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DEPARTMENT OF MINES

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Preliminary Report on the Bituminous Sands of Northern Alberta

BY

S. C. Ells.

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Letter of Transmittal.

Dr. Eugene Haanel,
Director Mines Branch,
Department of Mines,
Ottawa.

Sir,—

I beg to submit, herewith, a preliminary report on the bituminous sands of Northern Alberta.

I have the honour to be, Sir,
Your obedient servant,
(*Signed*) **S. C. Ells.**

Ottawa, Jan. 15, 1914.

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PRELIMINARY REPORT ON THE BITUMINOUS SANDS OF NORTHERN ALBERTA

BY

S. C. Ells.

THE BITUMINOUS SANDS OF NORTHERN ALBERTA.

INTRODUCTORY.

Exploration in northern Alberta commenced with the advent of fur traders, in 1778. Subsequently, other explorers, either as private individuals, or in official capacities, have mapped out various portions of the area, and reported on the physical features and natural resources.[1]

Present knowledge of the geology of northern Alberta is based largely on the work of Dr. Selwyn,[2] Dr. Dawson,[3] Dr. Robert Bell,[4] and R. G. McConnell.[5] Mr. McConnell's report, published in 1893, still constitutes the most complete description available of the general geological features, and of the character of much of the country lying between the Peace and Athabaska rivers.

While, however, much of the areal geology of northern Alberta is known, there is, at the present time, very little definite information available, official or otherwise, with regard to the extent and actual value of the mineral resources of this area. But notwithstanding the lack of detailed exploration and prospecting—which has been discouraged in the past, because of the absence of adequate transportation facilities—the occurrence of deposits of bituminous sands and sandstones has long been recognized. And when, in the near future, the proposed Alberta and Great Waterways railway is completed, it is fully

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[1] Harman, D. W. A Journal of Voyages and Travels in the Interior of North America, 1820.
Tache, A. A. Sketch of North West America, 1870.
Ogilvie, Wm. Report on Athabaska and Peace Rivers, 1884.
Reports of Select Committees of the Senate, enquiring into the resources of the Mackenzie Basin, 1888-1891.
Fawcett, T. Exploratory Survey of Athabaska and Churchill Rivers, 1889.
Canada's Fertile Northland. Report of Senate Committee, 1907.
Preble, E. A. North American Fauna, No. 27; Athabaska-Mackenzie Region, 1908.
Crean, F. J. Report of Exploration, 1908-09, issued by Department of Interior.
Ponton, A. W. Survey of Fifth Meridian, from township 77 to township 107, 1909.

[2] Report on Exploration in British Columbia by A. R. C. Selwyn, G.S.C., 1875.

[3] Report on Northern Part of British Columbia and the Peace River Country, by Geo. M. Dawson, G.S.C., 1879.

[4] Report on part of the basin of the Athabaska River, by Robert Bell, G.S.C., 1884.

[5] Report on a portion of the District of Athabaska, by R. G. McConnell, G.S.C., 1893.

expected that the greatest hindrance to the development of the mineral and other natural resources of the region, will be removed.

Owing to the large areal extent of these deposits, and to a somewhat curtailed field season, this report on the bituminous sands of the McMurray district[1] can be regarded as little more than a series of brief reconnaissance notes. It is thus possible that further and more detailed investigation may, to some extent, modify the views here expressed. It is hoped, however, that the present notes may prove of some value, not only as a means of expressing certain conclusions that have been established, but as a possible basis for further investigation. Meanwhile, it is not the writer's intention to attempt the introduction or reproduction of a mass of miscellaneous data on various recognized methods and standards of road construction, manufacturing processes, and laboratory procedure. A complete discussion of such technical considerations will be found in an extensive bibliography, of which the following is a selection; also in a great number of contributions to technical journals, and to the proceedings of various societies.

BIBLIOGRAPHY.

