

CANADA
DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN MCLEISH, DIRECTOR

INVESTIGATIONS IN 1921

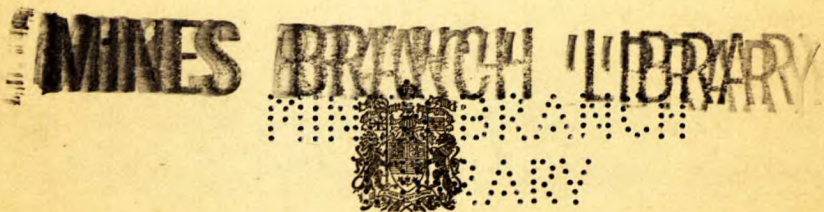
MINERAL RESOURCES AND TECHNOLOGY

- (a) Coalmont amber: by Dr. A. W. G. Wilson.
- (b) The iron industry: by A. H. A. Robinson.
- (c) Iron oxide pigments in Ontario: by Howells Fréchette.
- (d) Talc and soapstone, calcite, feldspar: by H. S. Spence.
- (e) Alkali deposits of western Canada: by L. H. Cole and F. M. MacNiven.
- (f) Cretaceous shales of Manitoba and Saskatchewan: their economic value as a possible source of petroleum: by S. C. Ells.
- (g) Oil shales of Canada: by S. C. Ells.
- (h) Chemical products from natural gas: by R. T. Elworthy.

CHEMICAL LABORATORY RESEARCH

- (i) The possibility of producing methanol (methyl alcohol) and formaldehyde from natural gas: by R. T. Elworthy.
- (j) Chemical and physical characters of bentonite: by E. A. Thompson and A. Sadler.

(Annual Summary Report of the Mines Branch, pp. 7-77.)



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SUMMARY REPORT OF MINES BRANCH INVESTIGATIONS, 1921.

MINERAL RESOURCES DIVISION

I

COALMONT AMBER

Alfred W. G. Wilson

It has been known for some time that fossil resin occurs in the coal seam at Coalmont, B.C., and it has been stated recently that the quantity present is sufficient to warrant commercial recovery. A sample of glossy black coal containing about 10 cubic inches of this resin was submitted to this office for examination and identification in December of 1921.

The resinous material possesses characteristic lustre and fractures conchoidally. Many of the fragments are translucent and pale amber in colour. The main portion of the sample is almost opaque, but in reflected sunlight fracture surfaces are strongly fluorescent and of a greenish tone. Other samples are of a cherry colour and very clear.

Fossil resins of this kind have previously been reported in small amounts from various Cretaceous coals in western Canada. A natural beach deposit of similar material also occurred at Cedar lake, Saskatchewan. This deposit was recently staked as a mineral claim, but close examination showed that most of the commercial amber which it contained had been removed and marketed in previous years. The Cedar lake deposit was originally discovered and reported by J. B. Tyrrell, in 1890, and the samples of fossil resin collected by him were examined by Dr. B. J. Harrington at McGill University in 1891. (Dr. Harrington's description of the Cedar lake fossil resin is published in the American Journal of Science, Vol. XLII, October, 1891, pp. 332-335. Extracts from this article are published in Volume V, Part I, Report E, Geol. Surv. Can., 1890-91, pp. 225-228.)

Fragments of the fossil resin from Coalmont were submitted to Mr. R. T. Elworthy for chemical examination. They yielded 60 per cent of volatile products, between the temperatures of 300° C. and 410° C. There was only a very small yield of succinic acid, on which basis the material would be classified mineralogically as retinite. No attempt was made to fractionate the amber oil obtained. Nearly half the residue after distillation was soluble in turpentine. The insoluble balance consisted largely of carbon, some of which may have been present as an impurity derived from the coal, and some of which was undoubtedly due to partial decomposition of the sample tested. If distillation had been stopped at a lower temperature there would have been less decomposition, less amber oil would have been recovered, and a larger proportion of turpentine-soluble colophony would have remained.

The specific gravity of different fragments varied between 1.03 and 1.10. The coal has a specific gravity of 1.31. It was found possible to separate the two easily by using solutions of either sodium chloride or calcium chloride diluted to a specific gravity of about 1.20.

The material is slightly harder than the higher grades of Baltic amber used in the manufacture of beads, pipe stems, and ornaments. The finer hand picked pieces, if available in sufficient quantity, would be suitable for use in this way if free from flaws. Smaller pieces, provided they are free from impurities, could be pressed into sheets and blocks suitable for commercial purposes. The bulk of the material will probably be found to be suitable for the manufacture of varnishes or lacquers for use in electrical work.

The immediate problem before the operators of this mine appears to be the question of separating the commercial amber from the coal. Arrangements have been made to conduct a series of experiments on the concentration of this product at the testing laboratories of the Mines Branch.

II

THE IRON INDUSTRY OF BRITISH COLUMBIA AND ONTARIO

A. H. A. Robinson

British Columbia

In British Columbia, little progress has been made towards the establishment of the much mooted iron smelting industry. So far it has not been possible to get capable and experienced iron masters financially interested in such a project. No insuperable technical difficulties appear to be anticipated, but the commercial side of the problem, especially as regards an assured market for an output of pig iron large enough to make operations profitable, is somewhat doubtful.

As regards electric smelting, at the time of my visit one firm in Vancouver was making steel from scrap in the electric furnace, very profitably it is said, but the prices quoted for electric power would appear to put out of consideration, for the present at least, any question of electric smelting for pig iron as a commercial proposition.

Ontario

Early in 1921, a company known as the Palatinate Mining Corporation, said to be a subsidiary of a large Polish American co-operative society having its headquarters in Chicago, secured an option on the Atikokan Iron Company's blast furnace at Port Arthur, with the declared intention of putting it into blast on ore from the old Paulson (magnetite) mine, just south of the international boundary in Minnesota. They also secured from the city of Port Arthur an option on 200 acres of land as a site for steel works. A start was made at overhauling the blast furnace plant and a little work was done in extending the Port Arthur, Duluth and Western

railway (C.N.R.) from North lake to Paulson mine. A change appears then to have been made in the original plans and the idea of using the Paulson mine ore abandoned. At the time of my visit, in October, work was practically at a standstill, and the Company was said to be considering the acquisition of the Atikokan magnetite mine and the Loon lake hematite deposits, both of which are in Ontario. Up to date no active operations have been reported.

During 1919 and 1920, seventeen diamond drill holes, having an aggregate length of 7,274 feet, were put down in one of the iron ranges east of lake Nipigon, by Cleveland, Ohio, parties. They proved up considerable quantities of low grade material, but no workable body of ore of present day merchantable grade was encountered.

In the Soo district, the Algoma Steel Corporation's Magpie mine was closed early in March, and for the balance of the year the supply of Magpie ore required by the furnaces at Sault Ste. Marie was drawn from stock piles at the mine. There has been no iron ore mined in Canada since the closing of the Magpie.

In July, 1921, bush fires destroyed completely the buildings and equipment at the Algoma Steel Corporation's Helen mine—both that remaining at the old Helen plant and that more recently installed to develop the siderite ore-body.

During the year some diamond drilling was done north of the Soo, on the old Hillier magnetite claims, which lie just south of the upper Goulais river and about 9 miles east of the Algoma Central railway, in ranges XII and XIII, township 22. The work was being done by Messrs. Smith and Travers, diamond drill contractors, for a Sault Ste. Marie syndicate. The Algoma Steel Corporation, in anticipation of possible developments in the utilization of low grade magnetites, restaked a number of mining claims in the same locality.

Experimental work was resumed at Moose Mountain during the year, under the supervision of Mr. A. J. Anderson.

III

IRON OXIDE PIGMENTS IN ONTARIO

Howells Fréchette

In continuation of the investigation of mineral pigments in eastern Canada, many reported occurrences of ferruginous pigment were visited and examined in the southern part of Ontario.

In the section of the province visited there are apparently no large deposits of high grade iron oxide pigments such as have been so extensively worked near Three Rivers, Quebec. While several deposits have been worked in the past, the more exacting requirements of the paint trade, and the necessity for producing in large quantity in order to meet competition, have forced discontinuation in all cases. It would seem that the greatest chances for economical production are with certain of the clays and shales, especially in Halton county, which can be used for cheap paints and as a coloured filler for linoleum.

LEEDS COUNTY

In Leeds county there are a number of small deposits of iron ochre in swampy ground, in most cases adjacent to Potsdam sandstone or Beekmantown dolomite. The deposits probably owe their origin to iron leached from these rocks. Such deposits were seen on lot 20, concession II, and lot 21, concession VII, Bastard township, and lot 24, concession X, Leeds township. None of these can be considered of commercial interest.

On lot 18 or 19, Broken Front, Yonge township, there are two deposits which, about forty years ago, were exploited for raw material for paint making. One is composed of earthy hydrated oxide, which has been deposited in a swamp by a spring issuing from rocks carrying much iron pyrites. The greater part of the deposit has been removed and what remains is very much contaminated with sand. When the uncalcined material is ground in oil it produces a fairly dark sienna paint with a slightly green tone. When calcined it produces a red paint lacking in intensity.

The other deposit is of a hard stony character, and the outcrop is so weathered and broken that a proper idea of the type of occurrence could not be formed. When ground in oil without previous calcining the paint produced is a rather light coffee brown, and the calcined material produces a bright reddish brown.

In this deposit there are many small stringers and inclusions of quartz which would interfere with the grinding of the material for paint making, but much of the quartz could probably be removed by screening during the grinding operations.

RENFREW COUNTY

While no deposits of value are known in this county, small deposits were seen on the north side of the old road which parallels the railway on lots 9 and 10, concession II, Blithfield township, in small catchment basins in a drainage course leading to a large swamp.

Since the rocks in the vicinity carry much pyrite, prospecting along the margin of this swamp might disclose deposits of bog iron ore, or ochre.

At the foot of a gully leading northwest from the Mile Lake pyrite mine on lot 1, concession I, Blithfield township, a deposit of sandy ochre was seen on the edge of a large swampy flat. This also would be a place worth prospecting.

HASTINGS COUNTY

From time to time occurrences of iron ochre have been reported from the neighbourhood of Madoc. A number of lots were visited in Huntingdon and Madoc, and many enquiries made in the vicinity, but no deposits of any interest were seen.

Several deposits of iron ochre are known to occur in the northern part of Hastings county. These will be visited in 1922.

MUSKOKA DISTRICT

In the townships of Oakley and Draper there are deposits of bog iron ore on many lots. These were visited in the hope of finding ochre associated with the hard bog ore. A few small patches of clean ochre were seen, but none of them could be worked for pigment.

SIMCOE COUNTY

About two thousand feet from the shore of Georgian bay, on lot F, concession XIX, Tiny township, springs issue from the face of a hill below an extensive sandy flat. These springs deposit iron ochre and have formed a number of small beds, with a maximum depth of about two feet. The ochre is much intermixed with sticks and leaves and is somewhat sandy. While paint of good colour can be made from the ochre, these deposits cannot be regarded as of any commercial value.

On lot 1, concession XI, Nottawasaga township, just below the falls of the Noisy river, springs issuing from the rocks of the river bank deposit calcareous sinter and iron oxide. In some places the amount of iron oxide is sufficient to strongly colour the material. Samples tested produced paint of a rather light umber colour, but the calcined material gave a very poor shade of brown. The deposits at one time, it is said, covered several hundred square yards to a depth of about four feet. Slides and floods have reduced the area to a few square yards. Owing to the smallness of the deposit, and the calcareous nature of the material, it is of no value.

GREY COUNTY

In the 1863 Report of the Geological Survey there is a record of a deposit of yellow ochre at the base of the hill "on the southwest side of the village of Owen Sound." The deposit was said to be four feet thick in places. This deposit could not be found as it has probably been built over.

Small patches of ochre are to be seen covering the rocks at various points along the face of the escarpment which surrounds the city. None of any value were seen.

BRUCE COUNTY

There are traces of ochre in many parts of Brant township, but no workable deposits were observed, although an effort was made to locate a deposit of ochre which is said to have been worked at one time.

HALTON COUNTY

Paint has been manufactured from Medina shales or from clay resulting from the weathering of these shales at several places in Halton county, but none has been produced in the last twenty years.

The Ontario Mineral Paint Works, Campbellville, procured clays and shale from lot 11, concession IV, Nelson township. This they ground and sold dry to paint manufacturers. Six colours or shades are reported to have been produced, namely red, drab, slate, olive and brown.

The above mentioned lot was visited and the deposits examined. The red clay and shale predominate. The shale is free from grit and grinds readily. In the uncalcined condition it produces a chocolate brown, and after calcining a brownish red. In places the clay is very sandy, while elsewhere it is comparatively free from sand. It produces paint of similar colour and quality. In both cases the paint has good opacity but poor tinting power.

The clays of other colour are only in small amount and are of little importance.

Similar clays and shales were prepared as pigment many years ago at Limehouse.

A sample of the red clay was taken on lot 15, concession IV, Esquesing, where there is a good development of it. It proved to be very free from grit.

The principal uses of these clays as pigment would be in the manufacture of cheap paints, or as fillers for linoleum.

NORFOLK COUNTY

Very extensive sandfields occur in the southern part of Norfolk county. Iron oxide, derived from these sands, has been deposited at many points as ochre or bog iron ore. The ochre for the most part is sandy and not in workable quantity, although one deposit was worked many years ago, on lots 12 and 13, concession IV, Walsingham township.

Deposits were visited on lot 12, concession VII, Charlotteville township; lot 15, concession I north of Talbot road, Middleton township; lot 12, concession XIV, Windham township; and lots 12 and 13, concession IV, Walsingham township.

On the two last mentioned lots a deposit of sandy ochre five or six acres in extent and about $1\frac{1}{2}$ feet thick was worked at various times, the last operations having been conducted by the Ontario Mineral Paint Co., about twenty years ago.

The best parts of the deposit have been removed, and what remains cannot be considered as of commercial grade.

Samples taken in this county produced paints of good colour, opacity and tinting power, but were mostly characterized by their grittiness. When ground, uncalcined, in oil the colours produced ranged from Peruvian ochre to raw sienna, and the calcined material produced good and rather brilliant oxide-red paint.

MIDDLESEX COUNTY

Old departmental reports refer to deposits of ochre in Middlesex county, but even after close enquiry in several sections of the county no deposits of more than a couple of hundred square feet could be located. They were of no value.

IV

INVESTIGATION OF MISCELLANEOUS NON-METALLIC MINERALS

H. S. Spence

A report on the barium and strontium minerals of Canada, entitled "Barium and Strontium in Canada," was completed during the year, and will be published during 1922.

Field work consisted in the examination of a number of deposits of talc and soapstone, as well as of occurrences of fluorite and feldspar, all the localities visited being in Ontario and Quebec.

The data on talc and soapstone will be incorporated in the writer's report on these materials, which is in course of preparation, and which will probably go to press during 1922.

TALC AND SOAPSTONE

Ontario

The occurrence of so-called soapstone or potstone in the Lake of the Woods region has been mentioned in earlier reports of the Geological Survey.

Lake of the Woods.—Some interest was evidenced a few years ago in a deposit of soapstone at Pipestone portage, between Moore and Andrew bays, Lake of the Woods, 12 miles south of Kenora.

The writer visited this locality in company with E. F. Kendall of Kenora, one of the persons interested in the deposit.

About 100 tons of material from this deposit is stated to have been taken out some years ago, and shipped to the Dryden Timber and Power Company (now the Dryden Pulp and Paper Company), of Dryden, Ont., who had it sawn into blocks for lining the smelting furnaces of their sulphate paper plant. The material is reported to have proved too seamy for the above purpose, and to have crumbled badly.

The stone was obtained by blasting out the side of the low ridge which divides the two bays, and was loaded directly into a scow, and towed up the lake to Kenora station, on the main line of the Canadian Pacific railway.

The deposit consists of a band about 75 feet wide, striking approximately east and west, and running diagonally across the neck of land separating the bays. The dip of the band and of the enclosing slates is nearly vertical. The band is well exposed in the face of the 20-foot bluff at the northwest end of the 100-foot portage on Moore bay.

The material of this band, while described as a soapstone or potstone, is more in the nature of a soft chloritic slate of a dark, greyish green colour. The stone is rather irregularly jointed, and possesses a somewhat schistose structure, but is massive enough to break out in large blocks, and stands up well under the hammer. The stone is rather harsh to the feel, but is soft enough to be cut with an ordinary saw; the powder possesses little or no slip. The main constituents of the rock appear to be chlorite and dark-coloured ferro-magnesian minerals. Little talc is apparent. The material cannot be classed as a true soapstone, and, apart from its softness, bears little resemblance to soapstone.

Wabigoon lake.—An occurrence of soapstone was examined one mile west of Wabigoon station, on the main line of the Canadian Pacific railway, about 95 miles east of Kenora. The mining location is HW133, township of Zealand, and the owner of the property is E. G. Pidgeon, Wabigoon, Ont. The soapstone outcrop lies 500 yards south of the railway track.

Beyond a small amount of stripping, no work had been performed on this deposit prior to the writer's visit. The body of soapstone is exposed on the top, and on the northwest slope of a low knoll, and is well situated for working. There is very little soil overburden.

From an examination of the outcrops, there appear to be two parallel bands of soapstone, lying between granite walls, and striking northwest. The band on the north side has been proved for a length of 500 feet, with a width of 35 feet. This band is separated from that to the south by 75 feet of hard igneous rock, having the appearance of a greenish granite.

The south body is probably the larger of the two, but its extent had not been determined at the time of the writer's visit.

The north band, to which most attention has been paid, consists of a massive, soft, and compact, dark green stone, that can be easily cut by an ordinary saw. The stone possesses no schistosity, and is of fairly uniform, medium grain. Only surface material was available for examination, but tests made show it to possess good strength, in spite of the rather flawed nature of the test pieces. It is hoped to secure more representative material during 1922, upon which a complete series of tests may be conducted. The outer two feet of this band, along the contact with the wall-rock, consists of rather hard grit (siliceous) stone, but between this zone and the main portion of the body, there occurs a narrow, 18-inch band of very soft and fine-grained soapstone.

The prospect appears to be a promising one, from surface indications, but it will be necessary to await further development work before the true nature of the stone can be determined. The surface material can be readily cut into blocks that possess high crushing strength, and retain heat well. It is hoped that the stone may prove to be suitable for cutting into bricks for lining the smelting furnaces of sulphate pulp mills, as well as for general electrical and heat insulation purposes, switchboards, laboratory slabs, etc. The whole of the stone used for such purposes in Canada is at present imported from the United States.

Although the term soapstone has been used to designate the stone of this deposit, the material is probably not a true soapstone. It resembles closely the Alberene stone of Virginia, which is used extensively for the purposes mentioned above.

Lanark county, township of Lavant, concession III, lot 24 E. $\frac{1}{2}$.—A body of talcose dolomitic serpentine occurs on this lot. It is well exposed in a low ridge, and the outcrop extends for 300 feet, with a width of 50 feet. A few small pits have been opened at the base of the ridge and disclose a white dolomitic serpentine, carrying foliated and fibrous talc. Quartz is also present as small irregular inclusions.

The deposit lies one-fourth of a mile from the Kingston and Pembroke branch of the Canadian Pacific railway, and 2 miles north of Flower station.

While analysis of this rock has not yet been completed, its behaviour with acid would indicate that it contains considerable carbonate, probably dolomite.

Quebec

The occurrence of soapstone on range V, lot 5, of Thetford township, Megantic county, near Robertson, has been mentioned in the Mines Branch Summary Report for 1919, p. 20. This locality was again visited in 1921.

The band of soapstone on the above lot is exposed in some small pits opened in the side of the ridge forming the north side of the valley, through which runs the Quebec Central railway. These pits have disclosed a band of friable, greenish schistose talc or soapstone, having a width of 12 feet. The material is very soft, and breaks up into thin layers.

Material similar to the above has been discovered at other points along this ridge, and at about the same general level. These outcrops indicate the existence of a persistent band of talc, extending for several miles. The most westerly outcrop seen was at a point about 100 feet north of the main pit of the Federal Asbestos Company, at Robertson, and the most westerly that on the lot mentioned above. The distance between these two points is about 2 miles.

About midway between the above outcrops there are some small workings, from which about 100 tons of material are reported to have been taken in 1920, for shipment to the United States.

The talc body at all these points measures from 12 to 15 feet in width, and dips 45° to 60° with the slope of the hill. The enclosing rock is variously slate, quartzite, or serpentine. The material is very uniform in character, and contains no gritty impurities. The surface material is too soft and friable to cut into blocks or slabs, but this characteristic may change with depth.

Diamond drilling of a talc deposit on range IV, lots 17 and 18, and range V, lot 18, township of Potton, Brome county, near Knowlton, was conducted in 1920 by the Talc Development Company of Canada, and the results are stated to have proven a promising body of talc. No further operations have been conducted to date.

CALCITE

Ontario

A very interesting and unusual occurrence of calcite occurs on concession VII, lot 4 W. $\frac{1}{2}$ of the township of Palmerston, Frontenac county. The deposit lies 2 miles distant by winter road from Robertsville station on the Kingston and Pembroke branch of the Canadian Pacific railway. It is controlled by T. B. Caldwell, Perth, Ont., who conducted development work during 1920 and 1921, and has quarried several hundred tons of calcite ready for shipment.

The calcite is coarsely crystalline, and of a white to cream shade. It is very uniform in grain. The deposit is in the form of a vertical vein or band, measuring 90 feet maximum width between walls, at the southeast end. The length of the deposit is not known accurately, but the band has been traced northwest for a distance of 850 feet from the point of attack at the southeast outcrop. At the west end the width between walls is 65 feet. The enclosing rock is a reddish grey, fine-grained granite gneiss.

While at first sight the deposit appears to be of vein form, closer examination indicates that it may constitute a down-faulted block of limestone, which has suffered re-crystallization. This view is based on the following grounds: the material does not possess the highly spathic character and perfect cleavage usually exhibited by vein calcite; the deposit is remarkably uniform in character and composition over its entire width; there are no inclusions of country rock within the calcite body; there has been no alteration of the country rock adjacent to the calcite, the contact being very sharp.

Work done on the deposit consists of stripping at the southeast outcrop and quarrying back the face of the low ridge into which the calcite body runs.

An analysis of the calcite shows it to be very pure. The following analysis was furnished by the owner:—

Lime*.....	54.20
Silica.....	1.02
Iron oxide.....	0.24
Alumina.....	0.86
Magnesia.....	trace
Loss on ignition.....	43.50
Moisture.....	0.16
	<hr/> 99.98

*Equivalent to 96.75 per cent calcium carbonate.

