department of Mines.

	McKay.	*Christina River.*
Water	17·32	19·67
Volatile combustible	37·96	35·10
Fixed carbon	35·79	34·27
Ash	8·93	10·96
	100·00	100·00
Fuel ratio	1 : 0·94	1 : 0·97

It was not practicable to determine the actual extent of the seams as this would have involved a considerable amount of excavation. It appears, however, that the seams are more or less local lenses associated with the bituminous sand, and that they are of doubtful commercial value.

For many years the occurrence of so-called "tar springs", or seepages of bitumen, has been recognized in the McMurray area, and these have constituted a limited source of supply for rivermen and others in pitching boats and canoes. Although familiar with upwards of a dozen of these "springs", the writer does not know of any of which the diameter exceeds four feet. In themselves, therefore, they are of no commercial significance. Apparently, no one had taken the trouble to determine the immediate origin of the bitumen in these "springs", and uninformed people have frequently pointed to them as definite indications of the presence of petroleum pools. Two of the "springs" were, therefore, excavated in order to try and determine the immediate origin of the more or less pure bitumen which they contain. In each instance the result was the same. Instead of coming from below, the bitumen merely seeps laterally from slightly inclined beds of particularly rich, coarse-grained bituminous sand. An underlying impervious clay parting, together with a small local depression in the ground, makes possible the formation of the small pool of bitumen.

In the river bottoms of certain streams, well-defined terraces have been noted at various times during the past three years. These terraces apparently consisted either of bituminous sand or of river wash. Certain of them occur immediately adjacent to the grade of the Alberta and Great Waterways railway. If they consisted of bituminous sand, they would at once become of considerable commercial importance.

Accordingly, two representative terraces were selected, and pits sunk to a depth of fifteen feet. In neither case was bituminous sand encountered. It is, however, still the opinion of the writer that certain of these terraces do consist, in part at least, of bituminous sand, and that further detailed prospecting may be well worth while.

BUILDING AND ORNAMENTAL STONES OF BRITISH COLUMBIA.

Dr. W. A. Parks.

In pursuance of instructions received from the Director of the Mines Branch, I spent the field season of 1916—May 27 to August 31—in making an examination of the quarries and possible sites for the production of building and ornamental stone in the Province of British Columbia. The itinerary was planned to cover the whole Province in one season's work. The results of the investigation will appear as Volume V of the Report on the Building and Ornamental Stones of Canada.

Disregarding small local quarries, and confining ourselves to actual production on a scale of commercial importance, the output of the Province may be summarized as follows:—

I. *Sandstone.*—Cretaceous sandstones of southern Vancouver island and the Gulf islands, with quarries at Nanaimo and Koksilah, and on Denman, Hornby, Newcastle, Protection, Gabriola, Mayne, Saltspring, Pender, and Saturna islands.

II. *Granite.*—(*a*) The granites of the Coast range with the chief quarries on Burrard and Jervis inlets, particularly on Nelson, Hardy, Granite, and Fox islands.

(*b*) The granites of the Nelson batholith with several quarries near Nelson.

(*c*) The granites of the Shuswap terrane with quarries on Okanagan lake.

III. *Marble.*—Quarries at Marblehead north of Kootenay lake, and on the east side of the same lake, opposite Kaslo. Quarries on Nootka sound on the west coast of Vancouver island.

IV. *Volcanic rock.*—The soft andesite of Haddington island in the Strait of Georgia, with a single quarry.

The sandstones vary in grain from coarse and pebbly to very fine, and in colour from buff to dark, blue-grey. The earliest production was from Newcastle island near Nanaimo, but more recently the quarries on Denman, Gabriola, and Saturna islands have yielded the chief output. The Vancouver Granite Company; the Denman Island Stone Company; and George Taylor of Saturna island, are the largest producers. Numerous buildings in Vancouver, Victoria, and Nanaimo, attest the suitability of these stones for fine architectural work.

The granites of the Coast grain are usually of grey colour, and medium grain. The only important production for building purposes is from the islands at the mouth of Jervis inlet —Nelson, Hardy, Granite, and Fox.

The excellent rift and grain of the stone make quarrying easy, but really favourable sites are by no means as numerous as the wide extent of the formation would lead one to expect. The chief producers at present are the Vancouver Granite Company, with quarries on Nelson island, and the Sechelt Granite Quarries operating on Hardy island. The stone from Granite island is somewhat darker than the average, and is in demand for monumental work.

Many fine buildings in Victoria and Vancouver are constructed of stone from Jervis inlet. Two excellent examples may be mentioned, namely, the post office and Winch building in Vancouver.

The granites of the Nelson district are coarser in grain and lighter in colour than the average Coast range type. Quarries are worked by the Kootenay Granite and Monumental Company at three-mile point, Kootenay lake, and the Canadian Pacific Railway Company has raised a large amount of stone for rough construction at a point on their line west of Nelson.

The granites of the Shuswap terrane are usually coarse in grain, and pinkish in colour. Excessive fracturing has rendered most of the stone useless, but a few favourable locations on the east side of Okanagan lake have been worked by the Vernon Marble and Granite Company. Practically the whole output has been used in Vernon.

The Shuswap marbles at Marblehead vary from white to blue in colour, and present a medium grain. The average output is an intermediate type, with a white base, clouded and streaked with blue. A complete quarrying plant, and an extensive mill have been installed by the Canadian Marble and Granite Works. The stone has been used for buildings in Nelson, and it may also be seen in the fine office building of the Great West Life Assurance Company in Winnipeg.

The Kaslo stone is much coarser in grain, and is suitable only for rock-face work.

The output of the Nootka quarries is essentially the same as the stone from Marblehead. Although a good plant was installed, there has been no production on a commercial scale.

On southern Texada island a very attractive red marble has been quarried to a slight extent by the Malaspina Marble Company of Vancouver. It is proposed to further exploit the deposits, and considerable confidence of commercial success is entertained.

Red and white marbles have been quarried at Grant Brook on the line of the Grand Trunk Pacific railway, but operations were never pushed beyond the experimental stage.

White and blue marbles, of undetermined value, occur on many of the islands along the coast.

The andesite of Haddington island is a very desirable building stone, of light, yellow-grey colour: it is easily quarried, and is capable of fine chiselling. The only quarry is the property of W. S. McDonald of Vancouver. The magnificent buildings of the local government at Victoria, and many other fine structures testify to the excellent qualities of this stone.

Ornamental stones other than the marbles are of little importance in British Columbia: the Ice River sodalite, the fine black slate of Queen Charlotte island, and certain dark basic rocks of the Strait of Georgia are of possible value. The dark-coloured monzonites of Rossland and Ymir are of value for monumental purposes, but their weathering qualities are not good.

In the vicinity of Victoria and Vancouver, quarries are worked for the production of crushed stone, for lime-making, and for the manufacture of portland cement. Most of these quarries were visited in order to ascertain their possibilities as producers of building material. Visits were also made to as many of the reported occurrences as time would permit. Investigations of occurrences of this kind were of necessity confined to points along the coast, in localities accessible by rail.

Owing to the war and to other causes, the present production of building stone is very small. All the sandstone and marble quarries were idle during the summer of 1916. The only actual production was from the granite quarry on Kootenay lake, where stone was being cut for the Mormon temple at Creston, Alberta, and from Hardy island where the Sir John Jackson Company was quarrying granite for the breakwater at Victoria.

FUELS AND FUEL TESTING DIVISION.

I

WORK AT THE FUEL TESTING STATION.

B. F. Haanel,
Chief of the Division.

During the year 1916, the Division of Fuels and Fuel Testing was engaged in the making of large scale tests on samples of coal received from the Province of Alberta; the examination and analyses of samples of mine air received from the principal producing coal mines of the Dominion; the chemical analyses and physical examination of oils for the different departments of the Canadian Government; and the general analyses and determination of the heating value of the samples of coal received from outside sources, and of those required in connexion with work of this Division. In connexion with the large scale tests of commercial coal samples, a very large number of anlayses of samples of gas are required. This work occupies the entire time of three chemists during the period the tests are in progress.

The machine shop, which is under the control of this Division, completed and had under way a very large amount of work. In addition to the construction and erection of apparatus for the Division of Ore Concentration and Metallurgy, which comprised by far the larger part of the output of the shop, the construction of new apparatus, and repairs to existing machines and apparatus, and the erection of apparatus in the other laboratories of the Mines Branch, devolved upon the staff of the machine shop.

During the latter part of the year, an investigation concerning the value of peat fuel for the generation of steam, was conducted by Mr. John Blizard, assisted by Mr. E. S. Malloch, and a report entitled "The Value of Peat Fuel for the Generation of Steam" prepared for the press. The issue of this work completes the investigation concerning the value of peat for the production of power.

Towards the close of the fiscal year, the writer was engaged in a special investigation concerning the briquetting of western lignite coals. This work was undertaken by the Mines Branch for the Honorary Advisory Council for Industrial and Scientific Research, and the results obtained will be embodied in the form of a report and issued by the Mines Branch.

The report of Mr. Stansfield—Chief Engineering Chemist of the Division—will show that the laboratory work has been steadily and rapidly increasing, and that new laboratory space will have to be provided in the very near future, in order that the work may be prosecuted efficiently, and without loss of time.

The summary reports of Mr. E. Stansfield, Mr. A. Anrep, and Mr. A. W. Mantle, show in detail the work done in the respective departments under their immediate control.

The staff of chemists was increased by the permanent appointment of Mr. Cantelo.

II

CHEMICAL LABORATORIES OF THE FUEL TESTING STATION.

Edgar Stansfield,

Chief Engineering Chemist.

The laboratories of the Fuel Testing Station were again utilized during the year, not only for the chemical work of the Division of Fuels and Fuel Testing, but also for the chemical work of the Division of Ore Dressing and Metallurgy under the immediate supervision of Mr. H. C. Mabee, of that Division.

Dr. F. E. Carter, Mr. J. H. H. Nicolls, Mr. V. F. Murray, Mr. R. C. Cantelo, Mr. J. B. Robertson, Mr. J. Moran, and Mr. R. T. Elworthy were engaged during part or all of the year in the work of fuel testing, and in the examination of oils, gases, etc. Mr. Mabee was assisted in the work of the Ore Dressing Division by Mr. R. J. Traill, and Mr. A. K. Anderson.

Mr. Robertson and Dr. Carter resigned their positions on March 25, and May 1, respectively. Mr. Anderson commenced work on January 31; Mr. Murray, February 4; Mr. Traill, March 2; Mr. Moran, July 3; and Mr. Cantelo, October 17. Mr. Elworthy, of the Chemical Division of the Mines Branch, took charge of all mine air analyses, and carried out special investigations on gas analysis, from the time Mr. Robertson left, until after Mr. Moran arrived.

The work was much hampered during the year by a serious lack of laboratory accommodation, consequently, a temporary building was planned, and at the close of the year was nearly completed. This will increase the total laboratory accommodation by about 1,250 square feet of floor area. The extra space will give a much needed immediate relief; but the important work in progress and waiting to be undertaken, has now reached such magnitude, that it is desirable that an entirely new laboratory building should be constructed, as soon as possible, to replace the scattered and temporary quarters at present available. Tentative plans for such a building have been prepared by the writer.

The equipment has been increased by the purchase of the following special apparatus: Sturtevant rotary crusher and automatic sampler, Becker balance, Hoskins tube furnace with rheostat and transformer, two drying ovens, Engler viscosimeter, two gas holders of five cubic feet capacity, cylinder for compressed oxygen, and apparatus for determining the specific gravity of gases. In addition, the following equipment has been designed and made on the premises: Centrifuge jacket for Redwood viscosimeter, and a set of oil lubricating cups on a stand. Twenty volumes have been added to the library, also a large number of reports, bulletins, and journals.

The total number of samples submitted for analysis during the year, exclusive of routine gas samples of which no count is kept, is 58% greater than in 1915. The increase is mainly due to mine air samples and to the work done for other government departments, notably in the testing of lubricating and fuel oils. Miscellaneous samples from outside parties again show a satisfactory decrease. Progress was made with several special investigations, although far less than had been hoped. In spite of overtime work by every member of the staff, it was not found possible to keep the routine work entirely up-to-date.

The samples received include 377 mine air, 127 coal, 75 oil, 22 ash, 4 natural gas, 2 peat, 2 oil shale, and 2 miscellaneous samples. Three hundred and seventy-seven of the above samples were received in connexion with the testing of mine air; 71 from the Department of Public Works, 40 from the regular laboratory of the Fuel Testing Division, 35 from the Geological Survey, 30 from the Department of Militia and Defence, 20 "official" coal mine samples furnished by the

Chief Inspector of Mines for the Province of Alberta, 12 from the Department of Naval Service, 9 from field parties of the Mines Branch, 2 from the Board of Railway Commissioners, 2 from the Royal North West Mounted Police, and 13 from other parties.

Much of the work of the laboratory consisted, as usual, of gas, coal, and ash analyses, in connexion with the large scale tests carried out on the premises. Twenty-eight of such tests—16 boiler trials and 12 producer trials—were conducted during the year.

Of the mine air samples, 185 came from British Columbia, 156 from Alberta, and 56 from Nova Scotia; 88 mines, belonging to 53 operators, being represented. Since the first inception of this work, 550 samples have been received from 130 mines, belonging to 67 different operators. Mine air samples, and investigations arising therefrom, have taken most of the time of one chemist, during the year. This work has now been systematized, and the samples have been analysed with little or no delay, except during such rush periods as, for example, in October, when more than twice as many samples as usual were received.

The most striking development during the year has been in the testing of lubricating and fuel oils. New apparatus has been purchased and made, and considerable work done towards the standardization of apparatus and methods; this latter includes comparison of Engler, Redwood and Saybolt viscosimeters, comparison of Pensky-Martens and open cup flash point tests, and work on cold, hot, gumming, emulsion and saponification tests on oils. Several Government departments have made use of the oil testing laboratory, and have submitted samples of many types of lubricating and fuel oils, and also of gasoline. They have also consulted the staff with regard to the drawing up or revision of their specifications for the purchase of oils. It is hoped that all the departments concerned may see their way to adopt a standard type of specification. A typical three clause example drawn up by the writer and Mr. Murray is given on page 64.

Several of the special investigations, etc., referred to in last year's report, and some new investigations, are still in progress; others which have been completed are referred to below.

Mr. Nicolls has worked on the classification of Canadian coals with especial reference to their suitability for use without fire risk in locomotives. His work in this connexion on the Hoffman Potash Test standardizes for general use a test whereby the gradual metamorphosis from vegetable refuse to a hard coal can be indicated by the colour given to a solution of caustic potash. A description of this is given on page 65.

A serious error was found in the analyses of certain boiler trial samples of ash. Mr. Cantelo investigated this matter, and traced the error to the iron ball mill used to grind the samples; his results not only enabled these analyses to be corrected before publication, but also showed that the trouble had only recently arisen, and that older published results were not seriously affected. A quartz pebble mill, similar to the ones used for grinding coal samples, is now used for all ash samples. This work is described at length on page 68.

The writer carried out a short preliminary investigation on the extraction of bitumen from the tar sands of northern Alberta. The sand was heated to a high temperature with water under pressure in an autoclave, to determine whether under these conditions the bitumen would become fluid enough to leave the sand and rise to the surface of the water. The small autoclave available for these experiments was surrounded by an oil bath which was heated to as high as 300°C., the pressure gauge registering up to 30 atmospheres. In some experiments the water was replaced by a heavy solution of calcium chloride, and in others the sand was previously mixed with oil. The results obtained were not very definite, but indicated that although on the small scale tried, simple heating as above did not give any notable separation, violent agitation at this temperature by ebullition or otherwise, would give a fairly clean separation. No consideration was given as to the commercial possibilities of such a method if successfully developed, and, in view of the fact that this work was being carried on elsewhere, it was decided not to build the necessary apparatus to proceed with the investigation.

Three new or modified pieces of apparatus in use in this laboratory are described by Mr. Murray on pages 71-78.

In February, the writer and Dr. Carter attended, by request, the sittings of the Parliament Building Fire Enquiry; and in November the writer gave an address on standard methods of analysis of fuels and oils, before the Society of Chemical Industry, in Montreal.

III

SPECIFICATIONS FOR THE PURCHASE OF OIL.

Edgar Stansfield and Victor F. Murray.

The following type of specification for the purchase of oils, gasoline, etc., has been employed in all cases where this laboratory was consulted. Three clauses are included: the first indicates, for the benefit of the tenderer, the general nature of the oil and, where necessary, the purpose for which it is required; the second describes the tests which all samples of the oil will be required to pass; and the third is a general clause requiring that the oil give satisfactory service in actual use.

The comparisons given between Saybolt, Redwood, and Engler viscosimeter times are taken from the conversion tables of the Bureau of Standards at Washington.[1]

One example will illustrate these points.

Specification for Marine Engine Oil.

1. The oil shall be composed of clean, refined, petroleum distillate compounded with not less than 15 per cent of non-drying, acidless, vegetable, or animal oil. It shall be free from water, mineral acid, alkali, grit, or other impurity due to adulteration, or to improper refining or compounding; and shall be free from tendency to gum.

2. The oil shall comply with the following tests and conditions:—

(*a*) Shall pass completely through a 40 mesh screen.

(*b*) Shall have a specific gravity at 60°F. of neither less than 0·910, nor exceeding 0·930. The specific gravity may be determined at a higher temperature, not exceeding 100°F., and corrected by the addition to the observed value of 0·0003 for each degree that the temperature is in excess of the standard.

(*c*) Shall have a saponification value of not less than 28.

(*d*) Shall have an open-test flash point of not less than 400°F. (204·4°C.).

(*e*) Shall have a viscosity not exceeding 550 seconds Saybolt Universal (equivalent to 750 seconds Engler, and 460 seconds Redwood) at 100°F., and not less than 50 seconds Saybolt (equivalent to 80 seconds Engler, and 45 seconds Redwood) at 210°F.

---

[1] Dr. C. W. Waidner, Proceedings American Society Testing Materials, Vol. XV. (1915), Part I, page 284. See also Journal Industrial Engineering Chemistry, Vol. VIII. (1916), page 434.

(*f*) Shall flow readily in a 5-8 inch test tube at 32°F.
(*g*) Shall not show any considerable precipitation when 5 c.c. of the oil are mixed with 95 c.c. of 85–88° B Naphtha, and centrifuged for five minutes.
(*h*) Shall not have a total acidity, expressed as oleic acid, exceeding 1·5%.
(*i*) Shall not bump or froth when heated in a flash cup.
(*j*) Shall pass such other tests as are necessary to show that the oil complies with clause 1.

3. In addition to all the above requirements, the oil to be accepted must prove to be thoroughly efficient in actual service, under working conditions, to the satisfaction of the Department.

IV

THE HOFFMAN POTASH TEST.

J. H. H. Nicolls,

Engineering Chemist.

This test is based upon the fact that low grade coals such as lignites impart a deep brown colour to a solution of caustic potash, whereas anthracite and the higher grade bituminous coals do not. The coals intermediate between the two impart various shades of brown according to their nature, so that the potash test may be used as a means of identification and classification.

With this idea in view, G. Christian Hoffman, late Chief Chemist to the Geological Survey, treated various western Canadian coals, under fixed conditions, with a boiling solution of caustic potash of 1·12 specific gravity.[1] He divided the coals tested into three groups: (1) "Lignites" communicating a deep brownish-red colour; (2), "Lignitic Coals", giving a brownish-red; and (3), "Coals", giving, practically, no colourization.

In a note to a later paper[2] the same authority described a modification of the test, in which finely powdered coals were treated at room temperature with a solution of potash, specific gravity 1·16, for two hours with frequent shaking. This gave "a greater number of shades of colour, thus admitting of a more accurate estimate of the nature of the fuel." Hoffman divided the solutions produced into ten grades, ranging from intense brownish-red to colourless, but his nomenclature would be somewhat difficult to standardize for general use.

When it was decided to apply the potash test to certain of the coals received in this laboratory, it was thought advisable to obtain, if possible, permanent standards with which to compare the colours produced. Accordingly, Dr. F. E. Carter carried on blending experiments with various coloured solutions, such as those of ferric chloride, cupric chloride, cobalt chloride, etc., and finally obtained a dark reddish-brown solution of practically the desired colour. This was prepared by dissolving 4 grams of ferric chloride and 16 grams of ammonium acetate in 40 c.c. of water, and adding 4 c.c. of acetic acid, followed by 1·6 grams of cupric chloride. Portions of this solution were diluted with 1, 2, 4, 8, 16, ... 1024 volumes of a 10 per cent solution of acetic acid. A series of solutions, numbered 1 to 12, was thus obtained, the colour of which decreased so that No. 3 was about the usual tint of "burnt sienna", No. 7 a very pale brown and No. 12 practically colourless. These were preserved in 2 × ½ inch specimen tubes, closed with corks previously coated with paraffin wax, with the top well covered with wax. After two years' keeping in a covered box they appear to be still in good condition.

---

[1] Coals and Lignites of the North West Territory—Report of the Geological Survey of Canada, 1882, 83-84.

[2] On the Hygroscopicity of certain Canadian Fossil Fuels—Proceedings and Transactions of the Royal Society of Canada, 1889, Vol. VII, Sec. III, page 41.

Before proceeding to the standardization of the test, the writer carried out a number of experiments to determine what effect fineness of grinding, different amounts of coal, and similar variations would have upon the colour produced by boiling with potash. To this end, two samples of the same coal, Nos. 980 and 987, from Coalspur, Alberta, were chosen, as representing extremes in fineness. No. 980 will practically all pass a 60 mesh sieve, while some 70 per cent passes the 100 mesh, and 40 per cent goes through the 200 mesh. About 95 per cent of No. 987 passes the 200 mesh sieve, so that it represents an extreme fineness.

The general procedure was as follows: ½ gram of coal was weighed into a test tube, 10 c.c. of potash solution (sp. gr. 1·12) were added, the whole heated to boiling, and boiled for half a minute. It was then filtered, and the colour of the filtrate compared with the standards.

The modifications and their results are as follows:—

TABLE I.

Treatment.	Resulting colour.
1. No. 987, following general procedure..................................	(5–6)
2. The same, but stirring thoroughly before boiling in order to wet all the coal.	5
3. As in last case, using 1 gr. of coal..................................	(4–3)
4. ½ gr. No. 987, stirring and boiling 1 minute..........................	(5–4)
5. " " " " " 2 minutes..........................	(5–4)
6. ½ gr. No. 987, adding 15 c.c. of potash solution, stirring and boiling 1 minute..................................	(5–4)
7. As last, but with 20 c.c. potash solution..............................	5
8. No. 980—Similar treatment to No. 4 test..............................	(5–6)

N.B.—In cases where two colour standards are bracketted, the colour produced lies between the two and nearer the one first named.

From these results it seemed that the quantity of coal treated, and its fineness, were the principal causes of variation in the colour produced, but that even these had a comparatively slight effect.

The potash test at room temperatures, or more briefly the "cold test," was tried out on a number of coal samples, which are referred to later in the report. In each case ½ gram of coal and 10 c.c. of potash solution were taken, and, after a thorough mixing, allowed to stand for 2 hours, with stirring at 15 minute intervals. The mixtures thus obtained were filtered, and the colours produced compared with the standards. In a few instances the mixtures were allowed to stand for 1 hour only; the colours obtained being practically identical with those from the longer tests, although, in one or two cases, slightly fainter. The colours resulting from the cold test were paler than those produced by a boiling solution, and had as well a shorter range on the scale, so that for general purposes the latter will be of more service. However, the cold test may be of use in the classification of low grade coals.

Accordingly the following was adopted as a standard procedure—Weigh ½ gram of coal into a test tube. Measure out 10 c.c. of a solution of caustic potash, specific gravity 1·12 (1 part by weight of potash to 5 of water), and add most of it to the coal. Stir with a glass rod, until the coal is thoroughly wetted, and then remove the rod, using the remainder of the potash solution to rinse it down. Heat to boiling over a small flame, and boil for 1 minute. Filter at once through a 9 cm. filter into a half-inch test tube, and compare the filtrate with the standard colours.

This test was applied to a number of coal samples having widely different chemical properties, and the results are shown in Table II, where they are compared with various chemical properties of the coals. In a number of cases the results of the cold test are also shown.

TABLE II.

Coal No.	Locality.	Hoffman test.		Coking properties.	Calorific value, ash and moisture free.	Moisture, air dried.	Carbon-Hydrogen ratio, air dried.	Fuel ratio.
		Boiling.	Cold.					
738	Blairmore, Alberta...........	(10–11)	..	Good coke.	8,490	0·9	17·3	2·45
849	Minto, N.B.	9	10	Fair coke.	8,340	..	..	1·50
847	" "	8	..	"	8,460	..	..	1·70
851	" "	8	..	Good coke.	8,220	..	..	1·75
751	Sydney, N. S.................	(7–8)	(9–10)	"	....	..	..	1·65
626	Merritt, B. C................	(6–7)	..	Very fair coke	....	..	..	1·45
628	" "	5	..	Poor coke.	....	..	..	1·35
627	" "	(5–4)	7	"	....	..	..	1·25
986	Coalspur, Alberta............	(5–4)	..	Non-coking.	....	..	..	....
988	" "	(5–4)	..	"	....	..	..	1·40
985	" "	(4–5)	7	"	....	..	..	....
720	Saunders Creek, Alberta......	(4–5)	7	"	7,470	8·5	13·4	2·05
558	Lovett, "	(4–3)	(7–6)	"	7,530	7·5	12·9	1·80
721	Commerce, "	3	..	"	7,430	8·0	11·9	1·85
321	Lethbridge, "	3	(6–5)	"	7,440	8·8	11.8	1·40
306	" "	(3–2)	..	"	7,510	8·9	11·6	1·40
722	" "	(3–2)	..	"	7,250	9·3	11·5	1·80
304	Commerce, "	(2–3)	(5–6)*	"	7,320	9·6	11·9	1·45
406	Taber, "	(1–2)	4	"	7,230	14·0	10·5	1·45
407	" "	(1–2)	..	"	7,010	12·4	10·6	1·55
875	Wabamun, "	(1–2)	4	"	6,720	19·7	10·1	1·50
682	Cardiff, "	(1–2)	4*	"	6,700	18·9	9·3	1·50
650	Drumheller, "	1	4	"	7,270	13·7	11·4	1·50
302	Evansburg, "	1	4	"	6,950	16·2	10·8	1·60
665	Rosedale, "	1	(4–3)	"	7,250	13·9	11·3	1·40
680	Edmonton, "	1	3	"	6,810	17·3	10·3	1·70
180	Tofield, "	1	(3–2)	"	6,930	15·9	10·1	1·30
982	Shand, Sask..................	1	(3–2)	"	6,690	26·9	..	1·30

*These two results from 1 hour test.

NOTE.—In cases where two colour standards are bracketted, the colour produced lies between the two and nearer the first named.

From the above figures it will be seen that the result of the Hoffman test on any coal bears distinct relation to its coking properties. It also appears to be more or less in accord with the calorific value on the ash and moisture free sample, and with its moisture when air dried. It does not, however, seem to have any agreement with the fuel ratio, or with the carbon-hydrogen ratio.

In conclusion, it may be stated that the Hoffman Potash Test has been satisfactorily standardized, though it does not seem possible at present to definitely classify coals by means of their Hoffman Numbers. However, these preliminary tests indicate that Nos. 1 to 3 designate lignites; 4 to 5 sub-bituminous coals, or those of a lignitic nature; and the higher numbers bituminous and anthracite coals.

V

NOTE ON THE ERRORS CAUSED BY THE EROSION OF AN IRON BALL MILL.

R. C. Cantelo,
Engineering Chemist.

In connexion with the boiler tests carried out at the Fuel Testing Station, in the latter part of 1916, the ash and clinker from each trial were crushed in a jaw crusher set to ¼″, cut down to a sample of about one pound, and ground for about two hours in an iron ball mill with iron balls. This finely ground material was used for analyses, which included determinations of combustible matter and calorific value and, in some cases, of carbon and hydrogen.

In the course of analyses of two samples, Nos. 905 and 906, for carbon and hydrogen, it was found that there was a large discrepancy between the carbon and hydrogen evolved, and the accompanying loss in weight of the sample.

For example, the carbon and hydrogen in No. 905 together constitute 21·69 per cent, and the loss in weight only 9·36 per cent. The combustible matter determined by the loss in weight upon heating for several hours, at 750°C. in an electric muffle furnace, was 9·45 per cent, in close agreement with the loss in weight found in the determination of the carbon and hydrogen. Similar results were obtained for No. 906.

It was naturally thought that the discrepancy was due to oxidation of iron compounds derived from the original coal and reduced to the ferrous condition in the furnace. Accordingly, experiments were made on samples 905 and 906, to extract any iron compounds present; the idea being first to extract the iron compounds and then to determine the combustible matter in the insoluble residue.

A 10 gram portion of each of the above samples was treated with hot concentrated hydrochloric acid, filtered, and washed: the insoluble residue dried and weighed; and the iron content of the extract determined.

The results obtained were as follows:—

	No. 905		No. 906	
Weight taken....................	10·00	gram.	10·00	gram.
Iron extracted (Fe.)..............	3·04	"	3·58	"
Insoluble residue................	6·98	"	6·31	"
Total......................	10·02	"	9·89	"
Discrepancy....................	+ 0·02	"	−0·11	"

This indicates that practically all the iron present in the above samples was there as metallic iron, which fact was confirmed with a magnet.

Accordingly other samples were similarly extracted, the iron in the extract and the combustible matter in the insoluble residue being determined. These samples were also found to be highly magnetic. Analyses of these ashes are given in Table II.

Table II also shows the total iron content of several other samples in which the combustible matter had been determined in the usual manner.

For purposes of comparison, 20 grams each of the coals used in the boiler tests were burned in a muffle, and the iron in this uncontaminated ash determined. In every case this iron was much less than in the corresponding boiler trial sample.

It was then suggested that the metallic iron found in the ash and clinker must have come from either the jaw-crusher or the ball mill. The jaw crusher was soon exonerated and the following experiments showed the blame to rest with the ball mill.

TABLE I

Experiment No.	Method of Grinding	Weight of Sample	Per cent Iron	Grams Iron	Magnet Test	Grams metallic iron added to 100 grms. of original refuse
1	4 hours in pebble mill	565	2·7	14·5	Non-magnetic	0·0
2	½ hour in ball mill	574	7·5	43·1	Magnetic	5·2
3	1 hour in ball mill	614	7·4	45·5	"	5·1
4	1½ hours in ball mill	650	8·8	57·2	"	6·7
5	2 hours in ball mill	646	11·6	75·0	"	10·1

Now, the metallic iron so introduced not only by its presence reduces the actual percentage of combustible matter in the sample; but also, by its gain in weight due to oxidation to ferric oxide, when the combustible matter is determined by loss in weight on ignition, correspondingly reduces the apparent loss in weight by an amount equal to 3/7 of the weight of metallic iron, 112 grams of iron producing on burning 160 grams of ferric oxide.

If the percentage of metallic iron in the ash and clinker sample from the ball mill, can be determined, it is possible to correct the determined combustible for these two errors.

Let X = the percentage of metallic iron in the ash and clinker sample ground in the ball mill. Then 100 grams of this sample contain 100 − X grams of the original boiler-trial ash.

Let I_1 = the determined percentage of iron in the specially prepared coal-ash. Then the iron from the original boiler-trial ash, contained in 100 grams of the ball mill sample is $I_1 \cdot \frac{100 - X}{100}$

Let I_2 = the total determined iron in the ball mill sample.

$$\text{Then } I_2 = \left\{ I_1 \cdot \frac{100 - X}{100} \right\} + X$$

$$\text{or } X = \frac{100\ (I_2 - I_1)}{100 - I_1}$$

The use which can be made of this formula will be clear after an actual sample has been considered.

Sample 906 gave upon analysis 35·8 per cent Fe. ($=I_2$). A sample of the original coal upon being burned in an electric muffle, yielded an ash analyzing 3·6 per cent Fe. ($=I_1$).

Therefore, $X = \frac{100\ (35{\cdot}8 - 3{\cdot}6)}{100 - 3{\cdot}6} = 33{\cdot}4.$

That is, sample 906 contains 33·4% of metallic iron.

Now the determined combustible in this sample was 8·94%. Correcting this for the iron contamination, first by the addition of 3/7 the weight of metallic iron, gives 23·24% as the actual combustible matter in the ball mill sample. The original ash, corresponding to (100 − 33·4)% of this sample, therefore contained $23{\cdot}24 \times \frac{100}{100 - 33{\cdot}4} = 34{\cdot}9\%$ of combustible matter—a vastly different figure from the 8·94% originally obtained.

An approximate check upon the above method of calculating true combustible matter was obtained in cases where the ash was extracted with hydrochloric acid, and the combustible matter determined on the insoluble residue. For example the above sample, extracted with acid, left 63·1% of insoluble residue which by ignition was found to contain 37·78% combustible matter. Correcting this to the original ash, assuming the presence of 33·4% metallic iron, gives $37{\cdot}78 \times \frac{63{\cdot}1}{100 - 33{\cdot}4} = 35{\cdot}8\%$ of combustible matter, a fairly close agreement with the 34·9% found above. As will be seen in Table II, the discrepancy in some cases is greater, but is still within reasonable limits.

A much better check was obtained in those cases where the percentage of carbon plus hydrogen had been determined (these, together, constituting the combustible matter in the ash). This result, corrected for the diluting effect of the metallic iron, agrees within a few tenths of a per cent with that obtained by correcting the combustible matter, determined by ignition of the ball mill sample, for the errors introduced by the metallic iron.

Following is a table of the data obtained and the results calculated therefrom:—

It is worth noting that some earlier samples taken from the same series of boiler tests showed only a small amount of metallic iron, and in these cases there was fairly close agreement between the determined carbon + hydrogen and the loss in weight on ignition.

For example, two samples gave the following values:—

No. 879 C + H = 22·31% Loss in weight = 23·17%.

No. 880 C + H = 20·46% Loss in weight = 21·74%.

It would seem therefore, that the contamination by iron from the ball mill became serious at some time during the grinding of the ash samples from this series of boiler tests.

If this be correct, ashes from trials previous to this series should be reasonably free from iron. It may be mentioned here that the same ball mill had been used to grind all ash and clinker samples. As proof the following ashes from previous trials were tested with a magnet. The results follow:—

Sample No.	*Result.*
619	No iron.
622	No iron.
648	Trace.
701	Trace.
702	Trace.
745	No iron.

TABLE II.

1	2	3	4		5	6	7	8	9	10	11	12	13	14	15
Sample No.	Iron in ash of original coal burned in muffle %	Iron in ball mill sample %	Analysis of ball mill sample		Calculated metallic iron in ball mill refuse %	Determined combustible in ball mill sample (muffle) %	Determined combustible in ball mill sample (combustion furnace) %	(6) Re-calculated, allowing for oxidation of metallic iron %	C+H in ball mill sample %	Determined combustible calculated to original refuse, from (8) %	Combustible in extracted ash %	(11) Re-calculated to original refuse %	Discrepancy between (10) and (12)	C+H (9) calculated to original refuse %	Discrepancy between (14) and (10)
			Iron %	Residue %											
883	11·6	23·2	23·2	65·9	13·1	19·38	....	25·0	....	28·8	43·53	33·0	4·2	....	....
882	3·4	16·1	....	....	13·2	12·02	....	17·7	....	20·4	....	....	....	....	....
887	3·4	25·0	25·0	69·6	22·4	8·43	....	18·0	....	23·2	27·21	24·4	1·2	....	....
903	3·0	16·8	16·8	75·3	14·2	18·35	....	24·4	....	28·4	33·23	29·3	0·9	....	....
904	3·0	15·4	....	....	12·8	18·72	....	24·2	....	27·8	....	....	....	....	....
905	3·6	30·4	30·4	75·3	27·8	9·45	9·36	21·4	21·69	29·7	33·22	32·2	2·5	30·04	0·34
906	3·6	35·8	35·8	63·1	33·4	8·94	8·57	23·2	23·37	34·9	37·78	35·8	0·9	35·09	0·19
909	3·4	29·4	29·4	67·4	26·9	2·02	....	13·5	....	18·5	20·88	19·2	0·7	....	....
911	11·6	21·1	....	....	10·8	15·53	....	20·2	....	22·7	....	....	....	....	....
913	3·0	17·3	....	....	14·7	8·84	....	15·1	....	17·7	....	....	....	....	....
914	3·6	10·7	....	....	7·4	27·73	....	30·9	....	33·4	....	....	....	....	....

The writer therefore suggests that this sudden contamination with metallic iron was due to the final wearing away of the outer hard surface of the balls, thus exposing the softer iron to the grinding action of the ash and clinker, this "critical" point having been reached at some time during the grinding of the ashes and clinker discussed above.

The above investigation was carried out in the Chemical Laboratories of the Fuel Testing Station, under the supervision of Mr. Edgar Stansfield, Chief Engineering Chemist. The ultimate analyses were made by Mr. J. H. H. Nicolls.

VI

OIL-BURETTE FOR FRACTIONAL DISTILLATION AND SPECIFIC GRAVITY DETERMINATION.

Victor F. Murray,

Engineering Chemist.

In the fractional distillation of petroleum or its derivatives, it is often necessary to determine the specific gravity as well as the volume of successive fractions. In dealing with small amounts, *e.g.* the fractions from 100 c.c., the following arrangement simplified from that described by Sanders[1] is used in the oil-testing laboratory at the Fuel Testing Station.

The apparatus sketched in Fig. 3 consists of a burette A, 13 mm. internal diameter, graduated in cubic centimetres, surrounded by a water-jacket B, 30 mm. internal diameter. By means of the three-way tap C, the level of the liquid in A can be altered, by running off the contents at E; or the burette can be put in communication with the water-jacket. The distillate can thus be adjusted to any desired position in the burette, balanced against a column of water, and finally drawn off at E. The volume of the fraction is given by the readings in the burette, and the height of the balancing column of water is the difference between the reading of the oil meniscus in the burette at the lower level, and the meniscus of the water-jacket as read on the burette graduations.

Thus if

X = the reading in the burette at the upper oil meniscus,
Y = " " " " " " lower " "
Z = " " of water meniscus on the burette graduations,
Y − X = the height of the column of oil expressed in terms of the burette graduations.
Y − Z = the height of the balancing column of water expressed in the same units;

and $\frac{Y - Z}{Y - X}$ = specific gravity of distillate.

The temperature is taken to be that of the water-jacket which is at room temperature approximately.