Although only the briefest reference is here possible the following may be noted:—

Operations of Engineering Dept., Washington, D.C., 1898-1913.
Dust Preventatives and Road Binders. Hubbard. Pub. by Wiley and Sons, N.Y.
Street Pavements and Paving Materials. G. W. Tillson. Pub. by Wiley and Sons, N.Y.
Die Asphalt und Teerindustrie. Van Wilhelm Friese.
Les Bitumes, par Phillippe Narcy. Pub. by P. Ving, Dunod et Cie, Paris, 1898.
Natural Rock Asphalts and Bitumens. Arthur Danby. (D. Van Nostrand and Co., N.Y.)
Engler-Hofer-Das Erdol, published by S. Herzil, Leipzig.
Asphalt and Petroleum in Oklahoma. Hutchison, 1911. (Issued by the State Bureau of Geology at Norman, Okla.)
Chemie und Technologie der Naturlichen und Kunstlechen Asphalte. Dr. Hopplnt Kolher.
Petroleum and Asphalt in Ungarn by Dr. Theodor Rosewitz. Pub. by Buchdruckerie des Franklin-Vereins, Budapest, 1907.
Roads and Pavements, by I. O. Baker. Pub. by John Wiley and Sons.
Solid Bitumens. S. F. Peckham.
Art of Roadmaking. H. Frost. Pub. by Constable and Co., N.Y.
Highway Construction, by A. T. Byrne. Pub. by John Wiley and Sons.
Road Preservation and Dust Prevention, by W. P. Judson. Pub. by the Engineering News Publishing Co., N.Y.
Asphalt Construction, by C. Richardson, N.Y.
The Modern Asphalt Pavement, by C. Richardson. Pub. by John Wiley and Sons, N.Y.
Preliminary Report on the Rock Asphalt, Asphaltite, Petroleum and Natural Gas in Oklahoma. Oklahoma Geol. Sur. Bull. No. 2.
Preliminary Report on the Road Materials and Road Conditions of Oklahoma. Oklahoma Geol. Sur. Bull. No. 8.
Gladwell System for using bituminous sand.
Mineral Industry—Vols. III to XXI.
Thirteenth Report State Mineralogist, California State Mining Bureau.

[1] The area here, for convenience referred to as the McMurray District, may be arbitrarily defined as lying between W. long. 110° and 113° and between N. lat. 56° 30′ and 58°. All exposures of bituminous sand in this area lie within a radius of 60 miles of McMurray.

At the present time the commercial value of certain classes of bituminous sands and sandstones[1] depends altogether upon their use in a more or less crude condition, in the construction and surfacing of certain classes of roads and pavements.[2] The possible commercial extraction of the included bitumen, and the question of the possible derivation of by-products will not, therefore, be discussed in the present paper.[3]

SCOPE OF PRESENT REPORT.

The bituminous sands of Alberta, heretofore commonly referred to as "tar sands," outcrop at a large number of points along the Athabaska river and its tributaries, for many miles to the north and south of McMurray.[4] Certain of these outcrops represent portions of the deposit that should prove to be commercially valuable, but it is also true that a very large portion of the area underlaid by bituminous sands cannot be considered as of any present economic value. (Plates VI, X, XI, XVII, XXIII, XXVI, XXVII). In many instances it has been possible to definitely eliminate certain outcrops from further consideration; but, for reasons noted elsewhere, it is not at present an easy matter to definitely assert that certain other deposits will prove of commercial value. Opinions here expressed relative to outcrops, as well as estimated thickness of strata and overburden, are necessarily based solely on present surface indications, for, as stated elsewhere, only extensive stripping and other systematic exploration can render accurate data available.

The Egg Lake (Legal) occurrence is described by Tyrrell[5] as in narrow veins in the post-glacial clay and in a bed of post-

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[1] Appendix IV.

[2] Appendix II.

[3] Appendix III.

[4] Besides deposits of bituminous sand in the McMurray district, other occurrences in the Province of Alberta have been recognized near Bonnie Glen (N. W. 1/2, Sec. 14, tp. 47, R. 27 W. of 4th Meridian); Nakamun (N.E. 1/4 Sec. 28, tp. 56, R. 2 W. of 5th Meridian); Legal (Sec. 28 and 32, tp. 57, R. 25 W. of 4th Meridian); Westlock (S.E. 1/4 Sec. 5, tp. 60, R. 26 W. of 4th Meridian), and elsewhere. At none of these localities has bituminous sand been found in commercial quantity, although it is only fair to say that as yet no systematic prospecting has been seriously undertaken. The deposits are, however, so situated that no great outlay would be required to finally determine their commercial value.

At present they are here referred to merely as easily accessible and typical examples of a type of deposit that appears to have a fairly wide distribution. In the opinion of the writer they are not "in place," and are therefore probably limited in extent. This conclusion has been arrived at after carefully examining such imperfect evidence as is at present available at the various localities mentioned.