It is hoped that the calcite may prove suitable for use in paints and as a filler or loader in rubber goods.

FELDSPAR

Ontario

A number of feldspar deposits were opened up during 1919-21, in the vicinity of Hybla, on the Trenton-Maynooth branch of the Canadian National railway. Most of the deposits proved to be small and were soon abandoned. The most important workings are those of the Verona Mining Company, on lots 18 and 19, concession VII, of the township of Monteagle. The quarry lies 2 miles from Hybla station, to which point the feldspar is hauled by wagon.

There is no machinery or plant on the property, drilling being done by hand. Operations to date (November, 1921) consist of considerable stripping on the crest and flank of the hill on which the deposit is situated, and a number of shallow pits have been opened. The chief opening is a pit 350 feet long by 30 feet wide, and averaging 15 feet deep. This pit exposes a rather irregular body of pink feldspar and quartz. The feldspar occurs as large crystals, or aggregates of crystals, separated by masses of quartz. In portions of the dike the two minerals occur predominantly in graphic granite intergrowth.

The nature of the ore entails close cobbing, and there is a large proportion of waste, but the quality of the clear feldspar is high. The company ships to its own mill at Rochester, N.Y.

Quebec

A deposit of feldspar was worked during 1921 on lot 47, range VIII, in the township of Aylwin, Hull county, the operator being W. G. Masson, of Ottawa. The workings lie one-fourth of a mile east of the Gatineau Valley branch of the Canadian Pacific railway, midway between Aylwin and Marks stations.

The deposit consists of a dike of grey to white soda feldspar (albite) mixed with a large proportion of quartz. The dike can be traced by isolated outcrops for a considerable distance, but the workings are all situated at

the most westerly exposure. This lies about 450 yards west of the railway, with which the quarry is connected by a tram line. Work was commenced early in 1921, and a considerable tonnage of feldspar was shipped. The whole of the output went to the Orford Soap Company, Manchester, Conn., for use in cleanser preparations.

An analysis of the feldspar of this deposit made in the Mines Branch laboratory showed it to contain 1.62 per cent of potash and 7.14 per cent of soda.

During 1921 considerable interest was evinced in the feldspar deposits of the Buckingham district, in Labelle county. The development, during the year, of a large body of very high grade feldspar, by M. J. O'Brien, Ltd., on lot 8, range I of the township of Derry, has led to active prospecting in the adjacent territory, and a number of deposits have been discovered. Many of these occurrences will doubtless undergo development during 1922, and shipments have already been made from one or two deposits.

The property now being operated by M. J. O'Brien, Ltd., lies nine miles north of the town of Buckingham, Que., and two miles from the Lievre river. In summer, the feldspar is hauled by wagon to the river, and loaded into scows, which are towed down to the railway at Buckingham. In winter transportation is by sleigh on the river ice to the same point.

A large, well-equipped camp has been established on the O'Brien property. A small, portable boiler supplies steam for two steam drills.

Feldspar is won from a single large opening. This is an open cut carried 130 feet into the upper portion of the ridge crossed by the deposit, and having a width of 35 feet, and about the same depth. The actual feldspar dike is somewhat wider than 35 feet, and averages about 50 feet. In mining, however, a band along the walls, consisting of a somewhat lower grade of spar, is left standing, to be taken down separately. It is intended to work this deposit—which has been proved for a length of 300 feet—by carrying in a series of benches at successive levels, and working out the feldspar the length of the deposit at each level. In this way, no hoisting is necessary, the feldspar and waste being run out of the cut by tram.

This deposit is remarkable for the unusually clean feldspar carried. An unusually small proportion of quartz is present in the dike, and this quartz occurs as segregations between large feldspar crystals, and can be readily removed separately. The accessory minerals so often present in feldspar dikes, such as tourmaline, hornblende, mica, garnet, etc., are virtually absent. The feldspar is predominantly of a light cream colour, and much of it is remarkable for its vitreous appearance and partial translucency. These are characteristics of the feldspar of many of the deposits recently uncovered in the same district, and in some cases, the colour is almost a pure white, the feldspar then having a remarkable milky appearance.

Analyses¹ of two samples of the shipping grade of feldspar from the O'Brien property yielded:—

Silica.....	65.09	65.80
Alumina.....	18.85	19.74
Ferric oxide.....	0.03	0.03
Lime.....	0.21	0.11
Soda.....	2.11	1.74
Potash.....	13.42	12.32
	<hr/> 99.71	<hr/> 99.74

It seems probable, in view of the encouraging results obtained by M. J. O'Brien, Ltd., on the above property, and the number of deposits carrying a similar grade of spar that have been located in the same district, that the Buckingham region will shortly become an important feldspar producing centre.

V

ALKALI DEPOSITS OF WESTERN CANADA

L. Heber Cole

F. M. MacNiven, Assistant

Introductory

The search for potash in western Canada during the years of the great war led to the staking of claims on many of the alkali lakes and sloughs which occur in numerous localities in the morainic areas of the prairies, as well as in British Columbia, in the hope that potash salts would be present in commercial quantities. While the search for potash up to the present time, has been disappointing, the prospecting of the alkali deposits has demonstrated that western Canada possesses large reserves of sodium and magnesium compounds: such as sodium sulphate, sodium chloride, sodium carbonate, and magnesium sulphate.

Occurrences

Natural occurrences of soluble mineral salts are known in the provinces of Manitoba, Saskatchewan, Alberta, and British Columbia, either in the form of bedded deposits, or as brines. Some are of considerable extent, and are probably of sufficient size to warrant commercial exploitation, provided economical methods of recovery can be developed, and sufficient markets established.

The occurrences of these salts may be broadly classed under two types:—

- (1) Solid salts and brines in undrained or partially drained basins.
- (2) Brines of flowing streams or springs.

¹ Furnished by the operator.

Type (1).—Those of the first class are very numerous in the prairie provinces, and are, generally, similar in character, although the percentage of the different salts varies in different localities. In many cases the name alkali lake has been appropriately applied to deposits of this nature, since in the early spring, and often into late summer, the deposits are covered with water. The water accumulating from the melting snow and rain is often a foot or two in depth, and carries a considerable quantity of the alkali salts in solution, due to the dissolving of the top layers of the crystallized salts. In the late summer, especially when the season is a dry one, these so-called lakes become deposits of white alkali, which when seen from a distance resemble snow covered basins. A day's rain, however, or a rise in temperature, which increases the solubility of the salts, will quickly cover the surface of the crystals with a saturated brine. This brine will, sometimes, entirely disappear during one night, if there is a fall in temperature.

The deposits vary greatly in size, some being many acres in extent, and ranging up to 15 feet or more in thickness. The salts are generally found interbedded or mixed with calcareous mud and peaty material, and in only a few instances are the deposits in a pure enough form to be commercially marketable in their crude state. In many cases the salt crystals contain included mud stringers, so that the salts would require to be redissolved, and the impurities allowed to settle out of the solution before a pure product could be obtained. The mud beds also contain numerous crystals of the alkali salts.

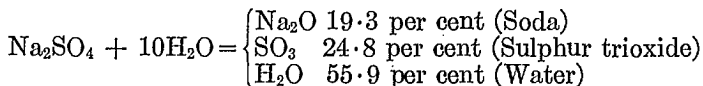
Type (2).—Brine streams or springs occur in many places, and may carry sufficient salts in solution to warrant their commercial exploitation for medicinal and other purposes. In some of the occurrences of this nature the principal salt present is sodium chloride, the other salts being present only in small quantities. The brine springs of northern Manitoba are good examples of this class of deposit.

Composition

The composition of the salts occurring in these basins consists chiefly of mixtures of sodium and magnesium sulphates, in varying proportions, with, generally, small quantities of sodium chloride, sodium carbonate, calcium carbonate, and calcium sulphate, etc.

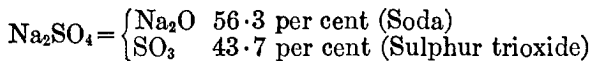
SODIUM SULPHATE

Sodium sulphate in the hydrous form (*known as Mirabilite or Glauber's Salt*) has the following composition:—



In its pure state it is white, transparent to opaque; and has a hardness of 1.5 to 2, with specific gravity 1.48. It is readily soluble in water, and at first is cool to the taste, and afterwards saline and bitter.

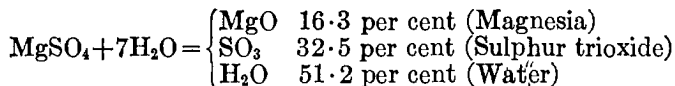
Sodium sulphate in the anhydrous form (*known as Thenardite*) has the following composition:—



Its colour, when pure, is white, translucent to transparent, and the mineral has a hardness of 2 to 3, with specific gravity 2.68.

MAGNESIUM SULPHATE

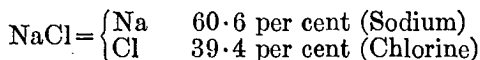
Hydrous magnesium sulphate (*known as Epsomite or Epsom Salts*) has the following composition:—



This is a soft, white or colourless mineral, readily soluble in water and with a bitter saline taste. Its hardness is from 2 to 2.5 and specific gravity 1.75.

SODIUM CHLORIDE

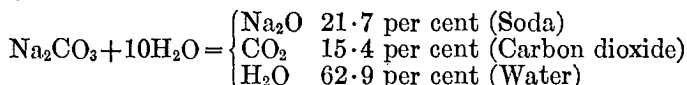
Sodium chloride (*known as Halite or Common Salt*) has the following composition:—



The natural salt is nearly always impure. It has a hardness of 2.5, and specific gravity 2.1 to 2.6. It is colourless or white when pure, but often yellowish, or red, or purplish, due to the presence of metallic oxides, or organic matter. It is readily soluble in water, and has a saline taste.

SODIUM CARBONATE

Hydrous sodium carbonate (*known as Natron*) has the following composition:—



This is very soluble in water, from which it crystallizes as such only below 20° C. It has specific gravity 1.4 to 1.7, and hardness 1 to 1.5.

With these salts may be associated other soluble salts, and in small quantities, salts of the potassium and alum groups.

Uses

Sodium sulphate in the anhydrous form is more commonly known by its trade name Salt Cake. As salt cake, it finds its chief use in the manufacture of sulphate pulp; in metallurgical work in the refining of nickel; in the manufacture of window, plate, and bottle glass; and in making water glass. In the hydrous form, it is marketed as Glauber's Salt, and as such, is used in tanning; in the textile industry as a mordant; and in medicine.

Hydrous magnesium sulphate or Epsom Salts is largely used in the cotton trade for warp-sizing; it is also employed for medicinal and agricultural purposes, and in dyeing with aniline colours, since goods thus dyed are found to withstand better the action of soap.

Sodium chloride is the ordinary Common Salt of commerce, and as such, has many uses.¹

Sodium carbonate in the anhydrous form, known under the trade name of Soda Ash, is one of the principal forms in which sodium is used in the alkali industry, since it frequently forms the base from which other sodium compounds are made. It is used extensively in the manufacture of glass, soap, and dyes, as well as in cleansing preparations, and tanning. In the hydrous form it is marketed under the trade names of Sal Soda, Washing Soda, or Crystal Carbonate, and is used in softening water and to replace soda ash when purity is essential. It is also used in cleansing compounds, or alone as washing soda. Sodium bicarbonate, or acid sodium carbonate, commonly known as Baking Soda, is generally marketed in a very pure form, and finds its principal use in baking.

Methods of Examination

The alkali deposits of western Canada are very numerous, and are scattered over a wide territory. On account of the great similarity of many of the deposits, it was thought best to confine detail work to several of the more typical deposits as representative of a district, and to obtain general data on the others.

Field Work

The field work on the deposits where detailed work was done consisted of:—

(1) Transit survey of the deposit and surrounding area, with contours at 10-foot intervals, sufficient to show the presence or absence of drainage to or from the deposit; also the location of springs and wells which might have any bearing on the source of the deposit.

(2) Detailed surface examination of the area included in the survey to determine the nature of soil and rocks of the surrounding country.

(3) Core drilling at regular intervals over the whole deposit, to determine its extent, depth, and composition.

(4) Sampling of all springs and wells in the area, and representative samples from all the cores obtained in the drilling operations.

(5) Collection of all data having any bearing on alkali deposits.

(6) Chemical analyses in the field, to quickly determine the quality of material in any deposit.

The field work on other deposits not studied in detail, consisted in visiting such deposits and obtaining representative samples from test pits, as well as brine samples from any springs feeding such deposits. In each case, general estimates of the size of such deposits were made from the township plans, and all available data collected.

¹ For details relative to the uses of Common Salt the reader is referred to "The Salt Deposits of Canada and the Salt Industry." No. 325, Mines Branch, Dept. of Mines. L. Heber Cole, 1915.

Apparatus and Methods

In surveying the lakes, a small light transit was employed, and measurements made with stadia. The elevations were determined by means of hand level.

The drilling was done with a power drill, built especially for this investigation, by the E. J. Longyear Company of Minneapolis, Minn., U.S.A. It consists of a type BD diamond drill, together with a hoist and a 2-inch by 3-inch Gould triplex pump, all operated by an 8 horse-power Cushman gasoline engine and mounted on a platform. The platform is bolted to a steel frame on wheels, so that the whole outfit is easily moved from place to place.

The entire weight is approximately 3,600 pounds.

In place of using diamonds for the bits, pieces of hardened steel with chisel edges were placed in the bit, and these were found to give good results. On account of the friable nature of the material being drilled, great care had to be taken in order to obtain satisfactory cores, since excessive vibration or too high a speed tended to break up the core into individual crystals. A saw tooth bit was tried, but it tore the crystals apart, instead of cutting them.

The drill is adapted to recover 1 inch and 2 inch cores.

A 200-foot steel cable attached to the hoist drum enabled the drill to be moved from place to place on the deposit, by its own power. When moving from one deposit to another the drill was hauled behind a Ford truck.

A complete chemical outfit for making preliminary analyses of samples in the field was included in the equipment. Aside from a standard Becker balance, Ralston still, and two coal oil burners, which were carried separately, the entire chemical apparatus was packed in two cases, with trays so arranged that any article could be taken out without having to remove all the apparatus. These boxes weighed, approximately, 300 pounds, and were shipped by freight to the west from Ottawa, and carted around from place to place without any breakage.

This outfit was sufficient for the determination of the principal salts in the lakes, and the composition of any deposit was quickly ascertained in the field. This knowledge was of great value in eliminating those lakes whose analyses showed them to be of no immediate commercial importance.

DESCRIPTION OF DEPOSITS

The following brief descriptions of deposits are of a preliminary nature, and only a few are given as typical of many examined.

Some of those visited, such as the large lakes south of Ceylon, Sask., and the one at Horizon, Sask., were covered with a considerable depth of water at the time, consequently little information was available.

Frederick Lake, Expanse, Sask.

This lake, situated in parts of sections 20, 21, 28, 29 and 33, township 12, range 28, W. 2nd meridian, was studied in detail, in order to obtain information relative to the nature of such deposits as would be applicable to all deposits of this character.

Frederick lake occupies a depression between a number of morainic ridges of the Missouri couteau, and covers an area of, approximately, 825 acres. It has a solid crystal bed composed principally of Glauber's Salt, with a small percentage of Epsom Salts.¹ It is separated from Johnson lake, on the north, by a narrow ridge composed of sand and gravel, which rises in places 30 to 40 feet. The level of Frederick lake is, approximately, 3 feet lower than Johnson lake. There is no apparent outlet, and some of the adjacent morainic ridges rise to a height of over 100 feet above the level of the crystal bed. Three springs feed into the depression from the shores. Analyses of these springs are given elsewhere in this report. Springs Nos. 1 and 2 are very similar in composition. Spring No. 3 varies considerably from the other two, but is very similar in composition to the water in Johnson lake. Inasmuch as this spring is situated on the shore of the lake nearest Johnson lake, it is quite probable that it is the result of seepage from the larger lake.

It is probable that at one time this lake was a bay of Johnson lake, since there are strong indications of beaches on the morainic slopes surrounding the lakes, at an elevation of from 30 to 40 feet above the present level. A rise of 40 feet in the present level of the water of the lake would submerge the narrow neck of land separating the two lakes, under about 10 feet of water. Conditions would, therefore, be favourable in this particular instance for the deposition of salts in the present basin of Frederick lake as a partially entrapped arm of the larger body of water of Johnson lake.

A series of some 65 holes were drilled over this deposit, and it was found that the hard crystal bed averaged 4.2 feet in depth. Beneath the crystal bed was a varying thickness of silty mud with salt crystals interspersed through it, and resting on a compact stoneless and highly calcareous clay. One typical hole drilled gave the following results:—

- 0—5' 6" hard, compact crystals.
- 5' 6"—10' 0" soft mud and crystals.
- 10' 0"—15' 0" silty clay, calcareous (stoneless).
- 15' 0"—20' 0" coarse sand, calcareous bond.
- 20' 0"—28' 0" boulder clay.

The materials comprising the surrounding country are boulder clay, gravel, sand, and silty clay.

The Canadian Pacific railway branch line from Moose Jaw to Assiniboia, Sask., runs along the south shore of this lake. A siding 200 yards long has been built at the lake.

Corral Lake, Sask.

This lake, situated on sections 14 and 23, township 14, range 20, west 3rd meridian, is, approximately, 12 miles northwest of the town of Gull Lake, Sask.

The deposit lies in an undrained depression in the eastern edge of the great belt of sand hills extending along the north side of the main line of the Canadian Pacific railway, between Swift Current and Maple Creek.

¹ Analyses of material from this deposit are given elsewhere.

The surrounding hills at this deposit are composed entirely of sand, no boulder clay or gravel area of any extent being noticed.

The deposit covers an area of 60 acres, and 15 test holes proved an average crystal bed of 5 feet.

There is one spring feeding this lake at the south end.

Alkali Lake near Ingebright, Sask.

This deposit occupies parts of six sections and is situated in sections 13 and 14, 23 and 24, 25 and 26 of township 16, range 25, west of the 3rd meridian.

By road, it is 40 miles almost directly north of Maple Creek, Sask., the nearest point on the railway.

The lake bottom is covered with a thick bed of hard crystals.

There are several springs along the shore, feeding into the lake, and in the deposit itself there are numerous springs coming up through the crystal bed. Some of these springs are 6 feet and 8 feet in diameter. When the deposit was visited October 24, 1921, there was one foot of water over the surface of the whole lake. This surface water was a saturated solution of sodium and magnesium sulphates.

There are 17 claims staked on this lake, under the Quartz Mining Regulations.

The impurity in the salts consists of sand rather than silt, such as is found in other deposits examined. One can walk onto the lake at almost any point, for the crystal bed is firm right to the shore. The shore is very sandy, and the banks, in most cases, are steep, rising from 10 to 40 feet above the lake level at a distance of 50 feet back from the shore.

The most noticeable feature of this lake, apart from its size, and the large amount of crystal present, is the numerous springs in the crystal bed at the north end of the lake. Many of these springs are bubbling up, and constantly depositing crystals in cones. It is said that in dry weather these springs build up cones, in places, to a height of 15 feet. Even with a foot of water on the surface of the crystals, these cones were noticed in the process of formation, projecting a few inches out of the water. No data were obtained as to the depth and tonnage of salts in this deposit, but it is evident that it is quite large.

Fusilier Deposit

(On the Lacombe-Kerrobert branch of the C.P.R.)

This deposit, owned by the Soda Deposits Ltd., Calgary, Alta., is situated on section 17, township 34, range 26, W. 3rd meridian, on Plover lake. Two claims of 40 acres each are located on this lake, taking in the whole area of the lake. When visited on Oct. 25, 1921, there was about one foot of water over the whole surface of the lake.

There are a number of springs feeding this lake, and the depth of the clean crystals on the top will average about 3 feet. The salts are practically pure sodium sulphate.

This deposit is being operated in a small way, and several thousand tons of clean salts have been excavated. These salts have been piled on the shore, and are gradually being dehydrated in drying sheds which have a capacity of 5 tons every two weeks. A service truck is being used to haul the material $5\frac{1}{2}$ miles to the Canadian Pacific Railway station at Fusilier, Sask., where a warehouse 24 feet by 40 feet has been erected.

Senlac, Sask.

An interesting lake was examined on sections 19 and 30, township 39, range 25, west 3rd meridian. This lake is 12 miles north of Denzil, Sask., and 8 miles east of Evesham, Sask. The area of the lake is 185 acres, and, unlike many of the other lakes examined, the salt present is sodium chloride. The lake is fed by numerous springs, and a company known as the Senlac Salt Co., Calgary, Alta., has done considerable development work. The springs, which are very numerous, occur over various parts of the lake, and the degree of saturation of the water in the lake varies at different times of the year.

The company operating this lake built wooden cribbing around a number of the springs, and pumped the brine to shallow mud vats built on the shore. The solar system of evaporation was employed, and when the evaporation was completed the salt was shovelled onto drying boards, and allowed to drain, after which it was bagged and sold locally. There is also a small plant with two open pans operated by direct heat supplied by coal fires.

When the property was visited on Oct. 26, 1921, the whole plant was idle.

Two samples of the salt, furnished by the company, were analysed:—

	No. 1 coarse	No. 2 fine
Na.....	38.13%	36.87%
K.....	none	none
Mg.....	0.23	0.45
Ca.....	0.05	0.18
SO ₄	0.08	0.35
Cl.....	59.43	58.14
Insol. in water.....	0.34	0.09
Loss at 110° C.....	1.02	2.24
Loss above 110° C.....	1.18	2.00
	<hr/> 100.46	<hr/> 100.32

A. SADLER, Analyst, Mines Branch.

Whiteshore Lake

This lake is situated in the northern part of township 36, ranges 16 and 17, west 3rd meridian. It is close to the stations of Oban and Palo on the main line of the Canadian Government railway, and Naseby, on the Winnipeg-Edmonton line of the Canadian Pacific railway. Its area is, approximately, 9 square miles.

When this deposit was visited, October 26, 1921, there was a foot of saturated brine over the whole surface of the deposit.

The clear surface deposit of crystals varied from a thin film to over 8 inches, underneath which is a thin layer of mud. Beneath the mud there is another bed of hard crystals of varying thickness, mixed with considerable mud.

An average percentage composition of the deposit, as calculated from a number of analyses, is shown in Table No. I, column 2.

Muskiki Lake (Dana, Sask.)

Muskiki lake, situated in townships 38 and 39, ranges 26 and 27, west of the 2nd meridian, contains large quantities of sodium and magnesium sulphates, as well as small percentages of other salts. The area of this lake is, approximately, 4,600 acres.