The water-inlet to the jacket is at D. This can be connected to a water-tap or levelling bulb as convenient. Through the glass T the jacket is also connected to the 3-way tap C.

---

[1] Journal of the Chemical Society: The Fractional Distillation of Petroleum. By James McConnell Sanders, July 1914, p. 1697.

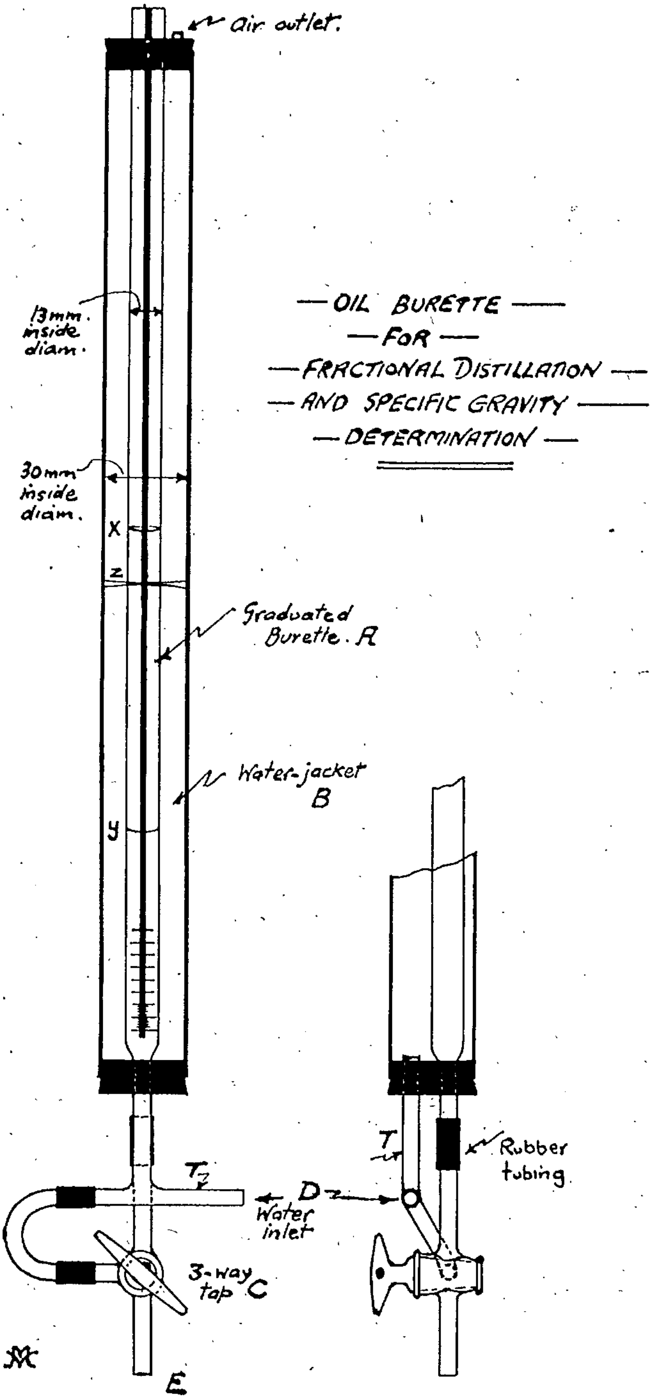

air outlet.
—OIL BURETTE—
—FOR—
—FRACTIONAL DISTILLATION—
—AND SPECIFIC GRAVITY—
—DETERMINATION—
13mm. inside diam.
30mm inside diam.
X
Z
Graduated Burette. A
Water-jacket B
Y
T
D
Water inlet
3-way tap C
E
T
Rubber tubing

Fig. 3.

For the sake of illustration the volumes and specific gravities found in the case of a crude oil are given below.

Lab. No. 401.

	Volume of Fraction (V)	*Specific Gravity* (G)	VG
	14·4 c.c.	0·702	10·11
	28·3	0·729	20·62
	19·3	0·746	14·40
	11·3	0·760	8·59
	11·3	0·774	8·75
	6·2	0·791	4·91
	6·6	0·874	5·77
Loss (L)	2·6	.....	.....
	100·0		73·15

The specific gravity of the original oil was 0·756 at 15·5°C., and the specific gravity, calculated from the values of the separate fractions and allowing for the loss in distillation is

$$\frac{\Sigma \mathrm{V\,G}}{100 - \mathrm{L}} = \frac{73 \cdot 15}{97 \cdot 4} = 0 \cdot 751$$

which is within the limits of experimental error, and checks the accuracy of the distillation.

If it is assumed that the specific gravity of L is $\frac{1}{2}$ (0·702 + 0·874) = 0·788, the corresponding VG = 2·05 and

$$\frac{\Sigma \mathrm{V\,G}}{100} = \frac{75 \cdot 2}{100} = 0 \cdot 752$$

The method is fairly rapid, and is usable where extreme accuracy is not required.

This simplification of Sanders' method is due to Mr. E. Stansfield, Chief Chemist at the Fuel Testing Station.

VII

AUTOMATIC REGULATOR FOR ELECTRIC WATER-STILL.

As some difficulty has been experienced at the Fuel Testing Station Laboratories by the water supply having been shut off without due notice, and the heating coils of the electric water-still being burnt out in consequence, the safety control, as described below, was designed to meet these conditions. The control operates so as to keep the still in action, but it could also be arranged so as to cut off the still when the receiver is full. It has proved thoroughly satisfactory in actual service.

The regulator, shown in detail in Fig. 4, consists of a triangular cast aluminium beam pivoted on a brass axle at C. The weight of the beam as shown is 121 grams.

From A a brass bucket is suspended by a steel split pin. As shown in the figure, the brass bucket is provided with 2 outlets—the main overflow, a brass tube $\frac{3}{8}''$ internal diameter, which keeps the level of water in the bucket constant, and a short tube $\frac{1}{8}''$ internal diameter, covered with a wire gauze cylinder to prevent blocking, which slowly empties the bucket when the water supply is cut off. The weight of the bucket when empty is 102 grams, when full 221 grams.

From B a brass counterpoise, 174 grams in weight, is suspended by a split pin.

The electric wire from the supply is fastened to the beam by the platinum-tipped connexion E, insulated from the beam, and completes the circuit to the still heating-coils through platinum in the cup F.

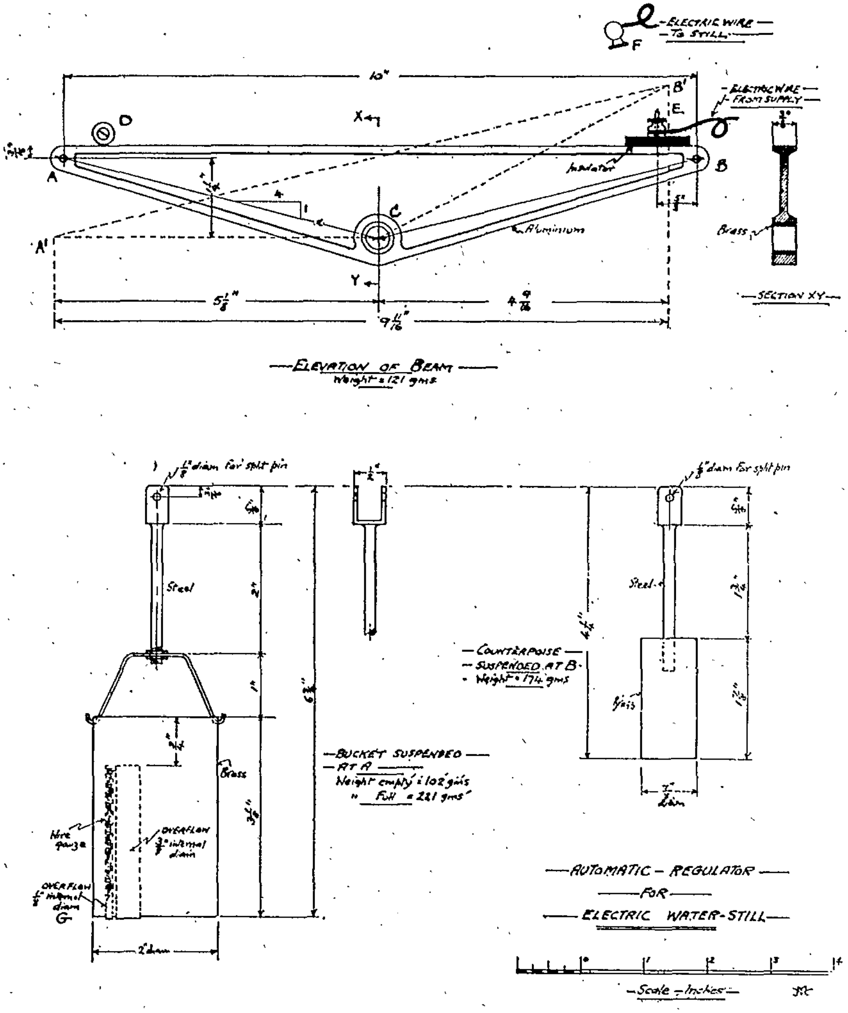


Fig. 4.

When the still is started the overflow from the supply water discharges into the bucket, and the beam swings to the position given by the dotted lines A'-B'-C, the electric circuit being made at F. In the event of the water supply being stopped, the bucket gradually empties through the tube G, the beam tilts, and the electric circuit is broken, the beam coming to rest against the stop D. The shape of the beam ensures an increasing moment in a counter-clockwise direction when the beam is displaced from this position; and thus when the water supply is turned on again and the bucket refills, the electric circuit is made rapidly. The break in the electric circuit is also sharp.

It is evident that this arrangement could be modified in a number of ways. For example, by having a bucket on the counterpoise end of the beam filled by an overflow from the distilled water receiving vessel, the circuit would be broken when the latter was full.

The arrangement could also be adapted to gas heating by replacing pivot C by a tap to the gas supply, altering the stops, and maintaining a pilot light to ignite the gas when turned on again. In the absence of a pilot light, the design of the beam is such that, by suitable adjustment of the weights at A and B, the gas supply, once interrupted, remains permanently shut off.

This automatic regulator was designed by Mr. E. Stansfield, M.Sc., Chief Chemist, and was made in the Machine Shop of the Fuel Testing Station, under the supervision of Mr. A. W. Mantle, Mechanical Superintendent.

VIII

NITROGEN DISTILLATION APPARATUS.

The distillation apparatus, fully detailed in Fig. 5, is used at the laboratories of the Fuel Testing Station in the determination of nitrogen in coal, etc., by the Kjeldahl method.

It consists of four copper flasks, tinned inside, the capacity of each flask being about 1,100 c.c. These are supported by ordinary screw-clamps, the arms of which pass through drilled holes with set-screws in bosses, adjustable to any desired height on the vertical wrought iron legs, ½" in diameter, supporting the condensers.

Each flask is connected by a cork, splash-head, and rubber cork to the tinned brass casting which forms the lower end of the vertical tin condenser, closed at the upper end by the cork. The steam from the copper flask condensing on the walls dissolves any ammonia given off, and collecting in the annular space at the bottom of the condenser, overflows through the tin discharge pipe into a receiving flask containing a measured amount of acid of known strength.

The condensers are surrounded by a copper cooling-box, 9" square, which rests on a ¾" angle iron frame supported from the 4 legs and is also steadied at the top by a strip of ¾" iron flat. The inlet and outlet for cooling water are shown in Figs. 6 and 7.

The apparatus has the advantage of compactness, simplicity in manipulation, and freedom from easily broken glass connexions. The distance between the splash-head and the discharge from the condensers is very short.

Before carrying out a distillation, as a drop of mercury is used as a catalyser in the preliminary digestion with concentrated sulphuric acid, about three grams of powdered zinc is added to the flask contents, to prevent the displacement of mercury from mercuric sulphate by the metal of the apparatus.

This distillation apparatus was designed by Mr. E. Stansfield, Chief Chemist, and made in the Machine Shop of the Fuel Testing Station, under the supervision of Mr. A. W. Mantle, Mechanical Superintendent.

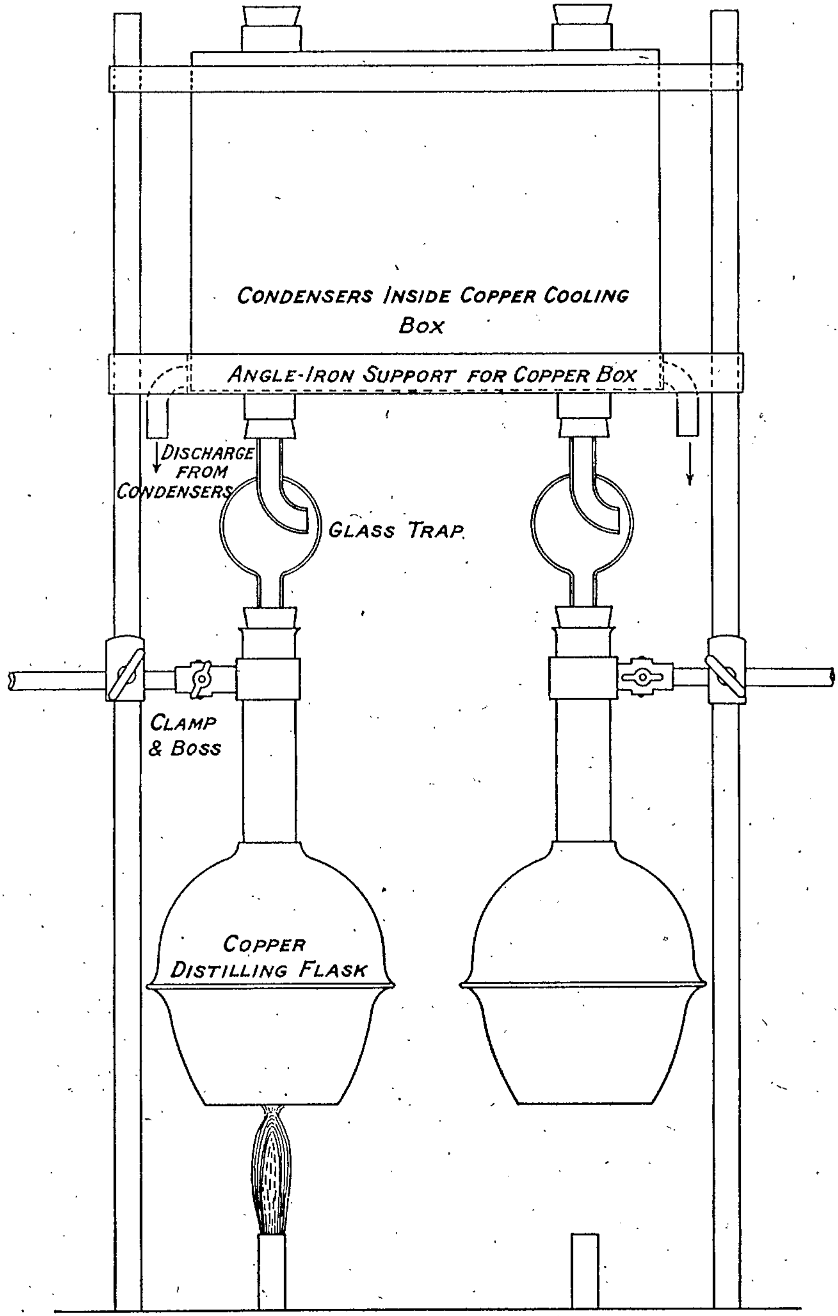


Fig. 5. Sketch showing general arrangement of nitrogen distillation apparatus.

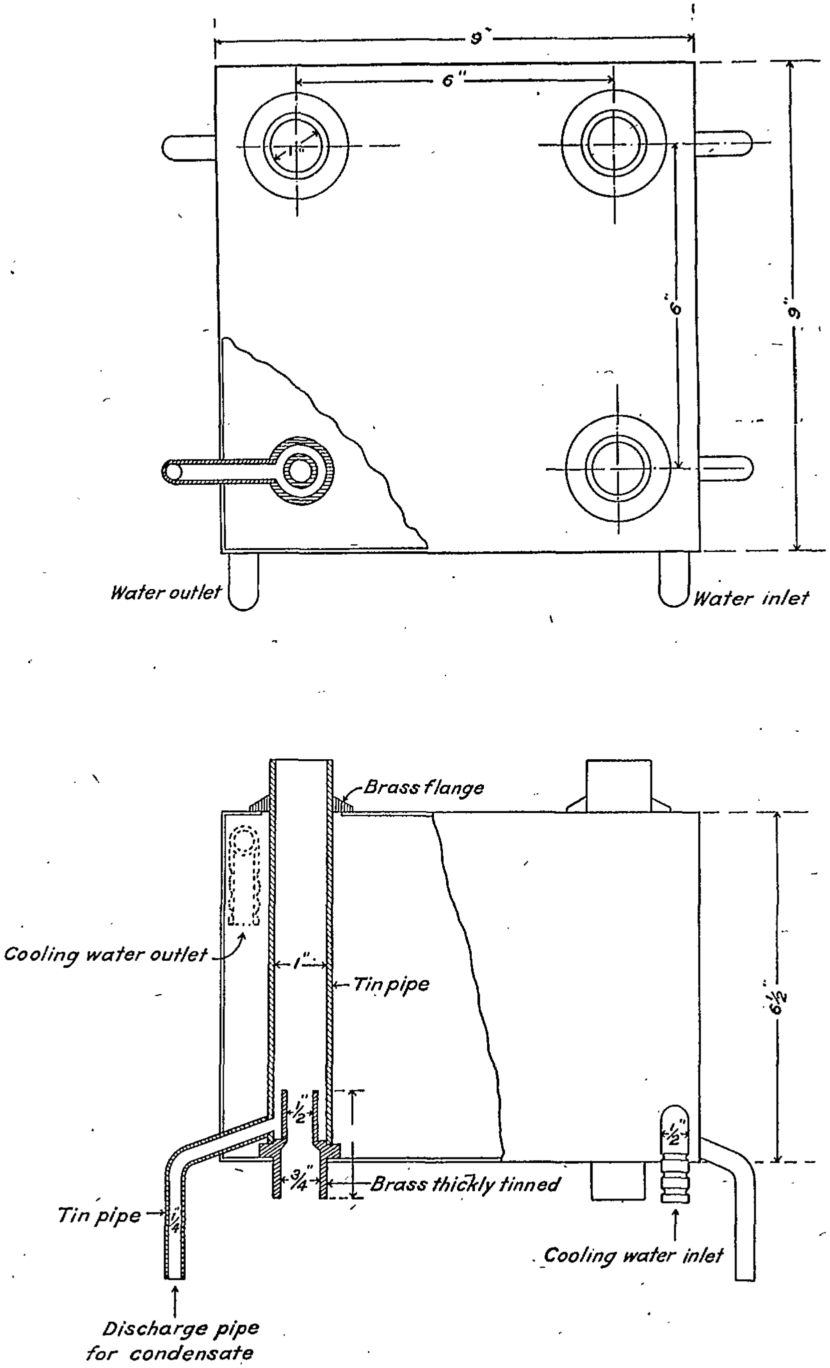


Fig. 6. Plan and elevation of condenser.

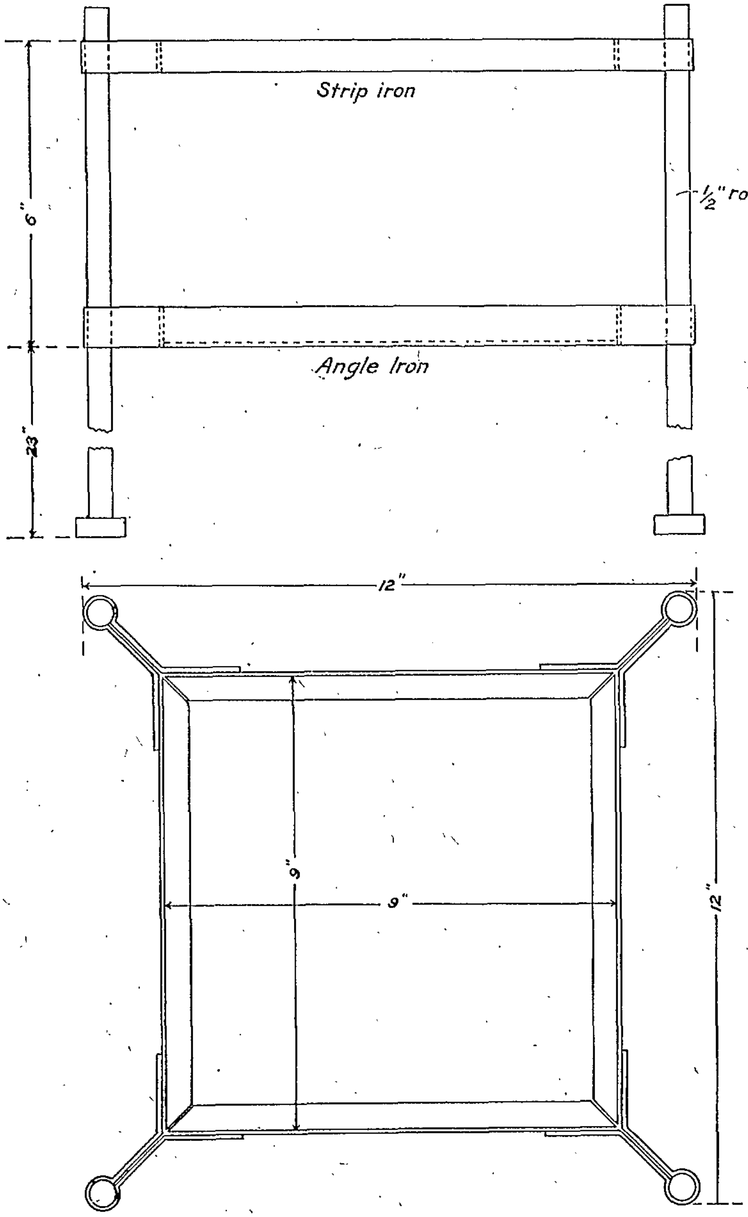


Fig. 7. Iron support for condenser: plan and elevation.

IX

INVESTIGATION OF PEAT BOGS.

A. Anrep,

Peat Expert.

In accordance with instructions, a survey of certain peat bogs was carried on during the season of 1916, in order to determine the extent, depth, and different qualities of the peat contained therein.

This investigation started late in June, when the writer left Ottawa with Mr. F. L. West as a temporary assistant, to perform the field work, which was carried on during July, August, and September.

The following statement summarizes briefly the results of the season's investigation.

(1) *Farnham* peat bog, situated about one mile to the east of the Ste. Brigide Station, and about three miles to the west of Farnham.

The larger part of the bog lies in the county of Iberville and a considerable portion in the county of Missisquoi, Province of Quebec; the bog crossing the county line to the southwest of Farnham.

The total area covered by this bog is, approximately, 5,100 acres, with an average depth varying from 5 to 15 feet.

(2) *Canrobert* peat bog, situated in the county of Rouville, Province of Quebec, about 2½ miles east of Canrobert Station, on the Canadian Pacific railway, and about the same distance west of Angeline Station, on the Vermont Central railway.

The total area covered by this bog is, approximately, 2,000 acres, with an average depth varying from 5 to 25 feet.

(3) *Napierville* peat bog, situated about four miles to the north of Hurrysburg Station, on the Grand Trunk railway, and about the same distance to the southwest of Napierville Station, on the Delaware and Hudson railway.

The bog lies almost entirely in the county of Napierville, Province of Quebec.

The total area covered by this bog is, approximately, 7,200 acres, with an average depth varying from 5 to 10 feet.

The total area investigated in the Province of Quebec for the season of 1916, comprised approximately 14,300 acres.

X

REPORT OF MECHANICAL WORK DONE AT FUEL TESTING STATION.

Fuel Testing Station,
May 9, 1917.

B. F. Haanel, Esq.,
Chief of Fuels and Fuel Testing Division.

Sir,—

I beg to submit herewith the report of machine work done in the Department's workshops at the Fuel Testing Station, Mines Branch, Department of Mines, during the past Fiscal Year ending March 31st, 1917.

The Plant during the Fiscal Year was in continuous operation night and day, the twenty four hours being divided into three shifts of eight hours each.

This continuous running necessitated the Mechanical staff's working overtime to ensure the perfect running of all machinery.

A large volume of work from the other Divisions of the Mines Branch has accumulated and in order that this work be finished with despatch, together with the other regular routine, it has been found necessary to increase our staff for the present Fiscal Year.

Yours respectfully,
(*Signed*) **A. W. Mantle,**
Mechanical Superintendent.

COST OF WORK DONE IN THE MACHINE SHOP FOR THE SEVERAL DIVISIONS OF THE MINES BRANCH.

	Time	Material
Ore Dressing Laboratory	$6,666.74	$3,834.54
Fuel Testing Division	1,033.25	240.67
Division of Chemistry	77.41	5.47
Mines Branch—General	326.41	122.62
Ceramic Laboratory	375.14	310.75
Structural Materials Division	69.28	26.01
Non-metalliferous Division	39.21	3.65
	$8,586.45	$4,593.71

Uncompleted work started during the past Fiscal Year and carried over to be completed the next.

Ore Dressing Laboratory	$ 353.00	
Ceramic Laboratory	13.80	
Chemistry Division (Sussex St.)	9.22	
Mines Branch (General)	4.84	
Fuel Testing Division	66.61	
	$9,033.92	$4,593.71

ORE DRESSING AND METALLURGICAL DIVISION.

I

REPORT OF PROGRESS.

G. C. Mackenzie,
Chief of Division.

The experimental work on the concentration of molybdenite ores, started in 1915, was continued through the first six months in 1916.

The mining and metallurgical treatment of Canadian molybdenum ores has, up to 1916, played a very small part in the world's production. This has been due to various factors, chief of which have been the limited demand for the mineral and at unattractive prices, together with the fact that no Canadian mine had, until 1916, been developed to the point of a steady producer.

In 1911, the Mines Branch of the Department of Mines, published a monograph entitled "Report on the Molybdenum Ores of Canada," by Dr. T. L. Walker, of Toronto University. While this report contained considerable detailed information regarding the various localities throughout the country in which ores of molybdenum occurred, it was, at that time, impossible to foretell with any degree of accuracy the probabilities of Canadian production, or to describe commercial methods of preparing the ore for the market.

In 1915, the Mines Branch, in response to a circular issued by the Colonial Institute of Great Britain, commenced a detailed examination of the molybdenum ores of Canada; and as the department at this later date was fully equipped to experiment on the problem of concentration, the investigation consisted, for the most part, in looking for a solution of the problem involved in preparing the ore for market.

The department secured large samples in carload lots, which were shipped to the testing laboratories of the Mines Branch in Ottawa. After much patient research work with the more common specific gravity types of ore concentrating machinery, the conclusion was reached that concentration methods based upon specific gravity would not yield commercial results, and therefore, a solution of the problem would have to be looked for in other directions.

After coming to the conclusion that the older processes of concentrating minerals would not apply, the possibilities of separation by flotation was carefully looked into, and for a time it was considered that the modern Oil Flotation Process would probably be adopted. However, during a laborious and detailed examination of this method, there were encountered certain difficulties in the application of the Oil Process, which indicated the desirability of continuing the investigation for an easier method of working. This method was eventually found in what has been called the Water Film Flotation Process; and although commercial results were not immediately attained, the process lent itself readily to adjustment; and as the factors governing the separation of molybdenite from its gangue by this method were more completely understood, a type of apparatus was gradually evolved which is at the present time in successful operation at the Ore Testing Laboratories of the Department.

The principle upon which this method is based, is the surface tension of water, advantage being taken of the fact that molybdenite resists wetting, while its associated minerals are more or less easily wetted and submerged.

The method of separating molybdenite from other minerals by means of projecting the ore upon a sheet of flowing water has been known for many years, but the first commercial application of the process on a large scale was made by Henry E. Wood, of Denver, Colorado, who patented the Wood Water Film Flotation Machine in the United States and Canada.

About the time the officials of the department had satisfied themselves that water film flotation was the most desirable process for the separation of the majority of Canadian ores, attention was directed to the Wood type of apparatus, and after consultation with Mr. Wood it was decided to install one of his machines at the Testing Laboratories in Ottawa. Subsequently, certain weaknesses in the Wood machine developed in the treatment of some of our Canadian ores, and the department in endeavouring to correct these weaknesses and to improve upon the general adaptability of the machine, have evolved a type of apparatus (Figs. 8 and 9) which has been found to work very satisfactorily, under almost all conditions.

While the department was experimenting for a solution of the separation problem, the search for molybdenite deposits of economic value continued throughout the country. Old deposits were re-opened and developed with more vigour than heretofore, and many new discoveries were made; but it was not until the spring of 1916, that the industry as a whole was strengthened by the development of the "Moss Mine" of the Canadian Wood Molybdenite Company, near Quyon, Pontiac county, Province of Quebec. The occurrence of a mineral resembling graphite had been known in this locality for many years, but it was not until January, 1916, that the identity of this mineral was definitely established as molybdenite.

Molybdenite ores and concentrates are marketed on their content of MoS_2, and are paid for at so much per unit of contained molybdenum sulphide. In Canada and the United States, the short ton of 2,000 pounds and the unit (1% of a ton) twenty pounds, are used, whereas, in Great Britain and Australia, the long ton of 2,240 pounds and the unit of 22·4 pounds always apply.

Under existing abnormal market conditions, brought about by the war, the prices being paid at the present time for molybdenite concentrates are from 100 to 200 % greater than pre-war quotations. In 1908, high grade concentrates containing 90 to 95% MoS_2 were sold for $6.50 to $7.60 per unit, and in 1909 the price was as low as $5.65 per unit.

In the fall of 1915, the Imperial Government fixed a price of 105 shillings per unit (long ton) for molybdenite concentrates containing not less than 85% MoS_2, f.o.b., London and Liverpool, and as the mineral was under embargo which prohibited its export to any country outside of the British Empire, this price naturally became the official standard quotation for all ores and concentrates produced within the Empire. Since that date, however, licenses have been granted for the export of the mineral to France and Russia, at the official quotations given above.

The quotation, it should be noted, means 105 shillings per unit, 22·4 pounds, of molybdenite (MoS_2), not 85% concentrates as many have imagined. This price corresponds to $1.09 per pound of MoS_2 contained in 85% concentrates, f.o.b., Ottawa, Ontario, at which point the Canadian production is purchased for the Allied Governments by the Imperial Munitions Board.

The Canadian miner of molybdenum ores, while encouraged by the reported prices for the mineral during 1915, had no definite guarantee that this product, when ready for market, would be accepted by the Imperial authorities; and as the great majority of these miners were men of small means, it was difficult for them to raise the necessary capital for development without such assurances on

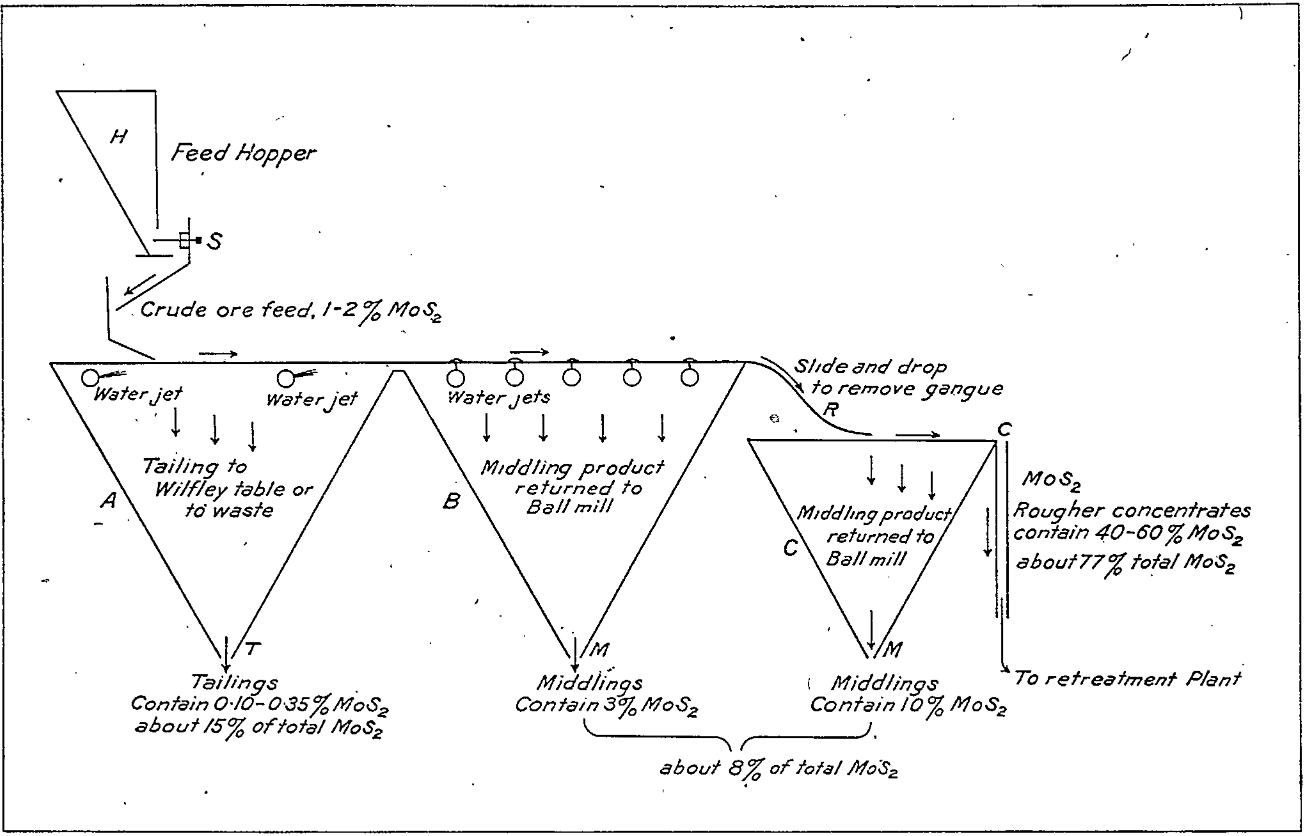


Fig. 8. Department of Mines film flotation machine.

contracts from the Imperial authorities. In June 1916, the Imperial Munitions Board at Ottawa, announced that they were in a position to purchase a considerable tonnage of molybdenite concentrates in Canada to be delivered before June 30, 1917. At this time, the Laboratories of the Department of Mines, Ottawa, possessed, not only the best concentration equipment, but were also in possession of a staff that had considerable experience with the problem of concentration.

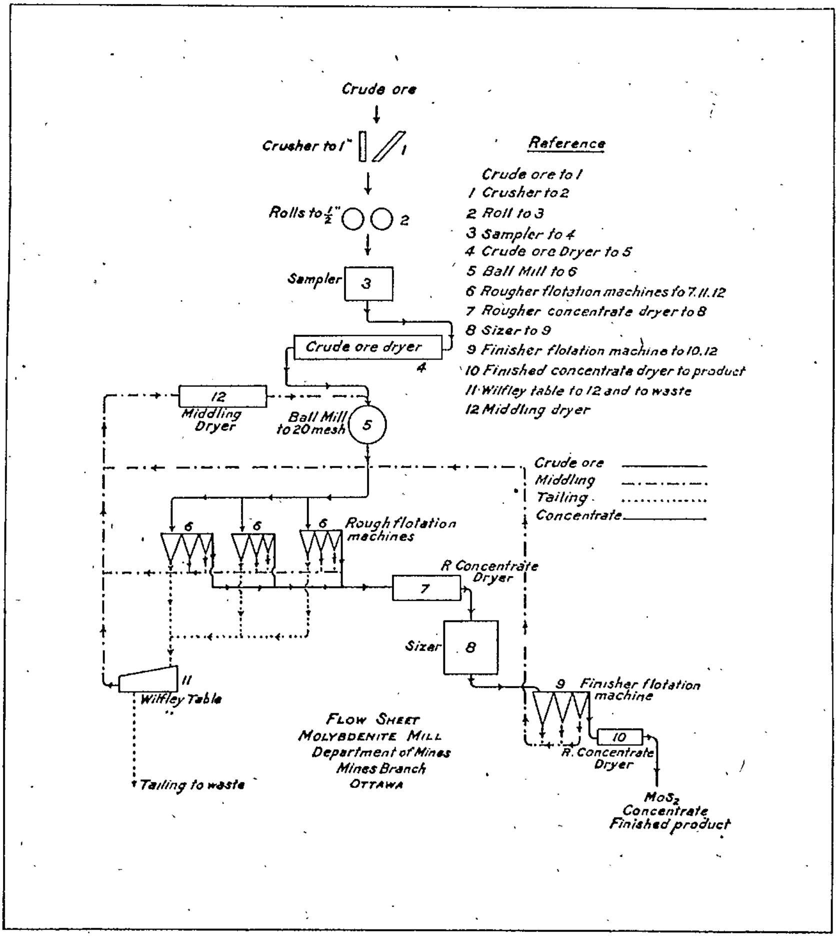


Fig. 9. Flow sheet: molybdenite mill.

It was, therefore, natural that the Imperial Munitions Board should turn to the Department of Mines for assistance in the securing of a part of the tonnage of concentrates above mentioned, and an arrangement was entered into between the Imperial Munitions Board and the Mines Branch of the Department of Mines, whereby the latter became the millers and assayers for the board in all matters pertaining to the supply of metallic ores and minerals.

The Moss Mine of the Canadian Wood Molybdenite Company having, at that time, developed sufficiently to make shipments, an agreement was drawn up with that company whereby they were to supply the Mines Branch of the Department of Mines with 100 tons of molybdenite ore weekly, the concentrates produced therefrom being purchased by the Imperial Munitions Board. At the same time, the Mines Branch advertised their willingness to treat small parcels of ore originating from other localities, and while no other mines of the magnitude of the "Moss" have been encountered to date, the department received during the year about 217 tons from other sources.

The method first adopted for the purchase and settlement of these ores was as follows:—

The miner was required to deliver his ore, carriage paid, to the Testing Laboratories of the Department, and after the ore had been milled, he was to receive the proceeds from the sale of his molybdenite at approximately $1.09 per pound of MoS_2, f.o.b., Ottawa, less the cost of concentration—between $5 and $6 a ton. No definite recovery was guaranteed. In December, 1916, it was found possible to standardize milling operations, and to fix a definite cost per ton for the ore treated, together with a definite schedule of guaranteed recovery of molybdenite. This schedule is as follows:—

TERMS OF PURCHASE OF MOLYBDENITE ORES, DEPARTMENT OF MINES, OTTAWA.