[5] Report of the Geological Survey, Vol. XI, p. 29A.

glacial sand. Dr. Dawson, on page 30A of the same report, states that the sandstone bed saturated with bitumen has been proved by boring to be but eight inches thick, and is inclined to believe that the rock strata underlying the glacial and post-glacial deposits is pierced by a small fault by means of which some bitumen from the deeply buried lower Cretaceous rocks had been enabled to force its way into the surface deposits.

GENERAL DESCRIPTION OF DEPOSITS.

Up to the present time no development work has been undertaken, nor has any effort been made to "prove-up" any of the outcrops of bituminous sands in the McMurray district. Consequently, in the present preliminary report, it would be unwise to venture a final opinion regarding the relative value represented by various outcrops. Mere measurements of what are frequently imperfect vertical sections, unless supplemented by accompanying topographical maps, cannot convey much information. Nevertheless, by indicating measurements of a number of such sections, an attempt is made to illustrate certain features common to many of the outcrops. It is, however, believed that, from information already secured, an opinion may be formed of the relative value of the various separate areas referred to in this report. Although the area represented by actual outcrops has not been accurately determined, it is probably not less than 750 square miles. Extensions of the deposit under heavy cover, particularly toward the south, will greatly increase this estimated area.

At various points wide variations occur in the quality of the material, the thickness and character of deposits, and, in those topographical and geographical conditions which must, to a large extent, control possible future development. These features will be more fully referred to elsewhere, in discussing subdivisions of the main area.

Geological Horizon of Deposits.

It is not the writer's present intention to discuss the probable conditions that have resulted in the formation of the deposits, nor the origin of the bituminous content. Geologically, however, the bituminous sands represent the Dakota sandstones, and directly, but unconformably, overlie limestones of Devonian age. Originally in the form of soft sandstones and uncompacted sands, subsequent and more or less complete impregnation by heavy asphaltic hydrocarbons, has resulted in the present coherent material. Overlying the bituminous sands are various soft Cretaceous sediments.

Assuming that the residual bitumen has been derived from an asphaltic petroleum, possibly originating in underlying Devonian strata,[1] it seems probable that the inflow has been a horizontal one, rather than an upwelling at many points over a large area. The very general absence of faulting appears to bear out this supposition. If such is the case, the enrichment of the deposit will vary from the main inlet or inlets toward the outer margins of the basin, an assumption which appears to be borne out by actual conditions. It also seems probable that the folding of the Devonian strata was developed prior to the impregnation of the Dakota sands. This assumption, if correct, may prove of importance in determining the position of the more enriched portions of the area, and in explaining the genesis of the asphaltic residuum. Variation in the physical character and chemical composition of the contained bitumen is, of course, to be expected, since the original petroleums would themselves probably vary somewhat from point to point over so extensive an area.

General Character of Deposits.

A bituminous sand that will comply with standard paving specifications, should, generally speaking, primarily possess a certain grading of mineral aggregate, and a certain percentage of suitable bitumen. Within well defined limits, each of these constituents may be modified to conform with specified requirements.

[1] North of this district, bitumen occurs, at intervals, in Devonian limestones exposed along the valley of the Slave and Mackenzie rivers. Moreover, in other parts of Canada, and the United States, Devonian strata are known to be petroliferous; therefore, in the absence of evidence to the contrary, it is quite possible, in the present instance, that the overlying Dakota sands have constituted reservoirs for petroleum—derived from this source.

Accurate and complete information regarding the various outcrops, can only be secured by careful and systematic prospecting with proper appliances,[1] and intelligent development of any deposit should be preceded by such preliminary work.

The lower limit of the bituminous sand is well defined by its contact with the Devonian limestone (Plates XVII, XXVIII). There is not, however, any such well defined upper limit. Nevertheless, there is, in many instances, a more or less well defined line between what may be termed the high grade material of commercial value, and what must be classed as low grade material of little or no value. In the majority of well exposed sections, the richer material occurs in the lower part, shading off into the leaner grades in passing upward. In no instance was high grade sand found to directly underlie the superimposed shales, sandstones, and drift.