The property is owned by Salts and Chemicals, Ltd., Kitchener, Ont., and this company has done a large amount of experimentation on the recovery of the salts in a commercial form, both at their plant at the lake and at their refining plant at Kitchener, Ont.

The country surrounding this lake is rolling prairie, and the lake is the lowest point for some miles around. There is no apparent outlet, and there are numerous springs feeding into the lake around the shores and in the lake itself. One group of springs was very noticeable, about 10 feet from the shore on the east side, bubbling up and keeping the surface water in constant agitation. The shore at this point is built up of calcareous sinter intimately mixed with an ochre. The gravelly material making up the beach shingle for quite a distance on the south side of this point is made up of nodules of tufa in varying sizes. These materials are probably deposition products from the springs.

The deposit of salts in the bed of this lake varies greatly in thickness from place to place. It is composed chiefly of Glauber's Salts, with an average of 10 per cent of Epsom Salts. The lake brine, on the other hand, runs high in magnesium sulphate and also carries a small percentage of potash salts.

The crystallized salts in the bed of the lake are harvested as such, when conditions are favourable, and stored in drainage sheds at the lake. When sufficiently drained they are shipped to Kitchener, where the refining of the salts for the market is accomplished. The brine is evaporated in the plant at the lake, from whence the crude salts are shipped to Kitchener, for the recovery of refined Epsom Salts, as well as magnesium carbonate and potash salts.

CHEMICAL ANALYSES

A number of analyses given below show the wide variation in the composition of the lakes visited.

Frederick lake, about $3\frac{1}{2}$ miles from Expanse, Sask., was examined first, and a number of samples from various parts were taken. The deposit of crystals varied in thickness from a few inches at the edge to about 5 feet in the middle. Core samples were taken, and an analysis was made of each foot, thus giving an idea of the uniformity of the bed. Some of the results are given below.

Hole No. 3—Frederick Lake, Expanse, Sask. Crystal bed 3 feet thick.

—	1st foot	2nd foot	3rd foot	¹ Composite
Insoluble	0.78	3.53	1.49	1.86
Iron oxide and alumina.....	0.06	0.20	0.09	0.20
Calcium carbonate.....	1.70	5.85	2.10	2.17
Magnesium carbonate.....	0.76	3.70	2.70	1.62
Magnesium sulphate.....	2.63	2.17	4.01	3.30
Sodium chloride.....	0.61	0.46	1.39	1.02
Sodium sulphates.....	92.80	83.65	88.09	89.28
Total.....	99.34	99.56	99.87	99.45

Hole No. 1—Crystal bed 4 feet thick

—	1st foot	2nd foot	3rd foot	4th foot	¹ Composite
Insoluble.....	2.54	3.30	3.46	3.55	3.49
Iron oxide and alumina.....	0.12	0.42	0.21	0.18	0.15
Calcium carbonate.....	2.53	2.04	4.08	3.13	2.88
Magnesium carbonate.....	1.65	1.15	3.67	2.32	1.11
Magnesium sulphate.....	5.25	5.32	4.20	5.25	6.03
Sodium chloride.....	0.90	0.98	1.02	1.00	0.87
Sodium sulphates.....	86.06	86.38	83.06	84.52	85.29
Total.....	100.05	99.59	99.70	99.95	99.82

¹The composite was not made up from the samples for each foot but was an independent sample through the crystal bed.

The water from several springs flowing into this lake was analysed, and the results are given below in parts per 1,000,000.

—	No. 1 spring	No. 2 spring	No. 3 spring
Insoluble.....	30.2	30.0	20.0
Iron oxide and alumina.....	7.9	3.6	5.6
Calcium carbonate.....	310.4	304.2	.....
Magnesium carbonate.....	209.8	242.0	180.6
Magnesium sulphate.....	.....	.....	1,222.0
Sodium chloride.....	5.14	8.8	.....
Sodium sulphate.....	968.8	925.8	4,395.0

Corral lake situated about twelve miles north of Gull lake, Sask.

¹Hole No. 1—on the shore

—	1st foot	2nd foot	3rd foot	4th foot	5th foot
Insoluble.....	70.09	67.80	59.13	67.87	70.52
Iron oxide and alumina.....	1.83	1.60	1.50	0.42	0.63
Calcium carbonate.....	0.84	0.35	0.63	0.71	1.49
Calcium sulphate.....					2.07
Magnesium carbonate.....	1.36		1.47		
Magnesium sulphate.....		1.94	2.11	1.83	3.50
Sodium chloride.....	0.60	0.50	0.40	0.55	0.81
Sodium sulphate.....	25.03	27.55	34.64	28.10	20.69
Total.....	99.75	99.74	99.93	99.48	99.71

¹This hole was sunk to ascertain whether the crystal bed extended farther than was indicated on the surface.

Hole No. 3—Typical sample of the deposit

—	1st foot	2nd foot	3rd foot	4th foot	5th foot
Insoluble.....	14.74	8.04	9.73	9.11	11.80
Iron oxide and alumina.....	0.10	0.004	0.005	0.008	0.008
Calcium carbonate.....	2.22	0.86	0.95	0.76	0.86
Magnesium carbonate.....	4.01	2.06	2.13	2.10	1.53
Magnesium sulphate.....					1.24
Sodium chloride.....	0.29	0.25	0.25	0.25	0.29
Sodium sulphate.....	78.32	87.89	86.56	87.49	83.93
Total.....	99.68	99.10	99.62	99.71	99.66

This lake is surrounded by sandy land, which may be either washed or blown on to the deposit, hence the high percentage of insoluble material.

The analyses of crystal beds in several lakes are given in the columns of Table I, and of brines in Table II.

TABLE I

Constituents	Lake near Gladmar, Sask.	Oban, Sask. Whiteshore lake	Lake Alta.
	%	%	%
Insoluble.....	trace	0.1	14.03
Iron oxide and alumina.....	absent		
Calcium carbonate.....	absent		0.59
Calcium sulphate.....		0.5	
Magnesium carbonate.....	absent		1.10
Magnesium sulphate.....		5.2	
Sodium chloride.....	0.12	1.3	0.10
Sodium sulphate.....	99.49	92.0	84.18

Column 1—Only pure crystals were taken in the analysis—E. A. Thompson, analyst.

Column 2—Average analysis made by Dr. Thorwaldson, Saskatchewan University.

Column 3—Analysis made by H. A. Leverin, Mines Branch, Ottawa.

TABLE II

Constituents	1 Parts per million	2 Parts per million	3 Parts per million	4 Parts per million	5 Parts per million
Organic matter.....	68.4	6.7	8.3	.....	477
Suspended matter.....	123.5	17.8	208.6	.....	.....
Silica.....	1.4	13.5	69.1	0.22	.....
Iron oxide and alumina.....	27.3	0.9	25.0	0.085	nil
Calcium carbonate.....	trace	121.9	trace	2.055	nil
Calcium sulphate.....	195.3	322.7	895.1	17.84	nil
Magnesium carbonate.....	501.3	192.3	309.6	0.186	146
Magnesium sulphate.....	197.7	.....	1,232.0	56.24	.....
Sodium chloride.....	58.3	15.4	96.7	17.84	823
Sodium sulphate.....	441.4	133.9	1,685.6	68.02	358
Potassium chloride.....	.....	.....	.....	1.63	.....
Sodium carbonate.....	.....	.....	.....	2.25	3,410

1. York lake, Melville, Sask.
2. A lake near Duff, Sask.
3. Water, Talmage, Sask.
4. Big Quill lake, Wynyard, Sask.
5. Soda lake, Maidstone, Sask.

PREPARATION FOR THE MARKET

In preparing this product for the market, the guiding principle, of course, will be the specifications laid down by the consumer. There are several markets for sodium sulphate. The chief ones, or those which would probably take the large tonnages, are the paper industry, in which the salt is used in the manufacture of sulphate pulp, or, more correctly, sulphide pulp, and in the manufacture of glass.

As to the glass industry, we have been unable to get a copy of the exact requirements, but the chief ones are (1) that the material be dry; and (2) that the iron content be very low, possibly in no case above .02-.03%.

A small percentage of insoluble material, if siliceous in nature, would not be objectionable, and small amounts of magnesia and lime would probably be permissible. It is to be remembered, however, that the soda base is the essential constituent, and that the materials mentioned above are to be regarded as impurities which may lower the effective value of the product.

Relative to the requirements of the paper industry, we are indebted to Dr. McLean of J. T. Donald and Company, Ltd., Montreal, for the analysis of a shipment of salt cake, which was accepted and used in the manufacture of sulphate pulp. He said that the analysis mentioned could be taken as a standard.

The following is the analysis of a shipment of salt cake obtained as a by-product in the manufacture of hydrochloric acid:—

	per cent
Moisture.....	0.24
Silica.....	0.19
Iron oxide.....	0.45
Alumina.....	trace
Sodium chloride.....	2.15
Free sulphuric acid.....	1.96
Sodium sulphate (calc.).....	95.01

Less than 1 per cent sodium chloride is advisable, and not more than .5 per cent iron; free sulphuric acid appearing in the analysis would not be found in the product of the alkali lakes. No allowance is made for calcium and magnesium sulphates. They would probably not prove detrimental to the product. It is thought that the magnesium salt would make the paper a little more flexible, although, perhaps, a little heavier. Possibly 5 per cent of each of these salts would be allowed, but so large an amount of impurities would, very appreciably, lower the value of the salt cake.

Keeping in mind, therefore, the specifications required, only those deposits which run approximately 90 per cent or over, sodium sulphate, in the dry state, should be worked at the present time.

The proximity of the deposit to a railway is also of the utmost importance, because of the cost of haulage.

Sodium sulphate, as it occurs in the lakes, is in the form of crude Glauber's salt. If the insoluble material (sand, organic matter, etc.) is high, it will have to be removed first. This may be done by bringing the salt into solution in water and then allowing the insoluble to settle out in settling tanks. The clear solution may then be decanted into crystallizing pans or tanks, and the salt allowed to crystallize out.

DRYING PROCESSES

There are a number of methods suggested for the dehydration of Glauber's salt. Some of these are given below.

Air Drying.—As is well known, Glauber's salt when exposed to the air loses its water of crystallization, and forms a fine white powder of anhydrous sodium sulphate. In this process, the hydrated crystals are exposed to the air, on trays with cotton bottoms which allow the air to circulate freely through the material. About two weeks is required to lower the moisture content from 56 per cent, approximately, to 15 per cent. The material is removed to a building where it is placed on trays, and the last traces of water are easily removed in a day or two by the heat of a stove.

This method is in operation at an alkali lake $5\frac{1}{2}$ miles from Fusilier, Sask. The company has erected a building or shed about 10 feet high by 12 feet wide by 100 feet long. In this shed, the trays are arranged in rows, one above another, about two inches apart, and are filled with hydrated crystals. The trays are pushed along one following another until the shed is filled. The sides of the shed are built in sections or doors on hinges, which open from the top, and lie back on the ground. This allows the air to circulate above and below the exposed crystals, and thus carry off the water. About five tons of the dried material is obtained in this way,

in two weeks. Two men can easily fill or empty the shed in one day. In order, then, to have an output of five tons per day, fourteen sheds of the size stated above would be required. This would necessitate quite an initial outlay, and the cost of maintenance would be considerable. However, this method is probably the most economical that has been devised so far.

Direct Evaporation of the water.—One method is, to heat the salt in large open iron pans, and to expel the water by direct evaporation. There are two main objections to this method: (1) that the dried salt cakes solidly in the pans, and would have to be loosened with picks, which would increase the cost; and (2) the cost of fuel in heating.

Rotating dryers have been suggested for drying purposes, but whether these would work on material which goes into solution in its own water of crystallization when the temperature is raised is doubtful. At about 33° C., approximately 30 per cent of the sodium sulphate in solution is precipitated, and forms a rather pasty mass. Special experiments will have to be conducted in order to ascertain whether the material would cake in the dryer, and thus clog it.

Cement kilns with certain modifications have been used in drying solutions of potassium salts. At the upper or feed end of the kiln, the inside was lined with 2 inch by 4 inch scantlings, placed lengthwise and on edge about 2 inches apart, blocks being inserted between to hold them rigidly in place. Then, at the end of the scantlings, the kiln was lined with 2 inch by 4 inch scantlings placed side by side for about 6 feet. The heat was applied at the lower end by either pulverized coal, oil, or gas.

The solution was fed in a constant stream and ran into the spaces or troughs between the scantlings. As the kiln revolved, the solution was carried up and then poured out through the hot gases, finally falling to the bottom only to be taken up again. The solution becoming more concentrated all the time, gradually worked forward, until finally all the water was expelled, and only the salts were left. These issue at the firing end as in cement making. The inside of the kiln at the feed end was arranged with alternate troughs and complete bands, but this work was only carried to a point where the lining was not affected by the heat. Looking into the kiln from the feed end, the appearance was strikingly similar to a shower of rain.

Unless this method could be used when feeding Glauber's salt crystals it is evident that it would be less economical than evaporation in open pans. Then, too, power would be required to rotate the kiln.

On account of the salt coming in direct contact with the fuel, the dried material may be contaminated with coal dust, if that is used for fuel.

PRODUCTION AND MARKET CONDITIONS

Sodium Sulphate.—The production of sodium sulphate from the natural deposits of western Canada is still in its infancy. There is a small but fairly steady market for this material in the anhydrous form in the pulp and paper industry, but the consuming centres are in eastern Canada, and the present high freight rates from the deposits to the markets are an important factor. Very little of the crude material, as such, can be marketed, and this necessitates the installation of refining plants.

The product has to compete against that produced as a by-product from acid manufacture, but there are hopes that simple refining methods and lower freight rates will eventually help this industry.

The Salts and Chemicals Ltd., of Kitchener, Ont., operating Muskiki lake, Sask. (townships 38 and 39 ranges 26 and 27, west 2nd meridian), as already stated, have erected refining plants at their lake, and also at Kitchener, Ont., in which they have conducted much experimental work, and hope shortly to be in a position to place refined products regularly on the market. The Soda Deposits, Ltd., operating Plover lake, Sask., (township 34, range 27, west 3rd meridian), have been producing small quantities of high grade anhydrous sodium sulphate.

Frederick lake, near Expanse, Sask. (township 12, range 28, west 2nd meridian), will likely be a producer shortly, as a plant is now being installed by the Bishopric and Lent Co., of Cincinnati, Ohio. There are many deposits which could produce sodium sulphate, but only those close to the railways can be considered at the present time as prospective producers.

Practically all the salt cake so far used in the country has been obtained as a by-product from the manufacture of hydrochloric acid. The amount produced by this process in future will necessarily be governed by the market for hydrochloric acid.

Salt cake is being produced in Canada by the following firms:—

Grasselli Chemical Co., Hamilton, Ont. (by-product).

Nichols Chemical Co., Montreal, Que.

Plants: Sulphide, Ont. (by-product).

Capelton, Que. (by-product).

Canadian Explosives, Ltd., James Island, B.C. (by-product).

Salts and Chemicals, Ltd., Kitchener, Ont.

Plants: Kitchener, Ont. (natural).

Dana, Sask. (natural).

Soda Deposits, Ltd., Calgary, Alta.

Plant: Fusilier, Sask. (natural).

The Canadian production of salt cake and Glauber's salt as furnished by the Dominion Bureau of Statistics for 1918-1921 was as follows:—

	1918		1919		1920		1921	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
		\$		\$		\$		\$
Salt cake.....	6,001	133,544	3,197	57,045	5,524	111,983	2,418	54,804
Glauber's salt.....	2,358	60,281	1,423	45,731	1,781	50,336	1,239	42,719

Canadian imports of salt cake and Glauber's salt are as follows:—

Calendar Year	Salt cake		Glauber's salt	
	Amount	Value	Amount	Value
	lbs.	\$	lbs.	\$
1910.....	17,728,543	95,054	1,080,309	5,217
1911.....	13,782,241	88,761	1,531,555	7,826
1912.....	19,243,823	97,768	1,951,619	9,129
1913.....	25,902,190	133,030	811,053	3,815
1914.....	38,175,604	170,333	810,062	3,407
1915.....	30,970,231	147,047	840,994	8,058
1916.....	42,194,077	178,370	522,703	8,133
1917.....	71,583,645	560,711	722,913	16,248
1918.....	68,773,441	676,571	686,712	9,748
1919.....	47,905,004	343,007	738,423	9,763
1920.....	85,948,000	958,628	565,746	8,364
1921.....	54,379,450	680,083	579,928	4,521

Magnesium Sulphate.—There is a small production of magnesium sulphate from the natural deposits of western Canada, the main producing districts being, five lakes near Basque, B.C.; a lake near Clinton, B.C.; and Muskiki lake at Dana, Sask. A big deposit is located near Kruger mountain, B.C., and it is possible that some of the alkali deposits of Saskatchewan and Alberta may, in time, become producers.

The market for this material remains quiet. The producing localities are unfavourably situated as regards the present market in eastern Canada, hence there is still a considerable import, mainly into the markets of the east. The Canadian production, however, seems to have caused a noticeable reduction in the import figures for 1921.

The Canadian producers of magnesium sulphate are:—

The Basque Chemical Production Co., Ltd., Vancouver, B.C.

Plant: Basque Ranch (near Ashcroft, B.C.).

Stewart-Calvert Co., Inc., Oroville, Washington, U.S.A.

Plant: Clinton, B.C.

Salts and Chemicals, Ltd., Kitchener, Ont.

Plants: Kitchener, Ont.

Dana, Sask. (Muskiki lake).

The production, imports and exports of magnesium sulphate are as follows:—

	1917		1918		1919		1920		1921	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value
		\$		\$		\$		\$		\$
Quantity extracted..	2,600	.....	4,500	.....	.....	.....	2,056	.....	.....	.....
Quantity shipped....	929	4,645	1,949	14,565	738	9,115	1,125	28,137	614	20,961
Exports.....	.....	.....	.....	.....	.....	15	743	3,737	119	4,562
Imports.....	.....	.....	.....	.....	(a)54,779	.....	72,709	.....	.....	29,987

(a) Not separately classified prior to April, 1919.

¹Figures furnished by Dominion Bureau of Statistics.

Market Prices.—The market prices for alkalis are constantly varying. The following figures, as reported in the Oil, Paint, and Drug Reporter, New York, give the New York market prices for the years 1914 to date:—

—	Aug. 14, 1914	Jan. 1, 1915	Jan. 1, 1917	Jan. 1, 1918	* 1919	* 1920	* 1921
	\$	\$	\$	\$	\$	\$	\$
Salt cake, ground—	11.00	11.00	.....	30.00	12.00	17.60	17.00
bbls. per ton.....	to 13.00	13.00	.....	to 35.00	to 30.00	to 80.00	to 28.00
Glauber's salt—cwt..	0.65	0.60	0.60	0.90	1.00	1.15	1.00
to 0.75	to 0.75	to 0.65	to 1.00	to 2.25	to 2.65	to 1.75	to 1.75
Epsom salt, U.S.P.—	Not quoted prior to 1918			3.62½	2.75	2.50	2.20
cwt.....				to 3.90	to 3.62½	to 5.50	to 2.75
Epsom salt, tech.—	1.00	1.75	1.75	3.37½	1.80	1.75	1.10
cwt.....	to 1.10	to 2.00	to 1.85	to 3.50	to 3.37½	to 3.50	to 1.75

*High and low figures for year.

VI

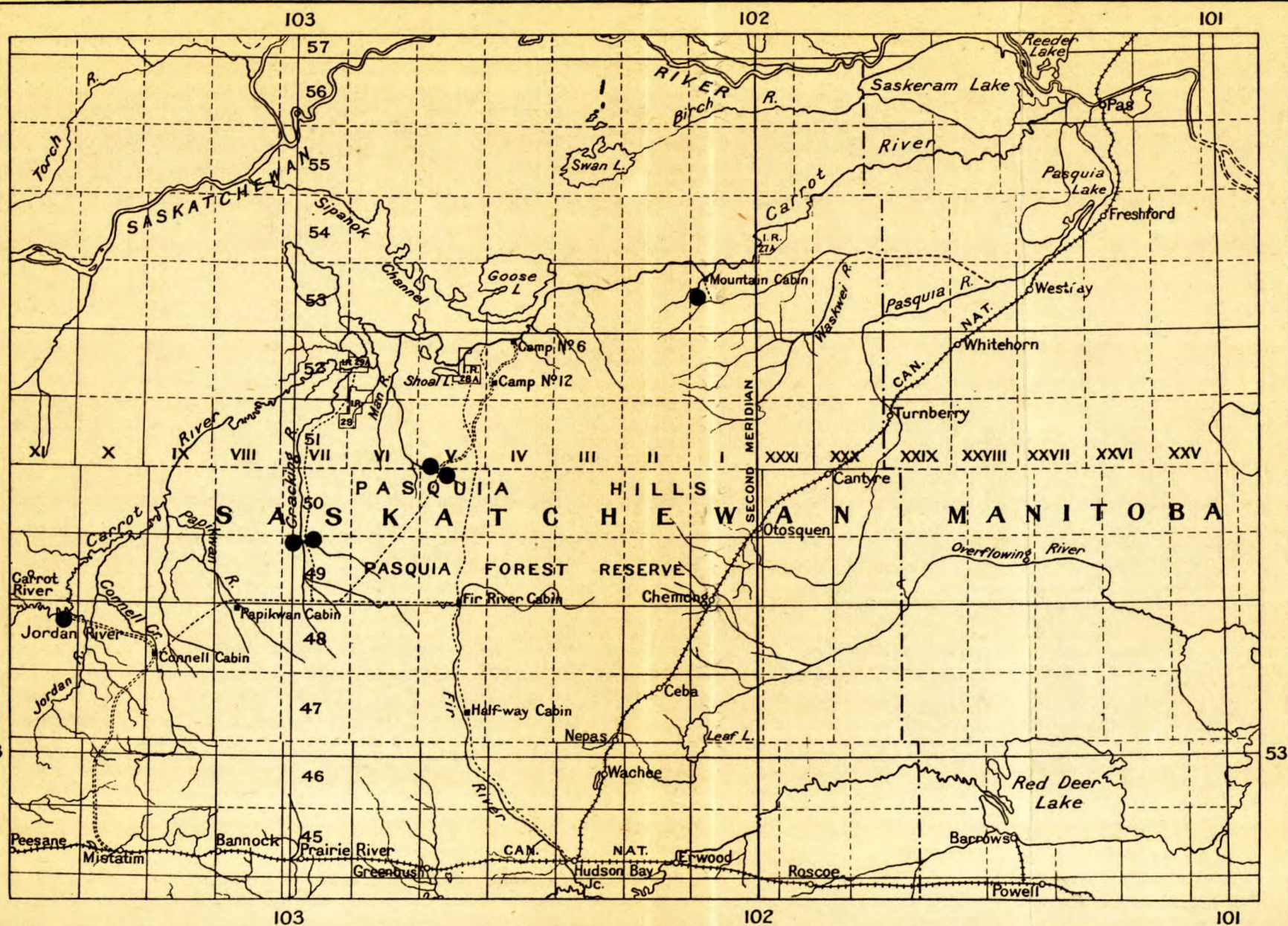
CRETACEOUS SHALES OF MANITOBA AND SASKATCHEWAN, AS A POSSIBLE SOURCE OF CRUDE PETROLEUM

S. C. Ellis

INTRODUCTORY

During recent years attention has been directed to reported occurrences of oil shale in the provinces of Manitoba and Saskatchewan. The shales are exposed along the escarpment of the Pembina, Riding, Duck, and Porcupine mountains, which border the lake plain and Red River valley of Manitoba. They are also found in the escarpment of the Pasquia hills, a northern extension of the same series. These hills, dignified by the name of mountains, constitute the erosion escarpment of the Cretaceous beds which form the first prairie step. The eastern edge is indented by drainage valleys of varying importance, which separate the hill features into groups. The Pasquia hills, and Porcupine, Duck, and Riding mountains, occupy an area which is bounded toward the north and northwest by the Carrot river, and toward the east by waterways, which include Moose lake, Cedar lake, and lake Winnipegosis. Broad, low-lying, slightly undulating, lacustral plains, which formed the bed of glacial Lake Agassiz, stretch away from the various waterways of the lower slopes of the hills. These lower slopes are marked by a series of old lake beaches, and rise by easy gradients, through some five or six hundred feet, to the more abrupt escarpment of the main ridge.