(1) On assay returns from samples dried at 212° F.

(2) For dry ores—moisture to be deducted.

(3) The cost of concentration to be $5.65 per net ton.

(4) The value of molybdenite (MoS_2) to be $1 per pound, Ottawa.

(5) Payment to be calculated as follows per ton of 2,000 lbs. dry ore delivered on siding at Mines Branch Testing Laboratories, Ottawa.

Molybdenite Ores Containing:—

(a)	Between	0·5 %	and	1 %	for	70%	of the	total	molybdenite	(MoS_2)	content.
(b)	„	1·1 %	„	1·5%	„	77%	„	„	„	„	„
(c)	„	1·51%	„	2·0%	„	84%	„	„	„	„	„
(d)	„	2·1 %	„	2·5%	„	87%	„	„	„	„	„
(e)	„	2·51%	„	3·0%	„	90%	„	„	„	„	„
(f)	„	3 %	„	....	„	92%	„	„	„	„	„

(6) The returns to the miner will be the value of the ore calculated as indicated above, less $5.65 per net ton concentration charges.

The departmental plant has operated since June, 1916, and up to the 1st of February, 1917, has treated 2,397 tons of crude ore, and picked flake with the production of 34·85 tons of pure molybdenite in the form of a concentrate averaging 80% MoS_2 (Fig. 10). The ore treated contained 1·84% molybdenite, and the actual molybdenite shipped has been 79·09% of the total amount received. The total recovery would be slightly over 80%, as no account has been taken in this calculation of the several tons of middling product in process of milling.

Among the companies who are operating in Canada to produce molybdenum are The International Molybdenum Company of Orillia, Ontario, who are under contract with the Imperial Munitions Board; The Canadian Wood Molybdenite Company; The Spain Mines, County of Renfrew; The Chisholm Mine; The Renfrew Molybdenum Mines, in Ontario; The Molly Mine, in the Kootenays; and The Molybdenum Mining and Reduction Company of Vancouver, British Columbia.

Statement

Molybdenite Ores Treated and Concentrate Produced During 1916 and to February 1st 1917.
Ore Testing Laboratories, Mines Branch, Department of Mines, Ottawa.

Crude Ore and Flake Received				Product Made			
Shipped By	Weight lbs.	% MoS_2	Content lbs MoS_2	Concentrate made lbs.	% MoS_2	MoS_2 Recovered lbs.	% of Recovery
Canadian Wood Co. Co. of Pontiac, Que.	4,360,749	1.74	76.303.2034	87,179.51 lbs 43·58 [illegible]	79.95%	69,696.7625 lbs. 34.85 Tons	79.09%
Horcroft, T. Co. of Victoria, Ont.	72,664	1.38	1,004.910				
Offer, William C. South Porcupine, Ont.	.915	15.31	140·09				
O'Brien M. J. Co. of Renfrew Ont.	50,324	1.45	732·15				
Padwell, George. Co. of Haliburton, Ont.	111,280	1·40	1,560.2368				
Renfrew Molybdenum Co. Co. of Renfrew. Ont.	109,558	1.29	1,410.40				
Ross, C. G. Co. of Renfrew, Ont.	19,784	0.45	88·6				
Spain W. J. Co. of Renfrew, Ont	69.482	9.89	6,868.72				
Urqhart, W. J. Toronto, Ont.	35	35.25	12.34				
Total	4,794,791 lbs. 2,397·4 Tons	1 84%	88,120.6502 lbs. 43.58 Tons				

Fig. 10. Table showing molybdenite ores treated, and concentrates produced.

A list of the ores received for experimental testing throughout the year follows:—

List of Ores Tested, 1916.

The following ores have been tested and reports made thereon during the calendar year 1916.

No. of Test	Ore	Locality	Shipper	Weight	
				Tons	Lbs.
44	Iron	Bessemer, Ont.	Canada Iron Mines, Trenton, Ont.	5	......
45	Molybdenum	Birdsville, B.C.	F. Younkin		10
46	Zinc-lead	Sullivan Mine, B.C.	Consolidated Mining & Smelting Co. of Canada		200
47	Tungsten	Burnt Hill, N.B.	Geological Survey of Canada		185
48(a) 48(b) 48(c)	Tungsten	Burnt Hill, N.B.	Holjohn Co., Montreal		815
49	Antimony	Lake George, N.B.	A. R. Slipp, K.C. Fredericton, N. B.		1,034
50	Gold	Sudbury	Dugald McPhee, Sudbury, Ont.		200
51	Pyrites	South Porcupine	I. J. Wright, South Porcupine, Ont.		900
52	Molybdenum	Tory Hill, Ont.	Geo. Padwell, Tory Hill, Ont.		1,267
53	Copper	St. John, N.B.	F. C. Kaye, St. John, N.B.		100
54	Molybdenum	St. Johns, Newfoundland	Chas. F. Stevenson, St. Johns, Newfoundland		10
55	Molybdenum	Indian Peninsula, Quebec	W. A. Magor, Montreal, Que.		147

TEST No. 44.

Magnetic Iron Ore.

A shipment of 5 tons of low grade magnetic iron ore was received from the Bessemer Mines of the Canada Iron Mines, Ltd., of Trenton, Ont., for purposes of experimenting for the production of a sintered magnetic iron concentrate. The crude ore was sampled and found to be of the following analysis:—

Analysis of Crude Ore.

Iron	Sulphur	Phosphorus	Insoluble Res.
43·9%	0·3%	0·028%	30·88%

The crude ore was pulverized in a Hardinge Ball mill, and from thence conveyed to tandem Grondal magnetic separators: the concentrate produced having the following analysis:—

Analysis of Magnetic Concentrate.

Iron	Sulphur	Phosphorus	Insoluble Res.
67·51%	0·11%	0·019%	5·98%

The concentrate was then dewatered, and after being mixed with charcoal dust alone, and charcoal dust mixed with blast furnace flue dust, was sintered by means of a Dwight and Lloyd sintering pan. The results obtained were as follows:—

Results of Sintering Magnetic Iron Concentrate.

Mixture			Vacuum ozs.		Time	Analyses		
% Concen.	% Charcoal	% Water	Start	Finish	Min.	% Fe	% S	% P
94	6	+ 7·5	8·5	7	15	65·71	0·044	0·019
94	6	+10·0	8·5	7	20	66·21	0·023	0·016
	Flue Dust							
75	25	+ 7·5	8·5	7	20	63·85	0·018	0·013
70	30	+ 7·5	8·5	7	20	63·71	0·017	0·018

The sinter produced was hard and extremely porous, making an ideal raw material for the manufacture of pig iron.

TEST No. 45.

Molybdenum Ore.

From F. Younkin.

This sample, weighing 10 lbs., was received from F. Younkin of Birdsville B.C. The sample contained a considerable quantity of molybdenum oxide. The greater part of this oxide would remain in the tailings, as it is only slightly soluble in water.

The ore was crushed to pass a 35 mesh Tyler Standard Screen, and tested by an oil flotation process.

The crude ore was found to contain 11·68% MoS_2.

Flotation test:—

Weight of ore charged	400 grams.
Water	1,200 c.c.
Density of pulp	1·4
Oil added, lbs. per ton of dry ore.	4/10 lbs. of coal oil; 2/10 lbs. of Eucalyptus oil. Total oil 6/10 lbs. per ton.
Temperature of pulp	40°F.
Time of treatment	10 minutes.

Products obtained:—

Concentrates:

Weight	52 grams.
Per cent MoS_2	78·67%
Content of MoS_2	40·91 grams.

Tailings:

Weight	348 grams.
Per cent MoS_2	1·52%
Content of MoS_2	5·3 grams.
Extraction	88·5%

The above test was carried out in a standard Janney oil flotation testing machine.

The tailings were closely examined for flakes of molybdenite, and were found to be very clean, hence it was assumed that the high tailing obtained was due to molybdenum oxide, which of course was not floated. The extraction which is 88·5% is very high, so the loss in the tailings is not excessive.

TEST No. 46.

Zinc Ore from the Sullivan Mine, B.C.

A shipment of Sullivan ore weighing 200 lbs. was received for purposes of experimental testing with the Ullrich magnetic separator.

Test (a).

A quantity of the ore was crushed in the Laboratory jaw crusher and rolls to pass a 40 mesh screen, and then fed wet to the Ullrich magnetic separator.

The poles of the machine were brought very near together so there was just room for the ore to pass between.

Crude ore fed to the machine:

Weight	39 pounds
Zinc	21·80%
Content	7·5 pounds zinc.

Zinc product (non-magnetic):

Weight	6 pounds
Zinc	31·85%
Content	1·91 pounds zinc.

Middlings:

Weight	6 pounds
Zinc	29·28%
Content	1·76 pounds zinc.

Iron product (magnetic):

Weight	20·5 pounds
Zinc	15·50%
Content	3·18 pounds zinc.

By combining the middlings and zinc product, the extraction of 43·0% obtained.

Loss due to slimes:

Weight	6·5 pounds
Zinc	25·2%
Content	1·64 pounds zinc.

This slime loss represents 21·9 per cent of the total zinc content in the crude.

Test (b).

The ore was again crushed to pass 40 mesh, as in Test (*a*). The adjustment of the magnetic separator was changed. The poles were placed farther apart, and the magnetic field increased by raising the amperage.

Crude ore fed to separator:

Weight	41 pounds
Zinc	21·82%
Content	8·95 pounds zinc.

Zinc Concentrate:

Weight	18 pounds
Zinc	27·60%
Content	4·97 pounds zinc.

Middling:

Weight	3 pounds
Zinc	22·77%
Content	·68 pounds zinc.

Iron product (magnetic):

Weight	13 pounds
Zinc	11·10%
Content	1·45 pounds zinc.

By combining the zinc product and middlings, an extraction of 63·1% is obtained.

Loss due to slimes:

Weight	7 pounds
Zinc	26·4%
Content	1·85 ponds zinc.

The slime loss represents 20·7 per cent of the total zinc content of the crude.

Test (*c*).

In this test, the ore was crushed to pass 14 mesh. The adjustment of the separator was the same as used in Test (*b*).

Crude ore fed to separator:

Weight	99 pounds
Zinc	21·80%
Content	21·58 pounds zinc.

Zinc concentrate (non-magnetic):

Weight	42 pounds
Zinc	27·50%
Content	11·55 pounds zinc.

Middling:

Weight	6·5 pounds
Zinc	25·50%
Content	1·67 pounds zinc.

Iron product (magnetic):

Weight	42 pounds
Zinc	16·30%
Content	6·84 pounds zinc.

By combining the zinc product and middling, an extraction of 61·3% is obtained.

Loss due to slimes:

Weight	8·5 pounds
Zinc	17·9%
Content	1·52 pound zinc.

This slime loss represents 7·05 per cent of the total zinc content in the crude.

SUMMARY.

In the first test the poles of the separator were so close together that the ore when passing came in contact with the upper pole. This accounts for the poor separation; particles of zinc were entangled in the magnetic product, and did not get the same chance to become freed as they do when the magnetic particles have to be lifted out of the water to come in contact with the pole.

The high slime loss was due to the fine crushing, but with better mechanical devices for settling, a great part of this loss might be prevented.

The results, respectively, of Tests *a* and *b*, represent very fairly what could be expected by magnetic separation on 40 and 14-mesh material. Such a large slime loss could, no doubt, be prevented by using proper settling devices.

TEST NO. 47.

Tungsten ore from Burnt Hill Tungsten Mines, N.B., submitted by the Geological Survey of Canada.

Weight of ore received, 185 pounds.

Crushed in jaw crusher and rolls to pass through 10 mesh ·075″ aperture screen. Sized on 20 mesh ·034 aperture screen. Sized material passed through magnetic separator.

Concentrates obtained	12·250 pounds
Middlings obtained	8·625 „
−10 + 20 tailings obtained	83·250 „
−20 tailings obtained	78·000 „
Total of	182·125 pounds

Concentrates sized and run over Air Jig.

Final concentrates obtained	9·862 pounds
Final tailings obtained	2·500 „
Total of	12·362 pounds

Middlings sized and run over Air Jig.

Final concentrates obtained	1·439 pounds
Final tailings obtained	6·708 „
Total of	8·147 pounds

Final weights and analysis of Products.

Concentrates:

Weighs	11·301 pounds
Analysis	70·74% WO_3
Content	7·994 pounds WO_3
Recovery	95·2%

Middlings (Air Jig Tails).

Weight	9·208 pounds
Analysis	4·35% WO_3
Content	0·401 pounds WO_3
% WO_3 values in crude	4·8%
Tailings:	
Weight	161·25 pounds
Analysis	trace.

Total weight of products	181·76 pounds
Loss in handling	3·24 "
Total	185·00 pounds

Total content in products	8·395 pounds
Average analysis of crude	4·62 % WO_3

TEST No. 48.

Tungsten Ore from Burnt Hill, N.B., submitted by The Holjohn Co., Montreal, Que.

Shipment No. (A).

Crude Ore Received.

Weight	242·5 pounds
Analysis WO_3	5·78%
Content WO_3	14·01 pounds

The ore was crushed through 20 mesh.

Over size on 20 mesh all molybdenite and gangue.

Weight	3·0 pounds

Under size:

Weight	239·5 pounds
Analysis WO_3	5·85%
Content WO_3	14·01 pounds

Concentration by means of the Ullrich magnetic separator.

Plumb air jig and Wilfley table yielded results as follows:—

Concentrates:

Weight	19·17 pounds
Analysis WO_3	66·6 %
Content WO_3	12·77 pounds

Tailings:

Weight	199·5 pounds
Analysis WO_3	Trace
Content WO_3	0·00 pounds

Total weight of product:

Concentrates	19·17	pounds
Tailings	199·50	„
Total	218·67	„
Crude Ore	239·50	„
Loss of weight	20·83	„

This loss is due to dust etc., in crushing and handling the ore.

The content of the crude	14·01	pounds WO_3
„ „ „ product	12·77	„ WO_3
Difference or loss	1·24	„ WO_3

The amount lost in handling was 20·83 pounds containing 1·24 pounds WO_3, therefore, the dust loss, etc., contained 5·95% WO_3 which is approximately the same content in WO_3 as the crude ore.

Recovery calculated from the content of the crude ore at 14·01 pounds Tungstic acid is $\frac{12 \cdot 77}{14 \cdot 01} = 91 \cdot 2\%$.

TEST No. 48 (*a*).

Tungsten ore from the Burnt Hill Tungsten Mines, N.B., submitted by The Holjohn Co., Montreal, Que.

The shipment of 17 bags containing 815 pounds of ore was crushed in the jaw crusher and rolls to pass through a 20 mesh screen. The crushed ore was sized on a 40 and 70 mesh screen for concentration.

The analysis of the shipment calculated from the analysis of the sized material showed it to contain 2·78% WO_3, a total content of 22·6826 pounds WO_3.

A shipment of 7 bags containing 374 pounds of ore was crushed and sized in a similar manner. The analysis of this lot obtained from a sample of the ore before sizing was 2·65% WO_3 giving a content of 9·911 pounds WO_3.

The sized material from the two shipments were concentrated on the Overstrom concentrator, and the middlings from the concentrator rerun over a small laboratory Wilfley table.

All concentrates were combined and all tailings were mixed for sampling.

The results obtained were as follows:—

Crude ore from two shipments:—

Weight	1,189 pounds
Calculated analysis	2·74 % WO_3
Content	32·5936 pounds WO_3

Concentrates obtained:—

Weight	51 pounds
Analysis	62·23 % WO_3
Content	31·7373 pounds WO_3
Recovery of WO_3 values	97·34 %.

Tailings obtained:—

Weight	1,138 pounds
Analysis	0·02 % WO_3
Content	0·2276 pounds WO_3

TEST No. 48 (*c*).

Tungsten Ore, from Burnt Hill, N.B., submitted by The Holjohn Co., Montreal, Que.

The ore was first crushed in a jaw crusher and then passed through a set of rolls until the whole was reduced to pass a 20 mesh screen.

The following sizes were made:—

Through	20	mesh on	40	weight	1,321
„	40	„	80	„	723
„	80	„	—	„	1,060
Total					3,104

Each of the above sizes was fed to an Overstrom table. Two products only were made, a concentrate and a tailing. The tailing went to waste. The concentrate was retreated on the same table, and a final concentrate was produced, together with a middling product which was retreated, and a tailing which was allowed to go to waste. This middling product was recrushed and retreated over a table. A final concentrate and a middling product were made. This middling product is held for further treatment.

SUMMARY.

Concentrate—	Weight	111·0 pounds
	WO_3	64·7%
	Content	71·82
	Recovery of total WO_3 content of crude in the concentrate	91·45%
Middling —	Weight	13 pounds
	WO_3	28·82%
	Content	3·75
	Percentage total WO_3 content of crude in middling	4·77
Tailing—	Weight	2,981 pounds
	WO_3	·10%
	Content	2·981%
	Percentage total WO_3 content of crude lost in tailing	3·78
	Analysis of crude	2·53 % of WO_3.

TEST No. 49.

Antimony Ore from Harvey Station, New Brunswick.

A shipment of 1034 pounds of antimony ore was received at the Ore Testing Laboratories from A. R. Slipp, K.C., of Fredericton, N.B.

The ore was crushed in the jaw crusher and Rolls to pass on 10 mesh screen. A head sample of the crude ore was taken, which gave the following analysis:—

Antimony	3·15%
Arsenic	0·28%
Gold	None
Silver	None

A series of tests were made, firstly, by oil flotation; secondly, by water flotation; and thirdly, by Jig and Table concentration. The best and most simple concentration was that obtained by oil flotation. The result of the work is given below.

Concentration by Oil Flotation.

Test No. 1. A 768-gram sample was placed in a small Abby pebble jar and ground to pass 50 mesh screen.

The oil was added before grinding and the grinding was made wet.

The oil used was crude hardwood wood creosote and eucalyptus.

6/10 pounds of creosote was added per ton of dry ore.

6/10 pounds of creosote was added per ton of dry ore.
2/10 „ „ eucalyptus „ „ „ „ „ „
8/10 „ „ total oil was used.

Other reagents.

Acid sulphuric—amount added 5 cubic centimetres.

Ratio of pulp.

The pulp used in the machine contained 5 parts of water to 1 part of ore. The pulp was not heated.

The testing machine used was a standard Callow Laboratory flotation testing unit, consisting of a rougher and a cleaner cell. The results were as follows:—

Concentrates	Weight	40 grams
	Sb	47·52%
	Content	19·00 grams
	Arsenic	0·96%
	Content	0·38 gram
Middlings	Weight	7 grams
	Sb	4·12%
	Content	0·288 gram
	Arsenic	1·70%
	Content	0·12 gram
Tailings	Weight	721 grams
	Sb	0·24%
	Content	1·73 grams
	Arsenic	0·24%
	Content	1·73 grams
Recovery of antimony in concentrates		90·4 %
Elimination of arsenic		82·96%

Test No. 2—O.F. 1000 grams were taken, ground as in test No. 1, but this time the whole was ground through approximately 100 mesh.

Oil used.

Wood creosote as Test No. 1	6/10 lbs. per ton of dry ore.
Eucalyptus oil	2/10 lbs. „ „ „ „ „

Other reagents.

Alkaline pulp was used, 10 c.c. saturated solution of caustic soda.

Results are as follows:—

Concentrates	Weight	37 grams.
	Sb	49·06%
	Content	18·14 gram
	As	1·00%
	Content	0·37 gram

Middlings	Weight	15 grams
	Sb	9·35%
	Content	1·40 grams
	As	1·05%
	Content	0·15 gram
Tailings	Weight	948 grams
	Sb	0·66%
	Content	6·26 grams
	As	0·28%
	Content	2·65 grams

Recovery of antimony in concentrate	70·31%
„ „ „ „ „ and middling	75·74%
Elimination of arsenic	88·32%

Test No. 3—O.F. 1000 grams of ore ground in pebble mill as in other tests.

Oil used.

Tar sand oil (asphaltum base)	5/10	pounds per ton.
Eucalyptus oil	3/10	„ „

Pulp.

Was neutral, no reagents added.

Results as follows:—

Concentrate	Weight	42 grams.
	Sb	58·52%
	Content	24·58 grams
	As	0·24%
	Content	0·10 gram
Middling	Weight	19 grams
	Sb	2·25%
	Content	0·43 gram
	As	0·28%
	Content	0·05 gram
Tailing	Weight	939 grams
	Sb	0·40%
	Content	3·75 grams
	As	0·282%
	Content	2·65 grams

Recovery in concentrates of antimony	85·47%
„ „ „ and middling of antimony	86·96%
Elimination of arsenic	96·43%

These tests show that the ore can be very easily concentrated in this manner. A high recovery of the antimony values is obtained with a high elimination of the arsenic content of the ore. A high grade concentrate is obtained.

A flow sheet of this process would be as follows:—

Crude Ore.

Crusher to 1 in.

Hardinge or Short Tube Mill.
Oil added to Mill—Ore crushed to about 50 mesh.

Oil Flotation Machine (Callow or Minerals Separation).

It would hardly be necessary to classify the product from the tube mill, as the mill can be adjusted so that 90% of the pulp from the mill passes a 50 mesh screen aperture. The density of the pulp in the mill can also be regulated to give the proper feed to the flotation machine.

Concentration by Water Flotation.

104·5 pounds of the ore crushed to pass a 20 mesh screen, were taken and fed to the feeder of one of the water flotation machines which is being used for the concentration of molybdenite ores. The products obtained were as follows:—

Concentrates	Weight	4 pounds
	Sb	34·44%
	Content	1·38 lbs. Sb.
	As	0·40%
	Content	0·016 lb. As.
Middlings	Weight	4·25 pounds
	Sb	3·00%
	Content	0·13 lb. Sb.
	As	0·44%
	Content	0·019 lb. As.
Tailings	Weight	77 pounds
	Sb	0·33%
	Content	0·254 lb. Sb.
	As	0·60%
	Content	0·462 lb. As.

This test shows a large slime loss, which could be eliminated by better mechanical devices for receiving the products. A recovery of the antimony values of 75 to 80 per cent, with an elimination of 90% of the arsenic values could be expected. Dry crushing and perfectly dry feed is essential for this process.

A flow sheet would be as follows:—

Crude Ore.
|
Crusher to 1 in.
|
Mechanical Dryer.
|
Ball Mill or Rolls to 20 mesh.
|
Water Flotation Machine (Woods type).

If desired, a low grade concentrate could be made, first by water flotation machine, and a cleaner machine put in for retreatment of concentrate. Middlings from rougher machine, as well as middlings and tailings from cleaner machines, could be returned to the feed.

Wet Concentration by Jig and Table.

The crude ore crushed through 10 mesh was sized, the coarse sizes were jigged, and the finer sizes were concentrated on an Overstrom table. The results were not nearly as satisfactory as those obtained by flotation.

There was not enough material of the coarse sizes to obtain very good results on the jig. There was hardly enough concentrate made to bed the jig. It was found, however, that the ore could be concentrated in this manner.

The sizes between 20 and 80 mesh gave the best result on the table, a concentrate and tailing being made, which gave the following analysis:

Concentrate	Sb	31·10%
	As	0·65%
Tailing	Sb	0·67%
	As	0·34%

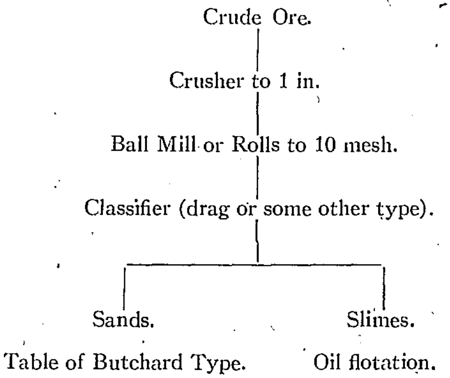
From size 80 mesh the following analysis of the products were obtained:—

Concentrate	Sb	31·02%
	As	2·71%
Tailing	Sb	2·10%
	As	0·28%

From these results it will be seen that the ore slimes badly, and a considerable loss of antimony values is to be expected by wet table concentration of the finer sizes.

Besides making a much lower grade of concentrate, the elimination of the arsenic values is low as compared with flotation.

If, however, a coarser grade of concentrate than that obtained by flotation is desired for smelting, table concentration would apply for the coarse sands, and flotation applied to the slimes. A flow sheet of such a plant would be as follows:—



CONCLUSIONS.

By any of the above methods, the ore can be concentrated very satisfactorily. The most simple process, and one in which the highest recovery is obtained, is that of oil flotation. The only point that could be raised against this process is the finely divided state of the concentrate, which might be objectional for the smelting of the concentrate.

Test No. 50.

Gold Ore from Sudbury, Ont.

A shipment of 4½ bags of gold bearing quartz, together with 2 bags of wall-rock was received from Dugald McPhee, Sudbury, Ont. He stated that the ore was obtained from lot 14, south half, concession IV, township of Davit.

The ore consisted of a clean quartz containing a few visible particles of fine gold.

The four and one-half bags of quartz were crushed up and sampled. This sample assayed 0·82 ounce of gold per ton.

A small sample was cut out and ground in a pebble mill with mercury. A maximum extraction of 89·3% was obtained by amalgamation.

The tailings from the amalgamation test were concentrated. The percentage of sulphides in ore was very small and they contained only 0·75 ounce of gold per ton. The concentration ratio was 1 in 500.

A final tailing was obtained assaying 0·04 ounce per ton.

The wall-rock was assayed, but only a trace of gold could be obtained.

TEST NO. 51.

Pyrites Ore from South Porcupine, submitted by I. J. Wright, Esq., South Porcupine, Ont.

Net weight received 900 pounds. Analysis 29·23% sulphur.

Observations.—Pyrite in quartz gangue, for the most part finely disseminated. Fine crushing necessary to free it from the gangue to obtain a high recovery of the sulphur content.

Concentration.—The ore was crushed to pass through 10 mesh screen, and sampled. A portion of the crushed ore, unsized, was concentrated on the James Jig. The results obtained were only partially satisfactory.

Another portion of the crushed ore, unsized, was concentrated on the Overstrom table, using the table as a roughing table, making two products, concentrates and tailings. The tailings were reground to pass a 30 mesh screen, and concentrated on the table. The results obtained were highly satisfactory, and are given below in the following tables:—

Rougher Concentration.

Crude ore			Concentrates				Tailings			
Wt. Lbs.	% Sul.	Contents Lbs. Sul.	Wt. Lbs.	% Sul.	Contents Lbs. Sul.	Recovery %	Wt. Lbs.	% Sul.	Contents Lbs. Sul.	% of Sul. in crude
141	29·23	41·22	61	41·16	25·11	60·9	80	20·78	16·62	40·3

Reconcentration of Tailings.

Concentrates				Middlings				Tailings			
Wt. Lbs.	% Sul.	Cts. Lbs. Sul.	% of Sul. in crude	Wt. Lbs.	% Sul.	Cts. Lbs. Sul.	% of Sul. in crude	Wt. Lbs.	% Sul.	Cts. Lbs. Sul.	% of Sul. in crude
16	41·69	6·67	16·2	16	30·55	4·89	11·8	48	6·51	3·13	7·6

From the tables it will be seen that the concentrates obtained from the rougher machine gave an analysis of 41·16% S., with a recovery of 60·9% of the sulphur content in the crude; and, that the concentrates obtained from the finishing machine gave an analysis of 41·69% sulphur, with a recovery of

16·2% of the sulphur content in the crude. The total recovery in both concentrates was 77·1%. The middlings from the finishing machine could be returned, if necessary to the operation.

It is a question of cost, whether it would pay to continue the concentration of this ore after the first rougher concentration from which 60·9 % of the values were obtained. The extra cost of regrinding the tailings may be greater than that received from the additional concentrates obtained.

TEST No. 52.

Molybdenite Ore submitted by Geo. Padwell, Tory Hill, Ont.

Weight of ore received, 1,267 lbs. net.

Observations.—The molybdenite in the ore was of the flake variety. The other minerals present were pyrite, pyrrhotite, and pyroxenite.

Concentration.—The ore was crushed in the jaw crusher and rolls until the gangue passed through a 16 mesh screen. Seven (7) pounds of flake were caught on the screen.

The material through 16 mesh was sent to the flotation machines and the products from the machines weighed and sampled.

The results were as follows:—

Flake obtained.—Weight	7·0 lbs.
Analysis	88·04 % MoS_2.
Content	6·1628 lbs. MoS_2.
Recovery of MoS_2 values	12·6 %
Rougher concentration.—Weight	68·0 lbs.
Analysis	54·65% MoS_2.
Content	37·1620 lbs. MoS_2.
Recovery of MoS_2 values	76·2%
Rougher middlings.—Weight	83·0 lbs.
Analysis	2·57% MoS_2.
Content	2·1331 lbs. MoS_2.
Percentage of MoS_2 values	4·4%
Tailings.—Weight	1,109 lbs.
Analysis	0·30% MoS_2.
Content	3·3270 lbs. MoS_2.
Loss of MoS_2 values	6·8%

From the above products the analysis of the crude was calculated

Total weight of crude	1,267 pounds.
Analysis	3·85% MoS_2.
Content	48·7849 lbs. MoS_2.

Conclusions.—This grade of ore can very readily be concentrated by water flotation, from which a recovery of 88·8% of the molybdenite values has been obtained. In the ordinary mill run of this ore, the rougher concentrates are re-treated to bring them up to over 80% MoS_2 grade, and the rougher middlings as well as the middlings obtained from the re-treatment of the rougher concentrates are added to the mill run. In this way, only final concentrates and tailings are made. The rougher concentrates from this shipment were not re-treated as there was an insufficient amount to treat satisfactorily.

Test No. 53.

Copper ore submitted by F. C. Kaye, St. John, N.B.

The sample of ore received by us consists of chalcopyrite, associated with a quartz gangue and contains 7·6% copper.

Flotation Tests.

These tests were made in a Janney laboratory flotation testing machine. The results from this machine have been proven to correspond very closely to those obtained in actual practice.

Test No. 1

500 grams of ore were crushed to pass a 50 mesh screen.
A charge was made up containing:—

Ore	500 grams.
Water	2000 "
Acid	None.
Alkali	None.

Oil mixture 0·375 grams (= 1½ lbs. per ton of ore.)
Temperature of pulp 10°C.

The oil mixture contained:—

25% pine oil (General Naval Stores No. 5).
65% coal tar creosote;
10% coal tar (Dominion Coal Tar Company, Sault Ste. Marie.)

The above charge was placed in the flotation machine and agitated until no more froth could be obtained.

The result of the test was as follows:—

Concentrates.	Weight	155 grams.
	Per cent Copper	23·4%
	Content	36·3 grams of copper.
Tailings.	Weight	345 grams.
	Per cent copper	0·94%
	Content	3·24 grams.
Extraction of copper		91·8%

Test No. 2.

The ore was again crushed to pass a 50 mesh screen and a charge was made up as follows:—

Ore	500 grams.
Water	2,000 "

Oil mixture 0·375 grams (= 1½ lbs. per ton of ore).
Temperature of pulp 10°C.

The oil mixture contained:—

40% heavy hardwood creosote (Standard Chemical Iron & Lumber Co.)
54% coal tar creosote (Dominion Coal Tar Company.)
6% coal tar (Dominion Coal Tar Company).

The result of the test was as follows:—

Concentrates.—	Weight	157 grams.
	Per cent copper	23·6%
	Content	37·10 grams.
Tailings.—	Weight	343 grams.
	Per cent copper	0·80%.
	Content	2·74 grams.
Extraction		93·1%.

The above tests show clearly that the flotation process is adaptable to this ore. But whether this process should be used alone, or in conjunction with gravity methods of concentration, will depend upon local conditions at the mine. If the mine only warrants a small mill, then the flotation process would seem to be the one to install, provided the nearest smelter can handle the fine concentrate.

An alternative to the flotation process would be, gravity concentration on jigs and tables, followed by flotation of the reground tailing from the jigs and tables.

Gravity concentration alone would not likely yield over a 70–75% extraction, and the concentrate would be of a lower grade.

TEST NO. 54.

Molybdenum ore submitted by Chas. F. Stevenson, St. Johns, Newfoundland.

A small hand-sample of molybdenite ore was received. This sample was crushed to pass a 35 mesh standard Tyler screen, to prepare it for flotation.

Oil flotation Test:

Charge of Ore	500 grams.
Water	2,000 c.c.
Density of Pulp	1·4.
Acid	None.
Oil lbs. per ton of dry ore	4/10 lbs. coal oil. 2/10 lbs. eucalyptus oil.

Total oil added, 6/10 lbs. per ton.
Temperature, 40°F.
Time of agitation, 10 minutes.

PRODUCTS OBTAINED.

Concentrates:	
Weight	59 grams.
Per cent MoS_2	68·40%
Content of MoS_2	40·356 grams.
Tailings:	
Weight	441 grams.
Per cent of MoS_2	1·20%
Content of MoS_2	5·292 grams.
Per cent extraction	88·5%

By calculation from assays of the products, the crude ore was found to contain 9·3% MoS_2. The above test was carried out in a Janney standard flotation testing machine.

TEST No. 55.

Molybdenum ore submitted by W. A. Magor, Montreal, Que.

The following results were obtained on a small test of 147 pounds of molybdenite ore from the Aplite formation on the Dion property, Indian Peninsula, Province of Quebec.

This small shipment of 147 pounds was crushed in the jaw crusher and rolls to pass through a 20 mesh screen. Three (3) pounds of flake were caught on the screen. The undersize, through 20 mesh was sent to the flotation separator from which were obtained: first concentrate, 3 pounds; first middling, 2 pounds; and first tailing, 139 pounds. The oversize flake and the first concentrate from the separator were mixed together for analysis. The following table gives the weights, analysis, and content of the products.

Product	Weight	Analysis	Content
1st concentrate	6·00 lbs.	62·24%	3·7344 lbs.
1st middling	2·00 „	13·50%	0·2700 „
1st tailing	139·00 „	0·21%	0·2919 „
Crude	147·00 lbs.	2·92%	4·2963 lbs.

From this table it will be seen that the ore gave an analysis of 2·92% MoS_2. Recovery in the first concentrate of 86·9% of the molybdenite values in the crude is calculated as follows:—

$$\frac{3\cdot7344}{4\cdot2963} \times 100 = 86\cdot9\%.$$

The first concentrate and first middling would necessarily have to be rerun to bring them up to 80 to 85% grade.

II

REPORT ON THE CHEMICAL LABORATORY.

H. C. Mabee,

Chemist.

The work of the chemical laboratory of this Division has been conducted in a portion of the general laboratory of the Fuel Testing Division, as in former years.

Owing to the greatly increased activities in connexion with the molybdenite industry throughout Canada during the past year, and the extent to which the mining public availed themselves of the privileges and advantages of the Ore Dressing Laboratory, the chemical laboratory of this Division has been almost constantly engaged in work of this class, though a variety of ores and concentration products, as well as furnace products, were submitted for examination.

During the year, 1304 samples were received and reported; 1,040 of these were samples of molybdenite; the whole involving some 3,648 chemical determinations.

The following classified list of ores, concentration products, etc., will give some idea of the charactor as well as the scope of work carried on in this laboratory:—

Ores, Metals, etc.	Crude Ore	Concent'rs	Middlings	Tailings	Totals
Molybdenite	245	333	297	265	1,040
Corundum	7	55	19	18	99
Iron ores	3	5	..	3	11
Tungsten ores	14	5	..	8	27
Pyrite ores	4	3	1	3	11
Antimony ores	6	5	4	5	20
Zinc-lead ores	1	2	2	2	7
Sintered iron ore	..	..	..	..	5
Cast iron	..	..	..	..	1
Charcoal	..	..	..	..	1
Ferro-silicon	..	..	..	..	13
Ferro-molybdenum	..	..	..	..	55
Metallic arsenic	..	..	..	..	1
Coal ash	..	..	..	..	4
Furnace slag	..	..	..	..	3
Copper ore	..	..	..	..	1
Silica sand	..	..	..	..	1
Furnace lining	..	..	..	..	1
Gold and silver	..	..	..	..	3
Total	..	..	..	..	1,304

The working capacity of the laboratory, which was greatly overtaxed during the early part of the year, has been very materially augmented in the appointment of two assistant chemists. In February, Mr. A. K. Anderson was engaged temporarily, and in March, Mr. R. J. Traill was appointed to the staff.

Owing to the very limited space available for this work, and with a continued increasing demand on this laboratory, it is to be regretted that much delay in handling the work promptly and efficiently was unavoidable. It is a matter of great satisfaction, however, to be able to state, that late in the year, steps were taken to remedy, to a great measure, the present inadequate accommodation for the chemical laboratory work of this Division.

An extension to one of the buildings of the plant is now in the course of construction, and in this new building some 650 square feet of floor space has been reserved for laboratory, balance room, and office accommodation. This building is well on the way to completion. The necessary chemical and other apparatus for its equipment have been provided for, and it is fully expected that it will be possible to transfer the work to this new building early in 1917.

CERAMIC DIVISION.

I

FIELD INVESTIGATION OF CLAY AND SHALE RESOURCES.

J. Keele,
Chief of Division.

About three weeks were spent in the northern portions of Ottawa and Pontiac counties, in the Province of Quebec, while engaged in a search for residual clays or kaolin. The results of this investigation were fruitless, as far as clays were concerned, but observations on the general geology of the region were noted. The only favourable evidence obtained, was the fact that the rocks of the Grenville series have a wider distribution in that region than had hitherto been suspected; and as it is in the Grenville rocks that the kaolin deposits at St. Remi d'Amherst occurs, the prospects for finding similar deposits are considerably enlarged.

As the kaolin is almost sure to be concealed beneath glacial drift, it is often difficult to detect its presence, except by close scrutiny. The surface indications of this kind of deposit do not often furnish much clue to its existence, except to one accustomed to prospecting for clays. To such a one, even very small amounts of the pink, yellow, or white colour of residual clays are noticeable in the monotonous drab or grey glacial drifts, and these indications are usually local, being confined to the neighbourhood of the concealed deposits.

Several days were occupied in a visit to the kaolin deposit at St. Remi d'Amherst, to examine the results of the recent development work done by the Canadian China Clay Company. Most of the work consisted of stripping the covering of glacial drift from the main kaolin vein, so as to make it accessible for surface mining over a greater area than formerly.