It is also noticeable that the lower part of nearly all exposed sections consists of unstratified sands, and, prior to impregnation by the bitumen, these sands were apparently uncompacted. Consequently, the lower portion of the resulting bituminous sands is generally of a more or less homogeneous character. In passing upward, however, narrow bands of sandstones and occasional quartzites are found interbedded with the originally uncompacted sands. These non-bituminous strata gradually increase until, by their preponderance, they entirely replace the bituminous sand. It will thus be seen that, in estimating the probable economic importance of any of the various outcrops, there are certain factors which demand careful consideration. Of these the following may be mentioned:—

Thickness and character of overburden. During the limited time available for such work, sections of a number of the more important outcrops were measured. In so doing, an attempt was made to determine thickness of bituminous sand of commercial grade, thickness of what may be referred to as low grade material, and of which probably the greater part must be classed as overburden, and finally, the probable thickness of surface drift and other overburden to be removed by stripping. In many instances, earth slides, the encroachment of the timber

[1] Appendix No. V.

line along the upper part of an exposure, and the presence of a more or less extensive talus pile along its foot (Plate XX), had partially obscured the outcrop. In such cases, the securing of accurate measurements would have necessitated extensive excavation work, and approximations were, therefore, made. For similar reasons it was found somewhat difficult to accurately indicate the length of many of the outcrops. Such data, even if available, would frequently have little significance, since the occasional outcrops, apparently, merely represent small portions of one more or less continuous deposit. Indeed it is quite possible that certain parts of the deposit, which are at present partially or wholly obscured by timber or drift, may, on examination, prove to be more advantageously situated for development purposes than are many of the sections at present well exposed. For exposures naturally occur at bends of the stream where the current, impinging against the outer shore, has caused the formation of cut banks. So uniformly does this rule apply that, given an accurate map of any of the streams flowing through the area underlaid by bituminous sands, it is possible to indicate very closely those points at which outcrops of bituminous sand are to be found. (Plate XVI).

In the case of each deposit, it is, of course, assumed that any development must take the form of open cut mining or quarrying, thus presupposing a preliminary stripping of all overburden. In order to form some relative idea of the probable extent of such preliminary work, contour maps of eleven of the more promising areas were prepared. A study of these maps has shown that, viewed from the standpoint of overburden alone, a very considerable percentage of the total area underlaid by bituminous sands may at once be eliminated from further consideration. (Plates V, X). In attempting to estimate the thickness and extent of overburden at any particular point, it is of value to remember that the upper horizon of the bituminous sand lies, for the most part, in an approximately horizontal position.

No discussion of geological sections[1] along the Athabaska river is here required. Between Athabaska[2] and the Cascade

[1] See R. G. McConnell, in G.S.C., Annual Summary Report, 1893.
[2] Formerly known as Athabaska Landing.

rapids, La Biche shales, Pelican sandstones and shales, Grand Rapids sandstones (Plate III), and Clearwater shales are, at various points, well exposed; but northward and eastward from the Cascades rapids, the Clearwater series and surface drift appear to constitute the entire overburden above the bituminous sand. Thus, in undertaking stripping operations, the class of material to be excavated should present no serious difficulty, since shales and sandstones, with occasional thin bedded quartzites, represent the strata to be removed. The surface drift consists chiefly of boulder clays and sand. Only accurate topographical maps of individual areas, supplemented by systematic boring, will furnish definite information regarding the quantity of overburden to be stripped. Meanwhile, possible stripping methods, and the important problem presented by the disposal of waste material, need not be discussed. Obviously, however, other things being equal, areas situated at the junction of two streams present material advantages from the standpoint of removal of overburden.

As already noted, the lower part of the exposures usually consists of higher grade, and of more or less homogeneous bituminous sand. But even here certain variable features must be carefully considered.

Variation in grading of mineral aggregate. Too much prominence cannot be attached to the importance of securing a product of uniform grade. Indeed, it would seem that this feature probably more than any other has, in the past, discouraged the development of many deposits of bituminous sand in the United States. In a body of siliceous sand of such wide areal extent as that under consideration, wide variations in the grading and purity of the mineral aggregate must be expected. Even within comparatively narrow limits, however, is this true in the McMurray district. In a number of cases where the grading of the mineral aggregate is not satisfactory, it appears possible that, by combining the product from two or even three separate outcrops, a satisfactory grading will be obtained.