The whole area is well watered by numerous small streams few of which have a width greater than 60 feet. In descending from the table lands, these streams, for the most part, flow with rapid current along boulder-strewn channels, deeply entrenched in precipitous valleys and ravines, where active erosion and landslides are much in evidence. On reaching the lower slopes of the hills, the current slackens, and many excellent geological sections are exposed in cut banks at concave bends.



S.C.E.II.s, C.E. 1921.

Map showing position of Outcrops of Cretaceous Shales
sampled during year 1921, in Pasquia Forest Reserve, Saskatchewan.

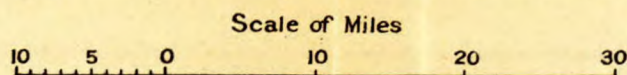


FIG. 1.

Through the low-lying alluvial lands, the banks, as a rule, are low, and the channels of the meandering type.

Outcrops of shales examined on Birch river, Favel river, Selater river, Pine river, Vermilion river, and Ochre river, are all near the Winnipeg-Prince Albert branch of the Canadian National Railways, and may be easily reached by highway roads. Outcrops examined on the Tee river—a branch of Pasquia river, Man river, Cracking river, and Papikwan river in the Pasquia hills, are somewhat remote from rail transportation.

Toward the east and northeast, the slopes of the Pasquia hills are marked by somewhat sharp gradients. In passing westward, however, the slopes become more gentle, and rock exposures along the various streams less frequent. The elevation of the summit has not been accurately determined, but apparently ranges from 2,000 to 2,300 feet above sea level datum. The area throughout is densely wooded. Apart from a number of comparatively limited areas reserved as timber berths, the forest growth consists, principally, of large poplar and birch. Much of the land is of excellent quality, and, when cleared, should prove well adapted to agricultural development.

Outcrops of shale along streams which drain the northeastern slopes of the hills (as on Tee river and Man river) can best be reached from the Pas. From Mountain cabin on Carrot river, some 60 miles W.S.W. from the Pas, a good summer trail, approximately $2\frac{1}{2}$ miles in length, leads south to Tee river. From Camp No. 6 on Carrot river, some 90 miles from the Pas, a fair bush road, approximately 17 miles in length, leads to Man river.

Papikwan and Cracking rivers can best be reached from McDonald's siding, $2\frac{1}{2}$ miles west of Mistatim station, on the Canadian National Railways. From McDonald's siding, a fair wagon road, some 24 miles in length, leads to Connell cabin. From Connell cabin to Papikwan cabin, a distance of approximately 12 miles, a fair pack trail is available; but between Papikwan cabin and the shale outcrops at the forks of Cracking river, the trail is wet and difficult. Other trails indicated on the accompanying map are, for the most part, poor, and in many instances, difficult to follow.

GEOLOGY

The general geology of the area was worked out many years ago by Tyrrell, Dowling, and McInnes, and the reports then issued¹ remain authoritative. The general geological features are simple, and may be very briefly summarized as follows:—

The Pasquia hills, and Porcupine, Duck, and Riding mountains, are built up of Cretaceous sediments, resting unconformably on limestones of Palaeozoic age. Apart from type fossils, which are found at many localities, the principal subdivisions of the Cretaceous, within the area under consideration, may frequently be recognized by lithological characteristics.

¹ Report on Northwestern Manitoba with portions of the adjacent districts of Assiniboia and Saskatchewan. J. B. Tyrrell and D. B. Dowling, Geol. Survey of Canada, 1892.
The Basins of Nelson and Churchill Rivers, Wm. McInnes, Geol. Surv. of Canada, Mem. 30, 1913.

A marker band of impure limestone, averaging some four feet thick, and containing typical fossils, occurs near the top of the Niobrara, and apparently extends over a wide area. Other marker bands are of local significance only. In the following general section, estimated thicknesses are given, but, pending the collection of further data, these must be considered as approximations.

Cretaceous	{ Montana	{ Pierre (upper) Odanah shales.....	400 feet
		“ (lower) Millwood shales.....	650 “
	{ Colorado	{ (Boyne shale)	
		Niobrara (Morden shale).....	130-240 “
		(Assiniboia shale)	
		Benton shale.....	180 “
	{ Dakota sandstone.		
Devonian.....		Unconformity.	

The detailed geological structure has not been accurately worked out, although numerous exposed sections, together with correlated elevations, indicate that the general dip of strata of Cretaceous age is almost horizontal. Between Winnipegosis and the well drilled by the Manitoba Oil Company, 11 miles southwest of Dauphin, the dip of Upper Palæozoic limestones is apparently about four feet to the mile, in a southwesterly direction. South of Swan River valley, Cretaceous sediments also dip at a very low angle toward the southwest. North of this point, the strata flatten out, and finally dip toward the north. The same general horizontal structure apparently typifies strata underlying the Pasquia hills. Minor local folding was observed, but this in itself can scarcely be considered as of economic importance. The general physical characteristics of members of the Cretaceous system may be briefly summarized as follows:—

Pierre.—Odanah series. Dark fissile shales, usually poor in fossils, and weathering to light grey fissile flakes. Often rusty along joint planes.

Millwood series. Soft grey shales, sometimes almost black in colour. Weathers to light grey flaky particles, which eventually disintegrate to dark plastic clay. Slopes adjacent to cut banks exhibit marked evidence of instability. Ironstone nodules are common, particularly near contact with Niobrara.

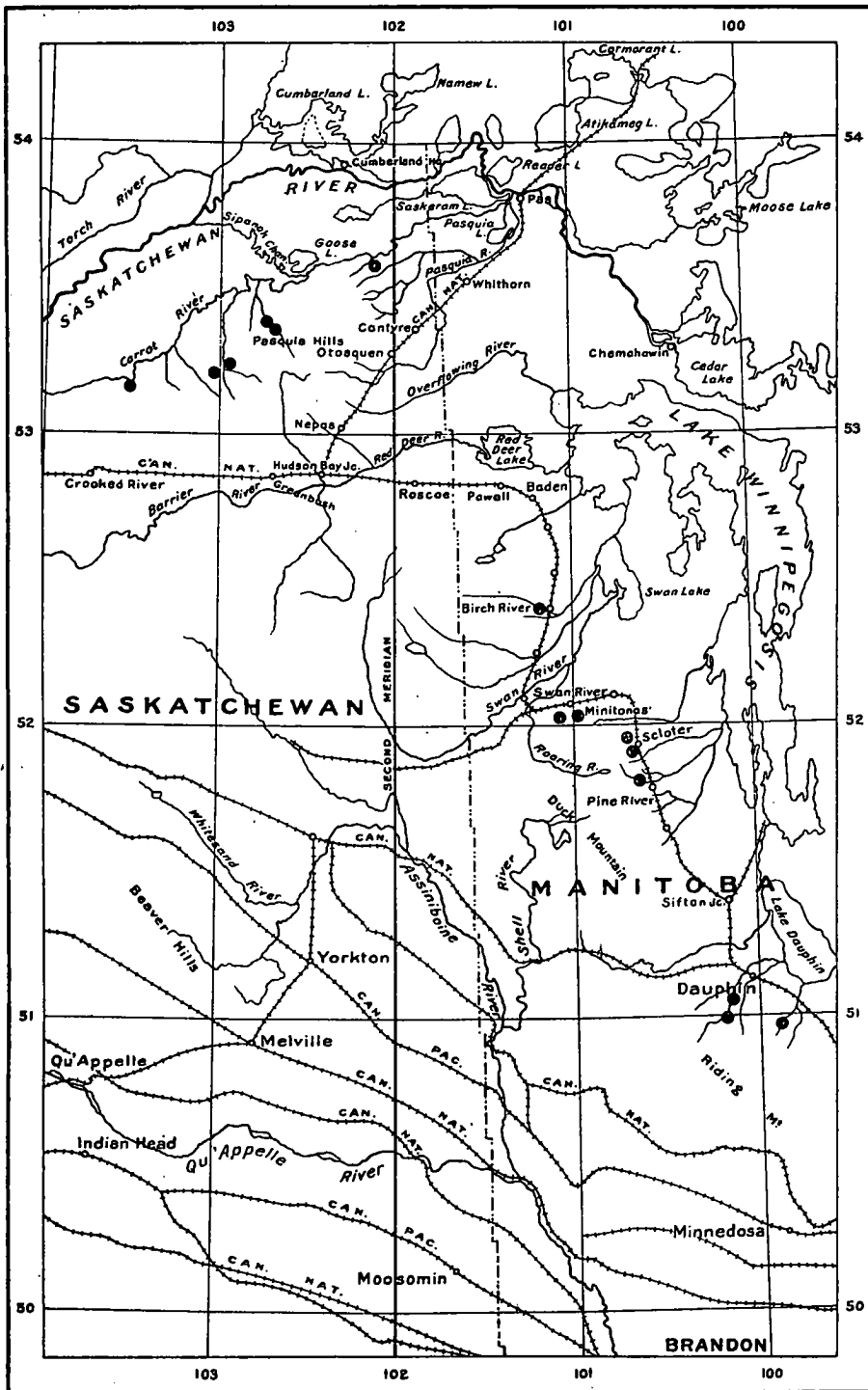
Niobrara.—Dark grey clay shales, frequently mottled, and interbedded with heavy bands of hard calcareous shale, usually highly fossiliferous, and almost black in colour. Shale weathers to light grey colour. Comparatively weather resistant.

Benton.—Very dark, soft, non-calcareous, somewhat carbonaceous, evenly bedded shale, poor in fossils. Weathers to small thin flakes, which rapidly disintegrate into dark plastic clay.

Dakota.—White, light grey or greenish sandstone. Usually somewhat soft, but in places having the hardness of quartzite.

With the exception of the upper and the lower members of the Cretaceous system, the sediments exposed within the area under consideration thus consist chiefly of rather soft, greenish grey, clay shales, more or less darkened owing to the presence of hydrocarbons and iron sulphides. Moreover, many of these shales, when freshly broken, emit a marked odour of petroleum, which, on exposure, rapidly passes off. When disintegrated by

HOWARD ZIMM
VASSALL



S.C. Ellis, C.E. 1921

Map showing position of Outcrops of Cretaceous Shales sampled during year 1921, in Manitoba and Saskatchewan

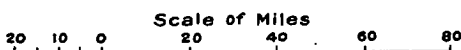


FIG. 2.

the drilling tools, in the presence of water, the shale forms an emulsion or a dark green colour. This emulsion gives off a faint odour of petroleum, and, after standing for a time, exhibits a thin film of petroleum on the surface. It is, therefore, not surprising that the presence of free petroleum in wells drilled through the shales has been reported from time to time.

Of Upper Cretaceous shales, the Niobrara formation is the most highly fossiliferous, hence it is within this horizon that bands of oil shales might have been anticipated. Fossils observed in this formation comprise a large number of foraminifera, among which *Globigerina cretacea* is conspicuous, and an abundance of shells of a large *Inoceramus*, together with the following species:—¹

Serpula semicoalita (Whiteaves. N. sp.).

Ostrea congesta (Conrad).

Anomia obliqua (Meek and Hayden).

Inoceramus problematicus (Schlotheim).

Belemnitella Manitobensis (Whiteaves. N. sp.).

Loricula Canadensis (Whiteaves. N. sp.).

Ptychodus parvulus (Whiteaves. N. sp.).

Lamna Manitobensis (Whiteaves. N. sp. loose).

Enchodus Shumardii (Leidy).

Cladocyclus occidentalis (Leidy).

ORIGIN OF SHALE

Oil shales of New Brunswick and Nova Scotia were deposited under different conditions from those of Manitoba and Saskatchewan. In the former provinces, material from which the shale beds were derived was originally deposited in the form of fine clays on the bottom of swamps and lagoons. If the theory of Steuart² is accepted, there was associated with these sediments vegetable matter converted into a pulp, as a result of maceration and microbe action in water, together with richer materials of various kinds, such as spores, and a proportion of animal matter. We may, therefore, conclude that the origin of the petroleum in the shales may be traced to fermentation and decomposition of organic matter, through microbe action. On the other hand, the shales of Manitoba and Saskatchewan were laid down in a muddy sea, and were, therefore, not subjected to the various influences that affected the shales of the Maritime Provinces.

PHYSICAL CHARACTERISTICS OF SHALES IN THE PROVINCES OF MANITOBA AND SASKATCHEWAN

It is evident that great areas of Cretaceous shales, with their notable content of organic matter, have been subjected to very slight disturbance. Had the shales been affected by folding or by compression, as a result of great earth movements, distillation of organic remains, due to heat and pressure, would doubtless have resulted in the formation of gas and petroleum.

¹ Geol. Surv. Report on North-Western Can., Manitoba, J. B. Tyrrell, 1892.

² Steuart, D. R., The Chemistry of Oil Shales. Oil Shales of the Lothians, Geol. Surv., Scotland, 1912.

Attempts to ignite fine splinters of the various shales examined, by means of a match, failed in nearly every instance. Niobrara shales, when partially dried, will, however, frequently ignite when placed on an open wood fire. Pierre shales examined ignite but rarely, and then with difficulty. Benton shales showed no evidence of being combustible. Sampling was, therefore, confined largely to Niobrara shales.

In appearance and physical characteristics, as well as in the conditions under which they were deposited, these upper Cretaceous shales are thus in marked contrast to the oil shales of Nova Scotia and New Brunswick. In these provinces, two general types of shale are recognized, viz., plain and curly. A sub-variety, usually referred to as paper shale, is apparently a weathered form of plain oil shale. It is thin-bedded, or papyraceous, separating readily into thin, flexible sheets of considerable surface dimensions. Plain oil shales are usually flat surfaced, showing more or less well defined lamination. On the other hand, curly shale usually occurs as massive bands, somewhat curled and contorted. It is very tough, breaks with a conchoidal fracture, and is, usually very rich in hydrocarbons.

As a rule, oil shales of Nova Scotia and New Brunswick are free from grit, and, although readily cut with a sharp knife, do not yield thin, flexible shavings as do the Scotch shales. They are strongly resistant to weathering, and fragments have remained, for many years, exposed to action of atmospheric agencies, with but little loss of their hydrocarbon content. When placed in a grate, fragments may be readily ignited, giving off an intense heat, and continuing to burn with a long yellow flame for periods of from one to three hours. Small splinters of the shale may usually be ignited by means of a match.

Oil shales of New Brunswick, Nova Scotia, and Scotland, do not contain hydrocarbons which are liquid at atmospheric temperature. Numerous wells have been drilled through the shales by various companies, but, although free petroleum has been encountered in interbedded sands and sandstones, practically none has been met with in the shales themselves.

WEATHERING OF SHALES

Weathering of the Cretaceous shales presents an interesting study. As a rule, the hydrocarbon content of shales examined does not prevent rapid weathering, while, on the other hand, the shales contain within themselves a variety of potent disruptive agencies. Apart from the high percentage of water present, this disintegration, due to the formation of secondary minerals, as iron and calcium sulphates, hydrated iron oxides, etc., and circulating solutions containing acids and sulphates, is very marked.

ASSOCIATED MINERALS

Incidental to the examination of the Cretaceous shales, the presence of certain associated minerals was noted. None of these minerals were observed in sufficient quantity to be of present economic importance, but, pending a complete chemical analysis of the shales, their somewhat complex geochemistry may be briefly alluded to.

These associated minerals fall into two classes, viz., those which, being deep seated, have not been subjected to oxidizing influences, and others, which have been deposited at, or near the surface, in the presence of circulating waters, and under the influence of other oxidizing agencies. In

addition to bentonite, the principal deep seated minerals comprise pyrite, siderite, and glauconite. Owing to the length of time during which they have been forming, these minerals occur in considerable quantity and exhibit comparative purity. Surface deposits comprise marcasite, iron sulphate, limonite, gypsum (in the forms of selenite and satinspar), native sulphur, and small amounts of iron oxide. Pyrite, in the form of small cubes, sometimes occurs in narrow lenses, but is more often disseminated and invisible to the naked eye. Siderite is most abundant in the Pierre series, at times forming beds a few inches thick. Bentonite occurs as uniform, sharply defined beds, having a maximum observed thickness of 24 inches. Pyrite and marcasite, in the presence of oxidation agents, give rise to the formation of small quantities of sulphurous and sulphuric acids. It may be possible that these acids, circulating through the shales, form soluble sulphates which are subsequently leached out, leaving bentonite as a residual product. To the oxidation of iron sulphides may also be attributed the nauseating sulphurous odour which, at times, emanates from shale banks, and has frequently been construed as indicating the presence of natural gas.

Absorption of oxygen, assisted by oxidation of iron sulphides, is responsible for slow spontaneous combustion in progress in many of the banks of shale. At one locality a column of thin blue smoke was observed rising from a smouldering bank, the talus at the foot of the bank being cemented together by various sulphates. Moreover, traces of free petroleum, released as a result of recognized chemical reactions, as well as small amounts of colloidal iron hydroxide, frequently accumulate to form a scum, which, at times, has been mistaken for a true petroleum seepage.

SAMPLING AND ANALYSES

In securing samples overburden was removed and trenches cut from top to bottom of exposed sections. The depth at which samples were taken varied from four to eight feet from the face, but it is considered that in each instance unaltered shale was procured. A number of samples were tested in the field, and satisfactory results were obtained by the use of a retorting apparatus¹ somewhat similar to that recommended by the United States Bureau of Mines. Only the petroleum content was determined. In the case of certain other samples, subsequently tested in the laboratory, the yield of ammonium sulphate was also determined. Twenty-two representative samples were procured on the northern branch of the Pas river, Man river, Cracking river, Papikwan river, Jordan river, and Carrot river, in the province of Saskatchewan, and nineteen samples from Steeprock river, Birch river, Favel river (east and west branches), Sinclair river, North Duck river, Sclater river, North Pine river, Vermilion river, and Ochre river, in the province of Manitoba.

Certain of these samples showed merely a trace of hydrocarbons, hence reference to them is omitted in the following summary.²

¹ Reports of Investigations, U.S. Bureau of Mines, Serial No. 2229.

² Determinations by Chemical Laboratories, Mines Branch, Department of Mines.

¹Calculations based on ton of 2,000 pounds.

Distillation range	Barom. 766-0 mm.
1st drop.....	79° C.
10 p.c.....	149° C.
20 ".....	170° C.
30 ".....	221° C.
40 ".....	254° C.
50 ".....	281° C.
60 ".....	301° C.
70 ".....	336° C.
80 ".....	350° C.
90 ".....	361° C.
92 " dry point (cracking occurred).	

The gas yield from 13 representative samples of shale was also determined, and varied from 410 to 1,130 cubic feet per ton, with an average yield of 695 cubic feet. Analyses of two samples of gas recovered from shale secured on Man river, Sask., (Tp. 50, R. 5, W. of 2nd) are as follows:—

	Sample No. 1825	Sample No. 1831
	p.c.	p.c.
Carbon dioxide.....	32.6	23.3
Oxygen.....	2.1	3.1
Ethylene.....	3.7	3.8
Carbon monoxide.....	2.4	1.9
Methane.....	28.7	30.6
Hydrogen.....	9.1	7.5
Nitrogen.....	21.4	29.8
Inflammable gas.....	43.9	43.8
Calorific value, gross.....	383	297 B.Th.U. per
		cu. ft.
Calorific value, net.....	346	359 "

CONCLUSION

It is, therefore, obvious that shales examined during the past season in the provinces of Manitoba and Saskatchewan are of little present economic importance as a possible source of petroleum or of ammonium sulphate. Should conditions at any time warrant commercial development, open cut mining could be undertaken in many areas under favourable conditions. Over very considerable areas the shales examined are covered by a comparatively light overburden, consisting chiefly of boulder clays and gravel, which could be readily removed by hydraulic methods.

VII

OIL SHALES OF CANADA

S. G. Ells

(SUMMARY AND REVIEW OF AVAILABLE INFORMATION)

Occurrences of petroliferous shales (commonly termed oil shales), within the Dominion of Canada, have, for many years, been known to exist. Nevertheless, with the exception of a comparatively brief period, Canada has had to depend largely on foreign sources for its supplies of crude petroleum and petroleum products. In 1859, near Collingwood, Ontario, and again in 1862 near Baltimore, New Brunswick, attempts were made to retort local shales. In each instance these attempts were abandoned owing to the rapidly increasing production of well petroleum from the newly discovered pools of western Ontario and Pennsylvania. Now, after a lapse of nearly sixty years, attention is once more directed to the commercial value of Canadian shales as a possible source of crude petroleum.