The kaolin is not all white, as large bodies of yellow and red clay are encountered when working the deposit. A good deal of the discoloured clay occurs just below the glacial drift covering, so that surface waters percolating through this dirty material may have caused the discoloration. The discoloured clay must be removed from contact with the white in mining, and is a waste product as far as the production of white clay is concerned. The results of some experiments with regard to the utilization of the yellow clay, as well as the wall-rock of the veins, are given in this report.

The shales and surface clay deposits in the Ottawa district were examined, sampled, and traced, over the greater part of the area during the summer of 1916—and a report dealing with them is being written.

Mr. N. B. Davis was engaged in field work in south Saskatchewan, where he examined the clay deposits over an extensive region. The experimental work on the samples he collected is nearly completed, and he is now engaged in writing a full report on the clays in the Province of Saskatchewan.

KAOLIN PRODUCTS.

Deposits of residual clay which have resulted from the decomposition of rocks in situ, are of rare occurrence in Canada, owing to the scouring by glacial ice to which most of the country was subjected. Kaolins are the most valuable of the residual clays, on account of their ability to withstand very high temperatures without softening, and the white colour which they possess both in the raw and burned state.

All residual kaolins must be subjected to a washing process in order to free them from impurities such as quartz or mica, which are always present in the deposits. The washed product, which is a fine-grained white material, is sold under the trade name of china-clay. It has uses in many industries besides the manufacture of pottery, which is the chief one.

The kaolin deposit at St. Remi in Amherst township, county of Argenteuil, is the only workable example of the kind at present known in Canada. A description of the geology in the vicinity of the deposits is given by M. E. Wilson in the Summary Report of the Geological Survey of 1916.

The kaolin is confined to vertical dikes or veins, varying in width from 20 to 40 feet in the main vein, to 1 or 2 feet in the small veins, or offshoots. The walls of shattered quartzite, which enclose the kaolin dikes, are impregnated with specks and stringers of kaolin for a considerable distance from the main veins.

The whole is overlain by glacial drift, consisting of boulders, small stones, sand and silt, of a thickness from 1 to 15 feet. This overburden has to be carefully removed and kept clear of the kaolin in mining, otherwise it will cause discoloration.

During the last five years, the Canadian China Clay Company Limited, who control these deposits, has done much in the way of stripping, test-pitting, and otherwise prospecting the ground, with the result that considerable information is now available concerning the size and character of the deposit.

The writer spent a few days in examining the properties of the Company, at St. Remi, during the summer of 1916, and is convinced that the area is of considerable economic importance.

The business of the Company is confined to mining and washing kaolin for the paper and pottery trades but it is proposed to extend operations so as to include a complete utilization of other portions of the deposit as well.

Samples of the various materials from the locality were collected and tested at the Ceramic Laboratory of the Mines Branch for the purpose of determining their possibilities for the following purposes:—

(1) The manufacture of firebrick from the crude kaolin;
(2) The manufacture of silica brick from the quartzite wall-rock;
(3) Whiteware pottery bodies;
(4) Low fire bodies for art pottery.

Firebrick.—There is a considerable quantity of yellow or pink kaolin in the upper part of the dikes, which is a waste product as far as the production of china-clay is concerned, as it is not white, either when washed or burned.

The chemical analysis of the yellow clay, as determined by A. Gordon Spencer, is as follows:—

Silica	54·24%
Alumina	34·24%
Iron oxide	2·04%
Lime	2·54%
Magnesia	0·46%
Loss on ignition	5·87%

A sample of this clay was found to remain intact in a carbon resistance furnace at the softening point of cone 25, but a washed sample of the same clay failed at cone 15.

The crude yellow clay could, therefore, be used in the manufacture of a low grade firebrick if the working qualities are adequate and the shrinkage within limits. The experiments, however, show that the material is rather short grained and inclined to be weak in the raw state, and its shrinkage is excessive.

A portion of the white clay, mixed with the yellow, improves the refractory qualities of the latter.

A good firebrick can be made from the white clay by adding about 10 to 20 per cent of a common brick clay, in order to supply the fluxes which the white clay lacks. This mixture, burns to a dense body at the temperature at which ordinary firebrick are generally burned. On account of the high shrinkage in the kaolin, it would be necessary to calcine some of the clay before moulding into the bricks. The calcined clay is ground and added to the raw clay, with the result that the shrinkage is considerably reduced.

Silica brick.—The wall-rock on the south side of the main kaolin vein is a fractured quartzite, containing disseminated specks, and occasional stringers of kaolin. Samples of this rock were collected over a distance of 133 feet, at right angles to the kaolin vein. A washing test of the crushed quartzite gave an average of 11 per cent of materials fine enough to pass through a 200 mesh screen, most of which is kaolin. The rock samples were crushed to pass a 10 mesh screen, milled with a little water, and pressed into bricklets.

The bricklets were burned in a gas kiln to a temperature of 1300 degrees C., and afterwards in a carbon resistance kiln, to a temperature of 1,530 degrees, a small portion of one of the bricklets was afterwards raised to a temperature of 1,650 degrees.

The bricklets burned to 1,530 degrees were hard and dense, and showed that a fused bond has been effected between the kaolin and the quartz. Raising the temperature to 1,650 degrees changed the character of the material only slightly, there being no evidence of sintering, as the quartzite grains on the surface were still angular.

Like all silica brick, this material expands somewhat in burning, but the expansion was slight, owing to the clay bond. The shrinkage of the clay seems to offset the expansion of the silica, so that it seems possible to take all the expansion out of this material at a lower temperature than would be required to do so in the case of a quartzite brick bonded with lime. The material, therefore, seems very suitable for the manufacture of an acid refractory brick of the gannister type, which could be used in puddling malleable, cupola, and crucible furnaces, and for converter linings, by-product coke ovens, and glass furnaces.

A quantity of the quartzite wall-rock was sent to the United States, and made up into full sized brick for further trial, which consisted in placing them along with some standard brick in the ports of steel furnaces in operation. The results of these tests were highly satisfactory, as it showed that the St. Remi material would remain intact while other well known brands of refractory brick failed alongside them.

Whiteware bodies.—All table ware, white tile, sanitary, and electric porcelain, are made from a mixture of quartz, feldspar, china-clay, and ball clay in varying proportions. The china-clay produced at St. Remi is of high grade, and compares favourably with the standard brands on the market. Cornish stone or china stone is largely used in England for pottery bodies instead of feldspar, and it is interesting to record that material similar to Cornish stone was found in one of the test-pits at St. Remi.

Ball clay is a highly plastic white burning clay, which serves to bond and make workable the non-plastic quartz and feldspar. So far we have not succeeded in finding ball clays in Canada, but some of the clays in southern Saskatchewan which we are at present examining, seem to approach them closely in character.

Compounding a white pottery body, therefore, from St. Remi materials alone is rendered difficult by the absence of plastic clays, but imported English or American ball clay could be used in the mixtures.

In making pottery by the casting process it is possible to dispense with ball clay in the mixture, so that a casting body could be compounded from the ground quartzite wall-rock, and china stone with the washed kaolin. These materials do not burn to an absolutely white body, owing to certain impurites in the stone and quartzite, which gives the mixture a decidedly greyish tone. A body such as this, however, could be used for high fire glazes with crystalline effects, a product which is much sought after for decorative purposes.

Art pottery or majolica ware.—As these wares are generally coated with coloured glazes or enamels, the colour of the body which carries the enamels is not important. The yellow kaolin when washed to pass a 60 mesh screen is a very good material to work on for this purpose, as it is more plastic than the higher grade white kaolin. Some of this material which was washed and screened in the laboratory, and allowed to stand wet for several weeks, was found to possess very good plasticity, and could be modelled into shapes or thrown on the potters' wheel with ease. It burns to a porous, rather weak, red body, at low temperatures, but becomes dense at high temperatures. The shrinkage is rather high, but this could be lessened by the addition of some fine quartz sand which remains in the trough used in the washing of the white kaolin.

A more plastic mixture can be made by using some of the grey brick clay which is exposed in the railway cutting a few miles east of the kaolin plant. This clay is very smooth and plastic, shrinks greatly in drying, and burns to a strong red body at low temperatures, but is easily overfired.

A body made up of equal parts of this clay, yellow kaolin, and quartz sand, would be suitable for either cast, built, turned, or pressed pottery.

The mixture burns to a sufficiently dense red body at a temperature of about 2,000 degrees F. If the white kaolin is used instead of the yellow in the above mixture, a greyish body results, which resembles a stoneware clay when burned to a temperature of about 2,200 degrees F. A body composed of yellow kaolin and brick clay could be used for plain red ware or terra-cotta.

II

APATITE: A SUBSTITUTE FOR BONE ASH IN THE MANUFACTURE OF BONE CHINA.

In eastern Canada there are large deposits of the mineral apatite (CaF) Ca_4 $(PO_4)3$ very little of which is being mined at present. It occurs in large coarsely crystallized masses, associated with mica and pyroxene in rocks of Pre-Cambrian age.

A number of years ago, between 1883 and 1891, the annual output was 25,000 tons. With the discovery and active exploiting of the sedimentary phosphates of the southern states, Canadian apatite lost its position as an important source of phosphate for the manufacture of commercial fertilizer and the production fell off to a few hundred tons. Hence the Canadian mines closed as apatite mines, but later some of them reopened as mica properties. A very small but increasing amount is being absorbed in the manufacture of phosphorus and pure salts of that element for certain special fertilizers and for increasing the phosphorus content of pig-iron.

It is important that some new use be found for this material, and what could be more natural than its use as a substitute for bone ash in the manufacture of bone china, and for opacifying enamels.

Turning to the literature on bone china, the English potters have the credit for developing this type of ware, and how simple is the reason given for the first English use of bone ash in a body. According to Mellor[1] "the information was sent to Europe from China by a traveller that the Chinese potters had said European potters might as well try to make a 'body without bones' as try to make porcelain with nothing but the pegmatitic flux which had been carried to Europe by Eastern traders." What more natural than "bone" should have been taken literally.

Edwards[2] states that "the value of bone for pottery purposes is determined by the percentage of phosphate, and also of the deleterious conditions such as carbonaceous and siliceous matter and iron." He gives the following as an analysis of an average quality of bone ash:—

Trical phosphate	85·25	$Ca_3(PO_4)_2$
Carbonate lime	2·88	
„ magnesia	2·45	
Fluoride lime	1·65	
Ferric oxide	0·32	
Insol. silica	4·57	
Loss (water and carbon)	2·85	
	100·00	

In experiments with a synthetic bone ash made up in two ways: (1) with commercially precipitated phosphate, (2) with calcium phosphate precipitated and purified by himself, Edwards found that the commercial material gave poor results because of the presence of alkalies, while the pure phosphate gave bodies as translucent, and showing no more fusibility or warping, than the ordinary bone mixture.

"It would seem from this that the reason why Mr. Moss and others, in experimenting with artificial phosphate, found it had not the holding up power of the phosphate obtained from bone was that the phosphate used was impure. Phosphate obtained by precipitation from solutions of calcium chloride and sodium phosphate, unless very well washed, contains alkali, which of course makes it fusible. The commercial phosphate which I used, when fired alone through china biscuit was fused quite hard."

"It would therefore appear that the cellular or fibrous structure of bone, to which is sometimes ascribed the permanency of form during firing of the china body, has no action whatever."

The important point to be noted in the above quotation is that pure calcium phosphate (free of alkalies) gave as good results as the commercial bone ash. Of course alkali-free chemically prepared phosphate would be too costly to be commercial, but this would not be true of the alkali-free mineral phosphate.

In answer to a question after reading a paper on "Bone China Bodies" before the American Ceramic Society in 1905, Watts[3] states that he had tried making bone china from phosphate supplied by a fertilizer company but failed to get results. The discussion did not bring out the composition of the fertilizer phosphate but it must have been impure. Apparently Mr. Watt never tried apatite as pure as the Canadian material.

The Canadian apatite, as it occurs in the district north of Ottawa, is usually pale green in colour and of two types: massive and granular (sugar apatite). It occurs in large masses in pyroxenite rock.

The mineral association is very similar to that of feldspar, except that in this case apatite assumes the principal role, mica, feldspar, and pyroxene being the

---

[1] Mellor: Trans. Eng. Cer. Soc., Vol. V, p. 79.
[2] Edwards: Trans. Eng. Cer. Soc., 1904, p. 32.
[3] Watts: Trans. Am. Cer. Soc., Vol. VII, p. 231.

principal accessory minerals. Some pyrite is also present but it is usually very small in amount.

A number of analyses to typical apatites of the mines of the Ottawa district are given in the following table. The analyses were made by Mr. M. F. Connor of the Mines Branch, from the standpoint of the requirements of the fertilizer industry, iron and alumina are given together and iron oxide probably averages half the amount.

	1	2	3	4	5
SiO_2	0·48	1·80	0·64	0·06	0·36
Fe_2O_3 Al_2O_3	1·00	1·30	1·30	0·72	8·72
CaO	54·20	53·30	54·40	55·70	55·60
MgO	0·35	0·28	0·31	0·20	0·33
Na_2O K_2O	0·77	0·64	0·88	0·80	0·75
H_2O	0·32	0·36	0·12	0·28	0·20
Cl	0·44	0·40	0·67	0·65	0·50
Fl	3·30	3·20	3·30	3·10	3·05
CO_2	0·66	....	1·75	....	....
P_2O_5	39·60	40·15	37·50	39·24	39·39

1. Massive reddish-grey apatite, McLelland mine north 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, Blackburn mine, lot 9, range XI, township of Templeton, Que.

Large samples of both the sugar and massive varieties of apatite were secured from the Blackburn mine for testing in a bone china body.

Each sample was broken down and ground to pass 200 mesh, care being taken throughout the process to avoid contamination by iron.

Binns[1] gives the following as the general range of body composition for bone china:—

Bone ash	42–32%
Feldspar	15–19%
China-clay	33–35%
Flint	10–14%

From this range, four bodies were calculated to have the following composition substituting the ground apatite for bone ash. English china-clay, Canadian spar and American flint were used.

Apatite China Bodies.

No.	1	2	3	4
Apatite	42	39	35	32
Feldspar	15	16	17	19
China-clay	33	34	34	35
Flint	10	11	14	14

Each batch was mixed and ground wet in a ball mill for 3 hours, the slips brought to the proper consistency, and, after standing in jars for a week, cups were cast in plaster moulds.

---

[1] Binns, Trans. Am. Cer. Soc. Vol. XII, p. 176. (1910.)

The test pieces were burned in saggers in a commercial floor tile kiln to cones 8, 9, and 10. The cups were not supported, but set to show any deformation. After burning, all the cups at cone 9 were slightly deformed but not badly, considering the thinness of the walls. Had they been set in supports as is the practice in burning bone china the cups would have been perfect.

At this temperature, all four bodies show good white colour and excellent translucency, with the greatest translucency in body No. 4.

The cups burnt to cone 8 had good colour and translucency, but not quite as good as at cone 9. Complete deformation took place with the cups burnt to cone 10, indicating a burning range for good ware of cones 8 and 9.

A second set of cups were sent to the Mayer China Company at Beaver Falls, Pa., and burnt in a commercial china kiln to cone 9. One cup (body No. 4) was covered with a glaze and the rest burnt without glaze. The results of this burn are very promising, the glazed No. 4 body being particularly good and at least equal in colour and translucency to the best English bone china.

A more extensive investigation of this subject is under way.

III

REFRACTORY MATERIALS IN CANADA.

INTRODUCTION.

The most important accessory to the practice of metallurgy and ceramics is a suitable refractory material; a substance that will withstand high temperatures and the accompanying physical and chemical conditions of abrasion and corrosion.

Blast furnaces, all kinds of melting furnaces, converters, etc., the tools of the metallurgist, kilns used in the lime, cement, glass, and clay industries, the tools of the ceramist, all require to be lined with a refractory material; acid, basic, or neutral in character, depending on the nature of the work.

In Canada, the great majority of the industries using refractories are dependent on American and European importations; a condition which has been a natural outcome of the transplanting of industries, a small population and a long frontier. There has also been a lack of knowledge of refractory raw materials in the older parts of the Dominion. It has been but recently, under the stress of war conditions that our industries using refractories have begun to appreciate the necessity of utilizing Canadian raw materials for the manufacture of refractory goods.

The fuel supply is a very important item in the manufacture of refractories, since high temperatures must be used in burning the ware. Ontario, the principal manufacturing Province, has not a local supply of coal, and hence imports both fuel and refractories, largely from Pennsylvania.

Quebec imports all its coal supply from Pennsylvania and Nova Scotia. Refractories are drawn from Pennsylvania and Scotland. There is a small local production of special shapes manufactured from imported American clays.

The Maritime Provinces draw coal from Nova Scotia fields, and refractories mainly from Scotland. The Scotia Company has recently installed a firebrick plant at Sydney Mines, and started the manufacture of fireclay shapes for use in ladle linings, generative chambers, flues, etc.

The industries in the middle west, Manitoba, Saskatchewan, and Alberta, draw coal from the United States and the Alberta fields. Refractories are largely imported from St. Louis district and from Pennsylvania.

In the Province of Saskatchewan there is one plant in operation making firebrick at Claybank, about 25 miles south of Moosejaw.

The Pacific coast industries use local coal, and import some refractory materials from the United States and Scotland. The most important plant manufacturing refractory goods in Canada is located at Clayburn, British Columbia. It includes the manufacture of retorts, in addition to standard firebrick and special shapes for furnaces.

The manufacture of refractory goods in Canada is therefore limited to a small plant at Sydney, Nova Scotia; one at Montreal; and one at St. John, Quebec; one fair sized plant at Claybank, Saskatchewan; and a larger plant at Clayburn, British Columbia.

DISTRIBUTION OF RAW MATERIALS.

NEUTRAL REFRACTORIES, CLAYS AND SHALES.

Maritime Provinces.

The clay and shale beds associated with the coal seams in Nova Scotia are, for the most part, easily fusible materials, which cannot be even classed as semirefractory.

The only materials, so far found in the coal districts, which approach the requirement for refractoriness, consist of a 3 foot bed of plastic clay overlying the 13 foot seam at Inverness, and a 4 foot bed of hard shale underlying the No. 3 coal seam at the mine of the Intercolonial Coal Company, at Westville.

The most refractory clay known in Nova Scotia does not occur in the coal measures, but is found in unconsolidated Cretaceous clays at Shubenacadie, on the line of the Intercolonial Railway. Tests on this material show it to be a number 2 refractory, deforming at cone 30 (3,100 degrees F.). The white or grey clay at Middle Musquodoboit, 16 miles east of Shubenacadie, is of similar age and character.

A felsite rock occurring at Coxheath near Sydney has refractory qualities, but is non-plastic. When crushed, and bonded with plastic fireclay, it can be manufactured into a very desirable firebrick.

The most refractory clay so far found in New Brunswick, occurs under the thin-coal seam at Flower Cove, in the Grand Lake coal area. It is only semirefractory, as it deforms at the softening point of cone 25 (2,966 degrees F.).

Quebec.

The only important source of refractory clay in Quebec is confined, at present, to the kaolin deposit at St. Remi d'Amherst, situated 70 miles northwest of Montreal.

Preliminary experiments with the crude kaolin for the manufacture of firebrick have given promising results, and the material is now being tested on a commercial scale. A large quantity of this material is being revealed in the development work at the mine; and it is probable that intensive prospecting of the adjacent ground will result in the finding of other bodies of kaolin.

An occurrence of residual clay is reported in Two Mountains county, near the line of the Canadian Northern Railway. This material has refractory qualities, but the deposit is considered too small to be of economic value.

Ontario.

Fireclay is of rare occurrence in the Province of Ontario, and none is found in the more settled portions. There is a heavy annual importation of refractory goods to supply the needs of the large and varied industries.

A preliminary survey of the Province has resulted in finding only two localities in which fireclay occurs; one being at the Helen Mine in Michipicoten, where a diabase dike has weathered into a residual clay. This material softens at about cone 26 (2,950 degrees F.). The other deposit occurs on the Missinaibi river, about 40 miles north of the crossing of the National Transcontinental railway. It appears to be extensive, but owing to the remoteness cannot be said to be of commercial importance at present.

The search for refractory materials in northern Ontario has never been seriously undertaken, but the prospects of finding new deposits are good.

Manitoba.

No good refractory clays are reported from Manitoba, but some prospecting for this purpose remains to be done, particularly in the Dakota horizon of the Cretaceous.

The Odanah horizon of the Cretaceous outcropping in Turtle Mountain, La Riviere, and in the Assiniboine valley near Virden, consists of a hard grey shale that may be regarded as semi-refractory. It withstands temperatures up to cone 15 (2,600 degrees F.) before deforming. Like the semi-refractory shale used at Sydney, N.S., it may have a local value as a refractory for medium temperature work.

This shale is known as far west as Tantallon in the Qu'Appelle valley.

Saskatchewan.

The southern part of the Province of Saskatchewan is particularly rich in refractory and semi-refractory clays. For a number of years a drypress face brick plant has been in operation at Claybank in the Dirt Hills south of Moosejaw. The material used is a high grade (No. 2) fireclay, and although the most of the brick manufactured in the past have been sold as face brick, a certain amount have been used as firebrick. During the past year the company has been reorganized, and it is proposed to manufacture standard firebrick and special shapes as well as the regular line of face brick.

Similar clays to those used at Claybank occur at the north end of Lake-of-the-Rivers, near Mitchellton on the Canadian Northern railway; also along the Sterling branch of the Canadian Pacific railway at Willows; south of Twelve Mile lake; and along the Frenchman river valley in the Cypress Hills, from Eastend to Palisade.

The clays of the Lake-of-the-Rivers valley, Wood Mountain and Dirt Hills, are more refractory than the clays farther west. The former deform around 3,150 degrees F., while the latter seldom remain intact above 2,900 degrees F. The clays of the Cypress Hills are more suitable for the manufacture of vitrified clay ware, such as sewerpipe and stoneware.

Alberta.

No fireclays have been found among the clay and shale deposits of southern Alberta up to the present.

Beds of high grade clays occur in northern Alberta along the Athabaska river for some distance north of McMurray. Most of these clays are of the stoneware type and semi-refractory, but one bed was found to meet the requirements of a fireclay.

These clays are apparently in the Dakota formation at the base of the Cretaceous, and intimately associated with the tar sands, in fact some of them are rendered almost useless by the impregnation of finely divided carbonaceous matter.

British Columbia.

The most important sources of refractory clays at present known in British Columbia are the Tertiary beds in Sumas mountain, where about 15 feet of hard fireclay is interbedded with other shales of a semi-refractory character, together with some useful vitrifying shales. This section on the whole contains the best series of materials known in Canada for the manufacture of a varied range of clay products.

Refractory shales with similar associations to those at Sumas mountain occur at Blue mountain, near Whonnock on the Canadian Pacific railway. Fireclay of residual origin, occurring at Kyuquot, is shipped to Victoria for the manufacture of stove linings and sewerpipe.

Several samples of so-called kaolin have been forwarded from British Columbia to the Mines Branch for examination, but all these have proved, on testing, to be either diatomaceous earth, or volcanic ash. It is quite probable, however, that kaolin deposits of commercial value will be discovered in the Interior Plateau region.

CHROMITE.

Of the neutral refractories, chrome brick are of the greatest importance in the metallurgy of iron, copper, antimony, and tin. In the manufacture of these brick, chromite—a sesqui-oxide of chromium (FeO, Cr_2O_3) usually termed chrome ore—is used. It is extremely refractory, and practically neutral, which properties gives it its commercial value. The natural chrome ore is mixed with a suitable binder, when necessary, such as fireclay, or a mixture of low calcined MgO and $MgCl_2$, and manufactured into brick. The chief use of chromite brick is as a buffer or separating course or lining between a basic bottom or hearth and acid or neutral wall and crown in order to prevent any reaction at high temperatures between the basic and acid materials.

The Province of Quebec, as in the case of magnesite, has become a large shipper of chromite, the production being 14,397 tons in 1915.

Most of the production comes from the Black Lake area, where it occurs as irregular masses and disseminated grains in serpentine rocks.

For refractory purposes chromite ore is sold on the market on the basis of a minimum of 25% Cr_2O_3. The material is hand cobbed and also wet concentrated for the market.

Chromite is known to occur at Tulameen and on Scottie creek in the Clinton Mining Division, and on Taylor creek in the Lillooet Mining Division, British Columbia.

The geological associations of the chromite and magnesite in these areas are upturned Cretaceous sediments, intruded by peridotite, being similar to the occurrence of the same minerals in California.

BONE ASH.

Bone ash is a less prominent neutral refractory, but has its use in the metallurgy of lead, and for assaying.

The amount of bone ash used in Canada for this purpose is limited, and the market for a substitute is small. Experiments are projected to ascertain the value of the mineral apatite as a substitute.

ACID REFRACTORIES.

Two kinds of silica refractories are used in the various industries, one having lime as the bonding material, and the other, clay.

For making silica brick, pure quartzite is crushed and milled in a wet pan, with milk of lime. The milling is done as thoroughly as possible in order that each particle of quartzite may be coated with lime, and a slightly cohesive mass produced. The bricks are made by hand, and partially dried, then re-pressed by machinery and sent to the kiln for burning.

Some hard sandstones in the coal measures in England contain enough clay in their composition to form a bond for the quartz grains when the rock is crushed and milled with a little water. This, when made up into shape and burned, is known as Gannister brick. A later development consists in grinding pure quartzite with plastic fireclay for the manufacture of this type of refractory.

Ordinary quartz begins to swell at a temperature of 850 degrees C., and continues to swell the higher the temperature rises, until most of it is converted into cristobalite and tridymite. If the burning of silica bricks is not carried to a high enough temperature in the manufacture they will expand on reheating, sufficient to cause serious damage to the furnaces into which they are built.

Some trials with various occurrences of quartz when bonded with lime and clay were made in the Mines Branch laboratories.

Quartz from the feldspar mines near Verona, Ontario, was bonded with 2 per cent caustic lime and 5 per cent plastic fireclay, and burned to cone 20. In both cases the quartz showed considerable expansion, and destroyed the bond produced in firing, making the bricks weak and crumbly.

Quartz from a large mass in Levant township, Ontario, was also tested in a similar manner and it likewise resulted in a swollen punky body.

Quartzite from Killarney, Ontario, bonded with 3 per cent caustic lime and with 5 per cent kaolin, produced a good strong body, with both bonds, and only a moderate amount of swelling.

The quartzite wall-rock in the kaolin mine at St. Remi, Quebec, is impregnated with specks and streaks of kaolin for a distance of 130 feet from the main kaolin body. An average sample of the rock contained about 11 per cent of clay. A sample of this material was crushed and milled, made up into trial pieces, burned to cone 9 in a gas kiln and afterwards to cone 18 in an electric kiln. The test pieces were hard and dense, showing that a fused bond had been effected between the quartz grains and the kaolin. The body was strong, and showed no undue swelling on the part of the quartz. This material appears to be suitable for the manufacture of an acid refractory brick of the gannister type, as it showed no indication of softening at a temperature of 1650 degrees C.

Quartzites of Pre-Cambrian age, like those occurring at Killarney and St. Remi, are also found conveniently situated at other points in eastern Canada.

The Potsdam sandstone at the base of the Palæozoic in the St. Lawrence and Ottawa valleys, is often a quartzite, but tests made on this material for the manufacture of refractory brick were not encouraging, as too much fine-grained material results from crushing, and the iron content is too high. The Potsdam sandstone, however, is used as a glass sand in places where it is free from iron, as at Beauharnois, Quebec.

Practically the same results were obtained in tests for silica brick when using the Oriskany sandstone in the Devonian rocks of southwestern Ontario. This sandstone is crushed and washed for glass sand at Nelles Corners.

A considerable quantity of white quartzite is contained in the Summit series of Lower Cambrian age in the Kootenay district, British Columbia. These quartzites outcrop on Kootenay Lake at Crawford Bay, and are probably the purest rocks of this kind in the province.

No tests were made of this material, but the character of the rock indicates that it might be used in the manufacture of silica brick or as a source of silica for other purposes.

The tests so far made show that all forms of quartz are not suitable for the manufacture of refractory ware. Quartzites give much better results than igneous quartz or sandstones. The sharp splintery particles which quartzite yields on crushing form an interlocking bond which is essential to strength in the finished brick. Brick made from the rounded grains of sandstone lack the proper strength for handling.

Although vein quartz breaks down into splintery particles on crushing, it is not a desirable material to use on account of its behaviour on heating.

BASIC REFRACTORIES.

Basic refractories include magnesite, dolomite, and bauxite, or the artificial product alundum, the first named being the most important. Until two years ago, the production of these materials in Canada was very small: 340 tons of magnesite exported in 1912. With the coming of the war and the consequent dislocation of trade, the American manufacturers of basic refractories hurriedly sought an American supply. Attention was turned to the occurrence of magnesian dolomite in the Grenville rock of Quebec, and prospecting in the vicinity soon developed the fact that there was considerable dolomitic magnesite available. The rock is sufficiently high in magnesite to enable the shippers to meet a requirement of approximately 85% $MgCO_3$. The production has grown rapidly as shown by the following table, supplied by the Statistics Division of the Mines Branch:—

Production of Magnesite in Canada.

	Tons	Value
1908	120	$ 840.00
1909	330	2,508.00
1910	323	2,160.00
1911	991	5,531.00
1912	1,714	9,645.00
1913	515	3,335.00
1914	358	2,240.00
1915	14,779	126,535.00
1916	55,413*	563,829.00

*Includes 635 tons marketed from Atlin, B.C.

Lining the bottoms of steel furnaces is the principal use to which the Grenville magnesite is applied.

For this purpose the magnesite is calcined, then broken into small fragments and mixed with from 15 to 40 per cent of crushed basic iron slag. It is said to give as good results as the magnesite hitherto imported from Austria.

None of the Grenville magnesite appears to be used in the manufacture of refractory brick, on account of its high lime content.

Experiments, designed by Mr. Howells Fréchette, are now in progress in the Mines Branch laboratories, with the object of reducing the lime content by mechanical means. The process of separating the lime from the magnesite is based on the difference in character between these materials after slaking the calcined mass. If this separation can be carried out in practice, a supply of high grade Canadian magnesite can be placed on the market.

A considerable quantity of high grade magnesite associated with serpentinized peridotite was found by Mr. C. W. Drysdale of the Geological Survey, in the Bridge River district of the Lillooet Mining Division, British Columbia; but these deposits are situated rather too far from railway transportation at present.

The hydro-magnesite deposits at Atlin, in the northern part of British Columbia, vary from the above mentioned occurrences, as they are superficial deposits in a finely divided condition, and not rock masses. This material although remotely situated, could be used to advantage on the Pacific coast in the chemical industry, and for the manufacture of special cements.

Where refractory bricks containing a high percentage of alumina and a low silica content are required, bauxite is the material employed in their manufacture. No record of the occurrence of bauxite in Canada, has, so far, been obtained.

IV

TESTS OF CLAY AND SHALES FROM PEMBINA MOUNTAINS IN SOUTHERN MANITOBA.

The following notes on tests of clays and shales were made for Mr. Alex. MacLean, of the Geological Survey, who collected the samples in the Pembina mountains, a short distance south of Morden, in southern Manitoba. The samples are mainly from the Millwood division of the Upper Cretaceous.

No. 278-C. Black shale occurring low down in the Millwood. Collected on the property of Mr. Smith. This shale breaks down very easily when crushed, and slakes readily in water. It is very fine-grained, and carries selenite disseminated in small scales. It absorbs 35 per cent of water in tempering, and forms a very smooth highly plastic mass, which is somewhat stiff, but would work well in clay working machinery. It will not crack if dried slowly after being moulded, but it is doubtful if it would remain intact in fast drying. The shrinkage on drying was large, being about 9 per cent.

This shale burns to a light red, steel hard, body at cone 08, with a fire shrinkage of 4 per cent. When burned to cone 03, the colour is darker, the body is vitrified, but the shrinkage becomes excessive, as the total shrinkage at this point is 14 per cent.

This shale contains a large percentage of carbon, so that it must be burned very slowly in order to avoid bloating.

Owing to its high shrinkage and carbon content, it would be a difficult material to use in the manufacture of clay product. The addition of quartz sand or calcined shale would probably render it workable.

No. 278. Soft, dark grey shale, containing disseminated selenite scales from beds in the Millwood lying higher than 278-C, collected on sec. 34, tp. 2, range 6. This shale is exceedingly plastic when ground and tempered with water, but makes a smooth soaplike mass which is hard to work. Small test pieces made from this shale would stand fast drying without checking, but full sized brick would be liable to crack on account of the dense character of the material. The shrinkage on drying is about 7 per cent.

This shale burns to a light red, steel hard, body at cone 06, the absorption being 5 per cent and the fire shrinkage 7 per cent. When burned to cone 03, the colour is darker and the body almost non-absorbent.

This shale also contains a considerable quantity of carbon, which causes it to bloat during the burning.

The poor working qualities, high shrinkage, and difficulty in burning render this clay a doubtful material for use in the clay working industry. It resembles 278-C in character, and like it, could doubtless be improved by the addition of about 25 per cent of quartz sand.

No. 278-A. Grey clay from bank of Souris river on sec. 2, range 7.

This is a transported clay, which appears to be mostly derived from the erosion of the Upper Odanah or Pierre shale.

It is highly plastic but has good working qualities, not being too stiff. If dried slowly after moulding it does not crack, the shrinkage on drying being 8 per cent.

It burns to a porous, light red body, at low temperatures, but becomes darker in colour and denser in body if burned to cone 1. This clay stands up at rather high heat, as it does not soften until the melting point of cone 9 is reached.

If this clay occurred in sufficient quantity, it might be used with the hard gritty Pierre shale for the manufacture of fire proofing or hollow building block, or possibly, for sewer pipe.

No. 278-B. Dark grey, calcareous shale, from beds in the upper part of the Millwood formation. This shale is highly plastic, works easily, and dries well; but it evidently contains too high a percentage of lime carbonate, as it burns to a weak, porous, buff coloured body of little or no value as a structural material.

No. 278-B-C. This is a mixture of equal parts of 278-B and 278-C, which give better results than either material does when used alone. It works and dries well, but has a rather high drying shrinkage.

It burns to a pink colour, with a light weight, porous, but fairly hard and strong body.

The mixture might be used in the manufacture of fire proofing, if the shrinkages were reduced by the addition of some non-plastic ingredient, such as sand, calcined clay, or saw dust.

No. 279. Black shale, from black and white beds at base of Odanah formation.

This material is very plastic when ground and tempered with water, but is stiff and hard to work. It does not stand fast drying after moulding, but if dried slowly it will not crack.

This clay contains so much carbonaceous matter that burning it out of the ware in practice would be a difficult process. It becomes light red in colour when burned, and has a rather punky and weak body. It is not recommended for use in the clay working industry.

The white or yellowish clay interbanded with the black shales resembles "bentonite" or soap clay, which occurs in several localities in the upper Cretaceous. Whatever uses this clay may have in the raw state, it has none in the manufacture of burned clay wares.

The following chemical analyses by N. L. Turner, show the composition of the black and white beds:—

	White bands	Black bands
Silica	49·46	47·88
Alumina	19·27	16·10
Ferric iron	2·06	2·62
Ferrous iron	·25	1·35
Titanium	·40	·59
Lime	1·70	1·38
Magnesia	3·59	1·84
Potash	·50	2·77
Soda	1·16	1·96
Loss on ignition	21·80	22·72
	100·19	99·21

V

CLAY INVESTIGATION IN SOUTHERN SASKATCHEWAN.

N. B. Davis.

The greater part of the summer was devoted to a completion of the field work on the clay resources of that part of Saskatchewan south of the 105th parallel. During 1915, the important refractory and semi-refractory clays of the southwestern part of the Province were examined, from the Alberta boundary east as far as the Big Muddy and Lake-of-the-Rivers valleys; an account of which will be found in the Summary Report for 1915.

This year particular attention was paid to the southeastern part of the Province to the Manitoba boundary. The eastern edge of the outcrop of the refractory clays was found in the Souris valley near Halbrite and the most northerly extension in the hills west of Ardkenneth post office, north of the South Saskatchewan river.

Estevan District.

Southeast from Estevan, along the railway or Souris valley to Roche Percee, the main coal horizon is overlain by calcareous clays that appear to thicken towards Roche Percee and Pinto. At Estevan, the Estevan Brick and Coal Company, have about 15 feet of the yellow and grey clays (over the coal) which they work for common wirecut brick. Six miles southeast, the Shand Brick and Coal Company are working a slightly thicker series of yellow and yellowish-grey clays, four distinct beds in all, separated by thin lignite seams. (See Plate IX.) Six miles southeast, again, near Roche Percee, the yellow and grey calcareous clays with interbanded silts and sands attain a thickness of about 130 feet. The individual bands are lens like, and are seldom continuous for more than a quarter of a mile. The same might be said of the calcareous clays outcropping in the tributary coulee on the north of the Souris valley near Pinto. Tests on most of the beds in this area show them to be calcareous, and buff or cream burning. Most of the clays dry well, and the total shrinkage after burning seldom exceeds 6 per cent.

At Bienfait, the yellow and grey calcareous clays are concealed by about 15 to 20 feet of boulder clay.

A good red burning, silty clay was found in the valley bottom near the schoolhouse at Roche Percee, and at the bridge over the Souris, near Estevan. Samples from both these localities worked much the same: although the Roche Percee material gave a stronger body, with a total shrinkage of 7 per cent at 1990 degrees F. (cone 03).

The sections near Shand show more good plastic clay than at Estevan or Roche Percee, the mixed clays at Shand would make excellent hollow block (fireproofing), the drying qualities being particularly good, requiring only 10 to 12 hours to dry brick in a radiation drier.

The examination of the clay resources of the Estevan district indicates that there is plenty of material suitable for making common wire-cut or soft mud brick, hollow ware, and dry-press face brick. No good refractory, or semi-refractory vitrifiable clays have been found. Experiments are now in progress with mixtures of refractory clays from Halbrite and Willows, and Estevan clays, in an attempt to develop a mixture suitable for making paving brick or sewer pipe.

Broadview District.

From Wolseley to Broadview along the line of the Canadian Pacific Railway, there are numerous extinct glacial lake basins, in which are found calcareous clays and silty clays, fairly free of pebbles. These clays have been worked for soft mud brick at Wolseley and Broadview.

A number of years ago, a small, soft mud, brick yard was in operation at Wolseley, but due to financial difficulties it ceased operation. The principal buildings of the town were constructed of the product, a cream coloured brick, and their excellent condition to-day attest the quality.