Variation in bituminous content. To some extent the degree of impregnation has depended on the grading of the sand. The medium grained and moderately compact deposit is usually the

Fig. 3. Approximate Section along part of Athabaska River, north of Athabaska
Horizontal Scale, 1 inch = $12\frac{1}{2}$ miles.
Vertical Scale, 1 inch = 1000 feet.

richest, whereas the finer grained aggregate has retarded a free penetration. Variation in the percentage of contained bitumen has already been referred to, and varies widely in all exposed sections examined. At some point, however, in the majority of outcrops measured, a bed of bituminous sand of commercial dimensions, with a sufficiently uniform impregnation of bitumen, was found. Indeed it is probable that lack of uniformity in the percentage of bitumen present in any one particular bed selected, will be one of the least serious difficulties to be overcome.

Impure partings. Throughout a large number of the exposed sections examined, impure partings occur to a greater or less extent. In the majority of instances these partings, being impervious, act as sills along which the bitumen from overlying sands concentrates. Seepages of semi-liquid bitumen, drawn to the surface by the action of the sun, are thus seen to follow roughly horizontal planes. In certain cases thin partings are so insignificant as to be negligible, but in other instances these are so numerous and of such dimensions as to render the whole deposit practically worthless (Plates VI, XI, XVII, XXIII, XXVI, XXVIII). The continuity or persistence of any band varies with its thickness. An interstratified band, 3 inches thick, may at times be traced hundreds of feet, while the length of a band, one quarter inch thick, rarely exceeds a few feet. Materials of which such partings are composed vary, but the more important may be briefly enumerated:—

1. Clay.—This is usually a tough, sticky, impervious clay, showing little or no trace of bituminous impregnation. Although the thickness may vary from that of a knife blade to 12 inches, it rarely exceeds 3 inches.

2. Sandy clay.—The proportion in which the sand and clay are combined is, of course, variable. When the sand predominates, the content in bitumen may be as high as 4 per cent. When the clay predominates, the percentage of bitumen is practically nil.

3. Roughly stratified partings of lignitic particles are frequent, and at times attain a thickness of 6 inches. The average fragments of lignite are usually not larger than a bean.

4. Roughly stratified partings of fine gravel, much of which would remain on a $\frac{1}{2}''$ sieve.

5. Narrow sandy partings having a high percentage of fine micaceous particles.

It will probably be possible to incorporate in paving mixes, a certain percentage of material from the various impure partings. To what extent this may be true can only be determined by laboratory tests and experimental mixes.

Having in view considerations such as the above, the desirability of securing accurate samples by the systematic boring of any selected area becomes obvious.

To some extent the percentage of contained bitumen, and the prevalence of impure partings, may be recognized in the appearance of an exposed section. Beds of high grade homogeneous bituminous sand are usually marked by a typical uneven cleavage roughly parallel to the face (Plates XXII, XXIV). Such a cleavage or flaking off is especially noticeable where heavy overburden has set up transverse pressure. Where the percentage of contained bitumen is low, the cleavage becomes more angular and follows more and more the line of bedding planes (Plate VIII).

When one considers the period of time during which the outcropping bituminous sand has been exposed to weathering agencies and to alteration resulting from movement in the river banks, the difficulty of correctly interpreting surface indications is at once apparent. Only actual exploration will render available data regarding the extent to which such alteration has taken place. Meanwhile analyses of samples taken at the surface and at a depth of 4 feet, show practically identical results, and it is probable that alteration will generally not extend beyond such a depth. On steeply inclined cut banks lying above high water level, this absence of alteration is due, in part, to the flaking off of bituminous sand at frequent intervals. In other instances, however, where low lying deposits, less steeply inclined, are exposed to action of water, the zone of alteration will doubtless extend to greater depth.

SUB-DIVISIONS OF BITUMINOUS SAND AREA.

For more convenient reference, waterways along which bituminous sands were observed, may be divided into three sections. These divisions are purely geographical, and are not based on any considerations connected with the bituminous sands themselves.

Section 1. Boiler rapids to McMurray—approximate length, 40 miles.

Section 2. McMurray to northern limit of bituminous sands on Athabaska—approximate length, 65 miles.

Section 3. Various tributaries, east and west of Athabaska river—approximate length, 65 miles.