Thus it is that only within very recent years, changing economic conditions appeared to warrant detailed study of existing shale bodies in Canada. Consequently, much work still remains to be done, not only in the field but in the laboratory, before the economic importance of such areas can be definitely determined. Meanwhile, such information as is available, may be credited almost wholly to the Geological Survey of Canada. The writer is personally familiar with the oil shales of Nova Scotia, New Brunswick, Gaspé peninsula, northern Ontario, Manitoba, and Saskatchewan. Reference to occurrences outside of these areas is based on information secured indirectly.

In the following summarized references to known or reported deposits of oil shales, occurrences will be grouped under the province or district in which they occur. In discussing shales, which vary widely both in physical characteristics and in hydrocarbon content, the use of the term oil shale is in certain instances provisional, and is necessarily applied in a broad sense.

In referring to the oil shales of Canada, it is not the writer's intention to discuss retorting methods and economic considerations. Fundamental principles relating to the former are well understood, though their application to various types of Canadian shale is as yet undeveloped. Reference to economic considerations would of necessity merely constitute a recapitulation of authoritative statements and conclusions. With these, all who are really interested in the commercial development of oil shales, are already familiar. Where oil shales can be cheaply mined by open cut methods, with reasonably high recovery of petroleum and of ammonium sulphate, competition with well petroleum may be possible at the present time. Under conditions involving the adoption of underground mining methods, the possibility of successful competition is by no means clear.

Province of Nova Scotia

The occurrence of oil shale in the province of Nova Scotia has been known for more than 60 years.¹ During the three years following its discovery, several thousand tons of a particularly rich sub-variety, known as stellarite (stellar coal or oil coal), was mined near Stellarton, in Pictou county. This output was derived chiefly from a rich band immediately underlying the McGregor coal seam; but shipments were also made from McLellan's brook, and from a point just west of Blackwood's mill dam. It is stated² that stellarite from the first named locality yielded upwards of 10,000 cubic feet of 36 candle gas, and that selected samples gave a yield equivalent to 170 Imperial gallons (204 U.S. gallons), of crude petroleum per ton. The average petroleum content of a cargo shipped to Boston was 48 Imperial gallons (57.6 U.S. gallons), while the associated shale "bat," gave a yield of 39 Imperial gallons (46.8 U.S. gallons). Part of the above output was shipped to retorting works in Boston and in Portland, and part was mixed with bituminous coals for the enrichment of illuminating gas. Following the discovery of well petroleum in Ontario and in the United States, the mining of stellarite ceased.

Oil shales of Nova Scotia are associated, in part, with strata of Lower Carboniferous age, and in part, with the Coal Measures and Upper Carboniferous rocks. The shales, as a whole, differ in character from those of New Brunswick, and with notable exceptions, as in Pictou county, are carbonaceous rather than bituminous. There is a general absence of the brown shales and hard massive oil bands, so typical of the New Brunswick field, and certain large deposits, which were at one time classed as oil shales, have been found to be too poor in hydrocarbons to warrant further consideration.

¹ Ellis, R. W., Can. Dept. of Mines, Mem. 1107, 1910.

Ellis, R. W., Jour. Min. Soc. of N.S., Vol. XIV, 1910-11.

² Poole, H. S., Trans. N.S. Inst. Sci., Vol. VIII, p. 340, 1893.

Areas of reported oil shales extend from near the mouth of the Avon river to the vicinity of East Bay, Cape Breton. Certain of these will be briefly discussed.

COLCHESTER AND HANTS COUNTIES

Along the south coast of Minas Basin, heavy beds of shales are well exposed, notably at Cheverie, between Split Rock and the village of Noel, and on the west side of the Avon, between Hantsport and Horton Bluff. The complete series consists of quartzose grits, interstratified with thick bands of carbonaceous shales, similar to those of Hallowell Grant, Antigonish county, and East Bay, Cape Breton. Certain of these shales will burn, and have been used as a substitute for coal, while others, full of rootlets, constitute true underclays. To the north of Minas Basin, similar shales extend along the south flank of Cobequid mountains, and are well exposed along Moose river, Harrington river, on the North river near Onslow, and elsewhere. These shales were styled the Horton series by Sir Wm. Dawson, and have been correlated with the Albert series of New Brunswick. As a class they are deficient in hydrocarbons, although further detailed examination may possibly discover associated oil shale bands. With these beds are frequently associated beds of dirty coal, high in ash, and of little commercial value.

PICTOU COUNTY

From present information, deposits of Pictou county comprise the most promising oil shales of the province of Nova Scotia. The principal occurrences are found in that portion of the Pictou bituminous coal field centering about the town of Stellarton.

The field has an area of approximately 20 square miles, and is chiefly occupied by Coal Measures and rocks of Lower Carboniferous age. Geological features of the area have been somewhat fully described¹ in publications issued by the Geological Survey of Canada, and in papers presented before technical and scientific societies.

The field may be divided into two main districts, eastern and western. In the eastern district coal seams occur in two horizons of the Productive Measures. In the upper horizon are five seams, varying in thickness from 3 feet to 8 feet. In the lower horizon six seams vary in thickness from 7 feet to 45 feet. With these latter seams have been correlated the four principal seams of the western district. Interposed between the upper and lower coal horizons are strata consisting chiefly of dark shales, and having an aggregate thickness of approximately 1,600 feet. With these are associated the principal oil shale bands.

¹ Dawson, J. W., *Proc. Geol. Soc., Lon.*, vol. IV, pp. 272-81, 1843-45.
 Dawson, J. W., *Quart. Jour. Geol. Soc. Lon.*, vol. X, pp. 42-47, 1854.
 Dawson, J. W., *Quart. Jour. Geol. Soc. Lon.*, vol. XXX, pp. 200-18, 1874.
 Dawson, J. W., *Acadian Geology*, fourth edition, supplement to second edition.
 Dawson, J. W., *Acadian Geology*, fourth edition.
 Fletcher, Hugh, *Geol. Surv. Can.*, vol. II, 1886, part P.
 Fletcher, Hugh, *Geol. Surv. Can.*, vol. V, 1890-91, part P.
 Hartley, E., *Geol. Surv. Can.*, *Report of Progress*, 1866-69.
 Lambe, L. M., *Proc. and Trans. Roy. Soc. Can.*, vol. V, sec. 4, 1911.
 Logan, W. E., *Geol. Surv. Can.*, *Report of Progress*, 1866-69.
 Poole, H. S., *Proc. and Trans. N.S. Inst. Sci.*, vol. VIII, 1890-94.
 Young, G. A. and J. E. Hyde, *Geol. Surv. Can.*, *Guide Book No. 1*, 1913.

Major and minor faulting has affected the whole district in a marked degree. A comparison of sections also indicates that coal seams vary widely in thickness from place to place, and that deterioration, due to replacement by shales and sandstones, frequently occurs within comparatively narrow limits. These features are of importance in considering the possible economic importance of associated oil shale bands.

Outcrops of certain of the more important bands of oil shale occur near the town of Stellarton, and along McCulloch's brook, McLellan's brook, Marsh brook (a branch of McLellan's brook), Shale brook, on the south shore of Deacon cove, and near the mouth of Smelt brook. The position of these is indicated on a map¹ of the area issued by the Geological Survey of Canada in 1904. Of these oil shales the sub-variety known as stellarite is particularly worthy of note. The following reference to this mineral is by Sir J. W. Dawson:—²

The material known as stellar coal is, as I have maintained in previous publications, of the nature of an earthy bitumen, and geologically is to be regarded as an underclay or fossil soil, extremely rich in bituminous matter, derived from decayed and comminuted vegetable substance

Stellarite underlies the McGregor coal seams at Stellarton, and also outcrops near the old Patrick slope in McLellan's brook, and on Marsh brook. The thickness of the various seams shows marked variation, and, at different points, has been estimated as ranging from 1 inch to 8 feet.

The following analyses³ are based on samples of oil shales, other than stellarite, secured by the writer in 1909 from a number of outcrops in the Pictou field:

Locality	Imperial gals. crude oil per ton	U.S. gals. crude oil per ton	Sp. gr.	Pounds ammonium sulphate per ton
McLellan's brook, (Patrick's slope).....	38	45.6	0.892	41
McLellan's brook, (Black's old mill site).....	15	18.0	0.889	35
Marsh brook (150 feet above McKay's house).	3	3.6	.....	.....
Marsh brook (300 feet above McKay's house).	1	16.8	0.903	.....
Shale brook (upper end).....	4	4.8	0.921	.....
Shale brook (near forks with McLellan's brook)	9	10.8	.....	.....
Woodburn sta. (one mile west of, on C.N. Ry.)	13	15.6	0.902	.....

From the above analyses³ it will be seen that, as a whole, shales from the localities noted are not of commercial value. Results of analyses of shales (including stellarite), from Stellarton and McLellan's brook, indicate that the seams represented are worthy of detailed investigation.

At the present time, plans are being made by the Oil and Nitrate Products, Limited, to develop certain of the shale deposits referred to above. It is claimed that a very large tonnage of shale can be cheaply mined.

¹ Poole, H. S., geological map of the Pictou coal field, Geol. Surv. Can. 1904.

² Dawson, J. W., *Acadian Geology*, 1868, p. 339.

³ All analyses quoted in this paper are by the Chemical Division, Mines Branch, Can. Department of Mines, Ottawa. Compilations are based on a ton of 2,000 lbs.

ANTIGONISH COUNTY

Shales of Lower Carboniferous age occupy a basin lying immediately to the north of the town of Antigonish. For the most part the shales are black and carbonaceous, thus bearing a marked similarity to those of Hants county. A large number of samples were secured within this area by the writer in 1909, and results of the laboratory determination of the more promising are as follows:—

Locality		Imp. gals. crude per ton	U.S. gals. crude per ton	Sp. gr. crude petroleum	Pounds Am. sulph. per ton
Sawmill brook	No. 1.....	9.7	11.6	.906	19.5
"	No. 2.....	8.9	10.7	.893	33.8
"	No. 3.....	8.9	10.7	.....	30.2
"	No. 4.....	20.4	24.5	.....	30.2

Certain of the outcrops represented by the above analyses are of considerable thickness and extent. Although the analyses do not indicate the presence of bodies of high grade shales, yet conditions on Sawmill brook appear to warrant further investigation.

CAPE BRETON

Shales, slightly bituminous in character, are exposed near Lake Ainslie and about the west shore of McAdam lake. None of these shales appear to have commercial value.

Province of New Brunswick

Of the oil shales of Canada, the most important are those which occur in the province of New Brunswick. This statement is based on incomplete data available at the present time. The oil shales constitute a part of the Albert shale series, the geological position of which is shown in the following ascending section:—

Palaeozoic	{ Carboniferous	Millstone Grit (grey and purple tinted shales, sandstones and conglomerates). Slight unconformity.
		Lower Carboniferous (gypsum, limestones, marls, shales, sandstones and conglomerates generally red or green in colour). Unconformity.
		Albert Series (black, brown and grey oil shales with numerous sandstone beds, grits and conglomerates).
Pre-Carboniferous.	{	Unconformity. (Slate, schist, diorite, and granite.)

Although the boundaries of the Albert shale series have not been accurately defined, the series constitutes a belt which may be traced through a distance of some seventy miles, from the Memramcook river on the east, to within a short distance of the village of Hampton. It is evident that the series extends still farther westward, since it may be readily

recognized in the grey and black shales associated with grey and brown sandstones exposed on Kennebecasis island, a few miles north of the city of St. John.

In many places the rocks of the series are concealed by drift and by unconformable Lower Carboniferous sediments, but as a result of folding, the shales reappear at a number of points along the general line of strike. In passing westward, the bituminous character of the shales becomes less marked.

The northern boundary of the Albert shale series has not been accurately defined. To the west of Albert Mines the shales dip away from the Caledonia mountains at various angles. Some six miles to the north, in the Stony Creek oil and gas field, the series approaches the surface in the form of a structural terrace. North of the Stony Creek field the structure is obscure, but it appears that the steeply inclined shales of Indian mountain, 7 miles north of Moncton, also belong to the Albert shale series, and represent the northern denuded limb of a broad syncline. Between the three points the Albert series is entirely obscured by Lower and Middle Carboniferous sediments.

The principal areas within which oil shales of commercial value have been recognized lie within the counties of Albert and Westmorland, and their approximate position is indicated on geological and topographical maps issued by the Geological Survey of Canada.¹ The actual areal extent of workable beds of oil shale has not been determined, but outcrops of shale of commercial quality have been recognized near Upper Dorchester, Taylor Village (or Taylorville), St. Joseph's College, Albert Mines, Rosevale P.O., Pleasant Vale, Mapleton, and near Catamount station, and also along Downing creek, Frederick brook, East and West branches Turtle creek, Hayward brook, Prosser brook, and Montgomery brook. It will thus be seen that the area underlain by oil shale of commercial value is of very considerable extent. At a number of localities, notably at Taylor Village, Albert Mines, Baltimore, Rosevale, and along the east and west branches of Turtle creek, beds of shale have been prospected to some extent by means of test pits and tunnels.² As a result of this work, it is evident that, at each of the localities noted, a number of oil shale bands of good quality and of workable thickness occur. Owing, however, chiefly to the effects of faulting and the prevalence of overburden, it is as yet impossible to indicate definitely the number and average thickness of such bands. This is particularly true of the Albert Mines area. In this area there apparently exists a great thickness of so-called paper shales, but

¹ Geological map of the Lower Carboniferous rocks of Albert and Westmorland counties, New Brunswick, showing the distribution of the Albert shales (1878). Scale, 1 mile to 1 inch.

Map sheet 1. N.E. (Grand Lake Sheet), province of New Brunswick, 1880. (Comprises parts of Sunbury, Queens, Kings, Albert, and Westmorland counties). Scale, 4 miles to 1 inch.

Map Sheet No. 4. N.W. (Cumberland coal field sheet). Province of Nova Scotia and part of New Brunswick (1886). Scale, 4 miles to 1 inch.

Reconnaissance map of parts of Albert and Westmorland counties, New Brunswick (Map 35A). Scale, 1 mile to 1 inch.

Moncton, Westmorland and Albert counties, New Brunswick (Map 63A) 1917. Topography. Scale, about 1 mile to 1 inch.

New Brunswick. Carboniferous areas, and positions of certain shale and clay deposits. (Map 108A). 1913. Scale, 20 miles to 1 inch.

Diagram showing portion of Albert Mines oil shale area, New Brunswick. (Geol. Surv. Can. Summ. Rept. 1913, p. 226).

Albert Mines Oil Shale Area, Albert county, N.B., Geol. Surv. Can. Publication No. 1833.

² Can. Dept. Mines. Report No. 1107, pp. 19-21.

owing to complex distortion of the rocks, through faulting and folding, a definite pronouncement regarding possible tonnage commercially available must await further underground exploration.¹

Apart from surface indications, considerable additional information has been secured through the drilling of numerous deep wells. During the period 1899-1906, a local organization known as the New Brunswick Petroleum Company drilled upwards of 80 wells, chiefly in Westmorland county between the Petitcodiac and Memramcook rivers. The majority of these wells were comparatively shallow, varying in depth up to 1,100 feet, although one at least reached a depth of more than 3,000 feet. In a number of these wells, small showings of petroleum were encountered, but the writer has no definite information regarding the number or character of the oil shale bands passed through.

Since 1909, Maritime Oilfields, Ltd., succeeded by its subsidiary, New Brunswick Oil and Gas Fields, Ltd., has successfully carried on an extensive drilling programme in the Stony Creek oil and gas field, 9 miles south of Moncton, and elsewhere. The wells in the Stony Creek field are located on a structural terrace, and vary in depth from 1,800 to 3,200 feet. Their aggregate shut in capacity has exceeded 100,000,000 cubic feet of gas every 24 hours. The gas is found in a large number of interbedded sandstones, ranging in thickness up to 100 feet, and grouped along indefinite horizons through a vertical range of 2,000 feet.

More recently, drilling to the dip of this gas area has resulted in a moderate production of high quality paraffin base petroleum, and during 1920 the year's production exceeded 6,300 barrels. The greatest thickness of the Albert shale series recorded by any log from the Stony Creek field is approximately 2,800 feet, and in this log the occurrence of some 16 oil shale bands is noted. Of these it is considered that six bands, with an aggregate thickness of 72 feet, are of commercial quality, while the remainder, aggregating in thickness 123 feet, are of somewhat poor quality. Interbedded with these oil shale bands are numerous other sandy, marly and limey shales and thin limestones, which show wide variation in thickness, character, and texture. The total original thickness of the Albert shale series, estimated to be not less than 7,000 feet, would doubtless include a much larger number of oil shale bands of commercial grade. It is considered that the richer bands of oil shale occur in the lower horizons of the series.

Owing to lateral variation, however, it has been found that, even when the horizontal distance between individual wells does not exceed 1,000 feet, serious difficulty exists in correlating individual beds recorded in the logs. This appears to indicate that, in parts of the field at least, rapid changes in thickness and in character of oil shale bands and associated strata may be anticipated. This tendency is in conformity with the habit of associated sandstones and shales of the Carboniferous series of eastern New Brunswick, many of which were laid down in basins of limited extent.

Between 1911 and 1913 other private interests, said to be identified with Sir Wm. Mackenzie, tested the area along the southern margin of the Albert shale basin, by means of diamond drills. It is said that upwards of 14 holes, varying in depth from 700 to 1,500 feet, were drilled in the

¹ Wright, W. J., Geol. Surv. Can., Summ. Rept. 1913 (pp. 223-227).

vicinity of Rosevale P.O., between the east and west branches of Turtle creek, while upwards of 10 other holes were drilled at scattered points. During the period 1919-21, eight other exploratory wells, some of which reached a depth of more than 3,000 feet, have been drilled in other parts of the Carboniferous basin of eastern New Brunswick, by the D'Arcy Exploration Company. The depth of most of these wells exceeds 2,000 feet.

Throughout the geological basin occupied by the Albert shale series notable erosion has taken place. In parts of the basin, several thousand feet of the series have been removed, and subsequently replaced by, unconformable beds of Middle and Lower Carboniferous age. Obviously, under such conditions, only extensive and systematic drilling will indicate the extent to which associated oil shale bands have been affected.

Oil shale bands, associated with the Albert shale series, vary in thickness from a few inches to more than 25 feet. In most instances the shale kindles readily and burns freely. Small splinters, when ignited by a match, frequently support combustion for considerable periods. In general, the oil shales weather through various shades of grey, but the colour of freshly broken surfaces ranges from grey to a typical chocolate brown or brownish black. The shales frequently contain thin laminae or partings of asphaltic bitumen resembling albertite.

In point of geological age, and in certain other respects, the oil shales of New Brunswick correspond somewhat closely with those of Scotland. In each instance two general types of oil shales are recognized, viz., plain and curly. A sub-variety, usually referred to as paper shale, is apparently a weathered form of plain oil shale. It is thin-bedded, or papyraceous, separating readily into thin, flexible sheets of considerable surface dimensions. In many instances, the surface of the sheets are almost covered with imprints of fossil fish remains. Plain oil shales are usually flat-surfaced, showing more or less well-defined lamination. On the other hand, curly shale usually occurs as massive bands, somewhat curled and contorted. It is very tough, breaks with a conchoidal fracture, and is usually especially rich in hydrocarbons, a condition which may have rendered it more easily crumpled than poorer grades of shale. As a rule, the New Brunswick shales are free from grit, and, although easily cut with a knife, do not yield thin, somewhat flexible shavings as do the Scotch shales.

In view of the similarity which exists between the oil shales of Scotland and those of New Brunswick, each may probably be attributed to a somewhat similar origin. In both countries there is little in the shale which is soluble in benzene, carbon disulphide, ether and other similar solvents, and it would therefore appear that petroleum derived by destructive distillation may be attributed to matter of organic origin¹. To express this carbonaceous substance, the term kerogen has been suggested.

Apparently, material from which the shale beds were derived was originally deposited in the form of fine clays on the bottom of lagoons and swamps. If the theory of Steuart is accepted, there was associated with these sediments vegetable matter converted into a pulp as a result of maceration and microbe action in water, richer materials of many kinds,

¹ Carne, J. E., "The Kerosene Shales Deposits of New South Wales".

Steuart, D. R., The Chemistry of the Oil Shales. Oil Shales of the Lothians, Geol. Surv. Scotland, 1912.

such as spores, and a proportion of animal matter. We may, therefore, conclude that the origin of the petroleum in the shales may be traced to fermentation and decomposition of organic matter, through microbe action. In certain cases such action may have been intensified by heat.

The present state of development of the New Brunswick oil shales may be briefly referred to. Attention was first directed to the possible economic importance of the oil shales of New Brunswick about 1849, when Dr. A. Gesner, a local geologist of marked ability, discovered on Frederick's brook, in Albert county, a valuable deposit of the mineral which subsequently became known as albertite. Some fifteen years later, apparently between the years 1860-64, a number of the oil shale beds were examined, and at Baltimore, in Albert county, a retort and stills were erected. At this plant several thousand tons of shale were treated, the crude oil thus produced being subsequently refined and used generally throughout New Brunswick and Nova Scotia. Following the discovery of well petroleum in Ontario and the United States, operations at Baltimore ceased, and it was not until 1908 that the question of retorting New Brunswick shale was again taken up seriously by the Albertite, Oilite and Cannel Coal Company of New York. In that year, a trial shipment of some forty-five tons of oil shale was mined by the company from the George Irving seam, which outcrops near Baltimore, and shipped to the oil shale works of the Pumpherston Oil Company, Limited, at Midcalder, in Scotland. In view of the importance that would attach to the results of retorting this trial shipment, the company interested requested that the work be placed under government supervision. Accordingly, Dr. R. W. Ells of the Geological Survey of Canada and Mr. W. A. Hamor on behalf of the company, were commissioned to proceed to Scotland. The results of their operations, embodied in a joint report¹ issued by the Canadian Department of Mines in 1909, were entirely favourable. Various considerations, however, quite apart from the actual merit of the New Brunswick shale deposits, and the subsequent outbreak of war in 1914, prevented commercial development at that time.

At the present time, representatives of the D'Arcy Exploration Company are making a detailed examination of certain portions of the area. In connection with this work, a small retort of the Wallace type, with the necessary condensor, scrubber, pumps, etc., has been installed on the west branch of Turtle creek, two miles west of Rosevale post office. The retort has a charged capacity of approximately 1,000 pounds. Oil shale and derived distillation products are examined and analysed in a laboratory erected in the immediate vicinity. No figures indicative of results of work undertaken are as yet available.

Detailed exploration of deposits of oil shale on Indian mountain, some 9 miles northwest of Moncton, is also contemplated by a local syndicate.