At Broadview there is a complete, soft mud, brick plant, but owing to financial difficulties it has not been in operation since 1914. The product is a good buff or cream coloured, soft mud brick, burnt with wood in scove kilns. (See Plate X.)

One mile east of Summerberry there is a wide flat, underlain by more clay. A sample, taken at a depth of 3 feet, at a point along the track near the centre of the flat, worked well in the stiff mud process, but required the addition of 20–25 per cent sand in order to air dry it without checking.

The clays of this district are all buff or cream burning, and make excellent common brick.

Regina District.

A careful survey was made of the area immediately tributary to Regina, in the hope of finding clay suitable for making common brick.

East of Regina, towards Pilot Butte, the Canadian Pacific railway line passes from the bottom of an old glacial lake into a sandy glacial outwash area, of which Pilot Butte appears to be the centre. Two brick plants are in operation at this station, one using the sand of the outwash for sand-lime brick, and the other, the silty clay found in small basins within the sand. These basins are very small and irregular, much trouble being caused by the presence of stiff gumbo clay lenses in the otherwise silty material. There is not much hope of making any large quantity of clay brick from the material of this locality, as the supply of material is insufficient.

More promising material was found in the flood plain of Waskana creek, about one mile north of Condie. A section of about 6 feet is exposed west of the northsouth road. Laboratory tests show it to have good working and slow drying qualities, but it would require 20 per cent of sand to make it dry fast. The total shrinkage at 1740 degrees F. is 6·5 per cent, and 8 per cent at 2,100 degrees F. It burns to a good, strong body, light pink to buff in colour, in a range from 1,740 degrees F. to 2,100 degrees F. Deformation take splace at about 2,200 degrees F.

A calcareous clay containing shells was found in the flood plain of Boggy creek along the north side of section 11, 18, 19, 2nd. In the laboratory it was necessary to add 50% of sand to overcome the checking in air drying. However, even with this large amount of sand, the material worked well for soft mud brick, and burnt to a good, strong body, in a range from 1,900 to 2,050 degrees F. There appears to be no gumbo layers or lenses in this deposit, hence the trouble experienced at Pilot Butte would not have to be considered here.

Plenty of sand is available in the large sand and gravel pits of the Grand Trunk Pacific railway, and Regina Works Department, one mile east of the claybeds.

Qu'Appelle Valley.

Near Tantallon, where the Canadian Pacific Railway Bulyea branch, crosses the Qu'Appelle valley, there are extensive outcrops of a hard grey shale of Cretaceous age in the Odanah horizon. It is particularly well exposed along the railroad grade up the south coulee. (See Plate XI.)

The shale is thin bedded and hard. It does not weather down to clay very readily, but breaks up into thin flakes or splinters. Because of this property, and its availability it is used in Rocanville for surfacing the mud roads.

Shale of this horizon occurs near Virden, Man., but at that locality it is not in the least plastic, even when ground to pass 16 mesh, and wetted with water.

A surprising difference was discovered in the behaviour of the shale from Tantallon. It develops excellent plasticity when ground to pass 12–16 mesh, and worked stiff mud. Its drying qualities are fair, but when ground finer than 12 mesh, it will not stand fast drying.

The burnt colour is a pleasant light red, that takes a brilliant flash in a range from 1900 to 2,100 degrees F. Burnt to a higher temperature (2,250°F.), the colour is a very rich deep red. It is fairly refractory, not deforming until a temperature of 2,550 degrees F. is reached.

The body is light and porous at the lower temperatures, showing an absorption of 23 per cent at 2,100 degrees F. (cone 1).

Beneath the hard Odanah shale there is a soft dark grey to dark brown clay shale. It works up very stiff and sticky, cracking badly in air drying. The burnt colour is red, but it is spoilt by a dirty scum. The defects of this material are so pronounced that it is practically unworkable for the manufacture of clay products.

Laboratory tests, so far completed, indicate that the Odanah shale from Tantallon will make excellent red brick and hollow ware, being particularly valuable for the latter class of ware. It burns to a good strong body, light in weight, at a commercial temperature (2000°F.). It takes an excellent salt glaze and burns to a good dense body in a range from 2200° to 2320°F.

Lancer District.

Northwest of Swift Current, along the Empress branch of the Canadian Pacific railway, from Shackleton to Portreeve, there occur extensive deposits of a stoneless glacial lake clay. Numerous exposures are to be found in railroad cuts, particularly in the vicinity of the town of Lancer. (See Plate XII.)

A typical section, illustrated in Plate XII consists of interbanded stiff brown clay, and yellow clay silt. The former averages one-quarter of an inch in thickness, and the latter, eight inches to each band. The stiff, brown clay bands are so thin that no difficulty is encountered in breaking it down to mix with the rest of the material. In places, the stiff clay increases in thickness, but in working a bank, such material could easily be thrown aside.

Samples were collected from the following localities: Lemsford, Lancer, and Mileage 53. All three samples were worked stiff and soft mud, and found to have very similar qualities. The drying properties were found to be good, with an average air shrinkage of 7 per cent. Test pieces burnt in a range from 1,750 to 2,000 degrees F. showed similar physical properties. The colour was a good red, the total shrinkage 8 to 9 per cent., and the body of good strength.

These clays will make good common red brick, and will be an important resource to this section of the province when the construction of the towns reaches a more permanent stage.

CLAY INDUSTRY IN GENERAL.

The demand for structural clay products showed some improvement in the middle west during 1916, largely due to the construction of the extensive oil refinery plant of the Imperial Oil Company, at Regina.

The Saskatchewan Clay Products Company has been re-organized under the title of the Dominion Fire Brick and Clay Products Company. The new company is going actively into the manufacture of firebrick and special fireclay shapes, as well as the established lines of face brick. The capitalization has been increased, and it is proposed to extend the plant at Claybank, and to install a producer gas firing system.

It is to be regretted that no Saskatchewan firebrick were used in the retorts and boiler settings of the new oil refinery at Regina; the order having been given for American firebrick before the qualities of the Saskatchewan brick were properly made known. However, the Dominion Fire Brick and Clay Products Company supplied the fireclay for setting the American brick.

Tests on the Canadian made firebrick have shown them to be in every way equal to the standard makes of refractory clay brick imported.

Considerable amounts of fireclay from Willows and stoneware clay from Eastend were shipped to Medicine Hat for use in the sewerpipe plant of the Alberta Clay Products Company, and the stoneware pottery operated by the Medalta Stoneware, Limited.

The common brick plants at Estevan, Shand, and Pilot Butte, operated most of the summer, shipping a large part of their output to the new oil refiner at Regina.

The Estevan Coal and Brick Company produced both common wire-cut and dry-press face brick.

Saskatchewan is particularly well supplied with materials for manufacturing structural clay products, and there is no necessity for the further importation of American brick. The plants established in southern Saskatchewan can, by the proper blending of the clays, supply all the ranges and combinations of colour that are required in face brick by architects.

PAINT MATERIALS.

An examination was made of the reported occurrence to red and yellow ochres near Lucky Lake post office, west of Elbow, with a view of ascertaining their value as paint materials.

Some ochre was found in a twisted mass of yellow, red, black, and white clay, included in the glacial drift exposed in a coulee on N.E. $\frac{1}{4}$ 24, 9, 3rd. Lignite fragments are present in the mass, associated with the black clay.

Without a doubt, this material was eroded from beds high up in the Tertiary of the hills to the immediate north of Lucky lake. Well boring, on and around these hills, has not revealed this material in place. Farmers of the vicinity have picked out sufficient of the red ochre to paint their barns. However, since the material is not in place, and the mass small in extent, the occurrence cannot be regarded as of commercial importance.

QUARTZITE GRINDING PEBBLES.

Considerable deposits of rounded quartzite pebbles, suitable for grinding purposes, were found in the southwestern part of the Province.

The Cypress Hills are capped by a gravel bed varying in thickness up to fifty feet. South of Maple Creek, on the north side of the hills, the slopes are covered with these pebbles, and at the top of the escarpment they are to be found in place. They are particularly well exposed in the road cuttings through the hills near Coulee post office, and in the escarpment south of Elkwater lake in Alberta.

The Canadian Pacific Railway Weyburn-Sterling line is ballasted for a considerable distance east and west of Gouverneur with quartzite gravel taken from a glacial deposit on 29, 9, 12, 3rd., near that station. This is south of the Cypress Hills, and the gravel was probably, in large part, derived from the tops of the hills by glacial ice and streams. (See Plate XIII). This deposit is of particular importance, because of its proximity to the railroad.

The pebbles vary in size from one inch up to six inches diameter, the greater proportion being about three inches diameter.

Small sample lots were shipped to two cement plants in Alberta for testing, but, to date, no information is available. However, there is no doubt of the quality of these pebbles for cement grinding, and for such work they are an important resource to the cement industries of Manitoba, Saskatchewan, and Alberta.

DIVISION OF CHEMISTRY.

THE CHEMICAL LABORATORY—SUSSEX STREET.

F. G. Wait,
Chief of Division.

The chemical staff has been more than usually busy during the year, a condition brought about partly by the increased activity in Canadian mining industries, and partly by the necessary examination of war materials. The staff remains the same as at this time last year.

Mr. M. F. Connor, in addition to the analyses of several rocks, has been occupied in the analyses, complete, or partial, of "war materials", which it is not, perhaps, expedient to enumerate here.

Mr. H. A. Leverin, has successfully carried out several score of furnace assays, and the analyses of a large number of limestones, dolomites and "magesites," as well as a wide variety of miscellaneous material.

Mr. N. L. Turner, since midsummer, has been almost exclusively occupied in the analysis of ferro-silicon for the War Purchasing Commission. In the periods between this special work, he has found time to complete several shorter or partial analyses. In the earlier part of the year, he was occupied with the analysis of rock and mineral specimens collected by our own field officers, or, in a few instances, those left by outside parties.

Mr. R. T. Elworthy, as has been the custom in previous reports, has devoted himself almost exclusively to water analysis. As the work upon samples now in hand is nearly completed, it is not likely that any fresh collections will be made in the immediate future, or at any rate until the demands being made upon this branch of the Department's activities by the abnormal war conditions are somewhat lessened. If this course be adopted, Mr. Elworthy's services will be applied to the lessening of the volume of accumulated work which it is impossible to overtake at present.

All the technical officers named above, have devoted themselves to the tasks given them with commendable zeal, and in a spirit which manifests deep interest in their work.

The samples examined during the year are of the same widely varying character as in former years, and may for convenience sake be classified as follows:—

GOLD AND SILVER ASSAYS.

208 specimens of rocks, minerals and ores; and 111 samples of concentrates and tailings from the Ore Concentration plant, taken in connexion with oil flotation experiments.

The 208 specimens of rocks or ores above alluded to were from the following provinces:—

Nova Scotia	1	sample.
New Brunswick	2	samples.
Quebec	20	„
Ontario	55	„
Manitoba	9	„
Saskatchewan	6	„
Alberta	1	sample.
British Columbia	11	samples.
From unspecified localities	103	„

ANTIMONY AND ANTIMONY ORES.

1 sample from Lake George, New Brunswick,
1 sample from West Gore, Nova Scotia, and
1 sample of metallic antimony, manufactured from the Lake George ore above mentioned.

CHROME IRON ORE.

British Columbia.—

1 specimen taken from the Taylor Basin, Lillooet Mining Division.

CLAY FOR BRICK OR POTTERY PURPOSES.

9 samples—none of the localities of occurrence of which were furnished me—have been subjected to partial analysis or to such physical examination as best suited each individual case.

CLAY SHALES.

Western Ontario.—

6 samples from the undermentioned localities:—

i. Haldimand county—Seneca township, lot 10 on the first concession west of the Hamilton and Port Dover plank road. Specimen taken from the basal beds of the Caledonia gypsum mine. Salina formation.
ii. Lincoln county—Niagara township, lot 53, St. Davids, lower cement rock, about the middle of the bed. Lockport formation.
iii. Wentworth county—Barton township, lot 2, concession VII, from the waterline beds at Redhill creek, west of Mount Albion, Lockport formation.
iv. Wentworth county—Flamboro township, lot 16, concession I, at Dundas, from the basal layer of the Clinton formation.
v. Wentworth county—At Hamilton, Rochester shale, from the old corporation quarry—3 feet above the beds of the Clinton formation.
vi. Wentworth county—At Hamilton—Rochester shale—upper 4 feet.

COPPER ORES.

59 samples distributed as follows:—

i. **New Brunswick**—1.
   Albert county—From a pointi n close proximity to the oil shale deposits.
ii. **Ontario**—7.
   Kenora—Near English Station. From unsurveyed territory. Five samples.
   Rainy River—Worthington township. Precise locality not stated.
   Timagami—Near White Bear lake.
iii. **Manitoba**—1.
   From the shores of Schist lake.
iv. **British Columbia**—2.
   From section 26, Lake Hill District of Vancouver Island.
   From Rocher de Boule Mt. near Hazelton.
v. **Bathurst Inlet**—Coronation Gulf—45 samples of copper-bearing rocks collected by Mr. J. J. O'Neill of the Southern Arctic Expedition.
vi. **Unspecified localities**—account for the 3 remaining specimens.

FERRO-SILICON.

During the year the Mines Branch, at the request of the War Purchasing Commission, assumed the responsibility of sampling in Welland, and analysing in Ottawa, the high grade ferro-silicon, which is being supplied for war purposes. As a result of this arrangement, 18 samples have been analysed during the latter half of the year 1916. This work will continue, it is expected, during the continuance of the war.

IRON ORES.

i. **Nova Scotia**: Hematite—an average sample of Piedmont iron ore; from a point 1 mile south of Piedmont Station, I. C. R. in Pictou co., N.S.

ii. **Ontario**: 23 samples.

From the following alphabetically arranged counties, or districts:

(*a*) Algoma—hematite—from a deposit occurring in Bruce limestone on Timber berth No. 155.

(*b*). Haliburton—magnetite—4 samples from:
Snowdon township, lot 20, con. I, Victoria mine.
„ „ „ 25, con. IV, 2 samples.
„ „ „ 26, con. IV, Howland mine.

(*c*) Hastings—magnetite—4 samples from:
Lake township, lot 17, con. XI.
Tudor „ „ 57 west of Hastings road.
„ „ „ 42 east of Hastings road.
„ „ „ 8 con. XV.

(*d*) Nipissing—hematite—Widdifield township, lot 8, con. II.

(*e*) Parry Sound—magnetite—Lount township,
Lot 125, con. A, 4 samples.
„ 126, „ A, 2 „
„ 129, „ B, 1 sample.
„ 144, „ B, 1 „
„ 17, „ III, 1 „
„ 22, „ VIII, 1 „

(*f*) Peterboro—magnetite, Belmont township, lot 24, con. III, 1 sample.

(*g*) Thunder Bay—magnetite—Conmee township, S.E. ¼ of N. ½, lot 4, con. III.

(*h*) Timiskaming—magnetite—Price township, 12 miles S. of Timmins.

Seven other samples were analysed, but there is no data at hand concerning the locality from whence they were taken.

LIMESTONES.

Nova Scotia.—
1 mile west of Orangedale, Inverness county, 30 samples.

New Brunswick.—
Vicinity of St. John—precise locality not stated.

Quebec: by counties.—

Argenteuil county.—

221. Grenville township North American Magnesite Co's. property. No. 2 quarry, white rock.
222. „ township North American Magnesite Co's. property. No. 2 quarry, blue rock.
223. „ township Grenville Lumber Co's. property.
224. „ „ „ „ „ „
225. Ste. Angelique. Near wharf at Papineauville.
226. „ „ Property of Presquile Miller, near Papineauville.

Bagot county.—

214. Cadoret's quarry—on the St. Rosalie road.
215. From a roadside quarry near St. Dominique.
216. Levis Loisel's quarry—three-quarters of a mile northwest of La Carriere.
217. E. Lapointe's quarry—one-half mile southeast of Loisel's, (above mentioned).

Beauce county.—

209. St. Joseph township—three-quarters of a mile south of St. Joseph.

Berthier county.—

168. From the bed of Bayonne river, 5 miles north of Berthier.
172. Stock and Leger's quarry on the property of Wilfred Drainville, immediately south of the village of St. Barthelemi.
174. Clement's quarry on west shore of Chicot river, near St. Cuthbert.

Brome county.—

125. Bolton township, lot 24, range IX, —(Magnesite).
126. „ „ „ 17, „ IX,— „

Champlain county.—

175. Quarry of La Compagnie de Marbre du Canada, Ltée.,—3 mi. N.W. of St. Thecle.
178. „ of The Canada Iron Corporation at Radnor.
179. „ on Mr. Lacomsiere's property on east bank of St. Anne river, 4 miles from St. Anne de la Perade.

Drummond county.—

212. Kingsey township, lots 4 and 5, range I (red marble).

Jacques Cartier county.—

127. One-half mile south of village of St. Genevieve.
130. Two miles south of village of St. Genevieve, at junction of St. Charles and Ste. Marie roads.
128. Isle Bizard—Theoret's quarry.
129. „ „ —Clement's quarry.
141. Joseph Lapointe's quarry near Cartierville.
142. The L. Deguire Co's. quarry, one-half mile northeast of St. Laurent Station, G. T. R.

Laval county.—

145. St. Laurent Quarry Co's. workings, one-half mile west of St. Martin Junction, C.P.R.
146. Chartrand's quarry on W. Allaire's property immediately west of Belanger.
147. Godfrey Lecavalier's quarry on St. Elzear Road—3 miles northeast of St. Martins.
148. Plouffe, Legace, et Cie quarry on A. Gauthier's property—upper 10 feet.
149. St. François de Sales—O. Lapierre's quarry—3 or 4 miles from St. Vincent de Paul.
150. St. François de Sales—The Felix Labelle Quarry Co's. property.
152. The St. Vincent de Paul Penitentiary quarry.

The three next following are situated on Isle Jesus:—

218. Quinlan and Robertson's quarry on St. Michel Road, east of Mt. St. Michel.
219. Turcot's quarry—lower 10 feet of light grey limestone.
220. Petitjean's quarry, one mile west of Turcot's quarry above mentioned.

Montreal City.—

134. From the Sovereign Lime Works Company's quarry—De Lorimer Avenue.
135. Immediately north of Mile End station, C.P.R., (Institution des Sourds-Muets.) 1st sample from lower beds, 2nd sample from upper beds.
136. Villeray group of quarries—Paysan's quarry.
137. „ „ „ „ —Gagnon's „
138. Joseph Gravel's quarry, Chambord St., north of C.P.R. from lower 14 feet.
139. Nicolet Street—from lower 12 feet.
140. Montrea prison quarry—upper 4½ feet.
143. R. C. Dickson's quarry, cor. Sherbrooke and Dickson Streets.
144. Joseph Rheaume's quarry—Rosemount Boulevard—lower 15 feet.

Joliette county.—

156. Joseph Beaudry's quarry, on east side of L'Assomption river, south of the bridge at Joliette.
157. Geo. Desroches' quarry on east side of L'Assomption river south of the bridge at Joliette.
158. Arnaud and Beaudry's quarry, on east side of L'Assomption river, south of the bridge at Joliette.
160. Standard Lime Co's. quarry, 2 miles southwest of the town of Joliette, lower 7 feet.
161. Standard Lime Co's. quarry, 2 miles southwest of the town of Joliette next 17 feet in order ascending.
162. N. Goulet's quarry, 2 miles northeast of Joliette, upper 17 feet.
164. Kildare township, lot 6, range IV, (or lot 11, range I (?)).
169. Madame Guilbault's quarry, 3 miles south of St. Elizabeth near Grand Chaloupe.
170. (*a*) Ovide Farland's quarry—3 miles south of St. Elizabeth on the Berthier road—upper beds.
170. (*c*) Ovide Farland's quarry—3 miles south of St. Elizabeth on the Berthier road—lower beds.

Laval county.—

145. St. Laurent Quarry Co's. workings, one-half mile east of St. Martin Junction, C.P.R.
146. Chartrand's Quarry on W. Allaire's property immediately west of Village Belanger.
147. Godfrey Lecavalier's quarry on St. Elzear road—3 miles northeast of village of St. Martin.
148. Plouffe, Legace et Cie quarry, on A. Gauthier's property—Upper 10 feet.
149. St. François de Sales—O. Lapierre's quarry situated 3 or 4 miles from St. Vincent de Paul.

150. St. François de Sales—The Felix Labelle Quarry Co's. property.
152. The St. Vincent de Paul Penitentiary quarry.
Note, those on Isle Jesus, Laval co.
218. Quinlan and Robertson's Quarry on St. Michel Road, east of Mt. St. Michel.
219. Turcot's quarry—lower 10 feet of light grey limestone.
220. Petitjean's quarry one mile west of Turcot's quarry above mentioned.

L'Assomption co.—
155. Ubald Hogue's quarry, one mile west of St. Lin.

La Prairie co.—
133. Caughnawaga, James Curotte's property.

Levis co.—
198. Quarry north of Mount Marie cemetery operated by the Levis Tramway Co.

Maskinonge co.—
171. From an exposure in the bed of Petite Riviere-du-Loup, one mile and a half down stream from Ste. Ursule.

Megantic co.—
210. An old quarry at West Broughton.

Missisquoi co.—
116. St. Armand township, near Phillipsburg. From face of bluff overlooking Missisquoi bay, just south of the wharf.
117. St. Armand township.
118. " " "
119. " " "
120. " " " From the hill top northwest of St. Armand.
121. " " " South of Phillipsburg, one-half mile beyond the cemetery.
122. St. Armand township, in an easterly direction from the location of No. 116.
123. Stanbridge township, lot 2, range IX, Morgan's farm.

Montcalm co.—
165. Rawdon township, lot 28, range IX, from old quarry, banks of Ouareau river near crossing pt. of St. Jacques-Joliette road: *a.* lower 15 feet; *b.* upper 20 feet.
166. From the beds of the Ouareau river at St. Ligouri.

Montreal City.—
See also Jacques Cartier county, above.

Montmorency co.—
199. Chateau Richer—Roberge et Giroux' quarry.
200. " " east of Baker's workings of the Chateau Richer Quarry Co's. property.
201. Chateau Richer—Syndicate's quarries.
207. G. Bilodeau's property, from a small quarry near Berube.

Ottawa co.—
227. Hull City, Federal Stone and Supply Co's. quarry: lower of 2 9-ft. layers.
228. " " " " " " " " lowest 5 feet.
229. " " N. Tremblay's quarry on west side of Chene Avenue.
230. " " Rochon and Filiatreault's quarry, on St. Louis Street.
3143. Templeton tp., lot 2, range VIII (dolomite).

Portneuf co.—

180. St. Marc, 2½ miles southeast of St. Albans bridge—over St. Anne river. From quarry of La Cie des Carrieres de St. Marc.
181. From quarry of Naud and Marquis.
182. „ „ „ Damase Naud—the northernmost quarry in the group.
183. „ „ „ E. Laforce.
184. From an old quarry between Portneuf and St. Marc—lying west of Portneuf near C.P.R.
185. Calcareous shale, from a deposit three quarters of a mile west of Portneuf station, G.T.P.R.
186. Ludger Leclerc's quarry at Pont Rouge.
187. Louis Dore's quarry at Pont Rouge.
188. Cap Sante—from the bluffs along the St. Lawrence along the highway cuttings.
189. From an old quarry, 2 miles east of Neuville.
190. Grondines, from Jackson Bros. quarry.

Quebec co.—

191. From the west end of the dam at Montmorency Falls—average of 20 feet.
197. Bourg Royal—F. Grenier's quarry.
208. Lorette, Savard's quarry.
192. Beauport, Elzear Verreault's quarry.
193. Beauport East, Pierre Robert's quarry.

Richmond co.—

213. Quarry of the Corporation of Richmond.

Lake St. John co.—

115a. Grand Ligne, Otis' quarry.
202. Standard Cement Co's. quarry one mile and a half east of Chambord Junction.
203. Price Bros. quarry near the railway station.
204. Corporation quarry, midway between Chambord and Chambord Junction.
205. Roberval township, lot 4, range A.—H. Lavoie's quarry.
206. Ouiatchouan township, lot 11, range I, Belanger's quarry.
(?) 231.

St. Maurice co.—

176. From the bed of the Machiche river at the bridge directly N.E. of St. Barnabe.
177. St. Boniface—from the southeasterly band lying due east of the railway station.

Soulanges co.—

131. Jos. Brisbois quarry a quarter of a mile east of the railway and half a mile north of Soulanges canal.
132. Quinlan and Robertson's quarry near Coteau du Lac.

Stanstead co.—

211. An old quarry on Magoon's Point.

Terrebonne co.—

151. Near St. Rose—from an old quarry.
154. An old quarry on Drouin's farm on the St. Margaret road.

Ontario: Arranged Alphabetically by Counties.

Bruce—Culross township, lot 15, con. VI, Salina limestone, used for lime—Teeswater, Ont.

Grey—Collingwood township, lot 8, con. XI, Cataract limestone, 6 feet above base—Mitchell's mills.

Haldimand—Seneca township, lot 10, of first concession west of the Hamilton and Port Dover plank road. Basal beds of Caledonia gypsum mine. Salina formation.

Halton—Esquesing township, lot 22, con. VI, from a 6-foot bed of Red Cataract limestone—Limehouse, Ont.

Halton—Nassagaweya township, lot 3, con. VI, from a 3-foot limestone bed above 6-foot bed of Wolcott dolomite, with Pentamerus at base—Kelso, Ont.

Lincoln—Niagara township, lot 53, Lockport formation, lower cement rock, about middle.—St. Davids, Ont.

Lincoln—Same locality as preceding specimen. Niagara limestone, about 23 feet above cement bed.

Manitoulin Island—Carnarvon township, lot 2, con. XII. Lockport dolomite from Government quarry at Providence Bay.

Wentworth—Barton township, lot 2, con. VII, Lockport formation; waterlime beds at Redhill creek, west of Mount Albion.

Wentworth—Flamboro township, lot 16, con. I, Clinton formation, basal layer.

Wentworth—Hamilton, on the mountain. From the second quarry east of the James st. incline—Wolcott limestone.

Wentworth—Same locality as the preceding specimen. Irondequoit lime stone.

Wentworth—Hamilton.—Old corporation quarry—Rochester shale, first three feet above Clinton formation.

Wentworth—Hamilton, on the mountain at the head of Wentworth st., Rochester shale, upper 4 feet.

Near Lewiston, N.Y.—Calcareous sandstone north of cement tunnel, N.Y.C. & H.R.R.

British Columbia.—

From Marshall ridge, Bridge River district, Lillooet.

CALCAREOUS SINTER.

From the hot springs at Ainsworth.

DOLOMITE.

From Liza lake, Bridge River district, Lillooet.

MAGNESITES.

From Liza lake, Bridge River district, Lillooet.

Quebec.—

Twenty-five samples—all from Argenteuil county:—

Grenville township, lot 18, range XI—23 samples.

Augmentation of Grenville, lot 9, range XI—2 samples.

These were submitted to partial analysis to determine the quantity of calcareous carbonate present in each. This constituent was found to range from 1·55 to 36·60 per cent of the whole, the mineral being in some instances little other than dolomite, although designated "magnesite."

MANGANESE ORES.

One sample from vicinity of Arthabaskaville, Que., and one from Glen Moore, Nova Scotia.

MOLYBDENUM ORES AND MOLYBDIC OXIDE.

2 samples of molybdenite-bearing ores from near English Station (C.P.R.) in Kenora, have been analysed in part.

1 sample of molybdic acid, or molybdenum trioxide, manufactured at Orillia from Canadian molybdenite, has been tested as to purity by a complete analysis.

Three other samples of molybdenite-bearing ores from undefined localities have been examined.

NICKEL ORES.

These are all from Ontario and British Columbia. The localities of occurrence are as follows:—

Ontario.—

6 samples—Sudbury district, Craig township, lot ?, con. E.
Kenora district, unsurveyed territory near English Station.

British Columbia.—3 samples:—

I. South bank of the Skeena river, 3 miles west of Miniskinisht (near Hazelton);
II. Rocher de Boulé Mt., also near Hazelton;
III. Sec. 26, Lake Hill district, Vancouver island.

5 samples from unspecified localities were examined.

Rock Analysis.

The complete, or, in a few instances, partial analysis of 20 rocks and minerals have been completed during the year. They are as follows:—

Quebec.—

Quartz syenite porphyry, from lot 3, range III of Portland West, Labelle county.
Peridotite, from lot 18, "12" Buckingham, Labelle co.
Granite, from lot 3, range IV of Bowman, Labelle co.
Feldspar—2 samples from lot 14a, range XIV of Hull, Ottawa co.
Feldspar—1 sample from lot 1, range VIII of Eardley, Ottawa co.
Rocks, unnamed—4 samples from Mount Royal tunnel.
Granite, from Roberval.

Ontario.—

Quartz norite from the southern part of Frechette township Sudbury district,
Feldspar—2 samples—one from Bathurst and one from the Upper Rideau lakes.

Manitoba.—

Granite gneiss—1 mile south of Kisseynew lake.
Granite—from the north side of Athapapuskow lake.
Mica gneiss—from the east side of Wekusko lake, and 5 miles north of the 18th base line.

British Columbia.—

Surface specimen from a 50-foot dike in the Nelson Granite area at a point 5 miles east of Nelson.
Aplite—East Sooke peninsula, Vancouver Island.
Olivine-gabbro— East Sooke peninsula, Vancouver Island.
Hornblendite " " " " "

Kaolin—from a deposit 18 miles east of Ashcroft.
Clay—diatomaceous earth and volcanic ash from Deadman's Creek.
Andesitic pumice—from the Bridge river map area.

Germany.—

Siliceous earth—used in manufacture, from Neuberg, Germany; analysed with the view to searching for a Canadian material which might be substituted for it.

SULPHUR CONTENT OF PYRITOUS ORE.

Six samples of pyrite bearing ores from unsurveyed territory near English Station in Kenora district, Ontario, and one from a deposit in close proximity to the oil shales of Albert county, N.B., have been subjected to partial analysis.

MINERAL WATERS.

The work commenced upon Canadian mineral waters has been continued during the year, and substantial progress made.

In addition to the springs enumerated in last year's summary, samples have been taken from, and field assays conducted at the following springs at Banff:—

Middle spring.
Upper Hot spring.
Kidney spring.
Spring on Automobile road
Cave spring.
Basin spring.
Alpine Club spring.

These springs were visited in the latter part of the year by Mr. R. T. Elworthy, by whom the samples were collected and the field tests made. The analytical work is being done in the laboratory here, and it is expected will be completed early in the year.

MISCELLANEOUS MATERIALS.

There have been many single samples of materials not susceptible of classification under any of the foregoing headings, which have been sent up for analysis and report.

An enumeration of a few will suffice to show their nature:—

Siliceous earth from Neuberg, Germany—used in an unnamed manufactory in England—which was submitted by the authorities of the Imperial Institute with an inquiry as to the occurrence of a like material in Canada.

Bronze caps for survey posts.

Various articles of hardware, cutlery, and samples of steel, submitted by the purchasing agents of other Government departments.

Sand and salts, used in glass making.

IDENTIFICATIONS.

130 individual specimens, embracing a wide variety of materials, have been sent, or brought, for identification, and for an expression of opinion as to their commercial value. None of the items placed in this group are deserving of special mention here.

DIVISION OF MINERAL RESOURCES AND STATISTICS.

I

REPORT ON MINERAL RESOURCES AND STATISTICS, 1916.

John McLeish,
Chief of Division.

During 1916, the staff of this Division was, as usual, occupied with the duties involved in the collection of statistics and information respecting the mining and metallurgical industries of Canada, and the preparation of Annual Reports on mineral production, etc.

Changes in Staff.

At the urgent request of the Chairman of the War Purchasing Commission, the services of Mr. L. L. Bolton, amongst others, were from March 14, 1916, loaned to the War Purchasing Commission. Subsequently on the first of September, Mr. Bolton was transferred to the Office of the Deputy Minister of Mines, as Secretary, taking the place of Mr. G. J. McKay, resigned.

Mrs. Jean Cornett was engaged as temporary clerk from November 9, to assist with the statistical and other work of the Division.

Collection of Statistics and preparation of Reports.

Statistics of production are collected by correspondence from smelter, mine, and quarry operators throughout the Dominion, who now number about 3,500.

The period covered by the statistical record being the calendar year, schedules requesting returns of production during the calendar year 1915 were, during December of 1915 and January of 1916, distributed to correspondents throughout Canada. As usual, sufficient information was available toward the middle of February to complete a preliminary report of 28 pages, which was sent to press during the last week of February and distributed during the first week of March.

Invariably, a large number of correspondents require to be reminded several times before returns are fully completed, and in many instances forms have to be returned for data which has been omitted.

In the completion of the final reports on mineral production during the calendar year 1915, Mr. A. Buisson, compiled the statistics with respect to metals and metallic ores, and has prepared the text of the chapters on production of gold, copper, lead, nickel, silver, zinc, and other miscellaneous metals. He also compiled for printing, the "List of Metal Mines and Smelters."

Mr. Casey, has, as usual, compiled all the statistics of production of non-metalliferous products and structural materials, as well as the record of imports of mineral products, and has prepared for publication the various "Lists of Mine and Quarry Operators," with the exception of the metal mines and smelter lists.

The following Reports and Lists were completed during the year, and sent to press on the dates indicated:—

Reports:—

Preliminary Report on the Mineral Production of Canada, during the Calendar year 1915—Feb. 22.

The Production of Iron and Steel in Canada, during the Calendar year 1915—July 13.

The Production of Coal and Coke in Canada, during the Calendar year 1915—August 19.

The Production of Cement, Lime, Clay Products, and other Structural Materials, during the Calendar year 1915—August 29.

A General Summary of the Mineral Production in Canada, during the Calendar year 1915—Sept. 1.

The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals of Canada, during the Calendar year 1915—Sept. 12.

The Annual Report of the Mineral Production in Canada during the Calendar year 1915—Sept. 21.

List of Mine Operators.

List of Metal Mine and Smelter Operators in Canada—July 12.

List of Coal Mine Operators in Canada—July 17.

List of Mines in Canada (other than Metal Mines, Coal Mines, Stone Quarries, Clay Plants, etc.)—August 29.

In view of the improbability of any large number of new operations in the manufacture of brick and production from quarries, etc., the brick, quarry, lime, and sand and gravel lists were not re-printed during the year.

Committee on Iron Industry.

A considerable portion of the time of the writer was given to the preparation of a Report of the Committee on Iron Industry. Mr. Bolton devoted himself entirely to this work, during January and February. The Report includes two chapters descriptive, respectively, of Iron Ore Mines, and Iron Ore Occurrences in Canada, which have been submitted for publication, and will be used as the basis of a Report to be issued by the Mines Branch on the Iron Ore Mines of Canada.

Field Work.

Mr. A. Buisson was from May 30, to July 10, engaged in field work in British Columbia, having been assigned as assistant to Dr. A. W. G. Wilson in a special investigation of the zinc industry in Canada. Subsequently, from October 27 to November 13, he visited the Eastern Townships and other sections in the Province of Quebec, in the interests of the Division, with a view to securing data regarding the current progress of the mining industry in those areas.

Collection of Monthly Statistics.

Hitherto, this Division has confined itself to the collection of annual records with the result that statistically, at least, the Department has not been adequately informed in respect to current production. Requests at the end of December for estimates of production based upon a ten or eleven months' record, with estimates for the balance of the year, could not be complied with. The desirability of the collection more frequently than annually, of a record of production of the more important products, such as iron, steel, coal, and the metals, has long been recognized. Some of the larger operating companies publish their production monthly. Certain railway shipments, or ore receipts at smelters, are published monthly, or weekly. The Ontario Bureau of Mines, has, for some years collected quarterly records of production of the more important metals.

As a preliminary move to a more frequent collection of statistics of certain products covering the whole of Canada, this office, toward the end of October, addressed an inquiry to all the producers of pig-iron and steel, the principal coal operators, all metal smelters, and the principal metal mines shipping ores to smelters outside of Canada, requesting a return of monthly production to the end of October. The inquiry was made as simple as possible, a mere record of output, and not complicated in any way by questions concerning values, labour, or wages. The response was decidedly encouraging, and the original inquiry was followed by a request for a return for the month of November, with estimates for December.

On the basis of these returns, an estimate was made of the iron, steel, and coal production during 1916, and the statements, as quoted below, were issued on December 22nd.

What are believed to be very close estimates, have also been made of the copper, gold, silver, and lead production.

The accuracy of these estimates will, of course, not be determined until complete detailed returns for the year have been received.

Pig-Iron and Steel in 1916,

The Dominion Department of Mines has received from the producers a record of the production of pig-iron and of steel ingots and castings during the first eleven months of the year which, together with estimates for December, show a probable production of pig-iron in Canada during the twelve months ending December 31, 1916, of 1,171,727 short tons (1,046,185 gross tons) and a probable production of steel ingots and direct steel castings of 1,454,124 short tons (1,298,325 gross tons), of which 1,423,485 short tons were steel ingots and 30,639 short tons were direct castings.

The production of pig-iron in 1915 was 913,775 short tons, and of steel ingots and castings 1,020,896 short tons, showing an increase in the production of pig-iron in 1916 of about 28 per cent and an increase in production of steel ingots and castings of over 42 per cent.

The 1916 production was greater than that of any previous year, the second largest production of pig-iron having been 1,128,967 short tons in 1913, and of steel ingots and castings 1,168,993 short tons in 1913 also.

The production in 1916, during the first six months, and monthly during the last six months, was as follows, in gross tons:—

	Pig-Iron	Steel Ingots	Direct Castings	Total Steel
	Gross Tons	Gross Tons	Gross Tons	Gross Tons
Six months ending June	501,872	577,999	11,715	589,714
July	82,154	101,178	2,284	103,462
August	78,450	108,889	2,299	111,188
September	91,736	116,828	2,524	119,352
October	101,436	126,677	2,924	129,601
November (partly estimated)	95,237	119,468	2,745	122,213
December (estimate)	95,300	119,930	2,865	122,795
Six months ending December	544,313	692,970	15,641	708,611
Twelve months ending December	1,046,185	1,270,969	27,356	1,298,325

Of the total production of steel ingots and castings in 1916, about 19,639 short tons (14,777 gross tons) were made in electric furnaces. In 1915, 5,625 tons and in 1914 only 61 short tons were reported as having been made in electric furnaces.

Production of Coal in 1916.