Along each of the above sections, and on both sides of the various streams, it is probable that bituminous sands may be traced as a more or less continuous deposit. The actual outcrop is, however, frequently obscured immediately along the shores by timber, drift, and also as the result of heavy slides, and of changes that at various times have taken place in the stream channels.

As might be expected in a country covered by a heavy mantle of clay, and through which streams are deeply entrenched, slips in the bank constitute a notable feature. Individual slides at times bring down many hundreds of tons of clay and soil (Plates IV, XII).

Slides of this type are especially prevalent and their effect most marked, where the retaining influence of forest growth has been removed by fire. This is particularly noticeable on the Christina river. Along the lower part of this stream the forest growth has, to a very considerable extent, prevented serious slips in the banks. A few miles from the mouth, however, where the country has been burned over, the greater frequency of slides is at once seen (Plates II, IV). The removal of forest growth as a preliminary to development work on deposits of bituminous sand, would thus necessarily intensify the effect of such slides; while subsequent stripping operations, undertaken on a larger scale, would tend still further to destroy the equilibrium of the adjacent ground. This feature is further emphasized by the presence of numerous fissures in the clay and other surface deposits. These fissures, often of considerable length and extent, lie parallel with the top of the bank, and, in places, the strip of country thus affected and rendered unstable, extends for upwards of 1000 feet from the shore line. This fissured zone decreases in width as the overburden decreases in thickness.

Beyond the occurrences indicated on the accompanying map, other exposures of bituminous sand are reported at points many miles to the east and west.[1] These, however, require no consideration at the present time. If among the deposits already recognized in the McMurray district none are commercially valuable, it is very doubtful if outlying areas of economic importance will be found north of Athabaska.

In considering possible development of any of these deposits, depth of overburden, freedom from impure partings, uniformity of material and accessibility to transportation facilities, have been considered as chief controlling factors.

Section 1.

ATHABASKA RIVER, BOILER RAPID TO McMURRAY.

In descending the Athabaska river, from Athabaska, the first outcrop of bituminous sand was observed just above the Boiler rapid on the west shore, although bituminous sand float was found some 4 miles farther south. At the former point, the valley of the Athabaska is over 400 feet deep, the sides for the most part, rising steeply from the water's edge. As such conditions implied a thickness of overburden altogether prohibitive, no samples were secured, nor were any actual measurements taken between this point and the Cascade rapid. Throughout this distance of upwards of 18 miles, bituminous sands are probably more or less continuous along both sides of the river, though the actual outcrop is frequently obscured. Such exposures as do occur are usually much banded, and much of the bituminous sand itself is of a low grade.

[1] Of these may be mentioned, reported exposures on Buffalo lake, Sask., and on the Wabiskaw river, Alta.

Between the foot of the Cascades and the forks at McMurray, a number of exposed sections were examined. Here, as elsewhere, owing to talus piles, clay slides and drift, difficulty was experienced in determining the lower limit of the bituminous sand, as well as the upper limit at which the material ceases to be of commercial grade. Thus, in considering data and measurements given on this and other sections in the McMurray district, these conditions must be borne in mind. Although at only one of these sections were samples taken, it appears probable that in nearly all, beds of bituminous sand of workable size and of commercial quality will be found. A serious difficulty is, however, presented by the heavy overburden (Plate V), a feature well illustrated by the measurements shown on page 14.

It will be seen at once that the thickness of overburden will probably prohibit commercial development at most points where the above exposed sections occur. It should, however, be remembered that these sections are usually found at the outer edge of river bends where the stream has cut back into the higher ground, and has thus exposed high sections that necessarily show a heavy overburden. It is possible that a careful study of the less abrupt topography of ground lying between such sections, may, if accompanied by systematic borings, result in the discovery of workable deposits. Considering the forest growth and surface drift that would be met with, such work would be somewhat difficult and expensive. Therefore, in view of the more favourable conditions under which bituminous sand is found elsewhere in the McMurray district, it is doubtful if, with one or two possible exceptions, the deposits referred to in Section No. 1, should be seriously considered at the present time.

Section 2.

ATHABASKA RIVER, NORTH OF McMURRAY.

Along the Athabaska river, north of McMurray, 19 separate outcrops of bituminous sand were noted. Of these, 13 of the more promising were examined in some detail.

Principal Exposures along Section 1, Athabaska River, Boiler Rapid—McMurray.