In view of the incompleteness of data at present available, it is difficult to indicate with assurance the probable economic importance that may ultimately attach to deposits of oil shale lying within the area under

¹ Joint Report on the Bituminous or Oil Shales of the Province of New Brunswick and Nova Scotia, Can. Dept. of Mines, Nos. 55 and 1107.

consideration. Quality of shale and conditions affecting mining operations will be controlling factors, since the development of successful retorting practice may be assumed.

As regards the quality of shale, results of practically all analyses at present available are based on samples taken from the more highly bituminous outcropping bands, and the extent to which these results may be applicable over considerable areas is as yet undetermined. It is considered, however, that the following summarized analyses represent fairly the various shale outcrops from which the samples have been taken:—

Locality	Imp. gals. of crude oil per ton	U.S. gals. of crude oil per ton	Sp. gr.	Pounds of ammonium sulphate per ton
Shale retorted in Scotland.....	35.5	42.6	0.920	69
George Irving's seam.....	35.0	42.0	0.895	68
Baizley farm, Baltimore.....	48.2	57.8	0.895	98
E. Stevens farm, Baltimore.....	43.8	52.5	0.892	60
Hayward brook, branch of Prosser brook....	26.8	32.1	0.895	67
Sample (85 lbs.) from Baltimore run in 1907...	45.5	54.6	0.910	100
Albert Mines—				
Sample No. 1.....	43.2	51.8	0.898	74
Sample No. 2.....	34.8	41.8	0.892	54
Sample No. 3.....	40.6	48.7	0.891	43
Sample No. 4.....	39.0	46.8	0.896	51
Sample No. 5.....	25.2	30.2	0.895	44
Albertite.....	100.0	120.0	0.857	58
Three samples of the thin-bedded or paper shale from Albert mines gave.....	30.0 16.2 36.5	36.0 19.4 43.8	..... ..... 0.892	42 36 36
Turtle creek, west branch, grey shale.....	50.5	60.6	0.891	27
Taylorville shale—				
Adams farm No. 1.....	37.8	45.3	0.897	86
Adams farm No. 2.....	42.5	51.0	0.901	79
Taylor's farm No. 1.....	42.0	50.4	0.902	76
Taylor's farm No. 2.....	40.2	48.2	0.903	90
Downing's creek.....	24.2	29.0	.....	26

It will be seen from the above analyses of samples taken over a wide area, that in the aggregate there is, in the counties of Albert and Westmorland, a very large tonnage of valuable oil shale. The problem of extensive commercial development therefore becomes largely one of mining.

In considering the important question of mining, open cut methods have been suggested, and may be found applicable within certain limited areas adjacent to outcrops. But, throughout the greater part of the area, conditions will probably necessitate the adoption of some recognized underground system, or systems, of selective mining, approximating those employed in the winning of coal. The principal factors which will affect mining operations are variation in thickness and in quality of oil shale bands; variation in character of associated strata, effects of major and minor folding and of faulting, and the possible presence of natural gas. Such considerations indicate the necessity of adequate underground exploration as a preliminary to commercial development.

Transportation in Albert and Westmorland counties presents no serious difficulty. No part of the area is distant more than 12 miles from

standard gauge railway, and branch lines can be constructed at reasonable cost. Much of the eastern portion of the area is immediately adjacent to tidewater.

In certain other respects, conditions may also be considered favourable. The country is well watered, and abundant fresh water is available. A natural gas field has been developed within the area. Climatic conditions are not severe.

Province of Quebec

Apart from certain deposits of oil shale in the Gaspé peninsula, no other occurrences have been recognized as yet in the province of Quebec.

The presence of oil shale in the Gaspé peninsula was reported by Sir Wm. Logan¹ in 1863; but until recent years no definite information has been available regarding the possible economic importance of these deposits. In the course of a brief examination in 1909, during which an area of some three hundred square miles was traversed by the writer, a number of oil bearing shaley sandstone bands were found and carefully examined. A number of samples, secured principally from outcrops along the St. John and York rivers, were subsequently tested in the laboratory.

The shales of the district, while of the same general horizon as those of New Brunswick and Nova Scotia, differ in marked degree in their physical characteristics. Associated strata usually consist of thin-bedded grey sandstones, the interstratified bands or layers being strongly charged with fossil plant remains. These fossil bearing strata have usually a limited local development, forming lenses of from 100 to 200 feet along the bedding of the associated sandstones. The thickness of these lenses varies from a few inches only to 15 or 16 inches. In places a number of these enriched bands unite to form a mineralized zone which, with the associated sandy layers, may reach a thickness of 8 to 10 feet. In the shales of New Brunswick and Nova Scotia the hydrocarbons are chemically combined and must be recovered by means of destructive distillation. In the case of shales examined along the York and St. John rivers, the hydrocarbon content is physically combined, appearing in the form of thin black or amber brown laminae, and fragments of a resinous substance. The thickness of these laminae and fragments rarely exceeds one-eighth of an inch, and is generally much less. The substance has a resinous lustre, conchoidal fracture, and is insoluble in alcohol or naphtha. It is scarcely fusible, but at high temperatures gives off abundance of inflammable vapour.

The following analyses probably indicate fairly well the content of much of this shale in crude oil and in ammonium sulphate:—

Locality	Crude oil in Imperial gals.	Crude oil. U.S. gals.	Ammonium sulphate lbs. per ton
31. St. John river.....	30	36.0	40
32. ".....	31.5	37.8	42.2
33. York river.....	20	24.0	22
34. ".....	36	43.2	59.5

¹ Geology of Canada, 1863.

In so far as these analyses furnish any indication, the shales should be rich enough to warrant further examination. Judging, however, from the limited extent, as well as the irregularity of the majority of the outcrops examined, the presence of workable seams of commercial importance may be considered as very doubtful.

Other shales, in the township of Port Daniel, appear to have little commercial value.

Province of Ontario

(a) *Southwestern Ontario*.—The occurrence of dark, fissile bituminous shales has long been recognized at various points in southwestern Ontario, notably on the Indian Reserve at Kettle point, Lambton co., along the Sydenham river, near Collingwood, and elsewhere. They underlie a considerable area but, owing to the prevalence of heavy drift, their boundaries have not been definitely defined.

Geologically these shales are correlated with the Ohio shale of northern Ohio, and have been described by T. Sterry Hunt,¹ Alexander Murray,² Sir Wm. Logan³, E. M. Kindle⁴, M. Y. Williams⁵, and C. R. Stauffer⁶.

In 1859, twenty-four longitudinal cast iron retorts, having a daily throput capacity of from thirty to thirty-six tons of shale, were erected near the town of Collingwood, and an attempt made to recover petroleum by distillation. It is stated that this quantity of shale yielded some two hundred and fifty gallons of crude oil, equivalent to about three per cent of the rock treated. It appears that, in the operation of these retorts, a certain degree of success was achieved, but operations ceased about 1861 following the discovery of well petroleum near Enniskillen.

The area underlaid by Ohio shales was not visited by the writer, but it appears that the shales, as a whole, are of little present economic importance. Analyses of two samples received from M. Y. Williams⁷ indicate a yield of approximately 10 pounds of ammonium sulphate and 10 Imperial gallons of crude petroleum per ton. Analyses of other samples taken from outcrops near Alvinston and Shetland indicate a yield of crude petroleum equivalent to 3 to 4 Imperial gallons and 6 pounds of ammonium sulphate per ton. Nine other samples of shale, said to be from southwestern Ontario, (exact localities not stated), have also been tested at the chemical laboratory of the Mines Branch, Department of Mines, Ottawa. These showed an average content of crude petroleum equivalent to 7.8 Imperial gallons (9.3 U.S. gallons), and 20.6 pounds of ammonium sulphate per ton of shale. The extent of the deposit of Ohio shale is estimated by Williams⁸ at 116,000,000,000 tons.

(b) *Northern Ontario*.—A broad, and generally level, sedimentary basin, frequently referred to as the James Bay coastal plain, extends south and southwest from the shores of James bay. This basin is underlaid by rocks of Palæozoic age, and is terminated toward the south and southwest

¹ Report of Progress. 1863-66, p. 242.

² Report of Progress. 1865, pp. 129, 130.

³ Geol. of Can. 1863, p. 387; pp. 524-28; pp. 622 and 627; pp. 784-92.

⁴ Geol. Surv. of Can. Summ. Rept. 1912, pp. 287-290.

⁵ Geol. Surv. of Can. Mem. 34, p. 287.

⁶ Geol. Surv. of Can. Summ. Rept. 1912, p. 285.

⁷ Geol. Surv. of Can. Summ. Rept. 1917, pp. 26E-28E.

⁸ Geol. Surv. of Can. Mem. 34, 1915, pp. 182-89; p. 228.

⁹ Geol. Surv. of Can. Summ. Rept. 1912, p. 285.

¹⁰ Geol. Surv. of Can. Summ. Rept. 1917, pp. 26E-28E.

¹¹ Geol. Surv. of Can. Summ. Rept. 1917, p. 28E.

by an escarpment of Pre-Cambrian rocks. The area is traversed by a number of large streams, notably the Abitibi, Mattagami, and Missinaibi. Along these Palæozoic sections, including strata of Ordovician, Silurian, and Devonian age, are exposed.

The possibility of discovering well petroleum in Palæozoic rocks of the James Bay coastal plain, has recently drawn attention to certain petroliferous shales which outcrop on the Abitibi and Mattagami rivers. These shales, which belong to the Ohio formation, are well exposed at the Long rapids on the Abitibi river, and to a limited extent above the Long rapids on the Mattagami river. Sections exposed along the Abitibi are marked by a series of low folds, the general strike of which is approximately east and west. The maximum thickness of shale observed at any point was approximately 55 feet.

In places the shales are covered by a comparatively light overburden of boulder clay and other unconsolidated materials. The construction of the proposed extension of the Timiskaming and Northern Ontario railway would bring the deposits within reach of rail transportation.

In 1911¹ these shales were examined by the writer, and samples subsequently tested in the laboratory showed a content of petroleum ranging from 7 to 16 Imperial gallons per long ton. The maximum yield of ammonium sulphate was equivalent to 16 pounds per long ton of shale. Partial analyses of three other samples, collected by Dr. M. Y. Williams,² indicated a yield of from 3.5 to 12 Imperial gallons (4.2 to 14.4 U.S. gallons) crude petroleum per ton of shale. The calculated yield of ammonium sulphate, based on the nitrogen content, was equivalent to from 18.8 to 38.6 pounds per ton. The amount recoverable in actual commercial practice would be considerably less.

Provinces of Manitoba and Saskatchewan

NOTE.—During the field season of 1921, the writer undertook a reconnaissance with a view of determining the probable economic importance of the Cretaceous shales of the Pasquia hills, Porcupine, Duck and Riding mountains. A complete report embodying the results of this work is in course of preparation.³

During recent years, attention has been directed to reported occurrences of oil shales of Cretaceous age in the provinces of Manitoba and Saskatchewan. Forty-one samples of the shales, representative of a wide area, were collected by the writer during the field season of 1921, and were subsequently tested in the laboratory. The maximum yield of crude petroleum from any sample was 10.9 Imperial gallons (13.1 U.S. gallons), while the maximum yield of ammonium sulphate was equivalent to 3 pounds per ton of shale. The specific gravity of the crude petroleum varies from .944 to .984. All shales examined carry a high percentage of water, the average content of 15 samples being equivalent to 15.4 Imperial gallons (18.4 U.S. gallons) per ton.

It appears, therefore, that the shales examined in the provinces of Manitoba and Saskatchewan are of little present economic importance as a possible source of petroleum or ammonium sulphate. Should conditions at any time warrant commercial development, open cut mining

¹ Report on James Bay Surveys, 1912, S. C. Ellis.

² Geol. Surv. Can. Summ. Rept. 1910, Part G.

³ Mines Branch, Dept. of Mines, Memorandum Series No. 3, 1921.

could be undertaken in many areas under favourable conditions. Over very considerable areas, shales examined are covered by a comparatively light overburden, consisting chiefly of boulder clays and gravel, which could be readily removed by hydraulic methods.

Province of British Columbia

The occurrence of oil shales has been reported¹ near Harper's camp in the Cariboo district, near Lytton, and along Calder creek, a tributary of Flathead river. Detailed exploration of these occurrences has not been undertaken, but from present information it appears that the maximum yield of crude petroleum from any sample tested does not exceed 7 Imperial gallons per ton.

On Graham island, the most northerly of the Queen Charlotte group, viscous hydrocarbons have a wide distribution throughout sedimentary and intrusive rocks of Cenozoic and Mesozoic age. Semifluid bitumen is seen as thin films along bedding planes and joint surfaces, as veinlets in various fractured rocks, and in amygdulæ of certain basalts, as at Tian point. This condition was observed by the writer in 1905, and has subsequently been fully described by J. D. Mackenzie in a report² dealing with the geology of Graham island.

The presence of traces of bitumen over a wide area on Graham island was, at one time, interpreted as a possible indication of petroleum pools. Mackenzie considers that the bitumen originates in the Maude formation, a series of dark coloured, fine-grained, thinly laminated and highly fossiliferous argillites, of Lower Jurassic age. He considers that the possibility of discovering commercial pools of petroleum, associated with sediments of Graham island, may be regarded as remote, but suggests the possibility that oil shale bands of commercial value may be found associated with the Maude formation.

Provisional District of Mackenzie

From time to time, during the past 30 years, the occurrence of oil shale has been reported³ along the Mackenzie river between Fort Norman and Fort Good Hope. These shales are associated with rocks of Devonian age, but little information is as yet available regarding their thickness, extent, and value as a possible source of petroleum and various by-products. The outcrops occur some 1,500 miles to the north of the city of Edmonton, the nearest large centre of population, and apart from other considerations, their geographical position thus renders them of little present economic importance.

¹Ann. Rept. of Min. of Mines, B.C., 1903, p. 24.

Ann. Rept. of Min. of Mines, B.C., 1904, pp. 23, 24.

²Can. Geol. Surv. Mem. 88, 1916.

³McConnell, R. G. "An Exploration in the Yukon and Mackenzie basins, N.W.T.", Geol. Surv. Can. Ann. Rept., new series, vol. IV, pt. D, 1888-89 (1890), p. 31.

Kindle, E. M. and Bosworth, T. O. "Oil Bearing Rocks of Lower Mackenzie Valley", Geol. Surv. Can. Summ. Rept., 1920, Pt. B.

Provisional District of Franklin

Among the specimens collected by Captain Bernier during the voyage of the SS. Arctic in 1908, were black oil shales, which were picked up on the beach of Melville island. These specimens are rich in hydrocarbons, kindling readily when ignited by a match. They are apparently of the same class and probably of the same horizon as the oil shales of New Brunswick, Newfoundland, and Bear island, Spitzbergen.

The results of a sample determined in the laboratory of the Mines Branch showed 64 pounds of ammonium sulphate and 140 Imperial gallons of crude oil per ton of shale.

CONCLUSION

In referring to possible commercial development of oil shales in North America, many writers have cited the admitted success which, until recent years, has attended the Scotch oil shale industry.¹ But new and well recognized factors are already reflected in declining output throughout at the Scotch oil shale works. Among these factors may be mentioned higher operating costs, increasing production of well petroleum from new and from established fields, the potential importance of recognized, but as yet unproductive oil bearing areas, and an increasing production—accompanied by declining market values—of ammonium sulphate derived from sources other than oil shale. Certain of these factors may be of temporary significance only.

Certain of the oil shale deposits of Canada warrant careful investigation. These deposits represent a large aggregate tonnage of valuable shale, and there is good reason to suppose that, under reasonably favourable conditions, they will eventually prove of sufficient merit to constitute the basis of a large and lucrative industry.

Commercial development of these deposits will be determined by the question of supply and demand, for it may be assumed that efficient retorts, adapted to the treatment of various types of shale, will be developed. Apparently mining charges will constitute the most important single factor in production costs, and for the immediate present, will adversely affect development. Exceptional instances may exist where shales carry reasonably high values, and where conditions affecting mining operations are unusually favourable.

Should conditions not appear favourable to commercial development in the immediate future, certain of the oil shale deposits of Canada should, nevertheless, be regarded as constituting potentially a valuable national asset.

¹Beilby, G. "Thirty Years of Progress in the Shale Oil Industry." Jour. Soc. Chem. Ind., Vol. XVI., pp. 878-886, 1897.

Caldwell, W., "The Working of Oil Shale at Pumpherston." Trans. Inst. Min. Engr. Vol. XXXVI, pp. 581-589, 1909.

Craig, Perkin and others, "The Scotch Oil Shale Industry," 1918.

Ells, R. W., "Bituminous Shales of Nova Scotia and New Brunswick, with notes on the Oil Shales of Scotland." Summ. Rep. Geol. Surv. Can. for 1908 and 1909.

Ells, R. W., "Joint Report on the Bituminous or Oil Shales of New Brunswick and Nova Scotia, also on the Oil Shale Industry of Scotland." Bulletins 55 and 1107, Can. Dept. of Mines, 1909.

VIII

CHEMICAL PRODUCTS FROM NATURAL GAS

R. T. Elworthy

Canada has large resources of natural gas, second only in importance to those of the United States. The chief fields are in western Ontario and Alberta, and the annual production in each province is between ten and fifteen thousand million cubic feet.

The supplies of gas from the Ontario fields are, however, decreasing. The old wells are falling off in output and the high cost of drilling new wells and small return upon capital outlay have retarded the development of new sources. The proper use of natural gas in Ontario is undoubtedly for domestic fuel, and the activities of the provincial authorities have chiefly been in economic enquiries and in securing the greatest efficiency of the combustion apparatus. There is great room for improvement in the efficient use and combustion of natural gas. People regard it as a never-failing gift of nature and use it in a correspondingly spendthrift manner.

The condition of affairs in the west is somewhat different. Although certain fields in the southern part of Alberta, such as the Bow Island field, are showing signs of exhaustion, new borings give indications of large resources. In the Athabaska region great quantities of gas have been struck. During the next decade, with the increased exploratory drilling for oil, many gas fields are bound to be opened up and millions of cubic feet of gas will be allowed to waste.

These supplies of gas are situated too far from centres of population to be used as fuel. What can be done with them?

In a recent and most suggestive paper¹ before the Institute of Petroleum Technologists on oil field wastes, Beeby Thompson states his opinion that the greatest waste is sustained in hydrocarbon gases. He says:—

Responsible Washington Officials have volunteered the information that in a few years prior to 1912 not less than 425,000,000,000 cubic feet of gas were allowed to discharge unheeded to waste in the mid-continent oil fields alone, equal to about 9,600,000 tons of oil, or say 14,000,000 tons of good quality coal, whilst gasoline to the value of millions sterling was simultaneously lost. In 1913 a single well in the Cushing oil field gave 1,500,000,000 cubic feet of gas, equal to 34,000 tons of oil, before being shut in, and four others were discharging 126,000,000 cubic feet daily into the atmosphere, equal to about 2,800 tons of coal.

Beeby Thompson suggests the following uses for waste gas:—

- (a) Transmission in pipe lines to industrial centres.
- (b) Development of local industries like glass-making, lime-burning, cement works, irrigation.
- (c) Generation of electric power on a large scale.
- (d) Production of carbon black.
- (e) Fixation of nitrogen from the air.
- (f) Isolation of special constituents.

¹ Jour. Inst. of Petroleum Technologists, Vol. 8, pp. 1-49, Jan. 1922.

Such uses are certainly possibilities in many fields in the United States, and they are rapidly being put to application. The situation is different in Canada where the gas supplies of this nature are too inaccessible to be utilized along these lines.

The solution lies in using them for the manufacture of commercially important chemical products by processes requiring simple plant and little labour, utilizing the gas both as the raw material and for the production of the necessary heat and electric power.

The object of this paper is to point out some of the ways in which natural gas can be used as a basis for the manufacture of such chemical products.

The Mines Branch has had this subject under consideration for some time, and although no striking results have been obtained, much information has been collected which it is hoped may be of value to the natural gas industry.

THE CHARACTER OF CANADIAN NATURAL GAS

Although the natural gas fields have been given considerable attention from the geological point of view¹ very little information exists, especially

Analyses of typical Canadian Natural Gases

Source	Estimated flow cu. ft. per day	Methane	Ethane	Oxygen	Carbon dioxide	Nitrogen	Helium
1. Stony Creek, Moncton, N.B.	10,000,000 (1913)	80.0	7.2	.....	.....	12.8	0.06
2. Simcoe, Ont., Dom. Natural Gas Co. ....	.....	80.3	7.6	.....	0.3	11.8	.....
3. Askew well, Til- bury tp., Kent co.	2,000,000 (1914)	84.4	10.8	(H ₂ S 0.3)	.....	4.5	0.18
4. Fairbanks well, Enniskillen tp. Lambton co., Ont.	15,000,000 (1914)	68.3	15.9	.....	.....	15.8	0.15
5. Welland No. 2, Bertie tp., Ont.	1,000,000 (1914)	80.0	12.9	0.2	.....	7.1	.....
6. Medicine Hat city gas. ....	.....	90.0	3.0	0.1	0.8	5.0	0.11
7. Bow island, Barnwell well No. 25.	4,000,000 (1919)	88.3	3.7	.....	.....	7.0	0.36
8. Sheep river, Calgary, Pe- troleum Pro- ducts well No. 1 and 2.	5,000,000 (1919) 3,000,000 (1918)	72.0 94.0	16.7 .....	..... 0.4	..... 0.6	11.3 5.0	..... 0.05
9. Viking, Alberta.	.....	97.0	.....	.....	1.2	1.8	0.002
10. Pelican rapids, Athabaska river.	870,000 (1916)	96.8	.....	.....	0.3	2.9	.....
11. Kamloops, B.C.	.....	22.5	.....	7.5	1.2	68.3	0.013
12. Port Haney, B. C. ....	.....	.....	.....	.....	.....	.....	.....

¹ Petroleum and Natural Gas Resources of Canada, Vols. I and II, F. C. Clapp and others, Mines Branch Report No. 201, 1914.

The Oil and Gas Fields of Ontario and Quebec, Wyatt Malcolm, Memoir 81, Geological Survey, 1915.
Investigations in the Gas and Oil Fields of Alberta, Saskatchewan and Manitoba, D. B. Dowling, S. E. per
and F. McLean. Memoir 116, Geological Survey, 1919.

Authority—

Nos. 1, 2, 8, 10 and 11	Mines Branch Laboratories
Nos. 3, 4, 5	Messrs. Ellis, Bain and Ardagh
Nos. 6, 7, 9, 12	Mines Branch Bull. No. 31

in the case of the gases in western Canada, concerning the character and nature of the constituents of the chief Canadian gas resources. Table I gives analyses of representative gases.