The Dominion Department of Mines has received from the principal coal operators in Canada, returns of their production for ten months, supplemented in most cases with estimates for November and December.

On the basis of the record available, it is estimated that the total production of coal in Canada, during the calendar year 1916, will approximate 14,365,000 short tons (equivalent to 12,825,892 gross tons). The estimate is believed to be fairly close for Nova Scotia and British Columbia. In Alberta, however, there are so many small operators that final returns may show a wider variation from the estimates now made.

By Provinces, the estimate is as follows, the figures for 1915 being included for comparison:—

Estimated Coal Production in Canada, 1916.

(IN SHORT TONS).

	Production of Coal		Increase or Decrease
	1915	1916	
Nova Scotia	7,463,370	6,950,000	− 513,370
New Brunswick	127,391	135,000	+ 7,609
Saskatchewan	240,107	260,000	+ 19,893
Alberta	3,360,818	4,400,000	+ 1,039,182
British Columbia	2,065,613	2,620,000	+ 554,387
Yukon	9,724	......	.....
Total	13,267,023	14,365,000	+ 1,097,977

The 1916 production exceeded that of the two previous years: the increase over 1915 being about 8 per cent. Nova Scotia is, apparently, the only Province that has not made an increased production, the falling off in this Province being a little less than 8 per cent. The increase in Alberta is nearly 32 per cent, and in British Columbia nearly 27 per cent. The production in New Brunswick, Saskatchewan, and British Columbia is the highest on record. No estimates are available yet as to the Yukon output.

The Mining Industry in 1916.

A detailed review of the mining industry in Canada based upon returns now being received, will be included as an appendix to this report.

It may be noted here, however, that the mining industry in Canada during 1916 has been marked by extraordinary activity in the mining of metalliferous ores and coal, as well as in the increased production of other products, such as asbestos, graphite, magnesite, chromite, fluorspar, coke oven by-products, etc., which are used either directly or indirectly for munitions purposes. The operations of quarries and clay works has not been stimulated by war conditions, but, on the contrary, has been limited to the supply of material for such structural activity only as has been deemed absolutely necessary.

The net result, however, has been a very large and important increase in the total value of the Canadian mineral production, an increase due not only to the increased quantities recovered, but greatly augmented by the higher prices obtained for nearly all metals and minerals required for war purposes.

With one or two exceptions, such as nickel, cobalt, molybdenite, and asbestos, the Canadian production is but a fraction of that which Great Britain and her

Allies have been able to draw from the world's markets, particularly the United States. It is gratifying, however, to realize that we in Canada possess these resources, since, while it is regrettably necessary to employ them at present for purposes of destruction, or defence, it will be equally necessary in the future, as it has been in the past, to utilize them for natural development and construction.

The war caught us unprepared, or inadequately equipped for the complete smelting and refining of our metalliferous ores; and one of the important developments of the year has been the improvements that have taken place in ore concentration and treatment, and the establishment of metallurgical works and refineries. Amongst the latter may be mentioned the electrolytic zinc refinery at Trail, B.C.; the electrolytic copper refinery, also at Trail (refined gold, silver, and lead had already been produced at Trail for some years); the nickel refinery under construction at Port Colborne, Ont.; electric furnaces for the production of ferro-molybdenum and other ferro-alloys at Orillia and Belleville, Ont.; electric furnaces for the production of steel, at Welland, Toronto, New Liskeard, Montreal, and Sherbrooke; the production of the new high speed tool metal, stellite, at Deloro, Ont.; and the production of metallic magnesium at Shawinigan Falls, Que.

The possession of enormous mineral resources, both proved and anticipated, assures a continued development in the mining industry, while, with more extended technical and industrial education, the immediate future should witness great developments in the application of our resources to industrial requirements.

Hitherto, we have been satisfied to export large quantities of our mineral production in a raw condition. The future should see a great growth in the manufacturing and chemical industries based upon these raw materials.

II

STATISTICAL DIVISION FIELD WORK.

Arthur Buisson.

In pursuance with the instructions of the Chief Statistician, I visited, early in November 1916, some of the mining centres in the Province of Quebec, with the object of getting first-hand information of the operations carried on during 1916, and help in the preparation of the Annual Report.

The principal fields visited were the zinc deposits of Notre-Dame-des-Anges, and the copper deposits of the Eastern Townships.

On the way to Notre-Dame-des-Anges, a visit was made to the property of the Canada Paint Company, at Red Mill, near Three Rivers, and to the metallurgical plants at Shawinigan Falls.

Three companies were operating at Notre-Dame-des-Anges:—

(1) The Zinc Company, Limited, subsidiary to the Weedon Mining Company, is operating under lease from Mr. P. Tétreault, 900 feet along the ledge, on lot 40, range I, Montauban township. This Company has completed a new 125-ton mill, also a roasting plant, and had under construction an elaborate plant for the production of zinc oxide. They are also reported to have built a zinc smelter at Shawinigan Falls.

(2) The mill of Mr. P. Tétreault was being operated, but only experimental operations were carried on.

(3) The Montauban Mining Company was laying foundations for a 100-ton concentrator, which it was hoped would be in operation early in 1917. No mining operations were carried on by this Company at the time.

At Shawinigan Falls, the Electro-Metals Company, which is producing magnesium from foreign ores, had just completed the erection of a plant for the manufacture of magnesium chloride, from Canadian magnesite.

In Quebec city, the metallurgical plant of F. X. Drolet, Limited, was visited. Messrs. Drolet were operating a 1-ton Baillot converter and working full time. Useful information was obtained about operations on molybdenite properties around Amos, in the Timiskaming district; also about a new metallurgical plant being erected at Montmagny, and called "The General Car & Machinery Company". They are reported to be installing two Martin-Seimens oil furnaces.

A couple of days were spent visiting the Asbestos field at Thetford, and the Chromite mine operators near Black Lake.

The chrome ore deposits being worked mostly by small operators and often the same property by different operators during the same year, made it urgent that a personal visit be made to ascertain the exact production from this field.

The copper mine of the Weedon Mining Company, near Weedon, as well as that operated at Eustis by the Eustis Mining Company, were both visited. These two companies are nearly the sole producers of copper ore in Quebec. The Eustis Mining Company had completed early in the summer their new concentrator and were experimenting with oil flotation, with a view to treating their tailings. These ores run usually very high in sulphur, and are shipped to chemical plants at Capelton, Que., and in the United States, for the production of sulphuric acid. The copper is derived from the residues of these operations, or from occasional shipments of ores high in copper, and treated as copper ores.

In Sherbrooke, a few parties were interviewed, and a visit made to the Brakeshoe Company's electric steel furnaces.

A visit was made to Ascot, near Sherbrooke, where an American Company, known as the "Arizona Canadian Copper Co.", was developing a copper deposit. The commercial results were very unsatisfactory, and operations were abandoned shortly after the writer's visit.

One day was spent visiting the copper properties near Eastman. The Ives mine had been operated under lease by P. Beaudoin, and later by the Eustis Mining Company, and a few cars of ore shipped. The Huntingdon mine also made a small shipment during the summer, and the owner, Mr. Têtreault, was having the mill completed so as to operate early in 1917. Both mines were idle at the time of the writer's visit. One day was spent in Montreal, to secure information from head offices of some of these operators.

The results of this trip are a first-hand knowledge of these mining centres, and the possibility of estimating fairly accurately the probable production of metals in the Province.

DRAUGHTING DIVISION.

H. E. Baine,

Chief Draughtsman.

The staff of this Division has been temporarily reduced by the enlistment for Active Service of Messrs. David Westwood and Alvarez Pereira, who are at present at Bramshott, England.

The staff, at present, consists of a chief officer; two map compilers and draughtsman; and a mechanical draughtsman. The following is a list of maps prepared and published during the calendar year 1916, with name of officer for whom they were prepared:—

Map No.

387. Geological map, Banff district, Alberta, showing location of phosphate beds, by Hugh S. de Schmid.
390. Christina river Bituminous Sand Deposits, by S. C. Ells.
391. Clearwater river " " " " "
392. Hangingstone-Horse rivers Bituminous Sand Deposits, by S. C. Ells.
393. Steepbank river Bituminous Sand Deposits, by S. C. Ells.
394. McKay river " " " " "
395. Moose river " " " " "
398. Ontario Phosphate Area, by Hugh S. de Schmid.
399. Quebec " " " "
403. Ontario Feldspar " " "
404. Quebec " " " "
405. Magnetometric map, Orton mine, Hastings co., Ont., by A. H. A. Robinson.
409. Magnetometric map, Kaministikwia, Thunder Bay district, Ont., by A. H. A. Robinson.
410. Geological map, Kaministikwia, Thunder Bay district, Ont., by A. H. A. Robinson.
416. Magnetometric map, Matawin Iron Range, Thunder Bay district, Ont., by A. H. A. Robinson.
434. Coal Fields of Nova Scotia and New Brunswick.
437. Map of Portions of Ontario and Quebec accompanying report on the Radioactivity of some Canadian Mineral Springs.
445. Map showing Iron Ore Occurrences and Blast Furnaces in the Dominion of Canada and Newfoundland.

400 charts, diagrams, and page-size maps were prepared to accompany the various reports, and bulletins issued by the Mines Branch.

REPORT COVERING THE OPERATIONS OF THE DOMINION OF CANADA ASSAY OFFICE, VANCOUVER, B.C., DURING THE YEAR ENDING DECEMBER 31, 1916.

I

REPORT OF THE MANAGER.

Eugene Haanel, Ph.D.,
Director of Mines,
Ottawa, Ont.

Sir,—

I have the honour to submit, herewith, Report covering the operations of the Dominion of Canada Assay Office, Vancouver, B.C., for the calendar year ending December 31, 1916, accompanied by Statements showing Assayers' and Melters' supplies on hand.

Changes in Staff.

R. D. McLellan, Assayers' Assistant, resigned January 22, 1916.

H. E. Warburton, Clerk, appointed Assayers' Assistant January 24, 1916.

Thos. Campbell, appointed Clerk, January 24, 1916.

H. Freeman, Assayer, resigned October 18, 1916.

R. D. McLellan appointed Assayer, October 19, 1916.

W. O. Wright substituted as Assayer from September 7 to 23, inclusive, during H. Freeman's absence on leave without pay.

Summary of Work Done.

There were 1,779 deposits of gold bullion received, melted, assayed, and purchased, and before disposing of same, the bars weighing under 500 ounces each, were assembled and melted into large bars, which were also assayed. A total of 2,001 meltings, and 2,001 assays, were required in connexion with the purchase and disposal of the bullion. All assays were run in quadruplicate.

Two hundred and twenty-five (225) ounces of quartation silver was manufactured and punched into discs ranging in weight from 25 to 750 mg.; 12,000 cupels of different sizes were also manufactured, and 370 pounds of slag treated and values contained in the same recovered.

Bullion.

The aggregate weight of the gold bullion deposits before melting was 180,292.83 troy ounces, and after melting 175,393·08 troy ounces, showing a loss in melting of 2·7177 per cent. The loss in weight by assaying was 30·81 troy ounces, making the weight of bullion after melting, and assaying 175,362·27 troy ounces, the average fineness of same being ·776¾ gold, and ·179 silver.

The net value of the gold and silver contained in deposits was $2,828,239.65, and received from the undermentioned sources:—

Source	Number of deposits	Weight		Net value
		Before melting (Troy ozs.)	After melting (Troy ozs.)	
British Columbia	1,199	85,043·13	81,806·65	$1,298,584.99
Yukon Territory	573	95,005·82	93,348·20	1,525,723.55
Alberta	5	33·43	30·93	554.14
Alaska	2	210·45	207·30	3,376.97
	1,779	180,292·83	175,393·08	$2,828,239.65

Credits and Disbursements for the Purchase of Gold Bullion.

Unexpended balance—"Letters of Credit," January 1, 1916	$ 113,537.53	
Credits established	3,150,000.00	
Balance written off at close of fiscal year, March 31, 1916		$ 60,649.29
Disbursements		2,828,239.65
Unexpended balance—"Letters of Credit," December 31, 1916		374,648.59
	$3,263,537.53	$3,263,537.53

Disbursements and Receipts for the Purchase and Sale of Gold Bullion and Difference between Amounts Paid and Received for Same.

Disbursements for the purchase of bullion on hand January 1, 1916, bars Nos. 1570 to 1612 inclusive	$ 38,536.33	
Disbursements for the purchase of bullion during year ending December 31, 1916, bars Nos. 1613 to 1880 inclusive and Nos. 1 to 1512 inclusive (less No. 420 cancelled)	2,828,239.65	
Proceeds from sale of bullion		$2,867,219.64
Value of bullion on hand December 31, 1916, bars Nos. 1509 to 1512 inclusive		3,082.87
Difference	3,526.53	
	$2,870,302.51	$2,870,302.51

Contingent Account.

Unexpended balance, January 1, 1916	$ 89.35	
Funds provided per official cheques Nos. 1789, 2017, 2220, 41, 165, 441, 758, 1116, 1416, 1659, 1957, and 2263	4,845.00	
Amount remitted Receiver-General, per draft No. 169, at close of fiscal year, March 31, 1916		$ 62.13
Expenditure		4,871.46
Unexpended balance, December 31, 1916		.76
	$4,934.35	$4,934.35

Contingent Expenditure.

Fuel (Gas)	$ 703.01
Power	250.32
Express charges on bullion	2,359.38
Electric vault protection service	300.00
Postage	70.00
Telephones	80.45
Duty, express, freight, etc., on supplies	56.13
Assayers' and Melters' supplies (purchased locally)	869.41
Sundries	182.76
	$4,871.76

Proceeds from Sale of Residues.

Residue sold to United States Assay Office, Seattle, Wash., U.S.A. (Bar No. A-10)	$832.18
50 empty acid bottles sold to B. C. Assay and Chemical Supply Co., Ltd., Vancouver, B.C.	6.00
	$838.18

Residues on Hand, December 31st, 1916.

Value of Residue recovered from slags, sweepings, old furnaces, old crucibles, etc.	$690.28
36 empty acid bottles	

Miscellaneous Receipts.

Draft No. 171, in favour of Deputy Minister of Mines (a payment for treating 92 ozs. quartz)	$3.00
Draft No. 179, in favour of Deputy Minister of Mines (a payment for cleaning 115 ozs. platinum)	1.50
Draft No. 203, in favour of Deputy Minister of Mines (a payment for one special assay)	2.00
Draft No. 218, in favour of Deputy Minister of Mines (a payment for melting, etc., 6·42 ozs. silver bullion)	1.50
Draft No. 223, in favour of Deputy Minister of Mines (Refund by Dominion Express Company of Stamp Tax on 3 shipments bullion)	3.00
Draft No. 227, in favour of Deputy Minister of Mines (a payment for treating 18½ lbs. slag)	5.50
	$16.50

The following shows the business done by the Assay Office during the past five years, viz.:—

Calendar Year	Number of deposits	Weight (Troy ozs.)	Net value
1912	527	59,068·83	$ 974,077·14
1913	783	111,479·95	1,448,625·37
1914	1,112	166,148·83	2,029,251·31
1915	1,901	183,924·49	2,736,302·31
1916	1,779	180,292·83	2,828,239·65

I have the honour to be,
Sir,
Your obedient servant,
(*Signed*) **G. Middleton,**
Manager.

II

REPORT OF CHIEF ASSAYER.

G. Middleton, Esq.,
Manager,
Dominion of Canada Assay Office,
Vancouver, B.C.

Sir,—

I beg to report the following Assayers' supplies on hand at above date, viz.:—

Silver Nitrate Crystals	¾	oz.
Lead foil, C.P.	107	lbs.
Lead granulated, C.P.	1	lb.
Zinc, Mossy, C.P.	2	ozs.
Litharge	½	lb.
Copper Wire	4	ozs.
Acid, Nitric, C.P.	6	Winchesters.
„ Hydrochloric, C.P.	⅔	Winchester.
„ Sulphuric, C.P.	⅔	„
Ammonia	1	„
Acid, Oxalic, C.P.	¾	lb.
Small Clay Crucibles	80	
Scorifiers, 2½ ins.	45	
Cupels	16,700	
Muffles, spare	65	
Muffle furnace lining, spare	1	set.
„ supports	20	
„ back stops	23	
„ plugs	33	
„ doors	9	
Gold Cornets	28·28	ozs.
„ Proof	6·91	„
Silver	229·39	„

Your obedient servant,
(*Signed*) **J. B. Farquhar,**
Chief Assayer.

III

REPORT OF CHIEF MELTER.

December 31, 1916.

G. Middleton, Esq.,
Manager,
Dominion of Canada Assay Office,
Vancouver, B.C.

Sir,—

I beg to inform you that we have the following supplies on hand in the Melting Department, viz.:—

4 sets of linings, supports and covers for No. 2 furnace.
3 „ „ „ „ „ „ „ „ 4½ „
4 „ „ „ „ „ „ „ „ 7 „
6 Graphite Crucibles, No. 6.
4 „ „ „ A.14.
25 „ „ „ 16.
5 „ „ „ 30.
2 „ „ „ 40.
o
20 „ „ marked o o
o
6 Crucible Covers, No. 6.
6 „ „ „ 14.
4 „ „ „ 30.
3 Graphite Stirrers.
90 lbs. Sodium Nitrate.
20 „ Carb. Soda.
95 „ Borax.

Your obedient servant,
(*Signed*) **D. Robinson.**
Chief Melter.

ACCOUNTANT'S STATEMENT, 1915-16.

Assay Office.

The following is a statement of the difference in value of assays between Seattle Assay Office and Dominion of Canada Assay Office, between 1st April, 1915, and 31st March, 1916.

Paid for bullion at Dominion of Canada Assay Office, Vancouver	$2,789,350.71
Received for gold bars from United States Assay Office, Seattle	2,792,670.46
Difference in favor of Dominion of Canada Assay Office	3,319.75

Statement of Deposits of Gold and Earnings.

Deposits of gold	$2,792,670.46
Earnings:—	
Melting 1·88 ozs. bullion for M. F. Keeley	1.00
Special assay for A. J. Brennan	2.00
Treating 2·46 ozs. bullion for M. F. Keeley	2.00
Treating 163·15 ozs. silver residue for G. S. Eldridge	2.50
Treating 25 lbs. slag for John Hopp	9.00
Value of 50 empty acid bottles sold B. C. Assay and Chemical Supply Co., Ltd.	6.00
Value of residue sold United States Assay Office	832.18
	$ 854.68
Difference between amounts paid and received for bullion	3,319.75
	$4,174.43

The following is a statement of the Appropriation, Receipts and Expenditure of the Dominion of Canada Assay Office for the year ending 31st March, 1916, and shows the unexpended balance to be $3,023.37.

	Appropriation	Expenditure
Appropriation, 1915-16	$20,000.00	
Receipts per the foregoing statement	854.68	
Difference between amounts paid and received for bullion	3,319.75	
Fuel		715.30
Power and Light		257.20
Postage and Telegrams		197.54
Telephone		80.00
Express charges		2,304.93
Assayer's supplies		880.84
Printing and stationery		226.18
Premium on bonds		630.00
Contingencies		200.86
Electric burglar alarm service		300.00
Wages:—		
G. Middleton		2,650.00
J. B. Farquhar		1,900.00
A. Kaye		1,800.00
H. Freeman		1,239.71
D. Robinson		1,575.00
G. N. Ford		1,500.00
T. B. Younger		1,200.00
R. Allison		1,080.00
E. A. Pritchett		900.00
H. E. Warburton		793.33
R. D. McLellan		528.23
T. Campbell		191.94
Balance unexpended		3,023.37
	$24,174.43	$24,174.43

Assay Office.

The following is a statement of the difference in value of assays between Seattle Assay Office and Dominion of Canada Assay Office, between 1st. April, 1916, and 31st. March, 1917.

Paid for bullion at Dominion of Canada Assay Office, Vancouver	$3,138,250.21
Received for gold bars from United States Assay Office, Seattle	3,141,670.43
Difference in favour of Dominion of Canada Assay Office	$ 3,420.22

Statement of Deposits of Gold and Earnings.

Deposits of Gold	$3,141,670.43
Earnings:—	
Treating 92 ozs. quartz for R. W. Dick	$ 3.00
Cleaning 115 ozs. platinum for F. H. Arnold	1.50
Special assay for Canadian Bank of Commerce, Vancouver, B.C.	2.00
Melting 6-42 ozs. silver bullion for G. S. Eldridge	1.50
Treating 18½ lbs. slag for John Hopp	5.50
Value of 43 empty acid bottles sold B. C. Assay & Chemical Supply Co., Ltd.	5.16
Special assay for E. B. Craton	2.00
Value of residue sold United States Assay Office	822.75
	$ 843.41
Difference between amounts paid and received for bullion	3,420.22
	$4,263.63

The following is a statement of the Appropriation, Receipts and Expenditure of the Dominion of Canada Assay Office for the year ending March 31, 1917.

	Appropriation	Expenditure
Appropriation, 1916-17	$25,000.00	
Receipts per the foregoing statement	843.41	
Difference between amounts paid and received for bullion	3,420.22	
Fuel		722.46
Power and Light		248.62
Postage and Telegrams		144.30
Telephone account		80.45
Express charges		2,567.01
Assayer's supplies		2,847.63
Printing and Stationery		214.32
Premium on Bonds		630.00
Contingencies		177.51
Electric Burglar Alarm Service		300.00
Wages:—		
G. Middleton		2,800.00
J. B. Farquhar		1,900.00
A. Kaye		1,800.00
H. Freeman		747.58
W. O. Wright		75.00
D. Robinson		1,575.00
G. N. Ford		1,500.00
T. B. Younger		1,200.00
R. Allison		1,080.00
E. A. Pritchett		900.00
H. E. Warburton		1,020.00
R. D. McLellan		677.42
T. Campbell		1,020.00
Balance unexpended and lapsed		5,036.33
	$29,263.63	$29,263.63

LIST OF REPORTS, BULLETINS, ETC., PUBLISHED DURING THE YEAR 1916.

Marc Sauvalle,
Chief of Publishing and Translating Division.

S. Groves,
Editor Department of Mines.

89. Reprint of "Proceedings of Conference on Proposed Legislation to Regulate the Manufacture, Importation, and Testing of Explosives." Published February 15, 1916.
92. Reprint of "Report on the Explosive Industry in the Dominion of Canada." By Captain A. Desborough. Published February 15, 1916.
338. The Coals of Canada, Vol. VII.: Weathering of Coal. Report on—by Dr. J. B. Porter. Published October 30, 1916.
346. Mines Branch Summary Report for 1914. Published January 22, 1916.
351. Investigation of the Peat Bogs and the Peat Industry of Canada, 1913-1914. Bulletin No. 11—by A. Anrep. Published June 28, 1916.
383. The Production of Cement, Lime, Clay Products, and other Structural Materials in Canada, during the calendar year 1914. Bulletin on—by John McLeish, B.A. Published February 29, 1916.
384. Mineral Production of Canada, 1914. Annual Report on—by John McLeish, B.A. Published June 6, 1916.
385. Investigation of a Reported Discovery of Phosphate at Banff, Alberta. Bulletin No. 12—by H. S. deSchmid, M.E. Published February 29, 1916.
401. Feldspar in Canada. Report on—by H. S. deSchmid, M.E. Published November 20, 1916.
406 Description of the Laboratories of the Mines Branch. Bulletin No. 13. Published April 18, 1916.
408. Preliminary Report on the Mineral Production of Canada during the Calendar Year, 1915. By John McLeish, B.A. Published February 29, 1916.
413. The Magnetic Properties of Cobalt and of Fe_2Co. Report on—by H. T. Kalmus, B.Sc., Ph.D. Published September 14, 1916.
419. The Production of Iron and Steel in Canada during the Calendar Year 1915. Bulletin on—by John McLeish, B.A. Published November 24, 1916.
428 The Production of Spelter in Canada, 1916. Report on—by A. W. G. Wilson, Ph.D. Published December 16, 1916.

FRENCH TRANSLATIONS.

223. French translation: Lode mining in Yukon: An investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc. Published March 27, 1916.
246. French translation: Gypsum in Canada: Its occurrence, exploitation and technology. Report on—by L. H. Cole, B.Sc. Published March 17, 1916.
260. French translation: Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D. Published March 22, 1916.
280. French translation: Building and ornamental stones of Canada, Vol. II.: Maritime Provinces. Report on—by W. A. Parks, Ph.D. Published April 3, 1916.
282. French translation: The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E. Published March 22, 1916.
308. French translation: Investigation of coals of Canada, Vol. IV. Report on—by J. B. Porter, E.M., D.Sc. R. J. Durley, Ma.E., and others. Published March 7, 1916.
310. French translation: The physical properties of the metal cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D. Published July 28, 1916.
321. French translation: Annual report on the mineral production of Canada, for 1913. Report on—by J. McLeish, B.A. Published January 7, 1916.
347. French translation: Summary report of the Mines Branch for 1914. Published August 11, 1916.
389. French translation: Building and ornamental stones of Canada, Vol. III.: Province of Quebec. Report on—by W. A. Parks, Ph.D. Published September 7, 1916.
415. French translation: Annual report on the mineral production of Canada for 1914. Report on—by J. McLeish, B.A. Published October 30, 1916.

ACCOUNTANT'S STATEMENT, MINES BRANCH.

Statement of Appropriations and Expenditure by Mines Branch for year ending March 31, 1916.

		Appropriations	Expenditure
Amounts voted by Parliament:—			
General Appropriations	$149,000.00		
Civil List Salaries	96,900.00		
Civil Government Contingencies	1,500.00		
		$247,400.00	
Receipts for Assays and Analyses		373.00	
Civil List Salaries			$ 86,760.42
Civil Government Contingencies			717.81
Publication of Reports, $42,074.02, less unpaid Printing Bureau, $695.13			41,378.89
Translation of Reports			3,029.40
Publication of Maps			3,462.34
Fuel Testing Plant			14,355.86
Concentrating Laboratory			12,098.62
Ceramic Laboratory			1,388.91
Chemical Laboratory			1,215.66
Metallographic Laboratory			204.75
Machinery, parts and supplies			8,724.21
Wages, mechanics and labourers			7,504.70
Printing, stationery, books, mapping material			6,558.65
Investigation re Tar Sands, Alberta			4,787.29
Tar Sands Paving, Edmonton, Alberta			3,214.12
Investigation re Iron Ores			3,534.83
Investigation re Non-metallic minerals			2,801.42
Investigation re Building Stones			2,798.99
Investigation re Moulding Sands			1,598.82
Investigation re Clay Deposits			1,534.13
Investigation re Peat and Coal			1,515.01
Forward		$247,773.00	$209,184.83

	Appropriation	Expenditure
Forward	$247,773.00	$209,184.83
Special Investigations re Iron Ore		1,321.14
Investigation re Limestones		1,117.98
Investigation re Explosives		1,085.81
Investigation re Mineral Waters		521.10
Investigation re Ore Deposits		132.41
Investigation re Oil Shales		49.25
Investigation re Copper Deposits		27.15
Instruments		1,538.23
Miscellaneous		1,474.24
Postage and Telegrams		963.91
Subscriptions, Membership Fees, etc		406.50
Advertising		137.50
Coal Tests		136.04
Brokerage Fees		54.03
Balance unexpended		29,622.88
	$247,773.00	$247,773.00

CASUAL REVENUE.

Sales of Publications	$383.22	
Hudson Bay Co., for canoe	65.00	
S. C. Ells, provisions, camp materials	47.00	
S. Younger, for canoe	12.00	
Baker and Co., Newark, N.J., platinum scrap	.18	
T. Denis, one old arithmometer	10.00	
		$ 517.40

Summary	Appropriation	Expenditure	Expenditure greater than vote	Expenditure less than vote
Civil Government Salaries	$ 96,900.00	$ 86,760.42		$10,139.58
Investigation of ore deposits, economic minerals, etc	62,000.00	57,993.28		4,006.72
Printing, books, stationery, apparatus, chemical laboratories expenses, miscellaneous	67,000.00	67,695.13	$695.13	
Investigation of manufacture and storage of explosives in Canada	5,000.00	1,085.81		3,914.19
Investigation of Iron Industry by Special Committee	10,000.00	1,005.68		8,994.32
Practical tests in road making of Tar Sands of Athabaska	5,000.00	3,214.12		1,785.88
Civil Government Contingencies	1,500.00	717.81		782.19
	$247,400.00	$218,472.25	$695.13	$29,622.88

(*Signed*) **Jno. Marshall,**
Accountant, Department of Mines.

DEPARTMENT OF MINES.

STATEMENT OF APPROPRIATIONS AND EXPENDITURE BY MINES BRANCH FOR YEAR ENDING MARCH 31, 1917.

This financial statement covers nine months of the calendar year, 1916, which is also period of greatest activity. Therefore it has been advisable to include report more closely associated with the work described in this Summary Report. The statement of the previous financial year is also published herewith:—

		Appropriations	Expenditure
Amounts voted by Parliament:—			
General Appropriations	$153,000.00		
Civil List Salaries	98,775.00		
Civil Government Contingencies	1,500.00	$253,275.00	
Receipts:—			
For Assays and Analyses		302.00	
From Imperial Munitions Board		19,167.07	
For Concentration, etc., Molybdenum Ores		18,920.11	
Civil List Salaries			88,571.48
Civil Government Contingencies			662.96
Publication of Reports	36,793.97		
Unpaid Department of Public Printing	1,417.96		35,376.01
Translation of Reports			3,046.59
Publication of Maps			5,246.96
Fuel-Testing Plant			16,718.05
Laboratories:—			
Fuel Testing			4,974.96
Concentrating			70,432.02
Ceramic			3,770.06
Chemical			2,170.27
Structural Materials			928.02
Metallographic			4.20
Wages, mechanics and labourers			9,035.53
Sundry printing, stationery, books, mapping materials			7,095.71
Mellon Institute; Investigation re Bituminous Sands			5,000.00
Forward		$291,664.18	$253,032.82

		Appropriations	Expenditure
Forward		$291,664.18	$253,032.82
Investigations:—			
Non-metallic minerals			2,765.37
Building Stones			2,752.88
Peat and Coals			2,687.97
Antimony Deposits	$2,789.90		
Unpaid W. F. Ferrier	750.00		2,039.90
Clay Deposits			1,547.86
Iron Ores			934.25
Zinc			871.31
Chemical Industries			596.78
Moulding Sands			561.30
Tar Sands			194.52
Limestones			141.44
Molybdenite Resources			57.85
Explosives			53.43
Mineral Waters			1.08
Mineral Statistics			80.16
Instruments			2,352.61
Postage and Telegrams			846.69
Subscriptions, Membership Fees, etc			246.20
Brokerage Fees			106.00
Advertising			37.49
Miscellaneous			3,047.24
Balance unexpended and lapsed			16,709.03
		$291,664.18	$291,664.18

CASUAL REVENUE.

From John McLeod, for saddle, bridle and pad	$ 40.00	
From J. Ward, for 1 horse	76.00	
Sales of Publications	386.59	$502.59

Summary	Appropriation	Expenditure	Expenditure greater than vote	Expenditure less than vote
Civil Government Salaries	$98,775.00	$88,571.48		$10,203.52
Investigation of ore deposits, economic minerals, etc	76,000.00	75,278.10		721.90
Printing, books, stationery, apparatus, chemical laboratories expenses, miscellaneous	67,000.00	68,417.96	1,417.96	
Investigation of manufacture and storage of explosives in Canada	5,000.00	53.43		4,946.57
Practical Tests of Bituminous sands of Alberta	5,000.00	5,000.00		
Civil Government Contingencies	1,500.00	662.96		837.04
	$253,275.00	$237,983.93	$1,417.96	$16,709.03

DOMINION OF CANADA ASSAY OFFICE.

Maintenance of Assay Office, Vancouver, B.C.	$25,000.00	$19,963.67		$5,036.33

APPENDIX

EUGENE HAANEL, Ph.D.,
Director of Mines.

SIR,—I beg to submit herewith, the annual preliminary report on the mineral production of Canada in 1916.

The figures for production in 1916, while subject to revision, are based upon direct returns from mine and smelter operators and are fairly complete.

Special acknowledgements are due to those operators who have promptly furnished reports of their operations during the year.

When complete returns shall have been received the usual annual report will be prepared, containing in greater detail the final statistics as well as information relating to exploration, development, prices, markets, imports and exports, &c.

I have the honour to be,
Sir,
Your obedient servant,
(*Signed*) **John McLeish.**

Division of Mineral Resources and Statistics,
February 28, 1917.

PRELIMINARY REPORT ON THE MINERAL PRODUCTION OF CANADA.

DURING THE CALENDAR YEAR 1916.

The total value[1] of the metal and mineral production in 1916 as shown in the preliminary report presented herewith was $177,357,454 which compared with a production in 1915 valued at $137,109,171 shows an increase of $40,248,283 or 29·3 per cent. The previous maximum production was $145,634,812 in 1913

The war has had a most pronounced effect not only in stimulating the production of those metals such as nickel, copper and zinc, iron and steel, molybdenum, etc., which are used so extensively for war purposes, but also in increasing the production of other products such as chromite and magnesite which can only now be obtained with difficulty if at all from sources previously available. The general industrial activity in metallurgical operations and in the manufacture generally of munitions of all kinds, including the freight movements required, have in turn increased the demand for fuel which has been met in Western Canada at least by large increases in coal production.

Increased production in quantity has in most instances been accompanied by large increases in prices, thus further enhancing the total value of the production.

Considerable progress has been made during the year in establishing and increasing smelting and refining capacities of which the installation of electrolytic zinc and copper refineries at Trail and the beginning of construction of a nickel refinery at Port Colborne, Ont., are conspicuous examples. In addition mention should be made of the production of metallic magnesium at Shawinigan Falls, of ferro-molybdenum at Orillia and Belleville, of metallic arsenic at Thorold, and of stellite, the cobalt alloy for high speed tool metal, at Deloro, and of the increased capacity for the production of steel particularly the installation of electric furnaces.

The mining output has been restricted and the efficiency of its operation considerably reduced by the withdrawal for war service of such a large proportion of the more highly experienced labour and engineering supervision. Higher costs have tended to offset the advantages to be derived from higher prices of output and in the case of gold mining have been a distinct burden.

The mining and metallurgical industries include a great variety of products so that in dealing with the industry as a whole the total value presents the only means of comparison, nevertheless, quantities of production and prices are at all times the items of essential importance.

The accompanying statistical tables show: (1) the detailed production in 1916, (2) a comparison of the production of the more important products in 1916 with the production in 1915, (3) a record of the prices of metals during six years and, (4) the production by provinces.

It will be noted that there has been an increased production of nearly all metals with the exception of lead and silver. The total value of the metallic production in 1916 was $107,040,035 as compared with $75,814,841 in 1915, an increase of $31,225,194 or 41·2 per cent.

---

[1] In presenting a total valuation of the mineral production as is here given, it should be explained that the production of the metals copper, gold, lead, nickel, silver, and zinc is given as far as possible on the basis of the quantities of metals recovered in smelters, and the total quantities in each case are valued at the average market price of the refined metal in a recognized market. There is thus included in some cases the values that have accrued in the smelting or refining of metals outside of Canada.

The Mineral Production of Canada in 1916.

SUBJECT TO REVISION.

Product.		Quantity	Value
METALLIC.			
Antimony ore (exports)	*Tons	794	$ 48,158
Cobalt metallic and contained in oxide, etc.	Lbs.	841,859	926,045
Copper, value at 27·202 cents per pound	„	119,770,814	32,580,057
Gold	Ozs.	926,963	19,162,025
Iron, pig from Canadian ore	Tons	115,691	1,328,595
Iron, ore sold for export	„	140,608	393,689
Lead, value at 8·513 cents per pound	Lbs.	41,593,680	3,540,870
Molybdenite, MoS_2 contents at $1.00 per pound	„	159,000	159,000
Nickel, value at 35 cents per pound	„	82,958,564	29,035,497
Platinum	Ozs.	15	600
Silver, value at 65·661 cents per oz.	„	25,669,172	16,854,635
Zinc, value at 12·804 cents per pound	Lbs.	23,515,030	3,010,864
Total		....	$107,040,035
NON-METALLIC.			
Actinolite	Tons	250	$ 2,750
Arsenic, white	„	2,186	262,349
Asbestos	„	136,016	5,133,332
Asbestic	„	18,500	27,147
Chromite, crude ore (*a*)	„	27,030	299,753
Coal (*b*)	„	14,428,278	38,797,437
Corundum	„	67	10,307
Feldspar	„	19,166	71,357
Fluorspar	„	1,284	10,238
Graphite	„	3,971	285,362
Grindstones	„	3,328	50,982
Gypsum	„	341,618	730,831
Magnesite	„	55,413	563,829
Manganese	„	979	90,791
Mica	„	914	122,541
Mineral pigments—			
Barytes	„	1,368	19,393
Oxides	„	8,811	58,711
Mineral water		....	114,587
Natural gas	M. cu. ft.	25,238,568	3,924,632
Peat	Tons	300	1,500
Petroleum	Brls.	198,123	392,284
Phosphate	Tons	203	2,514
Pyrites	„	309,411	1,084,019
Quartz	„	135,803	241,806
Salt	„	124,033	668,627
Talc	„	10,651	36,475
Tripolite	„	620	12,139
Total		....	$ 53,015,693
STRUCTURAL MATERIALS AND CLAY PRODUCTS.			
Cement, portland	Brls.	5,359,050	$ 6,529,861
Clay products—			
Brick: common, pressed, paving		....	2,358,245
Sewerpipe		....	716,287
Tile, pottery, refractories		....	1,104,901
Kaolin	Tons	1,750	17,500
Lime	Bush.	5,482,876	1,089,505
Sand and gravel (not complete) (*c*)		....	1,498,009
Sand-lime brick	No.	13,825,307	113,136
Slate	Sq.	1,262	6,223

Product	Quantity	Value
Stone—		
Granite	....	1,277,019
Limestone	....	2,326,519
Marble	....	118,810
Sandstone	....	145,711
Total structural materials and clay products	....	17,301,726
All other non-metallic		53,015,693
Total value, metallic		107,040,035
Grand total, 1916		$177,357,454

*Tons of 2,000 pounds.
(*a*) Ore and concentrates finally marketed estimated as 13,834 tons.
(*b*) Additional returns increase production to 14,461,678 tons, $38,857,557.
(*c*) „ „ „ value to $1,734,183.

Increase or Decrease in Principal Products, 1916.