The chief Ontario gases have been analysed by Messrs. Ellis, Ardagh and Bain, and well described by G. R. Mickle.¹ Their analyses show that the gases are dry gases and usually contain about 80 per cent methane and 10 to 12 per cent ethane. The western gases, as far as the few analyses indicate, seem to be higher in methane, mostly about 90 per cent, though this is probably due to the fact that the analyses are chiefly commercial, with all the hydrocarbons reported as methane, lacking the refinements of the modern gas analysis. There is undoubtedly need for a careful investigation of the western gases.

CHEMICAL PRODUCTS FROM NATURAL GAS

One of the chief developments in chemical technology in recent years has been the number of important chemical processes based on gas reactions. As example may be cited the Haber process for the synthesis of ammonia, ammonia oxidation, the great advances in the production of gaseous fuels, the Shawinigan production of acetone and acetic acid from acetylene, ethyl alcohol from coke oven gas in England, isopropyl alcohol from oil gases, and helium production in Canada and the United States.

The future will see many more advances in this line, especially in the field of hydrocarbon chemistry.

The following, in order of their importance and value, are now being produced on a large scale in the United States.

Gasoline

According to the latest U.S. Geological Survey statistics, of the 5,133,000,000 gallons of gasoline produced in 1920, 383,000,000 gallons, or over seven per cent of the total, were separated from natural gas and casing head gas. In 1919 the amount was about 13 per cent of the production.

The chief methods, fully described in the recent literature,² are (1) compression and condensation (2) absorption in mineral oil or by activated charcoal. The charcoal absorption method, developed by Mr. G. Burrell,³ gives excellent results with gases containing as little as one pint of gasoline per thousand cubic feet, and would undoubtedly be applicable to many Canadian gases.

Dr. D. B. Dowling⁴ carried out some tests of the gasoline content of certain gases from the Bow river, Medicine Hat and Viking fields using an oil absorption method. The Bow island gases contained from 1 to 3 pints gasoline hydrocarbons per 1,000 cu. ft. gas. Tests on gases from the other

¹ Ontario Bureau of Mines, 23rd Annual Report, 1914, pp. 237-273.

² R. P. Anderson, Jour. Ind. and Eng. Chem., 1920, 12, 547.

³ Chem. and Met. Eng. 24, 155-160, 1921.

Geol. Sur. Summary Rep. 1918, pt. C, p. 17.

fields gave negligible results. More work of this character should be done. Only one natural gas gasoline plant is in operation in Canada at the present time, at the Dingman well at Okotoks, near Calgary.

Carbon Black

Carbon black, made by burning natural gas with an insufficient supply of air is a very important product. In 1921 fifty-eight million pounds, valued at over \$5,000,000, were obtained from 49,000,000,000 cubic feet of gas in the United States. The process is very inefficient, as only about 1 to 1.2 lbs. of black is produced from 1,000 cubic feet of gas, compared with a theoretical yield of about 40 (about 2.5 per cent recovery). Although investigations have been carried out with a view to increasing the efficiency, thus far it has only been obtained by a corresponding sacrifice of quality in the product. Here is an opportunity for the physical chemist.

The chief value of this form of carbon lies in its high absorptive property, and it is estimated¹ that the United States product is used in the industries in the following way:—

35 per cent for printer's ink.

40 per cent as a filler in automobile tyres and rubber goods.

10 per cent miscellaneous.

15 per cent exported (to Canada?)

During the first three months of 1921, 380,715 lbs., valued at \$59,053 were imported into Canada, duty free.

The miscellaneous uses include its incorporation in almost every article that is black, such as paints, enamels, stove and shoe polishes, phonograph records, buttons, carbon paper, typewriter ribbons, celluloid, cement colours, drawing and marking inks.

No carbon black is made in Canada at the present time, though several inquiries have been received by the Mines Branch as to suitable locations for carbon black plants. Many of the western gases would probably be satisfactory, but so few complete analyses of these have been made that the proportions of ethane and higher hydrocarbons are not known. The most suitable gases for carbon black manufacture are high in these constituents.

One field which has been considered is at Pelican, on the banks of the Athabaska river, Alta. One well drilled by the Geological Survey in 1897 has yielded ever since a considerable flow of gas, and other wells drilled in more recent years have also afforded proof of the existence of a large reservoir of gas. An analysis of the gas from the government well, made in 1916 by Mr. E. Stansfield, gave:—

Carbon dioxide.....	1.2 per cent
Methane.....	97.0 per cent
Nitrogen.....	1.8 per cent

assuming that the oxygen found in the sample was due to air contamination. Together with gasoline extraction, carbon black manufacture is undoubtedly one of the best uses for waste western gases at the present time.

¹ U.S. Geol. Sur. Mineral Resources of the United States, 1920, Pt. 11, pp. 145-149. Carbon black produced from natural gas in 1920. E. G. Sievers.

Helium

Canada is the only place in the British Empire where helium bearing natural gases are found, and even these contain a lower percentage than the best American sources. The Bow island gas, from which several thousand cubic feet of helium was separated in 1920, due to the efforts of Professor J. C. McLennan, carries about 0.36 per cent. The gas used at the United States plant at Fort Worth, in Texas, from which about 2,300,000 cubic feet of pure helium has been obtained, runs as high as 0.9 per cent. In this connection United States Geological Survey professional paper 121, "Helium bearing natural gas," by A. Sherburne Rogers, is a most valuable and complete study of the subject. The Canadian sources are described in Bulletin No. 31, 1920, Mines Branch, Department of Mines.

Although at the present time there is no market for helium, it would seem a wise policy to investigate every potential source of supply of this gas and to develop the most efficient methods of separation, for, undoubtedly, the scientist will find very valuable uses for helium, and great developments in airship transportation will take place when the European countries recover from the paralysing effects of the great war.

Halogen Derivatives

Natural gas chlorination is a well established chemical process, the chief products being methyl chloride, chloroform, and carbon tetrachloride. Several Canadian patents have been taken out, but none of them have been established on a manufacturing scale in this country.

Some experiments have been carried out in the Mines Branch on the iodation of natural gas. The heat of formation of methyl iodide is much lower than the corresponding heat of formation of methyl chloride, and the reaction should be more controllable so that the monohalide could be made the primary product.

The best arrangement of apparatus was found to be: natural gas→flow meter→preheater→iodine vapourizer→heated catalyst tube→condensing coil→wash bottles→gasometer.

Activated charcoal was used as the catalyst in the first series of experiments. In others the activated charcoal was impregnated with (1) silver, (2) platinum, (3) antimony. The effect of various catalyst temperatures and flow rates was studied. In most experiments small quantities of methyl iodide were formed, but the best yield, at 200° C. with activated charcoal, was only about 4 per cent of the theoretical.

Oxidation Products

Processes using natural gas as a source of formaldehyde and methanol have been the subject of several patents in the United States and Germany, and this problem has been the subject of an investigation in the Mines Branch chemical laboratories for some time. The chief methods examined have been oxidation by passing mixtures of natural gas and oxygen or air over catalysts, oxidation by means of ozone, oxidation by reaction with carbon dioxide, and oxidation in solvents.

The chief catalysts used in the first method were: magnetite, ferric oxide, copper oxide, silver oxide, platinum, thorium oxide, borosilicate glass, uranium oxide and vanadium oxide.

The effect of changing the various factors such as temperature of catalyst, flow rate and ratio of methane to oxygen was studied. The data in the following table were obtained using copper oxide as catalyst and are representative of the results found with the other catalysts. The results were all poor.

CATALYST. Copper oxide on asbestos.

Temp. Catalyst °C.	Ratio CH ₄ , O ₂	Flow rate mixture litres per minute	Space velocity L. per L. Catalyst per hour	Gas analyses							
				Initial gas			Final gas				
				CH ₄	O ₂	CO ₂	CH ₄	O ₂	CO ₂	CO	
410	3 : 1	0.10	187	78.5	20.8	0.2	.....	1.8	12.0	.....
410	5 : 1	0.10	210	78.5	14.4	0.4	.....	1.8	6.2	.....
500	3 : 1	0.10	187	74.6	25.1	0.3	.....	4.5	1.3	.....
500	3 : 1	0.10	187	74.2	24.7	0.7	81.6	1.4	16.8	0.2	
500	2 : 1	0.10	165	65.0	30.3	0.6	.....	4.2	17.6	0.2	
500	5 : 1	0.10	210	78.4	17.4	0.6	.....	2.3	16.3	.....
500	9 : 1	0.10	225	85.2	9.4	0.6	.....	1.4	2.8	.....

In the second method no action occurred when natural gas was mixed with oxygen containing 3 per cent ozone. The gas and oxygen were then mixed before passing through the ozoniser and the mixture subjected to the silent discharge.

A gummy liquid was formed consisting chiefly of polymerised aldehyde, though methanol, formic acid, and formaldehyde were also detected. The apparatus used was not very satisfactory and several explosions occurred. Further experiments with faster flow rates and a better type of ozoniser should be carried out. Only traces of formaldehyde were obtained in the third method.

The results obtained thus far have not been very encouraging, agreeing with the experience of investigators working on the same problem in the United States. Formaldehyde is usually formed by either method, but the yields are very low and far too small for the establishment of a commercial process. Methanol is seldom detected in the products of reaction, though it is a theoretically possible product. Formaldehyde is rapidly becoming a very important and widely used chemical, and a cheap process of manufacture from natural gas would be of great value.

Some work has been done in the Mines Branch laboratories on the hydrogenation of formaldehyde. According to Sabatier and Senderens¹ formaldehyde is quantitatively converted to methanol when passed with hydrogen over nickel at 90° C.

A number of experiments were therefore carried out in which formaldehyde was formed by heating paraformaldehyde in a current of hydrogen, and the mixture of gases passed over nickel catalyst prepared in the usual way by reducing pure nickel nitrate, heated to 300° C. in a current of hydrogen.

¹ Comp. Rend. 137-302.

The gases issuing from the catalyst chamber were scrubbed by passage through a series of wash bottles containing water, and the methanol and unchanged formaldehyde were estimated. The following table gives some of the data obtained:—

Exp. No.	Catalyst	Catalyst temp. °C	Rate of flow hydrogen c.c. per min.	Methanol % of theoretical formed	Total formaldehyde recovered %
VI A.....	nickel	150	200	15.7	31.9
X A.....	"	125	300	13.5	43.5
XII A.....	"	100	300	23.7	61.4
III C.....	"	150	200	19.0	64.0
I B.....	platinized asbestos	100	300	23.5	53.2
II B.....	"	130	300	26.8	54.3
XI B.....	cobalt	100	200	35.2	70.0
XII B.....	"	200	200	34.0	54.5
IX B.....	glass wool	100	300	15.5	87.6

It will be observed that the reaction was far from complete, under the conditions employed. There was also a loss of formaldehyde, which has not yet been quite satisfactorily accounted for.

The most probable explanation is that an acetal or an aldol condensation takes place and experiments now in progress seem to confirm this.

Hydrocarbons

With the increasing development of the synthesis of complex organic substances, such as rubber and camphor, the higher paraffin hydrocarbons, e.g. butane and pentane, will become important, as these substances can be readily converted by chlorination and reduction into higher unsaturated compounds such as isoprene and butadiene, the starting point for rubber synthesis. By hydrolysis the chlorides can be made into various alcohols and thence by oxidation into complex aldehydic and acidic substances.

Butane and pentane occur in some natural gases and casing head gases, and might be isolated. These compounds have never been reported to occur in any Canadian gas, probably because no examination has been made for them. It has been recently reported that a process has been established in Germany for the manufacture of liquid hydrocarbons from methane or natural gas on the lines of the Haber process.

Ethylene

Several suggestions have been made that ethylene might be made from methane by passage over carbon mixed with catalysts.

Ethylene is a gas which is rapidly growing in importance, and methods for its separation from the gases given off in coke oven¹, oil cracking and oil shale retorting plants are being developed, with the subsequent production of ethyl alcohol for fuel purposes.

¹ Jour. Soc. Chem. Ind. 1920, 94, 593A.

Experiments on the formation of ethylene by the passage of natural gas over mixture of heated copper oxide and carbon have been conducted in our laboratories. The greatest percentage of ethylene found under the conditions employed has been 3 per cent. Even this amount is greater than would be expected according to the studies of V. B. Lewes and of Profs. W. A. Bone¹ and H. F. Coward on the decomposition of the simpler hydrocarbons by heat.

Other possible products from ethylene besides alcohol are the chlorinated derivatives and from them by hydrolysis, glycols. The polymerization of ethylene yields higher hydrocarbons of commercial value, though the reactions have been given little attention from an industrial view point.

CONCLUSIONS

This list of products, some of them not yet produced commercially shows the possibilities of natural gas as a raw material for chemical products of great value, and is a sufficient argument for the expenditure of time and money for the conservation and development of this natural resource. The Mines Branch laboratories are well equipped to carry out much of this work, though the successful solution of these problems will be obtained only by the widest exchange of opinions and by co-operation with the natural gas and chemical industry.

¹ Jour. Chem. Soc. Trans. 93, 1197, 1903.

CHEMICAL DIVISION

F. G. Wait

Chief of Division

During the year 1921, in addition to the usual analytical work, two special lines of investigation were pursued in the chemical laboratory of the Mines Branch, Sussex Street, Ottawa.

I. To discover if it be possible to prepare in commercial quantities methanol (methyl alcohol) and formaldehyde from the natural gas which occurs in several parts of Canada, particularly in Alberta and Saskatchewan.

II. A study of the properties of the colloidal clay known as bentonite, and its possible application in the industries.

The work in both these investigations is still incomplete, but it is realised that sufficient progress has been made to warrant publication of the important results already attained.

I

THE POSSIBILITY OF PRODUCING METHANOL (METHYL ALCOHOL) AND FORMALDEHYDE FROM NATURAL GAS

R. T. Elworthy

During the last three or four years, owing to the efforts made by Great Britain and the United States to establish dye and other organic chemical industries, methanol and formaldehyde have rapidly grown in importance, and increased attention has been paid to their production.

The only source of methanol is from the wood distillation industry; formaldehyde is, of course, manufactured from it.

Methanol, however, is one of the minor products in the distillation of wood, and the supply—until the recent depression in trade—has not kept pace with the demand. When conditions improve it is anticipated that increasing quantities of these essential chemicals will be required. The wood distillation industry will not be able to meet this demand, hence other methods of production must be found. One possible source is by chemical processes, using natural gas as raw material.

THE USES OF METHANOL AND FORMALDEHYDE

Methanol

The chief use of methanol is, probably, in the manufacture of formaldehyde, in which process a very pure grade of alcohol is required. The operation consists in passing a mixture of air and alcohol vapour over hot copper gauze, the success of the reaction being dependent on careful control of the temperature. The resulting formaldehyde is absorbed in water, the solution concentrated, and usually sold in the form of a 40 per

cent solution by volume, or 36.5 per cent by weight. A certain amount of methanol—about 12 to 14 per cent—is added, to prevent the polymerization of the aldehyde. Paraformaldehyde or paraform, a white crystalline powder, is a polymerized product, produced by evaporating solutions of formaldehyde. When heated, this substance evolves formaldehyde vapour and is used for disinfecting purposes.

Methanol is largely used as a solvent for varnishes, lacquers, and celluloid products. The dye industry requires considerable quantities both for solvent purposes, and for conversion into such compounds as dimethyl sulphate, and methyl iodide, both of which are used for introducing the methyl group into the complex organic dye molecules. The methyl radicle is of great value in the manufacture of organic substances for medicinal and photographic purposes, and is a constituent of many synthetic perfumes and flavours. Much of the crude methanol finds a use as fuel for stoves and lamps.

Formaldehyde

The uses of formaldehyde are many, and this compound is being increasingly employed in the chemical industries.

When mixed with phenols and similar compounds, and subjected to the action of alkali, heat and pressure, various synthetic resins are formed, known in commerce as bakelite, redmanol, condensite, etc. This field of industry takes a large quantity of formaldehyde.

Dilute solutions of formaldehyde have the property of hardening nitrogenous material such as gelatin, casein, etc., and on this account formaldehyde is of great value in the tanning and photographic industries.

It is also largely used as a disinfectant, deodorizer, and insecticide. Other minor uses are in the manufacture of medicinal compounds, in dyeing and textile printing, and in embalming and preserving.

THE CHEMICAL TREATMENT OF NATURAL GAS

Some of the chief developments in industrial chemistry during the last ten years have been based on gas reactions, in which gases have been utilized as the raw materials. The outstanding example is the synthesis of ammonia from hydrogen and nitrogen, by the Haber process, the success of which was one of the chief factors that enabled Germany to declare war in 1914. On the other hand, another process which perhaps helped to defeat Germany was the development in Canada of acetone and acetic acid manufacture from acetylene. Other processes using gases as raw materials are the manufacture of ethyl alcohol from ethylene present in coke oven gases, of isopropyl alcohol from propylene derived from the unsaturated gases evolved in the cracking of oils, also the production of gasoline from many natural gases, together with helium from the same source. Controversy has arisen in the United States over the rightful use of natural gas, whether it should be used as raw material for chemical processes or as domestic and industrial fuel. Whichever may be settled, there are many millions of cubic feet of natural gas which are being wasted in Canada, a commodity which would provide ample raw material for wealth producing chemical industries.

THE OXIDATION OF NATURAL GAS

When natural gas is burned in an unlimited supply of air or oxygen, carbon dioxide and water are the only products. The theory of the mechanism of combustion postulates the process as occurring in stages with the intermediate formation of complex compounds composed of water bound to the carbon atom of the methane molecule. Such compounds might be CH_3OH , $\text{CH}_2(\text{OH})_2$, $\text{CH}(\text{OH})_3$ and $\text{C}(\text{OH})_4$.

It would be expected that these, on further oxidation and decomposition, would form HCOOH , HCHO , CO_2 , CO and H_2 .

If suitable conditions could be found, therefore, it should be possible to stop the oxidation halfway, and to isolate the more stable intermediate compounds, such as methanol and formaldehyde. Thus formaldehyde can be often smelled on lighting a natural gas burner in a cold furnace.

These compounds have been found qualitatively in the partial combustion of natural gas, and it is recognized that in the near future commercial processes will be established for their production in this way.

PATENTS COVERING THE OXIDATION OF NATURAL GAS

Several patents of processes for the production of formaldehyde and methanol have been taken out at various times. One of the earliest is that of H. S. Blackmore, U.S. Pat. 774824, 1904. According to this patent, methane is passed over substances such as ferrous ferric oxide, cupric or manganese oxides at 260°F. to produce methanol, or at 315°F. to give formaldehyde. He claims to get 125 pounds of methanol, or 118 pounds of formaldehyde, from 1,500 cubic feet of methane, which works out to be an efficiency of over 90 per cent. Considerable quantities of the oxides are used up, so that the process cannot be considered a catalytic one.

A somewhat similar German patent assigned to Glock, D.P.R. 107014, specifies the passage of equal volumes of methane and air over granulated copper on pumice heated to 800°F. , with the resulting production of formaldehyde.

Fernekes in U.S. Pat. 1038546, 1911, employs a special form of combustion furnace, in which the oxidation is regulated so as to isolate the products of partial combustion.

Unruh U.S. Pat. 891,753, 1907, subjects mixtures of methane and air to the catalytic action of specific vegetable products, such as oak bark, at a temperature of 30° to 60°C. , and claims high yields of formaldehyde, formic acid, and methanol. Another early patent was that of Lance and Elworthy, Brit. Pat. 7297, 1906, who claimed to oxidize methane by hydrogen peroxide with the addition of ferrous sulphate or monopersulphuric acid.

A number of inventors have attacked the problem by first chlorinating methane, separating the methyl chloride—which is one of the products of the reaction—and then hydrolysing the chloride to form alcohol. The chief patents on chlorination are those of Lacy, U.S. 1,111,842 and Can. Pat. No. 173,969, 1916, C. W. Bedford U.S. Pat. 1,245,553. J. Walter, German Pat. 222,919, 1909. A further list is given in U.S. Technical Paper 255, "The chlorination of natural gas," U.S. Bureau of Mines, 1921.

The second stage, the conversion of methyl chloride to alcohol, is also the subject of patents, Lacy, Can. Pat. No. 191,542, 1919, but the efficiency of the reaction is doubtful.

CANADIAN NATURAL GAS FIELDS

The chief gas fields in Canada are situated in southwestern Ontario and Alberta, and have been fully described, at least from a geological point of view, in several reports¹ issued by the Department of Mines. Two other reports² give more information from the chemical side.

In Ontario, the fields may be grouped into seven districts which yield the following approximate annual production:—

	Cubic feet per year
Oil Springs, Petrolia field.....	170 million
Tilbury and other Kent fields.....	8,000 "
Selkirk, Rainham, Dunville field.....	2,100 "
Brant-Onondaga field.....	60 "
Blackheath-Seneca field.....	500 "
Welland field.....	3,000 "
Toronto field.....	negligible

Chemical analysis of many gases from these fields, made by Messrs. Ellis, Bain, and Ardagh², show great similarity of composition, the average being about 80 per cent methane, 12 per cent ethane, and 8 per cent nitrogen. The following are typical analyses:—

County and well	Methane	Ethane	Nitrogen	Carbon dioxide	Hydrogen sulphide	Flow, cubic feet per day
Askew, Kent No. 2.....	84.4	10.8	4.5	.....	0.3	2,000,000
Lambton, No. 3.....	80.2	11.7	8.1	.....	.....	.....
Haldimand, No. 2.....	79.7	11.4	8.9	.....	.....	470,000
Welland, No. 2.....	80.0	12.9	7.1	.....	.....	1,000,000
York Scarboro tp.....	85.1	.....	13.2	1.6	.....	.....

More recent analyses of Ontario natural gases, carried out in this Department, follow:—

	Methane	Ethane	Nitrogen	Carbon dioxide
Dominion Natural Gas Co., well at Simcoe, Ont.....	80.3	7.6	11.8	0.3
St. Bernardin, Prescott co.....	86.2	.....	33.0	0.8

1. Petroleum and Natural Gas Resources of Canada, Vols. I and II, F. G. Clapp and others, Mines Branch Report No. 291, 1914.

The Oil and Gas Fields of Ontario and Quebec, Wyatt Malcolm, Memoir 81, Geological Survey, 1915.

Investigations in the Gas and Oil Fields of Alberta, Saskatchewan, and Manitoba, D. B. Dowling, S. E. Slipper and F. M. McLean, Memoir 116, Geol. Survey, 1919.

2. Ontario Bureau of Mines 23rd Annual Report, 1914, pp. 237-273. Report on some Sources of Helium in the British Empire, by J. C. McLennan and Associates, Bull. No. 31, Mines Branch, 1920.

In Alberta, the fields may be considered under the following districts:—

	Approximate supply per year, cubic feet.
1. Medicine Hat field.....	7,300 million
2. Bow island field.....	13,000 "
3. Sweet Grass country, Milk River field.....	1,000 "
4. Suffield Brooks Bassano, Calgary field.....	1,200 "
5. Okotoks field.....	700 "
6. Wetaskiwin, Viking, Vegreville field.....	1,300 "
7. Athabaska field.....	300 "

The figures for the available supply are only very approximate, calculated from the estimated daily flow. They are larger too than the reported production, which was 8,230 million cubic feet, valued at \$1,365,127, in 1919.

On an average, the Alberta gas is higher in methane than the Ontario gas, as shown by the following analyses:—

Locality of well	Methane	Ethane	Nitrogen	Oxygen	Carbon dioxide
Medicine Hat city gas.....	90	3	5	0.1	0.8
Calgary and Bow island.....	91.3	.....	8.4	0.2	0.1
Pipe line, Okotoks gas, Dingman well—					
(i) Casing head gas.....	66.1	34.1	.....	0.49	0.25
(ii) Bottom gas.....	99.0	.....	.....	0.2	0.5
Viking.....	94.0	.....	5.0	0.4	0.6
Barnwell well No. 25.....	87	5.0	7.6	.....	.....
No. 9 and 10 and Southern Alberta.....	88.2	0.9	11.0	.....	.....

1. From Bulletin 31, Mines Branch, pp. 21 and 55.

The quantity of gas produced in New Brunswick, chiefly from the Stony Creek field, is small, and amounted to 6.82 million cubic feet in 1919.

A recent analysis of gas from this field, collected near Moncton, gave the following result:—

	Per cent.
Methane CH_4	80.0
Ethane C_2H_6	7.2
Carbon dioxide.....	none
Oxygen O_2	none
Nitrogen and rare gases N_2	12.8
Density.....	0.82

Very little natural gas has been found in Quebec, and no analyses are to hand.

Similarly, in British Columbia natural gas has been struck only at Port Haney, Pitt Meadows, on Pender island in the Gulf of Georgia, and recently near Kamloops.

The following analyses show that in two cases the gas is almost entirely nitrogen:—

	Methane	Ethane	Nitrogen	Carbon dioxide	Oxygen
Port Haney.....	22.5	0.15 (olefines)	68.3	1.2	7.5
Pitt Meadows.....	none	.....	99.0	0.5	0.5
Pender Island.....	none	.....	99.0*	.....	.....
Kamloops.....	96.8	absent	2.9	0.3	.....

*A recent analysis does not agree with this result.

The latter gas was analysed by the fractional distillation method, an apparatus for this purpose having been assembled during the year. Other Canadian gases should be analysed in this way, as this method gives the proportions of gasoline hydrocarbons present, and is far more valuable than the ordinary combustion analysis.

This brief survey shows that although there is comparatively little reliable information on the composition of Canadian natural gases, there are undoubtedly many which would serve as suitable raw material for chemical processes.

EXPERIMENTAL WORK IN THE MINES BRANCH LABORATORIES

After a survey of the patents and the scientific literature, the following lines of attack were decided upon:—

- (I) Oxidation in the gaseous phase by passing methane and oxygen or air over various catalysts.
- (II) Oxidation by ozone.
- (III) Iodation, and subsequent hydrolysis.
- (IV) The reaction between carbon dioxide and methane.
- (V) The formation of ethylene from methane, and its subsequent oxidation.
- (VI) Oxidation of methane in solution, and by liquid oxidizing agents.

The following pages outline briefly the results of the experiments on each of those methods.

Method I: Oxidation in the gaseous phase

A natural gas containing 80.3 per cent methane, obtained from a well at Simcoe, Ontario, by the courtesy of the Dominion Natural Gas Co., was used for the experiments. This gas, mixed with oxygen, after being purified, was led at varying flow rates over catalysts in a special furnace. The products of the reaction were absorbed in water or collected in a gasometer, and examined qualitatively and quantitatively for methanol, formaldehyde, formic acid, carbon dioxide, carbon monoxide, oxygen, and methane, by the usual methods.

The chief conditions which control the reaction are:—

- (1) Ratio of methane to oxygen.
- (2) Nature and form of catalyst.
- (3) Temperature of catalyst.
- (4) Time of contact, and space time yield.
- (5) Effect of water vapour and impurities in the gases.
- (6) Pressure conditions.

Several series of experiments were carried out, using gas mixtures containing two, three, five, and nine parts of methane to one of oxygen, respectively, at flow rates from three to fifteen litres per hour.

The catalysts employed were natural magnetite, ferric oxide, copper oxide, copper, silver oxide, silver, platinum, thorium oxide, and borosilicate glass, distributed on materials such as pumice, asbestos, and activated charcoal.

Tests were made with the catalysts maintained at temperatures between 150° and 500° C.

In some experiments the gases were thoroughly dried, in others water vapour was present.

Analyses showed that carbon dioxide was always a product of the reaction at temperatures over 250° C. Formaldehyde was detected at 500° C. with each catalyst, and in the case of the copper oxide catalyst at 400° C. It was never in sufficient amounts for a satisfactory quantitative measurement.

Method II: Oxidation by ozone

Several observers have studied the effect of ozone on hydrocarbons, especially Otto (*Annales de Chimie et de Physique Series*), Vol. 13, 1898, p. 109) and Drugman (*Jour. Chem. Soc.* 89, 1614, 1906).

They obtained traces of methanol, formaldehyde, and formic acid, when methane and ozonised oxygen were mixed, both at room temperature and at 100° C., but the amounts formed were very small, even though 200 litres of methane was used in some experiments.

Hauser and Herzfeld (*Ber.* 45, 3575, 1912) state that small amounts of methane are quantitatively oxidized to formaldehyde at ordinary temperatures.

Experimental.—A special ozoniser was constructed, and many experiments carried out to obtain a highly ozonised oxygen. The usual concentration of ozone was about 3 per cent by volume of the oxygen used.

This ozonised oxygen was mixed with natural gas, and the mixture led through a reaction tube at various temperatures, and finally through condensers and wash bottles.

In some experiments, activated charcoal, or platinized asbestos, was used in the reaction tube. No formaldehyde or methanol was detected.

The arrangement was then changed, and natural gas and oxygen passed through the ozoniser, in the proportion of 1:2 and at varying speeds. An oily liquid was formed in the ozoniser tube, which was found to be a mixture of polymerised aldehydes, methanol, acetone, and formic acid. The wash waters gave strong positive reactions for aldehyde and alcohol. Owing to experimental difficulties, and occurrence of explosions, only preliminary experiments were made. It seems one of the most promising methods of the oxidation if it can be controlled and prevented from going too far.

Method III: Iodation

Many investigations have been conducted on the chlorination of natural gas, and many patent processes are recorded. The U. S. Bureau of Mines Technical Paper 255, 1921, contains a good bibliography on this subject. Although the production of methanol by the hydrolysis of methyl chloride, one of the products of chlorination, is said to be difficult to carry out, one corporation in the United States has developed a process for the manufacture of methanol in this way, though at the present low prices it is not economically practicable.

The reaction between methane and iodine should be much more under control so that the mono-halide could be made the chief product. It would be expected, too, that methyl iodide would be more easily hydrolysed than the corresponding chloride.

Experimental.—Apparatus was arranged so that mixtures of natural gas and iodine vapour were passed over activated charcoal, with and without metallic catalysts. The products of the reaction were separated by condensation and water absorption.

The rates of flow, temperature, and nature of catalysts were varied, and in every experiment methyl iodide was obtained. The yields were small, however, never amounting to more than 5 per cent of the theoretical yield, assuming only the formation of the mono-halide.

The efficiency of the hydrolysis of methyl iodide with water, and with alkali solutions, was also studied, and was found to be far from complete at ordinary pressures. The best results with solutions of sodium hydroxide containing 40 gms. per litre showed only 38 per cent of the theoretical yield of alcohol.

Even though the difficulty of recovering and re-using the iodine could be successfully overcome the process could not be made economic.

Method IV: Reaction between methane and carbon dioxide

British Pat. No. 156,148, 1921, by H. Plauson and J. A. Vielle, specified the production of formaldehyde and methanol by passing a mixture of methane and carbon dioxide through a constricted metal tube of copper, silver, nickel, or alloys of these metals with aluminium, tin, or zinc, heated to several hundred degrees temperature.

Although carbon dioxide is only dissociated into carbon monoxide and oxygen at very high temperatures (2,500-3,000° C.) it is possible that in contact with heated metals some decomposition may take place at lower temperatures, and the products may react with the methane present giving the desired intermediate oxidation products.

Experimental.—Natural gas containing 80 per cent methane was mixed with carbon dioxide in various proportions, and the mixtures passed over copper gauze, platinized asbestos, or silver on asbestos, packed into a quartz tube. These catalysts were heated to various temperatures between 500° and 800° C. Gas analyses were made of the initial and final gases and the wash waters were examined for the presence of formaldehyde and methanol. No indication of these substances was obtained below 700° C. At 750-800° C. traces of formaldehyde were detected, and in three experiments qualitative measurements were carried out. The results showed that only about one-thousandth of the theoretical yield was formed.

Method V: Formation of ethylene from methane

It has been recently shown that ethylene may be readily oxidized to formaldehyde.¹

Ethylene does not occur naturally, though it is present to the extent of 3 to 5 per cent in coal gas. The recent development of the manufacture of ethyl alcohol from ethylene derived from this source has received much attention. Other uses would undoubtedly be found if a cheap supply of ethylene was developed.

It is stated (De Boistesselin and Dubosc in "Rubber, its Production, Chemistry and Synthesis," Griffin, London, 1918) that ethylene can be formed by passing methane over carbon deposited on copper, heated to 400-450° C., though from the work of V. B. Lewis (Proc. Roy. Soc. 55, 99-107, 1894) on the decomposition of ethylene such a result does not seem probable. Some experiments were therefore undertaken to see if ethylene could be obtained in this way.

Natural gas was passed over copper gauze on which carbon black had been deposited at temperatures of 500° to 850° C.

Analyses of the initial and final gases were carried out. At 620° C. and at 845° C., 1.6 per cent and 2.8 per cent ethylene was found in the exit gas. Several experiments were made to determine the optimum flow rate and the space time yields. The best yield of ethylene obtained was 3.6 per cent of the volume of methane in the initial mixture. A much higher yield would be necessary for a commercial process to be successful, working along this line.

Method VI: Oxidation of methane in solutions

A special apparatus has been constructed to measure the solubility of methane in various solvents, and to carry out experiments on oxidation of this dissolved gas.

Only preliminary experiments have, as yet, been carried out.

The work on these various methods has been summarized very briefly, and results given in a few lines have been only obtained by a series of experiments and analytical work occupying many weeks and months. Although the data collected does not give promise of a successful industrial process, only the fringe of the investigation has really been covered. There remains to be studied further extensions of the methods already tried: the effect of catalysts such as uranium, molybdenum, and vanadium, which are being employed so much at the present time, and other methods based on new principles. Much more data must be collected on the equilibria between the lower hydrocarbons and their oxidation and decomposition products, without which no real progress can be made. There are many other problems connected with natural gas and with the hydrocarbon gases which will amply repay solution, such as the more efficient separation of gasoline, and production of carbon black, and the synthesis and utilization of the higher hydrocarbons, with the ulterior production of liquid paraffins, the higher alcohols, aldehydes, and acids, and all the valuable industrial products of which they are the raw materials.

¹ R. Willstätter and Bommer *Annalen* 422, p. 36046, 1920. *Chem. Abs.* 15, 1925, 1921.

II

CHEMICAL AND PHYSICAL CHARACTERS OF BENTONITE

E. A. Thompson and A. Sadler

An investigation of the chemical and physical characters of bentonite has been undertaken as part of a general study of this interesting material referred to by Mr. H. S. Spence, at page 15 of Summary Report of Investigations by the Mines Branch during 1920, and by Mr. Joseph Keele, at page 159 of the Summary Report of the Mines Branch for 1918.

As noted by Mr. Keele and by Mr. Spence in the reports above referred to, the variety of clay known as bentonite occurs at several localities in western Canada.

It differs in several respects from ordinary clay, and possesses properties which it is believed will make it of considerable economic importance.

It is described by Mr. Keele as follows: "When freshly exposed it varies from a light yellow to light olive green, with waxy lustre..... The clay is exceedingly fine-grained and has a soapy feeling when wet. It swells and forms a jelly-like mass in an excess of water." (1918 Summary Report, p. 159).

Its chief use, hitherto, has been as a filler in paper manufacture, but it has been suggested that it might be employed for any of the following purposes: (1) soap making, in which process it can actually replace a portion of the soap substance; (2) as a filler in rubber, textiles, leather, phonograph records, cordage, pressed and moulded insulations; (3) as an ingredient in gypsum and lime plasters; (4) in ceramics; (5) for replacing, in part, the bonding clay in abrasive wheels, graphite crucibles, chemical and electrical porcelain; (6) as an adhesive paste; (7) for dehydrating crude petroleum; (8) as a water softener, and base for massage creams; (9) in printer's ink; (10) as a substitute for fuller's earth.

Analyses.—Eight samples from five widely separated localities have been analysed, as follows:—

1. British Columbia—near Merritt. Top of an 8-foot bed.
2. British Columbia—near Merritt. Middle of an 8-foot bed.
3. British Columbia—near Merritt. Bottom of an 8-foot bed.
4. British Columbia—near Princeton.
5. Alberta—Camrose.
6. Alberta—Rosedale.
7. Wyoming, U.S., from the earliest discovered deposit.
8. Wyoming, U.S. (?), wilkinitite, a trade name for bentonite, precise locality where found is not stated.

Analyses by Mr. A. Sadler upon air dried material gave the following results:—

	British Columbia Top	British Columbia Middle	British Columbia Bottom	Princeton	Camrose
H ₂ O at 105°C.....	3.92	6.64	6.09	7.71	5.94
H ₂ O over 105° C.....	4.28	4.92	4.73	3.24	3.70
SiO ₂	69.70	67.04	69.60	68.60	60.78
FeO.....	0.23	0.22	0.22	0.32	0.43
Fe ₂ O ₃	2.88	2.79	1.79	2.00	3.67
Al ₂ O ₃	14.00	13.46	11.84	12.10	17.08
CaO.....	1.56	1.78	2.28	1.84	2.84
MgO.....	1.81	1.93	1.75	1.84	2.16
TiO ₂	0.23	0.25	0.20	0.14	0.22
P ₂ O ₅	0.014	0.09	0.09	0.17	0.033
Na ₂ O.....	1.09	0.53	0.48	0.50	1.54
K ₂ O.....	0.29	0.22	0.14	0.23	0.46
SO ₃	none	none	none	0.61	0.005
S.....	0.016	0.008	none	none	0.04
CO ₂	0.04	0.02	0.73	0.17	0.11
Cl.....	trace	trace	trace	trace	trace
C.....	0.09	0.10	0.07	0.08	0.13
N.....					
	100.150	100.008	100.01	99.55	100.138

	Rosedale	Wyoming (I)	Wyoming(?) (II) Wilkinite
H ₂ O at 105°C.....	8.10	5.80	11.91
H ₂ O over 105° C.....	4.28	3.67	3.24
SiO ₂	54.88	66.90	53.90
FeO.....	0.22	0.12	0.18
Fe ₂ O ₃	4.10	2.80	3.21
Al ₂ O ₃	19.92	15.26	18.00
CaO.....	2.22	0.46	1.00
MgO.....	2.83	2.26	3.61
TiO ₂	0.25	0.11	0.65
P ₂ O ₅	0.09	0.04	0.10
Na ₂ O.....	1.75	2.12	2.72
K ₂ O.....	0.26	0.42	0.21
SO ₃	0.16	0.08	0.19
S.....	none	0.018	none
CO ₂	0.37	0.05	0.21
Cl.....	trace	trace	trace
C.....	0.07	0.03	0.53
N.....			none
	99.50	100.138	99.66

The foregoing analyses were undertaken with four objectives in view:—

- To ascertain if any definite chemical relationship existed between the several samples.
- To calculate, if possible, a definite (mineralogical) formula for bentonite.
- To discover its origin.
- To have an accurate and complete record of its composition.

Comments—

(a) The silica content in these clays varies widely from 53.90 per cent in the wilkinitite to 69.70 per cent in the British Columbia (top) sample. The wilkinitite (53.90 per cent) and the Rosedale samples (54.88 per cent) do agree fairly closely, which, however, may be only a coincidence. The alumina varies from 11.84 per cent in No. 3 to 19.92 per cent in No. 6. These variations of the alumina and silica do not indicate a very definite relationship between the materials of the different deposits. Apart from these the amounts of the other constituents agree quite closely.

It was noticed that a high silica content is attended by a low alumina. The converse is also true.

(b) The calculation of a formula does not appear to be possible, at present. This may be accomplished after a microscopic examination has been made.

(c) Analysis does not give any definite information as to the probable origin of these clays as it does in the case of kaolin. The probability is that these were derived from highly siliceous rocks, possibly volcanic, which have undergone subsequent alteration.

(d) These analyses, it is believed, constitute the most complete record of composition of Canadian bentonite at present available.

ANALYSES OF CERTAIN AMERICAN BENTONITE CLAYS

The following analyses of similar material are published in Bulletin No. 2289 U.S. Bureau of Mines Reports of Investigations, 1921, entitled "Bentonite Supplies, Properties, and Uses," by Raymond B. Ladoo, Mineral technologist, U.S. Bureau of Mines.

It was deemed advisable to include these analyses, in order to afford comparison with the Canadian bentonite clays.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
SiO ₂	60.54	57.98	58.68	59.84	60.18	63.20	54.00	55.22
Al ₂ O ₃	23.26	22.46	25.91	11.84	26.53	12.90	24.48	21.00
Fe ₂ O ₃	3.92	3.80	3.97	3.26	.....	2.46	3.00	3.61
TiO ₂	0.12	.....	0	.....	.....	0.11	.....	.....
CaO.....	0.59	1.92	1.45	2.90	0.23	0.82	2.08	4.94
MgO.....	2.19	3.24	1.49	2.32	1.01	2.09	2.75	3.04
K ₂ O.....	0.37	1.35	0	2.34	1.23	0.26	.....	.....
Na ₂ O.....	4.33	.....	1.39	2.13	.....	0.66	1.74	1.56
SO ₃.....	.....	0.75	0.11	.....	.....	.....	.....	0.43
CO ₂.....	.....	.....	tr.	.....	.....	3.50*	.....	tr.
Cl.....	.....	.....	0.10	.....	.....	0.20**	.....	0
P ₂ O ₅.....	.....	.....	0.06	.....	.....	.....	0.71	.....
Ign. loss.....	.....	7.93	.....	10.50	.....	.....	.....	.....
H ₂ O.....	2.83	.....	6.84	.....	10.26	13.80	9.12	10.28
Total.....	98.25	99.43	100.00	95.13	99.49	100.00	97.88	100.08

*Sand, etc. **Water soluble.

No. 1. Yellow colloidal; Belle Fourche, South Dakota. Analyst, W. A. Selvig, U.S. Bureau of Mines.

No. 2. Yellow, colloidal; Medicine Bow, Wyoming. Analyst, A. G. VanEman, Owyhee Chemical Products Co., Chicago, Ill.

No. 3. White colloidal; near Barstow, California. Analysis from California Master Products Co., Los Angeles, California.

No. 4. White, fine-grained; Otay, San Diego county, California. Analysis from Otaylite Products Co., Los Angeles, California.

No. 5. Type material from near Rock Creek, Laramie Basin, Wyoming. Analyst, T. T. Read, Cassa Mining Co.

No. 6. From Big Horn Basin, Wyoming. Analyst, R. C. Wells, U.S. Geological Survey.

No. 7. Supposed bentonite, near Shelbyville, Tenn. Analyst unknown.

No. 8. Ardmorite, probably variety of bentonite, Ardmore. South Dakota. Analysis from the Refinite Co., Omaha, Nebraska.

Physical Properties

(a) Absorptive Powers, for Water, Oils and Glycerine.

One gram from each of the undermentioned samples was found to absorb the indicated number of grams of water. Clay and water in contact for 24 hours:—

British Columbia.....	1.53
Camrose.....	4.15
Rosedale.....	4.71
Wyoming.....	4.93
Wilkinite (?).....	4.95

Experiments with oils and glycerine have not yielded any satisfactory results.

(b) *Specific gravity*.—Crude material, ground to 100 mesh, dried at 105° C. for 2 hours. Determination by pycnometer, gave the following results:—

British Columbia (composite).....	2.44
Rosedale.....	2.72
Camrose.....	2.73
Wyoming.....	2.77
Wilkinite (?).....	2.78

(c) *Fusion point*.—

	Cone No.	Temp.
British Columbia.....	15.....	1430° C.
Rosedale.....	14.....	1410° C.
Camrose.....	1.....	1150° C.
Wyoming.....	11.....	1350° C.
Wilkinite.....	10.....	1330° C.

(d) *Effect of heating on the swelling, and colloidal properties of the crude material*.—Determinations were made of the water remaining in the clay after it has been heated to the indicated temperatures for a period of one hour. It was also found that after heating to a certain temperature, which differed in the different samples, that the swelling property was destroyed, and that the other colloidal properties were diminished as the temperature increased. The results obtained are indicated below.

Percentage amount of water remaining in the clay.

	Before heating	450° C.	500° C.	550° C.	600° C.	700° C.
B.C. Composite.....	4.64	*4.04	3.94	.....	2.53	1.50
Camrose.....	3.70	.....	*3.60	.....	2.09	1.14
Rosedale.....	4.28	.....	.....	*4.17	.....	.....
Wyoming.....	3.67	.....	3.49	.....	*3.43	0.77

*Swelling property completely destroyed.

The foregoing results show that there is no fixed relation between swelling properties and the quantity of combined water present. In the B.C. sample, swelling was destroyed at 450° C., and in the Wyoming sample at 600° C., and yet they both retained the greater quantity of their combined water.

It was also found that after heating from 400° C. to 600° C., there remained only a very small quantity in suspension after standing in water for 24 hours. Heating to 700° C. destroyed the colloidal property altogether. Even at 700° C. combined water still remained in the clay.