Principal Products		Increase (+) or Decrease (–) in Quantity			Increase (+) or Decrease (–) in Value		
				%			%
Copper	Lbs.	+	18,985,664	18·84	+	$15,169,422	87·13
Gold	Ozs.	+	8,907	0·97	+	184,124	0·97
Pig-iron from Canadian Ore (*a*)	Tons	–	42,904	27·05	–	387,279	22·57
Lead	Lbs.	–	4,722,770	10·20	+	947,149	36·52
Nickel	„	+	14,649,907	21·45	+	8,542,900	41·69
Silver	Ozs.	–	956,788	3·59	+	3,625,793	27·41
Total			....	......	+	31,225,194	41·19
Asbestos and Asbestic	Tons	+	17,674	12·91	+	1,585,494	44·35
Coal	„	+	1,194,655	9·00	+	6,746,375	21·01
Gypsum	„	–	133,197	28·05	–	124,098	14·52
Graphite	„	+	1,336	50·70	+	161,139	129·71
Magnesite	„	+	40,634	274·94	+	437,245	345·40
Natural gas	M. ft.	+	5,114,406	25·41	+	216,997	5·86
Petroleum	Brls.	–	17,341	8·05	+	91,712	30·51
Pyrites	Tons	+	23,373	8·17	+	98,829	10·03
Quartz	„	+	8,695	6·84	+	36,653	17·87
Salt	„	+	4,133	3·45	+	68,401	11·40
Cement	Brls.	–	321,982	5·67	–	447,163	6·41
Clay products			....	......	+	282,445	7·22
Lime	Bush.	+	435,632	8·63	+	73,803	7·28
Sand and Gravel			....	......	–	126,758	7·80
Stone			....	......	–	376,938	8·88
Total non-metallic			....	......	+	9,023,089	14·72
Grand Total			....	......	+	40,248,283	29·35

(*a*) The total production of pig-iron shows an increase, see page 167.

Metal Prices.

(In cents per pound or ounce.)

	1911	1912	1913	1914	1915	1916
Antimony (ordinaries).........Per lb.	7·540	7·760	7·520	8·763	30·280	25·370
Copper, New York............ „	12·376	16·341	15·269	13·602	17·275	27·202
Lead „ .... „	4·420	4·471	4·370	3·862	4·673	6·858
„ London................. „	3·035	3·895	4·072	4·146	4·979	6·715
„ Montreal*.............. „	3·480	4·467	4·659	4·479	5·600	8·513
Nickel, New York............. „	40·000	40·000	40·000	40·000	45·000	45·000
Silver, „ ....Per oz.	53·304	60·835	59·791	54·811	49·684	65·661
Spelter, „ ....Per lb.	5·758	6·943	5·648	5·213	13·230	12·804
Tin, „ .... „	42·281	46·096	44·252	34·301	38·500	43·480

*Quotations furnished by Messrs. Thomas Robertson & Company, Montreal, Que.

Mineral Production by Provinces, 1915 and 1916.

	1915		1916		Increase (+) or Decrease (–)	
	Value of Production	Per cent of total	Value of Production	Per cent of total		
Nova Scotia................	$18,088,342	13·19	$19,963,985	11·26	+ $ 1,875,643	10·37
New Brunswick.............	903,467	0·66	878,446	0·49	– 25,021	2·77
Quebec.....................	11,619,275	8·48	14,397,909	8·12	+ 2,778,634	23·91
Ontario.....................	61,071,287	44·54	80,379,352	45·32	+ 19,308,065	31·62
Manitoba...................	1,318,387	0·96	1,819,921	1·03	+ 501,534	38·04
Saskatchewan..............	451,933	0·33	583,708	0·33	+ 131,775	29·16
Alberta.....................	9,909,347	7·23	13,336,702	7·52	+ 3,427,355	34·59
British Columbia............	28,689,425	20·92	40,191,744	22·66	+ 11,502,319	40·09
Yukon......................	5,057,708	3·69	5,805,687	3·27	+ 747,979	14·79
Dominion..............	$137,109,171	100·00	$177,357,454	100·00	+$ 40,248,283	29·35

The total value of the non-metallic production including clay and quarry products in 1916, was $70,317,419, as compared with $61,294,330 in 1915 showing an increase of $9,023,089, or 14·7 per cent. The aggregate production of structural materials showed a slight decrease, the value in 1916 being $17,301,726 as against $17,920,759 in 1915. The total of all other non-metallics increased from $43,373,571 to $53,015,693 in 1916.

GOLD.

The total production of gold in placer and mill bullion and in smelter production in 1916 is estimated at 926,963 fine ounces valued at $19,162,025 as compared with 918,056 fine ounces valued at $18,977,901 in 1915, an increase of $184,124, or about 1 per cent. It is the largest production since 1902. The highest production recorded was $27,908,153 in 1900, and the lowest since then was $8,382,780 in 1907.

Of the total production in 1916 $4,957,663 or 26 per cent were derived from placer and alluvial mining; $10,472,723, or 54 per cent in bullion and refined gold, and $3,731,639, or 20 per cent contained in matte, blister copper residues and ores exported.

The production in Nova Scotia was about $103,359 a decrease of 24·4 per cent from that of 1915 and was due to the water shortage which interfered seriously with the operations of the hydro-electric plants.

The production in Quebec is derived from the pyrites ores of the Eastern Townships. The gold content of these ores is very low and is not paid for to the mine operators.

Ontario is, since 1914, the largest gold producing province in Canada. The production for 1916 was 489,679 fine ounces valued at $10,122,563, being 52·8 per cent of the total production for Canada and an increase of 20·4 per cent over that of 1915, and 82 per cent over the production of 1914.

The Hollinger Consolidated mines contributed about 48 per cent of the output, and the Dome about 21 per cent.

Apart from a very small recovery of alluvial gold in Alberta no production is recorded from this Province nor from Manitoba, or Saskatchewan.

The production in British Columbia was $4,520,868 as against $5,651,184 in 1915, a decrease of 20 per cent; this total includes $575,000 estimated by the provincial mineralogist as being the output of placer mining, and $3,945,000 recovered from milling and smelting operations.

The production from the Yukon Territory amounted to $4,391,669 as against $4,750,450 in 1915, a decrease of 7·5 per cent and was derived from the alluvial deposits with the exception of about $9,000 which was produced from the gold and copper ores of Whitehorse and the silver-lead ores of the Silver King mine near Mayo.

The exports of gold-bearing dust, nuggets, gold in ore, etc., in 1916 are reported by the Customs Department as $18,382,903.

SILVER.

The production of silver in 1916 was 25,669,172 fine ounces valued at $16,854,635 as against 26,625,960 fine ounces valued at $13,228,842 in 1915, a decrease of 3·6 per cent in quantity, but an increase of 27 per cent in value.

The production in Ontario amounted to 21,975,942 ounces valued at $14,429,623 or 85·6 per cent of the total production for Canada. The production from the ores of Cobalt and adjoining silver camps was 21,885,057 ounces including 18,418,392 ounces in bullion recovered in smelters and reduction plants in Canada and 3,466,665 ounces estimated as recovered from ores exported to the United States smelters, thus 84 per cent being recovered as bullion in Canada; of this bullion 9,665,516 ounces were recovered in southern Ontario smelters and 8,752,876 ounces in the mills of Cobalt. The balance of the Ontario production—90,886 ounces—was the output of the gold and copper mines.

The production in Quebec was about 97,000 ounces valued at $63,691 as against 63,450 ounces valued at $31,524 in 1915 and is derived from the pyritic ores of the Eastern Townships and the zinc-lead ores of Notre Dame des Anges.

In British Columbia the production was 3,235,764 ounces valued at $2,124,635 as against 3,565,852 ounces valued at $1,771,658 in 1915, showing a decrease in quantity of about 9 per cent and an increase in value of about 20 per cent. This production includes refined silver, silver contained in smelter products and estimated recoveries from ores exported.

The Yukon production was 360,466 ounces valued at $236,686 as against 248,049 ounces valued at $123,241 in 1915, an increase in quantity of about 45 per cent and in value of about 92 per cent. The 1916 production includes 47,703 ounces derived from the placer operations, the balance being the product of the gold and copper mines of the Whitehorse district and the high grade gold-silver-lead mines of Mayo.

The exports of silver bullion and silver in ore, etc., as reported by the Customs Department were: 25,279,359 ounces valued at $15,637,885, as against 27,672,481 ounces valued at $13,812,038 in 1915.

The price of silver in New York which started in January with a minimum of 56¼ cents, increased quite regularly throughout the year, reaching a maximum of 76¾ cents in December. The average for the year was 65·661 cents, as against 49·684 cents in 1915.

COPPER.

The production of copper has shown large increases during the past three years. In 1916 the total copper contents of smelter products credited to Canadian ores and estimated recoveries from ores exported amounted to 119,770,814 pounds which would be worth $32,580,057 at the average monthly price of refined copper in New York 27·202 cents per pound. The production in 1915 was 100,785,150 pounds, and at 17·275 cents per pound the average price for the year would be worth $17,410,635. There was thus an increase in 1916 of 18,985,664 pounds, or 18·8 per cent in quantity and $15,169,422 or 87·1 per cent in total value.

An electrolytic copper refinery which has been installed at Trail began active operations about November 1 and has a capacity of 10 tons of refined copper per day.

Of the total 1916 production 92,763,603 pounds were contained in blister copper and in matte, and 27,007,211 pounds estimated as recovered from ores exported.

In addition to the recoveries from domestic ores there was also recovered in British Columbia smelters 5,551,166 pounds of copper from imported ores.

The production in Quebec from pyrite ores was 5,707,200 pounds as against 4,197,482 pounds in 1915. These are the quantities reported as being paid for; the actual ore contents were much higher.

The Ontario production is derived chiefly from the nickel-copper ores of the Sudbury district and of the Alexo mine in Timiskaming supplemented by a small recovery from the Cobalt district silver ores and by shipments made from six copper properties under development.

The total production in 1916 was 44,997,035 pounds as against 39,361,464 pounds in 1915, an increase of 12·5 per cent.

The British Columbia production was somewhat less than early estimates seemed to indicate. The quantity reported being 65,086,119 pounds as compared with 56,692,988 pounds in 1915, an increase of 8,393,131 pounds, or 14·8 per cent. The 1916 production in this province included 47,904,282 pounds recovered in blister and matte and 17,181,837 pounds recovered from ores shipped to United States smelters. The Coast mines including the Britannia, Texada Island and Anyox mines together with the shipments from Hazelton are credited with 43,048,065 pounds and the Trail Creek and Boundary mines with 22,038,054 pounds. The increase in 1916 has been entirely from the Coast properties.

The high price of copper has stimulated production from the Whitehorse district of the Yukon. Complete returns have not yet been received but the ore shipments were approximately 49,000 tons with a recoverable copper content estimated at 3,980,640 pounds. In 1915 the production from this source was 533,216 pounds.

The New York price of electrolytic copper increased from a minimum of 22½ cents during the first week of the year to 29¼ cents in May, falling to 22½ cents again about the middle of July. From that the price increased steadily to 33½ cents during the first half of December closing the year at about 30 cents. The average monthly price was 27·202 cents as compared with an average of

17·275 cents in 1915, an increase of 9·927 cents or 57·5 per cent. Higher prices for copper have not been recorded since 1873 when the average for the year was 28 cents.

Exports of copper according to Customs records were: copper fine in ore, matte, regulus, etc., 124,942,400 pounds valued at $20,776,536; copper in pigs, bars, sheets, etc., 2,430,400 pounds valued at $581,268. There were also exports of old and scrap copper amounting to 5,846,600 pounds valued at $1,284,895.

The total value of the imports of copper in 1916 are recorded as $7,566,080 as against $3,957,770 in 1915. The imports in 1916 included 25,594,029 pounds of copper in pigs, ingots and manufactures valued at $7,133,117; other manufactures of copper valued at $234,421 and copper sulphate 1,803,655 pounds valued at $198,542. There was also a considerable import of copper contained in brass.

NICKEL.

The production of nickel in 1916 has as usual, been derived from the ores of the Sudbury district supplemented by the recovery of a small quantity of metallic nickel, nickel oxide and other nickel salts as by-products in the treatment of ores from the silver-cobalt-nickel ores of the Cobalt district.

The total production was 82,958,564 pounds which at 35 cents per pound would have a total value of $29,035,497. The total production in 1915 was 68,308,657 pounds showing an increase in 1916 of 14,649,907 pounds, or 21·5 per cent.

The nickel-copper ore, derived from 9 separate mines in the Sudbury district supplemented by a small tonnage of similar ores from the Alexo mine in Timiskaming, is reduced in smelters and converters at Copper Cliff and Coniston to a Bessemer matte containing from 77 to 82 per cent of the combined metals and shipped in that form to Great Britain and the United States for refining, the product of the Canadian Copper Company going to New Jersey and that of the Mond Nickel Company to Wales. A refinery is now under construction at Port Colborne, Ont., by the International Nickel Company, in which a portion of the matte produced by the Canadian Copper Company will be refined.

Although not shipping during the year, the British America Nickel Corporation, Ltd., has been actively engaged in the development of its nickel properties in the Sudbury district and in the erection of a smelter.

The total production of matte in 1916 was 80,010 tons, containing 44,859,321 pounds of copper and 82,596,862 pounds of nickel. The tonnage of ore smelted (part being previously roasted) was 1,521,689 tons. The production in 1915 was 67,703 tons of matte containing 39,216,165 pounds of copper and 68,077,023 pounds of nickel.

Nickel was recovered as a by-product in smelters at Deloro Thorold and Welland, from the silver-cobalt-nickel ores of the Cobalt district, the total nickel contents of nickel oxide, nickel sulphate and metallic nickel produced being 361,701 pounds. The products recovered included 79,360 pounds of metallic nickel; 323,418 pounds of nickel oxide and 232,450 pounds of nickel sulphate having a total reported value of $132,896. The recovery from these ores in 1915 was 231,634 pounds of nickel.

The exports of nickel in ore matte or other form are reported by the Customs Department as 80,441,700 pounds valued at $8,622,179 or an average of 10·77 cents per pound of which about 83 per cent were exported to the United States.

The imports of nickel into the United States during 1916 which included small quantities from other sources as well as from Canada are recorded as 72,611,492 pounds contained in ore, matte, or other form valued at $9,889,122 or an average of 13·62 cents per pound. The exports of nickel and nickel oxide etc., were 33,404,011 pounds valued at $12,952,493 or an average of 38·775 cents per pound of which about 50 per cent were consigned to Great Britain and 40 per cent to France, Italy, and Russia in Europe. The United Kingdom, it will be observed, has continued to receive through United States refineries a much larger quantity of nickel than is exported directly from Canada to Great Britain. The published records do not show the details "To other countries" for 1916, but a large portion of the 2,906,665 pounds thus exported went to Russia in Asia with smaller quantities to Norway, Sweden, and Spain, etc. The value of the exports in 1916 ranged from 37·128 cents to 45·211 cents per pound. The average values of the exports in 1915 to different countries ranged from 35·925 cents to 43·188 cents per pound, the total average being 38·338 cents per pound. The total average value in 1914 was 34·265 cents with a range of from 32·6 to 38·8 cents per pound.

The price of refined nickel in New York according to quotations published by the Engineering & Mining Journal remained throughout the year at from 45 to 50 cents per pound for ordinary forms with 5 cents more per pound asked for electrolytic nickel.

The following table shows the production of nickel by smelters in the Sudbury districts, the exports from Canada and United States records of imports and exports;—

Production of Nickel in Canada	1912	1913	1914	1915	1916
	Tons*	Tons*	Tons*	Tons*	Tons*
Ore mined	737,584	784,697	1,000,364	1,364,048	1,566,333
Ore smelted	725,065	823,403	947,053	1,272,283	1,521,689
Bessemer matte produced	41,925	47,150	46,396	67,703	80,010
Copper content of matte	11,116	12,938	14,448	19,608	22,450
Nickel " "	22,421	24,838	22,759	34,039	41,298
Spot value of matte	$6,303,102	$7,076,945	$7,189,031	$10,352,344	....
	1912 Lbs.	1913 Lbs.	1914 Lbs.	1915 Lbs.	1916 Lbs.
Exports of Nickel from Canada.					
Nickel contained in matte, etc.—					
Exported to Great Britain	5,072,867	5,164,512	10,291,979	13,748,000	11,136,900
Exported to United States	39,148,993	44,224,119	36,015,642	52,662,400	69,304,800
Exported to Other Countries	....	70,386	220,706	....	....
	44,221,860	49,459,017	46,538,327	66,410,400	80,441,700
Imports of Nickel into United States	1912	1913	1914	1915	1916
Gross tons of ore and matte	33,101	37,623	29,564	45,798	59,741
Nickel contents ... Lbs.	42,168,769	47,194,101	35,006,700	56,352,582	72,611,492
Exports of Nickel from United States					
To France ... Lbs.	5,083,947	3,631,858	3,457,157	3,018,354	2,823,132
To Italy ... "	....	....	....	....	2,715,521
To Netherlands ... "	7,387,447	6,622,811	855,168	129,557	516,331
To Russia in Europe ... "	....	....	....	....	7,767,875
To United Kingdom ... "	8,191,364	8,221,640	10,836,369	14,801,565	16,674,487
To other Countries ... "	5,152,258	10,096,779	12,446,458	8,469,074	2,906,665
Total ... "	25,815,016	29,173,088	27,595,152	26,418,550	33,404,011

*In tons of 2,000 lbs.

LEAD.

Notwithstanding the demand and high prices, the actual recovery of lead as bullion and refined was less than during the previous year. The total production in 1916 of lead in bullion credited to Canadian mines and estimated as recoverable from ores exported was 41,593,680 pounds which at the average price of lead in Montreal 8·513 cents per pound, was valued at $3,540,870. In 1915 the production was 46,316,450 pounds valued at $2,593,721 (5·600 cents per pound). There was a decrease of over 10 per cent in quantity, but an increase of over 32 per cent in total value.

The 1916 production included 38,838,372 pounds of lead in bullion of which a large portion was electrolytically refined, and 2,755,308 pounds recoverable from ores exported. The lead bullion was produced chiefly at Trail with small contributions from smelters at Kingston and Galetta, Ontario. The lead ores exported were derived from Notre Dame des Anges, Quebec, Hollandia mine, Bannockburn, Ont., Surprise mine, Slocan, B.C., and the Silver King mine, Mayo, Yukon district.

Although the recoveries of lead were small in 1916, shipments of lead ores from mines appear to have been greater than in the previous year. Lead ore shipments in 1916 were approximately 82,000 tons, containing 51,083,000 pound of lead, while zinc-lead ores shipped to Trail contained considerable quantities of lead which would be recoverable in large part after the extraction of the zinc. In 1915, the ore shipments were 73,752 tons containing 48,708,005 pounds of lead.

The exports of lead in 1916 included: lead in ore, etc., 9,048,400 pounds valued at $558,180 and pig-lead 112,100 pounds valued at $7,710. Exports in 1915 were: pig-lead, 2,066,929 pounds valued at $79,067, and lead in ore, etc., 1,845,100 pounds valued at $40,273.

The total value of the imports, as shown by the Customs records of lead and lead products in 1916 was $2,077,986, as against a value of $2,482,916 in 1915. The 1916 imports included old and scrap lead 19,865,800 pounds valued at $1,258,284; bars, sheets, pipe, etc., 3,427,233 pounds valued at $1,312,067; other manufactures valued at $155,368, litherage 2,767,200 pounds valued at $211,359 and lead pigments containing approximately 1,474,979 pounds of metallic lead valued at $140,908. The total imports would thus exceed 13,629 tons by the quantity contained in "Other manufactures" which would probably not be greater than 500 or 600 tons. The imports in 1915 were about 25,000 tons.

The average monthly price of lead in Montreal varied between a minimum of 7·29 per pound in January and a maximum of 9·42 in December, averaging for the year 8·513 cents. This is the producer's price for lead in car lots as per quotations furnished by Messrs. Thomas Robertson and Company.

The average monthly price of lead in New York was 6·858 cents per pound and in London £30-19s-6d per gross ton equivalent to 6·715 cents per pound.

ZINC.

With the exception of a small production in experimental work, there was no recovery of zinc spelter, or refined zinc in Canada previous to 1916. Hitherto the production of zinc has been recorded in terms of the tonnage of ore shipped and metal contents thereof. The establishment of an electrolytic zinc refinery at Trail, and of zinc recovery plant at Shawinigan Falls, has placed the metallurgy of this metal in Canada on a similar basis to that of lead and copper and it will be in order to record the production accordingly.

In 1915 the shipments of zinc ores to United States smelters for reduction were 14,895 tons valued at $554,938 and containing 12,231,439 pounds of zinc.

Assuming a probable recovery of 80% of the metal, the production of zinc may be recorded as 9,785,151 pounds which at the average price of zinc for the year 13·23 cents per pound in New York, would be worth $1,294,575.

In 1916 the total zinc ore shipments from mines including the zinc-lead ores from the Sullivan mine, and ores exported were about 80,965 tons containing 47,243,575 pounds of zinc (partially estimated in the absence of complete returns). A portion of the ores shipped to Trail were not treated during the year and the percentage of zinc recovered at the Trail refinery in the early stages of operation was probably not as large as will be secured when primary difficulties have been eliminated. Adding to the actual recovery of refined zinc at Trail 80 per cent of the zinc contents of ores sent to the United States smelters, we have a zinc production of 23,515,030 pounds, which, at the average price of zinc for the year, 12·804 cents, would be worth $3,010,864. Of the total production thus recorded 1,774,080 pounds is credited to the Notre Dame des Anges ores in Quebec, and 21,740,950 pounds to British Columbia.

The exports of zinc are not separately recorded by the Customs Department. The imports of zinc not including zinc contained in brass, were valued at $3,690,577 in 1916, as against $2,797,042 in 1915. The 1916 imports included: zinc in blocks or pigs 14,839,400 pounds valued at $2,141,355; zinc white 14,171,673 pounds valued at $1,314,629; zinc dust 691,704 pounds valued at $162,186; sulphate and chloride of zinc 297,061 pounds valued at $24,306; and manufactures of zinc valued at $48,101. The total imports were equivalent to 13,465 tons of metallic zinc, as against 12,817 tons in 1915 and 11,022 tons in 1914. From 1,000 to 2,000 tons of zinc are probably imported in the form of brass.

The price of spelter in New York on the first of January was about 15½ cents and at the end of December about 9 cents. The highest and lowest prices quoted were respectively 20½ cents, about middle of February and 7¾ cents early in August. The average for the year being 12·804 cents per pound.

COBALT.

Cobalt is being recovered at the smelters at Deloro, Thorold, and Welland, Ontario, in the form of metallic cobalt, cobalt oxide, cobalt sulphate and other salts and also stellite, the cobalt alloy used for high speed tool metal, from silver-cobalt-nickel ores of the Cobalt district. Some cobalt residues from the Nipissing mill have also been shipped to Great Britain.

The total production of cobalt contained in smelter products recovered and in cobalt residues exported during 1916 is estimated at 841,859 pounds valued at $926,045. In 1915, the production was equivalent to 504,212 pounds of cobalt valued at $536,268.

The 1916 production included 215,215 pounds of metallic cobalt; 670,760 pounds of cobalt oxide together with smaller quantities of cobalt sulphate, cobalt carbonate, cobalt hydroxide, unseparated oxides, stellite and cobalt residues.

The 1915 production included 211,610 pounds of metallic cobalt and 423,717 pounds of cobalt oxide and cobalt sulphate.

The price of cobalt was quoted at various times during the year by the Engineering & Mining Journal of New York at from $1.25 to $1.50 per pound.

MOLYBDENUM.

The demand for molybdenite has resulted in considerable exploration of known occurrences and the development of several properties of considerable promise. Shipments were made during 1916 from at least 17 different localities in Quebec, Ontario, and British Columbia of which that at Quyon operated by the Canadian Wood Molybdenite Company is probably the most important. Most of the ores produced were shipped for concentration to the International Molybdenum Company's mill at Renfrew, or the concentrating plant operated by the Mines Department at Ottawa. Some ores were also shipped by the Canadian Wood Molybdenite Company for concentration in Denver, this company has also built a mill near the mine at Quyon and a second mill at Hull, Que. A concentrating mill has also been built by the Renfrew Molybdenum Mines Company at Mt. St. Patrick.

The total MoS_2 contents of concentrates produced and shipped during the year was about 159,000 pounds for which approximately $1.00 per pound has been paid, the official price being 105 shillings per unit of MoS_2 at Liverpool.

A portion of the concentrates have been used in the manufacture of molybdic acid, and ferro-molybdenum at Orillia, Ont. Ferro-molybdenum is also now being made at Belleville, Ont. The Imperial Munitions Board, Ottawa, is an agent for the purchase in Canada of molybdenum for the British Government.

IRON ORE.

Mining operations have been confined to the Helen and Magpie mines of the Algoma Steel Corporation in the Michipicoten district of Ontario, together with a small production of ilmenite at Ivry-on-the-Lake, Quebec, by the Manitou Iron Mining Company. There was also a shipment of concentrates from the concentrator at Trenton, Ont., produced in previous years from ores derived from the Bessemer and Childs mines in Hastings county.

The total shipments in 1916 were 275,176 short tons valued at $715,107 as compared with 398,112 tons valued at $774,427 shipped in 1915. The 1916 shipment included 109,965 tons of Helen ore part of which was sent to Magpie for roasting, 210,522 tons of roasted siderite and blended ore from Magpie; 15,904 tons of magnetite concentrates and 3,209 tons of ilmenite. The shipments in 1915 included 205,989 tons of hematite, 132,906 tons of roasted siderite and 59,217 tons of magnetite (including some ores with an admixture of hematite.)

In the Great Lakes area the ore prices for 1916 were Old Range Bessemer $4.45 per gross ton; Messabi Bessemer $4.20; Old Range Non-Bessemer $3.70, and Messabi Non-Bessemer $3.55, an increase of 70 cents over 1915 prices. The 1917 quotations already fixed are $1.50 in advance of those of 1916.

Mine operators reported 140,608 tons of ore exported to the United States, and 198,992 tons shipped to Canadian furnaces.

According to the records of the Customs Department exports of iron ore amounted to 161,260 tons valued at $541,779, and imports of iron ore to 2,339,667 tons valued at $4,419,013.

Shipments of iron ore from Wabana mines, Newfoundland in 1916 by the two Canadian companies operating there were 1,012,060 short tons all of which was shipped to Cape Breton.

In 1915 the total shipments were 868,451 short tons of which 802,128 tons were shipped to Cape Breton and 66,323 tons to England.

PIG-IRON.

The total production of pig-iron in 1916, not including the output of ferro-alloys was, according to complete returns now received, 1,169,257 short tons (1,043,979 long tons), valued at $16,750,903 as compared with 913,775 short tons (815,870 long tons), valued at $11,374,199 in 1915, showing an increase of 255,482 tons, or 27·9 per cent.

The 1916 production was greater than that of any previous year, the second largest production of pig-iron having been 1,128,967 short tons in 1913.

The production in Nova Scotia in 1916 was 470,055 tons as against 420,275 tons in 1915, an increase of 49,780 tons or 11·8 per cent while the production in Ontario was 699,202 tons in 1916 compared with 493,500 tons in 1915, an increase of 205,702 tons, or 41·7 per cent.

Of the total output in 1916, 17,304 tons were made with charcoal as fuel as against 13,692 tons made with charcoal in 1915.

By grades the 1916 production included: Basic 953,627 tons; Bessemer 31,388 tons; Foundry and Malleable, etc., 184,242 tons. The 1915 production included: Basic 739,613 tons: Bessemer 29,052; Foundry and Malleable, etc., 145,110 tons.

The blast furnace plants operated were the same as in the previous year, viz.: the Dominion Iron & Steel Company at Sydney, N.S., the Nova Scotia Steel & Coal Company, at North Sydney; The Standard Iron Company at Deseronto, Ont., The Steel Company of Canada, at Hamilton, Ont., The Canadian Furnace Company, at Port Colborne, Ont., and the Algoma Steel Corporation at Sault Ste. Marie, Ont.

The production of ferro-alloys in Canada in 1916, chiefly ferro-silicon, but including also ferro-phosphorus and ferro-molybdenum, all made in electric furnaces was 28,628 tons valued at $1,777,615, as compared with a production in 1915 of 10,794 tons valued at $753,404.

The exports during 1916 of pig-iron were 23,304 tons, valued at $374,383 or an average per ton of $16.07 and of ferro-silicon and ferro-compounds 22,802 tons valued at $1,352,013, or an average of $59.29 per ton.

The imports during 1916 included 57,337 tons of pig-iron valued at $1,128,557, or an average of $19.68 per ton; 793 tons of charcoal pig valued at $16,593, or an average of $20.92, and 14,777 tons of ferro-products valued at $1,879,538, or an average of $127.19 per ton, making a total import of pig-iron and ferro-alloys of 72,907 tons valued at $3,024,688.

STEEL INGOTS AND CASTINGS.

The estimated production of steel ingots and castings in 1916 as published at the end of December (complete returns have not yet been received) was 1,454,124 short tons (1,298,325 gross tons) of which 1,423,485 short tons were ingots and 30,639 tons direct steel castings. The total production in 1915 was 1,020,896 short tons, showing an increase in 1916 of 433,228 tons, or over 42 per cent. The 1916 production was greater than that of any previous year the second largest production having been 1,168,993 short tons in 1913.

Of the total production of steel ingots and castings in 1916, about 19,639 short tons (17,535 gross tons) were made in electric furnaces. In 1915, 5,625 tons, and in 1914 only 61 short tons were reported as having been made in electric furnaces.

ASBESTOS.

The asbestos industry has been particularly active during 1916, the value of the production having been the highest on record though the quantity was slightly exceeded in 1913. Stocks on hand at the end of the year were reduced to a minimum. Production, as usual, has been confined to the asbestos district of Black Lake, Thetford, Robertsonville, Danville, and East Broughton, in the Eastern Townships, Province of Quebec.

The total output in 1916, was 118,246 tons which, compared with 106,559 tons in 1915, shows an increase of 11,687 tons or 11 per cent. The sales during 1916 were 136,016 tons valued at $5,133,332 or an average of $37.74 per ton, as against sales in 1915 of 111,142 tons valued a $3,553,366 or an average of $31.97 per ton, showing an increase of 24,874 tons or 22·4 per cent in quantity, and $1,579,966 or 44·4 per cent in value. The 1916 sales included 5,893 tons of crude asbestos valued at $1,867,064 or an average of $316.82 per ton, and 130,123 tons of milled fibre valued at $3,266,268 or an average of $25.10 per ton. The 1915 sales included 5,370 tons of crude asbestos valued at $1,076,297 or an average of $200.43 per ton, and 105,772 tons of milled fibre valued at $2,476,869 or an average of $23.42 per ton.

Stocks on hand at December 31st, 1916 were reported as only 6,081 tons, as compared with 24,345 tons on hand December 31st, 1915, and 31,171 tons on hand December 31st, 1914. Sales of asbestic in 1916 were 18,500 tons valued at $27,147 an average of $1.46 per ton, as compared with sales in 1915 of 21,031 tons valued at $17,540 or an average of $0.83 per ton.

The total quantity of asbestos rock sent to mills during the year was 1,822,461 tons from which was obtained 112,832 tons of fibre or an average recovery of 6·20%.

Output, Sales and Stocks of Asbestos 1915 and 1916.

	1915			1916		
	Crude	Milled	Total	Crude	Milled	Total
Output..........Tons	3,987·2	102,572	106,559·2	5,414·34	112,832	118,246·34
Sold.............. „	5,370·0	105,772	111,142	5,893·13	130,123	136,016·13
Value sales............	$1,076,297	$2,476,869	$3,553,166	$1,867,064	$3,266,268	$5,133,332
Average per ton........	$200.43	$23.42	$31.97	$316.82	$25.10	$37.74
Stocks, Dec. 31, 1916. Tons	906·6	23,439	24,345·6	1,079	5,002	6,081

Exports of asbestos during the calendar year 1916 were 96,775 tons valued at $3,872,463, or an average of $40.01 per ton, as compared with exports in 1915 of 84,584 tons valued at $2,734,695, or an average of $32.45 per ton. There was also an export of asbestos sand and waste amounting to 33,564 tons, valued at $241,272, or an average of $7.18 per ton, and of manufactures of asbestos valued at $4,741. The exports of sand and waste in 1915 were 25,103 tons, valued at $157,410, or an average of $6.27 per ton, and of manufactures of asbestos valued at $125,003.

Imports of asbestos manufactures for the year were valued at $136,670 as against a value of $168,894 in 1915.

CHROMITE.

The total shipments of crude chromite ores in 1916 were 27,030 tons, valued at $299,753. These ores contained a total of approximately 6,574 tons of Cr_2O_3 or an average of about 24 per cent. A considerable portion of the low grade ore and sand, however, amounting to 14,242 tons, was sent to concentrating mills for concentration before being marketed. The quantity thus concentrated was 10,992 tons from which were recovered 1,046 tons of concentrates, averaging from 42 per cent to over 50 per cent of Cr_2O_3. The final shipments of ore and concentrates would approximate 13,834 tons.

The exports of chromite are reported by the Customs Department as 12,633 tons, valued at $152,534.

Production in 1915 was reported as 12,341 tons, valued at $179,540, with exports of 7,290 tons, valued at $81,838.

Practically the entire production has been obtained in the district tributary to Thetford, and Black Lake, in the Eastern Townships, Quebec.

COAL AND COKE.

Coal. The total production of marketable coal during 1916, (comprising sales and shipments, colliery consumption, and coal used in making coke, or used otherwise by colliery operators), was 14,461,678 short tons, valued at $38,857,557, as against 13,267,023 short tons, valued at $32,111,182 in 1915, showing an increase of 1,194,655 tons or 9 per cent in quantity, and of $6,746,375 or 21 per cent in total value.

Arbitrary values are assumed for Nova Scotia and British Columbia, viz.: $3.00 per long ton for the former, and $3.50 per long ton for the latter. In the other Provinces values are as furnished by the operators.

Each of the coal producing provinces of the West shows not only an increase, but also its maximum production. New Brunswick shows a slight increase, while Nova Scotia and the Yukon report decreases.

The Nova Scotia production was 6,894,728 short tons, a decrease of 568,642 tons or 7·6 per cent as compared with 1915; the Alberta production, 4,563,020 tons, shows an increase of 1,202,202 tons or 35·8 per cent over the previous year; the British Columbia production, 2,582,737 short tons, an excess of 517,124 tons or 25·1 per cent; the Saskatchewan production, 280,835 tons, shows an increase of 40,728 tons or about 17 per cent; the New Brunswick production, 137,058 tons, shows an increase of 9,667 net tons or 7·6 per cent. The Yukon production is reported as 3,300 tons.

Production of Coal.

Province	1914		1915		1916	
	Tons	Value	Tons	Value	Tons	Value
		$		$		$
Nova Scotia	7,370,924	16,452,955	7,463,370	16,659,308	6,894,728	18,468,021
Alberta	3,683,015	9,350,392	3,360,818	8,283,079	4,563,020	11,496,106
British Columbia	2,239,799	6,999,374	2,065,613	6,455,041	2,582,737	8,071,053
Saskatchewan	232,299	374,245	240,107	365,246	280,835	442,136
New Brunswick	98,049	241,075	127,391	309,612	137,058	367,041
Yukon Territory	13,443	53,760	9,724	38,896	3,300	13,200
	13,637,529	33,471,801	13,267,023	32,111,182	14,461,678	38,857,557

The exports of coal in 1916 were 2,135,359 tons, valued at $7,099,387, as compared with exports of 1,766,543 tons in 1915, valued at $5,406,058, showing an increase of 368,816 tons or 20·9 per cent.

The total imports of coal in 1916 were 17,580,603 tons, valued at $38,289,666, made up as follows: bituminous, round and run of mine, 9,504,552 tons, valued at $12,368,679 or an average of $1.30 per ton; bituminous slack, 3,505,236 tons valued at $3,704,624, or an average of $1.06 per ton; and anthracite, 4,570,815 tons, valued at $22,216,363, or an average of $4.86 per ton. There were thus increases in all three classes of coal, bituminous, round and run of mine increasing by 3,397,758 tons, or 55·6 per cent; bituminous slack by 1,218,320 tons or 53·3 per cent; anthracite by 498,623 tons or 12·2 per cent, or a total increase of

5,114,701 tons or over 41 per cent in quantity, while the total value shows an increase of $9,944,061 or 35·1 per cent. Details of imports follow:—

Imports of Coal.

	1915			1916		
	Tons	Value	Aver.	Tons	Value	Aver.
		$			$	
Bituminous, round and run of mine	6,106,794	7,564,369	1·24	9,504,552	12,368,679	1·30
Bituminous, slack...............	2,228,916	2,027,256	0·89	3,505,236	3,704,624	1·06
Anthracite, coal and dust........	4,071,192	18,753,980	4·61	4,570,815	22,216,363	4·86
Total........................	12,465,902	28,345,605	2·27	17,580,603	38,289,666	2,18

The apparent consumption of coal during 1916 was therefore 29,884,139 tons as against 23,906,692 tons in 1915. Canadian mines contributed 41 per cent of the domestic consumption and the balance was imported. The total Canadian production was equivalent to about 48·4 per cent of the consumption.

Coke. The total output of oven coke during 1916 was 1,448,782 short tons made from 2,134,911 tons of coal of which 1,501,835 tons were of domestic origin and 633,076 were imported. The total coke used or sold by the producers during the year was 1,469,741 tons, valued at $6,045,412, or an average of $4.19 per ton. In 1915 the output was 1,200,766 tons, and the quantity sold or used by the producers was 1,170,473 tons, valued at $4,258,580, or an average of $3.64 per ton. Returns in 1916 show a recovery of 67·9 per cent of the total coal charged, as compared with 64·7 per cent in 1915.

By provinces the output was: Nova Scotia, 653,836 tons, an increase of 68,843 tons; Ontario, 452,502 tons (all from imported coal), an increase of 136,291 tons; Alberta, 42,548 tons, an increase of 18,361 tons; and British Columbia, 299,896 tons, an increase of 24,521 tons. By-products from coke ovens included: 11,040 short tons of sulphate of ammonia; 9,012,202 gallons tar; 5,058,636 thousand cubic feet of gas; and were in excess of the previous year's production. Benzol, toluol, naphtha, and naphthalene were also produced in 1916. The ovens operated during the year were those at Sydney, and Sydney Mines, N.S., Sault Ste. Marie, Ont., Coleman, Alta., and Fernie, Michel, and Union Bay, B.C.: all others were idle throughout the year. At the close of the year, 1,907 ovens were in operation. The imports of coke in 1916, the highest recorded, were 757,116 tons, valued at $3,229,078, while the exports were 48,539 tons, valued at $221,334.

FELDSPAR.

Feldspar was derived from the same district as in previous years, viz.: Frontenac county, Ontario, and Hull and Villeneuve townships, Quebec. Shipments in 1916, which were the highest recorded amounted, to a total of 19,166 tons, valued at $71,357, or an average of $3.72 per ton, and included 14,878 tons, valued at $53,332 from Ontario and 4,288 tons, valued at $18,025 from Quebec.

FLUORSPAR.

Shipments of fluorspar were made from Madoc, Ontario, during 1916 amounting to 1,284 tons, valued at $10,238. This was practically the first commercial operation of these deposits.

Imports of fluorspar are not shown separately in the Customs records, but there is an annual consumption in steel furnaces of from 10,000 to 15,000 tons.

GRAPHITE.[1]

The total shipments of milled and refined graphite were 3,955 tons, valued at $325,362, or an average of $82.28 per ton, and included 479 tons, valued at $75,776 from Quebec, and 3,476 tons, valued at $249,586 from Ontario.

The production includes material varying in value from $54 to $270 per ton.

The production in 1915 was 2,635 tons, valued at $124,223.

Exports of plumbago, crude and concentrates, were reported as 311 tons, valued at $13,114, and of manufactures of plumbago to the value of $304,919.

GYPSUM.

The total quantity of gypsum rock quarried in 1916, was 422,741 tons, of which 92,864 tons were calcined. The shipments of gypsum of all grades totalled 341,618 tons, valued at $730,831, and included lump, 249,759 tons, crushed 15,680 tons, fine ground 6,057 tons, and calcined 70,122 tons.

In 1915, the quantity quarried was 505,989 tons, of which 84,763 tons were calcined. The shipments included: lump 346,947 tons, crushed 48,735 tons, fine ground 6,453 tons, and calcined 72,678 tons, or a total of 474,815 tons, valued at $854,929.

Exports of crude gypsum were 221,234 tons, valued at $252,476, while exports classed as gypsum or plaster, ground, rose to a value of $154,630. The corresponding exports in 1915 were crude gypsum 292,234 tons, valued at $336,380, and gypsum or plaster, ground, valued at $80,933.

MAGNESITE.

Magnesite was quarried and shipped chiefly from Grenville township, Argenteuil county, Quebec, supplemented by several hundred tons from Atlin district in British Columbia.

The total shipments in 1916 were 55,413 tons, valued at $563,829, or an average of $10.17 per ton.

In 1915 the shipments were 14,779 tons, valued at $126,584, or an average of $8.56 per ton, and in 1914, 358 tons, valued at $2,240.

NATURAL GAS.

The total production of natural gas according to returns received, was 25,238,568 thousand cubic feet, valued at $3,924,632, as compared with a production in 1915 of 20,124,162 thousand cubic feet, valued at $3,706,035. The production by provinces was as follows: Ontario 17,838,318 thousand cubic feet, valued at $2,730,653; New Brunswick 610,118 thousand cubic feet, valued at $79,628, and Alberta 6,818,131 thousand cubic feet, valued at $1,114,351.

PETROLEUM.

There has been comparatively little change in the production of petroleum during the past three years although since 1907 there has been a distinct falling off. A bounty of 1½ cents per gallon is paid on the marketed production of crude oil from Canadian oil fields through the Department of Trade and Commerce. From the bounty statistics it appears that the 1916 production in Ontario and New Brunswick was 198,123 barrels on which bounties amounting to $104,014.13

---

[1] Statistics revised.

were paid. The market value of the crude oil at $1.97-11/12 per barrel amounted to $392,284. In Alberta there was a small production of crude oil, but no bounty was paid on this as the specific gravity was below the standard set by the Petroleum Bounty Act and complete records have not as yet been received from the producers.

The total production of crude oil (exclusive of Alberta), in 1916 was therefore 198,123 barrels, valued at $392,284 as compared with a production in 1915 of 215,464 barrels, valued at $300,572, showing a decrease of about 8 per cent in quantity, but on account of the higher price an increase of over 30 per cent in total value.

The price of crude increased from $1.73 at the beginning of the year to $2.13 on March 16, declining to $1.83 on August 14 and increasing again to $1.98 at the end of the year, the average for the year being $1.979.

The Ontario production in 1916 was according to the records of the Department of Trade and Commerce at Ottawa, 196,778 barrels. The production in barrels of the various fields as furnished by the Supervisor of Petroleum Bounties at Petrolia was as follows: Lambton 142,208 barrels, Bothwell 33,856 barrels, Dutton 2,851 barrels, Tilbury 16,296 barrels, Onondaga and Belle River 1,663 barrels, or a total of 196,894 barrels.

The production in New Brunswick was 1,345 barrels as against 1,020 barrels in 1915 and 1,725 barrels in 1914.

Exports of petroleum entered as crude mineral oil in 1916 were 137,647 gallons, valued at $11,439, and of refined oil, 446,595 gallons, valued at $48,137. There was also an export of naptha and gasoline of 54,806 gallons, valued at $14,195.

The total value of the imports of petroleum and petroleum products in 1916 was $14,701,521, as against a value of $8,047,781 in 1915.

The total imports of petroleum oils, crude and refined in 1916 were 292,340,271 gallons, valued at $14,600,674. These oil imports included: crude fuel and gas oils 253,007,420 gallons, valued at $8,456,020; coal and kerosene and illuminating oils 8,080,107 gallons, valued at $542,893; lubricating oils 5,466,076 gallons, valued at $973,253; gasoline 18,321,891 gallons, valued at $3,624,931 and other oils, products of petroleum 7,464,777 gallons, valued at $1,003,577. The imports of petroleum products included 1,061,112 pounds of paraffin wax, valued at $70,308 and paraffin wax candles 220,264 pounds, valued at $30,539, or a total of $100,847.

PYRITES.

The production of pyrites in 1916 was 309,411 tons, valued at $1,084,019 and included 130,799 tons, valued at $523,196 from Quebec, 177,552 tons, valued at $555,523 from Ontario, and 1,060 tons, valued at $5,300 from British Columbia. In 1915 the total production was 286,038 tons, valued at $985,190, which included 142,735 tons, valued at $570,940 from Quebec, and 143,303 tons, valued at $414,250 from Ontario.

Exports of pyrites in 1916 were 156,722 tons, valued at $557,024, or an average of $3.55 per ton. Exports of sulphuric acid were 3,151,700 pounds valued at $74,527.

SALT.

The Canadian salt production is obtained from southern Ontario. The total sales in 1916 were 124,033 tons, valued at $668,627 (exclusive of the cost of packages). The 1915 sales were 119,900 tons, valued at $600,226.

In addition to the production of salt, brine is pumped for use in chemical works at Sandwich, Ontario, where caustic soda and bleaching powder are manufactured by the Canadian Salt Co.

The exports of salt in 1916 were 305,900 pounds, valued at $2,223. The total imports of salt were 151,208 tons, valued at $694,835, and included 34,035 tons of fine salt in bulk, valued at $111,130; 7,679 tons of salt in packages, valued at $59,980, and 109,493 tons of salt imported from Great Britain for the use of fisheries, valued at $523,725. The total imports in 1915 were 137,486 tons, valued at $517,526.

CEMENT.

The production of structural materials and clay products which showed a large falling off in both 1914 and 1915, shows a further decrease in 1916. The total value of the production in 1916 was $17,301,726, as against $17,920,759 in 1915, and $26,009,227 in 1914.

The total quantity of portland cement including natural portland, made in 1916 was 4,753,034 barrels of 350 pounds each, as compared with 5,153,767 barrels in 1915, a decrease of 400,733 barrels, or about 7·8 per cent.

The total quantity of Canadian portland cement sold, or used during 1916 was 5,359,050 barrels, valued at $6,529,861 or an average of $1.218 per barrel, as compared with 5,681,032 barrels sold or used in 1915, valued at $6,977,024, or an average of $1.228, showing a decrease of 321,982 barrels, or about 5·7 per cent.

The total imports of cement in 1916 were 72,087 cwt., equivalent to 20,595 barrels of 350 pounds each, valued at $31,621 or an average of $1.54 per barrel, as compared with imports of 28,190 barrels, valued at $40,426, or an average of $1.43 per barrel in 1915.

The total consumption of cement, therefore, neglecting a small export was 5,379,645 barrels, as compared with a consumption of 5,709,222 barrels in 1915, showing a decrease of 329,577 barrels, or about 5·8 per cent.

The average price per barrel at the works in 1916 was $1.218 as compared with $1.228 in 1915, $1.28 in 1914, $1.27 in 1913, $1.28 in 1912, and $1.34 during 1911 and 1910.

The imports of cement in 1916 included 72,083 cwt., valued at $31,616 from the United States, and 4 cwt., valued at $5 from Great Britain.

Production and Sales of Portland Cement.

	1913.	1914.	1915.	1916.
	Brls.	Brls.	Brls.	Brls.
Portland cement sold or used	8,658,805	7,172,480	5,681,032	5,359,050
" " manufactured	8,886,333	8,727,269	5,153,763	4,753,034
Stock on hand Jan. 1st	862,067	1,073,328	2,620,022	2,061,756
" " Dec. 31st	1,089,595	2,628,117	2,062,961	1,444,876
Value of cement sold or used	$11,019,418	$9,187,924	$6,977,024	$6,529,861
Wages paid	$3,466,451	$2,271,096	$1,184,459	$1,307,222
Men employed	4,276	2,977	1,686	1,696

Consumption of Portland Cement.

Calendar Year.	Canadian.		Imported.		Total.
	Barrels.	Per cent.	Barrels.	Per cent.	Barrels.
1911	5,692,915	90·0	661,916	10·0	6,354,831
1912	7,132,732	83·3	1,434,413	16·7	8,567,145
1913	8,658,805	97·1	254,093	2·9	8,912,988
1914	7,172,480	98·7	98,022	1·3	7,270,502
1915	5,681,032	99·5	28,190	0·5	5,709,222
1916	5,359,050	99·6	20,595	0·4	5,379,645

Exports of Products of the Mine and Manufacture of Mine Products, Calendar Year, 1916.

Products.		Quantity.	Value.
Arsenic	Cwt.	39,505	$ 197,458
Asbestos	Tons.	96,775	3,872,463
Asbestos sand and waste	„	33,564	241,272
Coal	„	2,135,359	7,099,387
Cobalt (nine months only)		....	712,880
Chromite (Chromic Ore)	Tons.	12,633	152,534
Corundum	„	56	8,583
Feldspar, Magnesite, Talc, etc.		....	329,215
Gold-bearing quartz, dust, nuggets, etc.		....	18,382,903
Gypsum or plaster, crude	Tons.	221,156	252,476
Metals, viz:—			
Copper, fine, contained in ore, matte, regulus, etc.	Cwt.	1,249,424	20,776,536
Lead, metallic, contained in ore, etc.	„	90,484	558,180
Nickel, fine, contained in ore, matte, or speiss	„	804,417	8,662,179
Platinum, contained in concentrates or other forms	Ozs.	532	41,945
Silver, metallic, contained in ore concentrates, etc.	„	25,279,359	15,637,885
Mica	Lbs.	1,308,793	379,720
Mineral pigments, iron oxides, ochres	Cwt.	33,917	25,312
Mineral Water, natural, not in bottles	Gals.	229	22
Mineral wax	Cwt.	80,987	201,653
Oil:—			
Mineral, coal and kerosene, crude	Gals.	137,647	11,439
Mineral, coal and kerosene, refined	„	446,595	48,137
Gasoline and naphtha	„	54,806	14,194
Ores:—			
Antimony	Tons.	794	48,158
Iron	„	161,260	541,779
Manganese	„	957	89,544
Other	„	69,331	1,348,540
Phosphates	„	103	1,543
Plumbago, crude ore and concentrates	Cwt.	6,223	13,114
Pyrites	Tons.	156,722	557,024
Salt	Cwt.	3,059	2,223
Sand and Gravel	Tons.	1,114,913	388,309
Stone, ornamental, granite, marble, etc., unwrought	„	15,967	7,989
Stone, building, freestone, limestone, etc., unwrought	„	128,453	103,796
Stone, crushed	„	26,754	27,611
Stone, for manufacture of grindstones, rough	„	356	1,764
Other articles of the mine		....	17,694
Total mine products		....	$80,755,461
MANUFACTURES.			
Agricultural implements and machines, viz.:—			
Mowing machines	No.	6,672	$ 233,024
Cultivators	„	4,219	142,028
Reapers	„	1,115	65,011
Drills	„	4,713	317,831
Harvesters and binders	„	7,495	814,517
Ploughs	„	17,700	483,650
Harrows	„	6,691	97,214
Hay rakes	„	2,011	43,746
Seeders	„	2	128
Threshing machines	„	1,522	465,209
All others		....	292,603
Parts		....	750,966
Asbestos, manufactures of		....	4,741
Bricks	M.	1,746	13,942
Cement		....	2,424
Clay, manufactures of		....	58,550

Exports of Products of the Mine and Manufactures of Mine Products, Calendar Year 1916—*Continued.*

Product.		Quantity.	Value.
MANUFACTURES—*Concluded.*			
Coke	Tons.	48,539	$ 221,334
Cream separators			34,567
Drugs, chemicals and medicines, viz.:—			
Acetate of lime	Cwt.	73,589	216,397
Acid sulphuric	„	31,517	74,527
Calcium carbide	„	1,469,663	4,369,085
Phosphorus	Lbs.	834,950	122,323
Earthenware, and manufactures of			7,620
Fertilizers			3,338,413
Gasoline engines	No.	529	86,310
Grindstones, manufactured			43,178
Gypsum or plaster, ground			154,630
Iron and steel and manufactures of, viz:—			
Stoves of all kinds			29,956
Gas buoys and parts of			2,484
Castings, n.o.p			167,881
Ferro-silicon and ferro-compounds	Tons.	22,802	1,352,013
Pig-iron	„	23,304	374,383
Linotype machines, and parts of			35,465
Machinery, n.o.p			1,206,863
Sewing machines, and parts of			82,032
Washing machines, domestic, and wringers			5,763
Typewriters	No.	3,597	246,761
Scrap iron or steel	Cwt.	2,285 991	1,357,018
Hardware, viz.:—			
Tools, hand or machine			376,549
Wire, and wire nails	Cwt.	2,450,517	8,597,320
Hardware, n.o.p			515,613
All other n.o.p			38,974,154
Lead in pigs, etc	Cwt.	1,121	7,710
Lime			66,406
Metals:—			
Aluminium in bars, blocks, etc	Cwt.	184,253	5,201,066
Aluminium, manufactures of			26,780
Brass, old and scrap	Cwt.	375,037	6,064,779
Copper, in pigs, bars, sheets, etc	„	24,304	581,268
Copper, old and scrap	„	58,466	1,284,895
Metallic shingles and laths and corrugated roofing			30,563
Plated ware, n.o.p			15,050
N.o.p			3,143,135
Mineral and aerated waters in bottles			1,576
Oil, n.o.p	Gals.	3,391,857	1,038,025
Plumbago, manufactures of			304,919
Stone of all kinds, dressed			4,592
Tar			50,352
Tin, manufactures of			16,284
Vehicles:—			
Automobiles	No.	12,579	6,078,668
„ parts of			672,060
Bicycles	No.	580	50,894
„ parts of			5,877
Total Manufactures			$90,423,122
Grand Total			$171,178,583

Mineral Production in Canada, 1915.

(Revised).

Product.		Quantity. (a)	Value. (b)
METALLIC.			
Antimony ore	Tons.	1,341	$ 81,283
Antimony refined	Lbs.	59,440	11,888
Cobalt metallic and contained in oxide, etc	„	504,212	536,268
Copper, value at 17·275 c per lb	„	100,785,150	17,410,635
Gold	Ozs.	918,056	18,977,901
Iron, pig, from Canadian ore (c)	Tons.	158,595	1,715,874
Iron ore sold for export	„	89,730	181,381
Lead, value at 5·600 c per lb	Lbs.	46,316,450	2,593,721
Molybdenite	„	29,210	28,450
Nickel, value at 30 c per lb	„	68,308,657	20,492,597
Platinum	Ozs.	23	1,063
Silver, value at 49·684 c per lb	„	26,625,960	13,228,842
Zinc ore	Tons.	14,895	554,938
Total		....	75,814,841
NON-METALLICS.			
Actinolite	Tons.	220	$ 2,420
Arsenious oxide	„	2,396	147,830
Asbestos	„	111,142	3,553,166
Asbestic	„	25,700	21,819
Chromite	„	12,341	179,543
Coal	„	13,267,023	32,111,182
Corundum	„	262	33,138
Feldspar	„	14,559	57,801
Graphite	„	2,635	124,223
Graphite (artificial)	„	249	....
Grindstones	„	2,580	35,768
Gypsum	„	474,815	854,929
Magnesite	„	14,779	126,584
Manganese	„	201	9,360
Mica	„	....	91,905
Mineral pigments:—			
Barytes	Tons.	550	$ 6,875
Oxides	„	6,248	48,353
Mineral water		....	115,274
Natural gas	M. cu. ft.	20,124,162	3,706,035
Peat	Tons.	300	1,050
Petroleum (*d*)	Bls.	215,464	300,572
Phosphate	Tons.	217	2,502
Pyrites	„	286,038	985,190
Quartz	„	127,108	205,153
Salt	„	119,900	600,226
Talc	„	11,885	40,554
Tripolite	„	317	12,119
Total		....	$43,373,571
Cement portland	Bls.	5,681,032	$ 6,977,024
Clay products:—			
Brick, common	No.	234,732,882	1,755,187
Brick, pressed	„	49,817,160	492,774
Brick, paving	„	1,227,647	20,694
Brick, moulded and ornamental	„	1,008,567	49,097
Fireclay, and fireclay products		....	110,693
Fireproofing architectural terra-cotta		....	253,401

Mineral Production in Canada, 1915.—*Concluded.*

Product.	Quantity. (*a*)	Value. (*b*)
Clay Products:—		
Kaolin... Tons.	1,300	$ 13,000
Pottery...	...	64,900
Sewerpipe...	...	799,446
Tile, drain... No.	...	355,296
Lime... Bus.	5,047,244	1,015,702
Sand-lime brick... No.	17,960,802	141,742
Sand and gravel...	6,445,717	1,624,767
Slate... Sq.	397	2,039
Stone:—		
Granite...	...	1,525,553
Limestone...	...	2,312,081
Marble...	...	158,027
Sandstone...	...	249,336
Total...	...	$17,920,759
Grand Total...	...	$137,109,171

(*a*) Quantity of product sold or shipped. Tons of 2,000 pounds.

(*b*) The metals copper, lead, and silver are for the purpose of these statistics valued at the prices of the metals as quoted in recognized markets. Nickel is valued at less than market price because a considerable portion of the output is marketed as monel metal and sold at a price less than that of nickel.

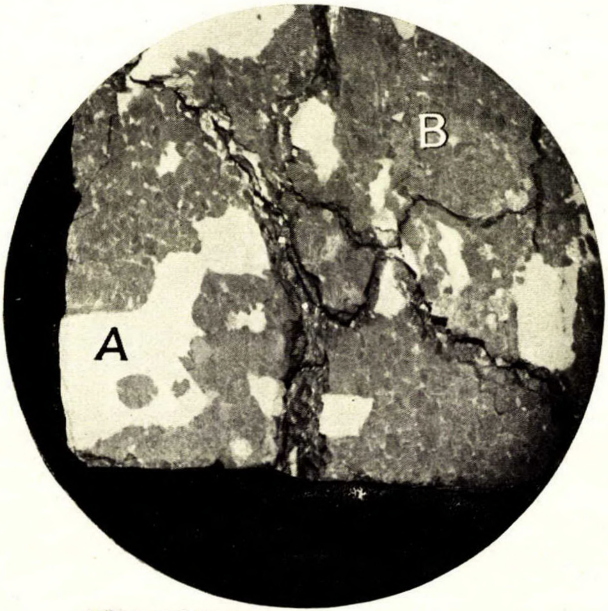
(*c*) The total production of pig-iron in Canada in 1914 was 913,775 tons of which it is estimated 158,595 tons should be credited to Canadian ore and 755,180 tons to imported ore.

(*d*) Production based on claims made for bounty.

Annual Mineral Production in Canada Since 1886.

Year.	Value of production.	Value per capita.	Year.	Value of production.	Value per capital.
1886...	$10,221,255	$ 2.23	1902...	$ 63,231,836	$11.36
1887...	10,321,331	2.23	1903...	61,740,513	10.83
1888...	12,518,894	2.67	1904...	60,082,771	10.27
1889...	14,013,113	2.96	1905...	69,078,999	11.49
1890...	16,763,353	3.50	1906...	79,286,697	12.81
1891...	18,976,616	3.92	1907...	86,865,202	13.75
1892...	16,623,415	3.39	1908...	85,557,101	13.16
1893...	20,035,082	4.04	1909...	91,831,441	13.70
1894...	19,931,158	3.98	1910...	106,823,623	14.93
1895...	20,505,917	4.05	1911...	103,220,994	14.42
1896...	22,474,256	4.38	1912...	135,048,296	18.27
1897...	28,485,023	5.49	1913...	145,634,812	18.77
1898...	38,412,431	7.32	1914...	128,863,075	15.96
1899...	49,234,005	9.27	1915...	137,109,171	...
1900...	64,420,877	12.04	1916...	177,357,454	...
1901...	65,797,911	12.16			

PLATE I.



[redacted]t of calcined magnesite rock.

Section at Highwood pass, Kananaskis lakes, Alberta, showing Triassic, sandy shales (A) resting against nearly vertical Rocky Mountain Quartzite (B). The phosphate bed occupies the position shown by the white line, or almost at the quartzite-shale contact.

Inclined Rocky Mountain Quartzite, Tent Mountain, between Crowsnest and Corbin, B.C. The bed forming the slope is the uppermost member of the quartzite, and is about 3 feet thick. The phosphate occurs in the form of small nodules in the lower 2 inches of this bed. The flat terrace at the base of the slope lies at a considerable height above the valley, and consists chiefly of shale weathered down from above.

PLATE IV.

Block of Rocky Mountain Qnartzite from bed shown in the preceding illustration, showing nodular phosphate (light-coloured) in the lower part of the bed. The block has turned over in falling and lies upside down. This was the most southerly outcrop of the phosphate found in the region examined.

Vein of amorphous graphite, near Marysville, B.C. A sample of selected material from this vein showed almost 25 per cent carbon.

EXPLANATION OF PLATE VI.

Microphotographs

No. 3 Albany Sand

(Oblique reflected light)
(Magnification—20 diams.)

1. Fresh sand,
2. After 1st. Burn,
3. „ 2nd. „
4. „ 3rd. „
5. „ 4th. „
6. „ 5th. „

PLATE VI.

1

2

3

4

5

6

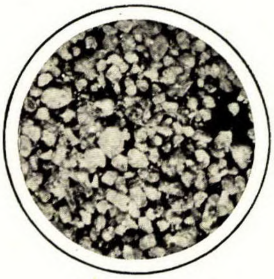
Explanation of Plate VII.

Microphotographs

Brockville Sand
(Fleck's Foundry)

(Oblique reflected light)
(Magnification—20 diams.)

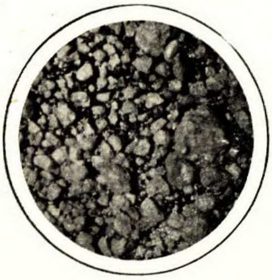
7. Fresh sand,
8. After 1st. Burn,
9. „ 2nd. „
10. „ 3rd. „
11. „ 4th. „
12. „ 5th. „



7

10

8



11

9

12

EXPLANATION OF PLATE VIII.

Microphotographs

Brockville Sand,
(Lawson's Foundry)

(Oblique reflected light)
(Magnification—20 diams.)

13. After 1st. Burn,
14. „ 3rd. „
15. „ 4th. „
16. „ 5th. „
17. „ 7th. „
18. No. 0 Albany Fresh Sand.

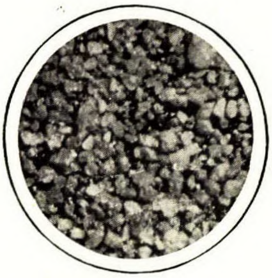
PLATE VIII.


13


14

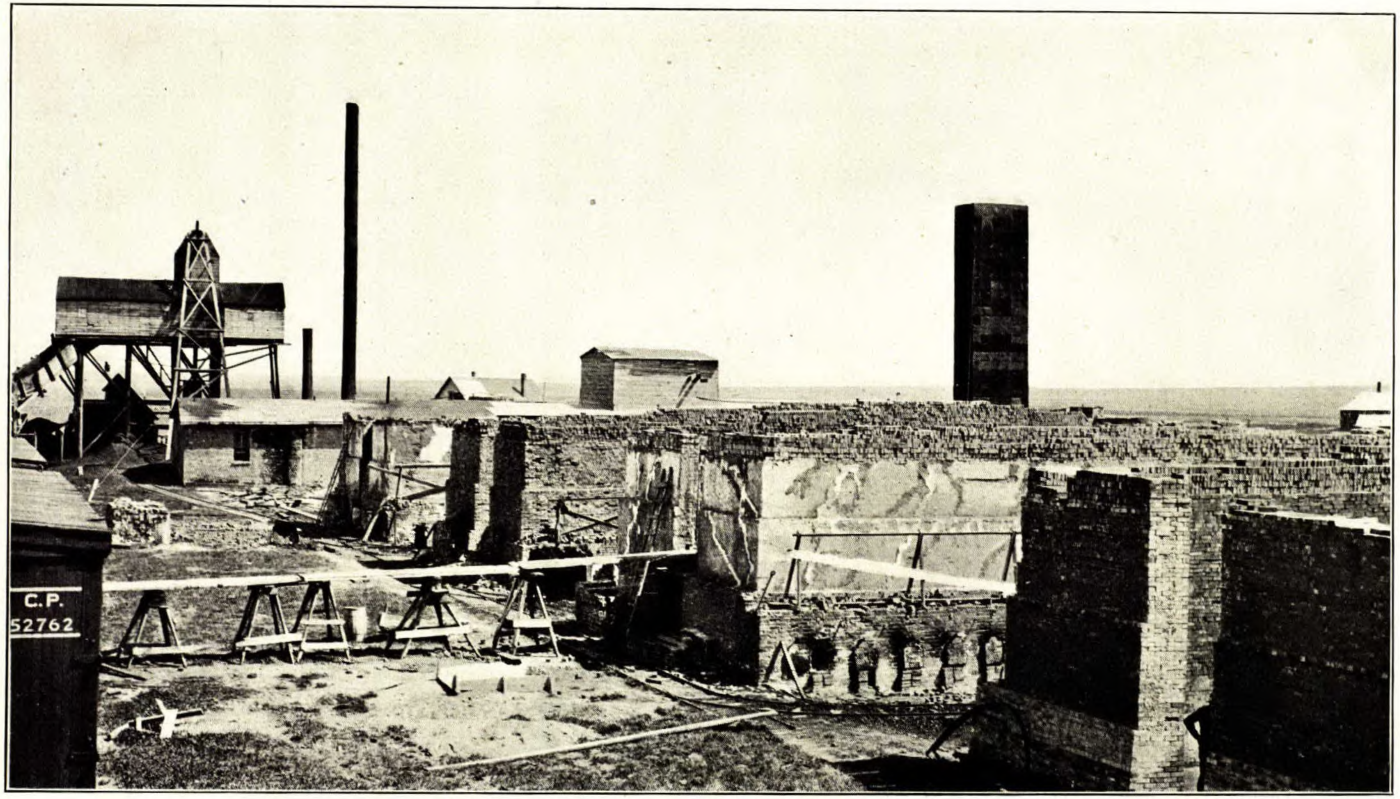

15


16


17

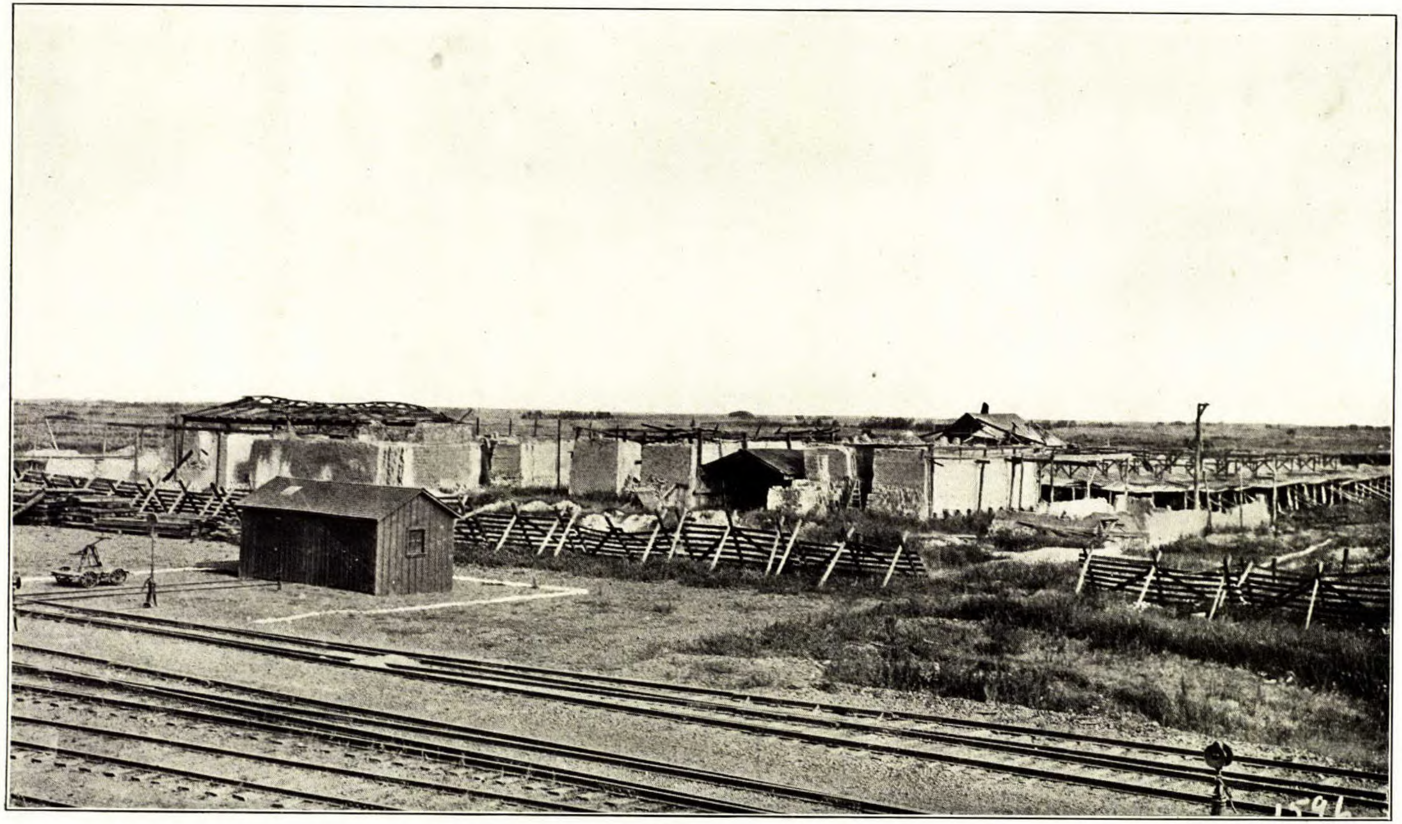

18

PLATE IX.



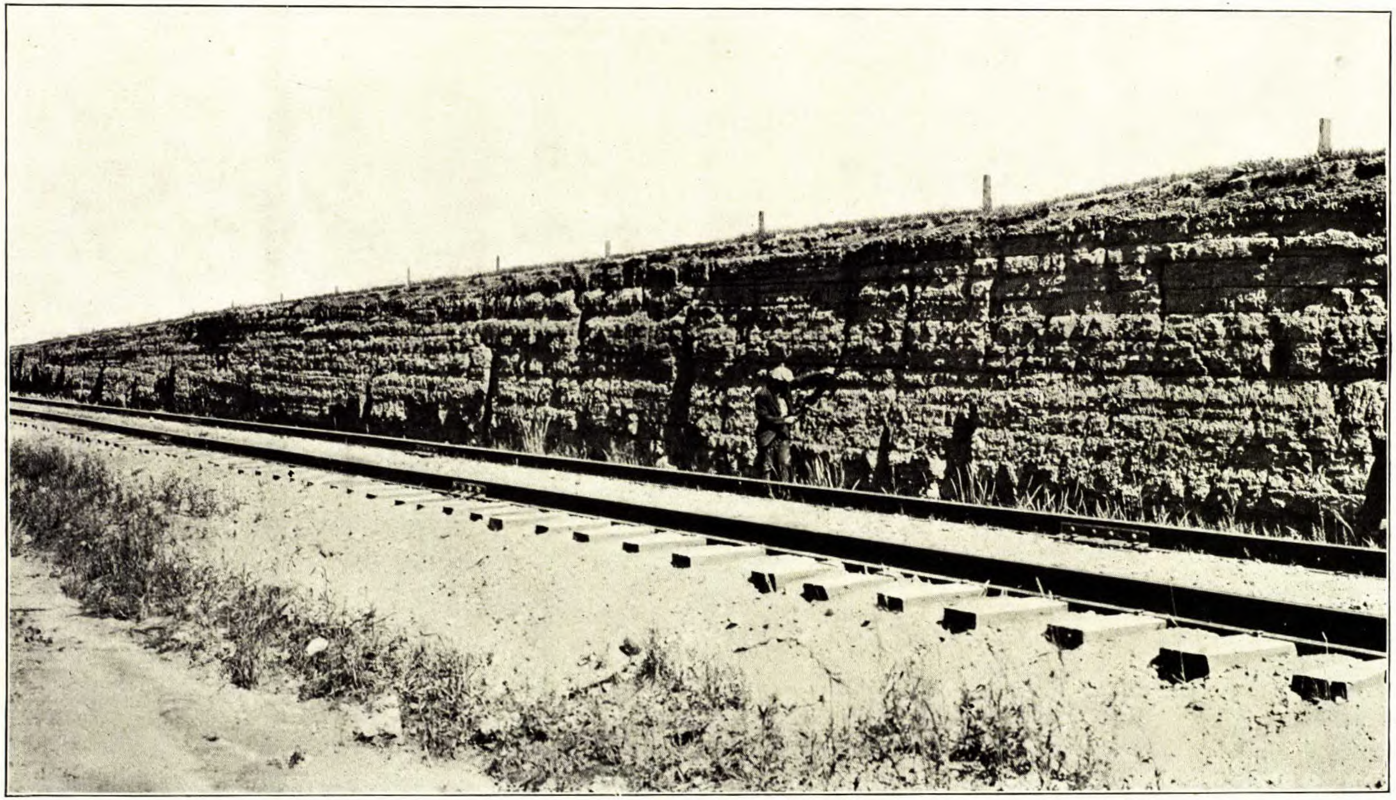
Clay plant and coal tipple of the Shand Coal and Brick Co., Shand, Sask.

PLATE X.



Plant of the Broadview Brick Co., Broadview, Sask.

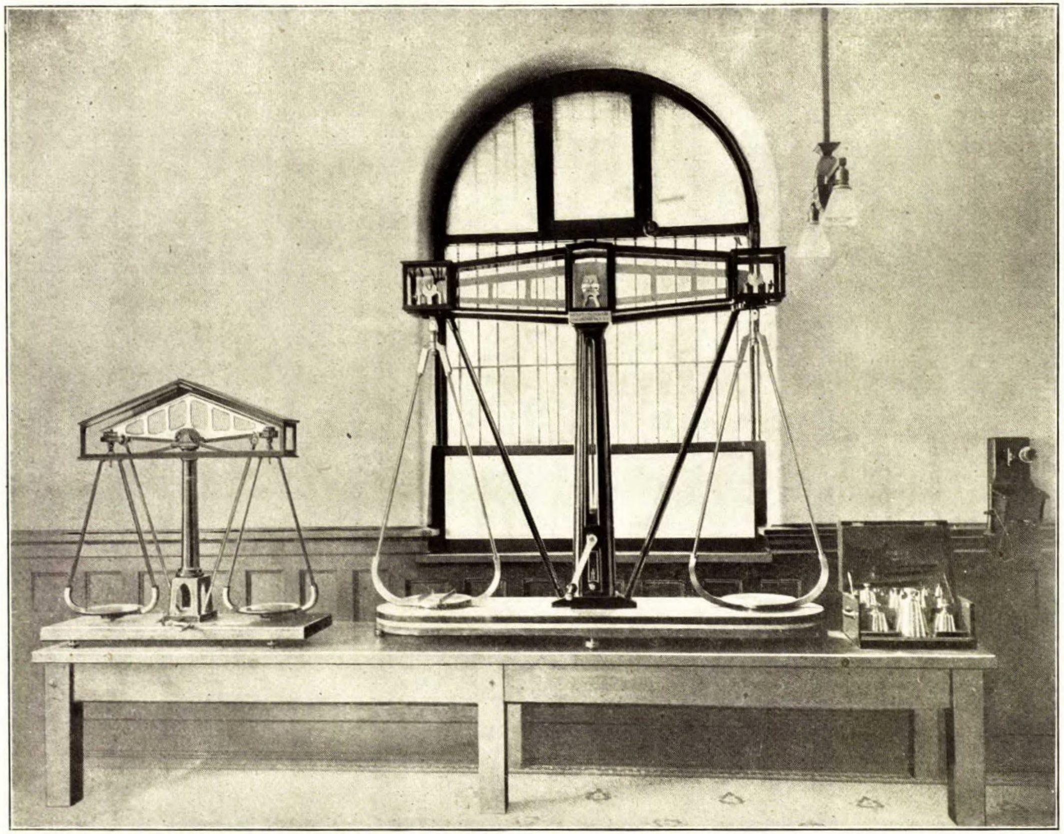
Odanah shale outcropping along railway cuts, east of Tantallon, Sask.



Stratified clay silt near Lancer, Sask.

PLATE XIII.

Quartzite pebbles in a gravel pit near Gouverneur, Sask.



Bullion balance, Dominion of Canada Assay Office, Vancouver, B.C.

INDEX