Number.	Average exposed thickness high grade material	Average exposed thickness low grade material.	Total average exposed thickness of bituminous sand.	Thickness of overburden.	Horizontal distance from foot of outcrop to point at which thickness of overburden is estimated.	Lower limit of bituminous sand above or below water level.	Side of river.	Miles south of McMurray.	Approximate length of outcrop.
	70	20	90	180+	650	Above.	W.		
1.	75	20	95	415	900	"	W.	14½	2500+
	55+		55+	395	855	"	W.		
2.	70		70	160+	690	"	E.	13½	2200
3.	65+		65+	140+	800	"	W.	13	600
4.	70	20	95	210+	800	"	E.	11½	3060
5.	75	60	135	320+	1200	"	E.	9	1400+
6.			155	200+	1110	"	E.	6	4000
			105	210+	700	"	E.	6	
7.			120	200+	600	"	W.	5	900
8.			115	220+	650	"	E.	3½	1200
9.			95+	150+	600	"	W.	2¼	700
10.			90	150	500	"	E.	1¾	600+
	35	45	90	40	200	"	E.		
11.	25	65	90	60	700	"	E.	¾	
	50	25	75	160	950	"	E.		2600
			120	125	900		E.		

Although all are outcrops of what is apparently one continuous deposit, there is, as elsewhere, considerable variation in quality of material, and mode of occurrence. Consequently it is probable that of the 13 outcrops examined, quite 50 per cent may, for the present, be eliminated from further consideration. The following table indicates measurements of representative sections, and requires no comment.

Section 3.

TRIBUTARY STREAMS IN THE McMURRAY DISTRICT.

Apart from exposures of bituminous sand along the Athabaska itself, frequent outcrops also occur on a number of tributary streams. Of these, Horse creek, Hangingstone creek, Steepbank, Muskeg, Moose, McKay[1] and Christina[2] rivers, may be referred to. Each of these has eroded a deep notch-like valley along the bottom of which winds a shallow, and often tortuous water course. In ascending these streams, swift current and almost continuous rapids are met with during the first few miles. At high or even medium stages of water, such sections may usually be navigated by light canoes, but rarely at low water. As, however, the general level of the surrounding country is approached, the water deepens, the current becomes slack, and navigation easier. It may be added that, owing to the topographical nature of the valleys, these streams are quickly affected by heavy rains, and, even at periods of low water, may thus for a few days, occasionally become navigable for canoes by poling and tracking.

Outcrops of bituminous sand on tributary streams may be grouped in two classes. A brief reference to the topography of Horse Creek valley will indicate the basis of classification. Less pronounced forms of these two types of deposit will be found along most of the other tributary streams of the McMurray district.

[1] Formerly known as Red river.
[2] Formerly known as Pembina river.

Horse creek flows through a deep, trough-like depression, older apparently than the relatively small and tortuous water course that at present winds along its bottom. The effective erosive force in this valley was, however, probably never equal to that of the Athabaska. Consequently, in the case of the Athabaska, we have today a river channel cut completely through the bituminous sand and well into the underlying Devonian limestone. The stream that eroded the Horse Creek valley has, at only two points, cut down to the base of the bituminous sand, and as a consequence, the floor of the present valley is, for the most part, made up of bituminous sand. Into this floor a diminishing flow of water has cut its way, and, in receding to its present insignificant channel, has left a series of well-defined terraces of bituminous sand. (Figs. 1 and 2).

Horse creek flows through one of the older valleys in the McMurray district, and with the exception of the Clearwater valley, its bottom lands are more extensive than those of any of the other tributary streams. Consequently, within the loops of its tortuous channel, areas of a few acres are sometimes found. Along the margins of certain of these bottom lands, erosion has exposed low faces of residual bituminous sand, overlaid by light gravel and other river wash. In other cases the bituminous sand appears to have been eroded almost to present water level, and to have been replaced by sand and gravel.

Thus, on Horse creek—and other tributary streams in this area—there are two types of deposits of bituminous sand.

a. Low lying deposits outcropping to a height of 5 to 30 feet immediately along the present channel. These exposures represent such small residual areas of bituminous sand as still remain in the original valley bottom, and have a relatively light overburden.

b. Exposures at points where the stream has impinged against the sides of the main valley. Such exposures, in general, resemble those already referred to along the Athabaska, and exhibit a thick section of bituminous sand and also a heavy overburden. (Plate XVI).

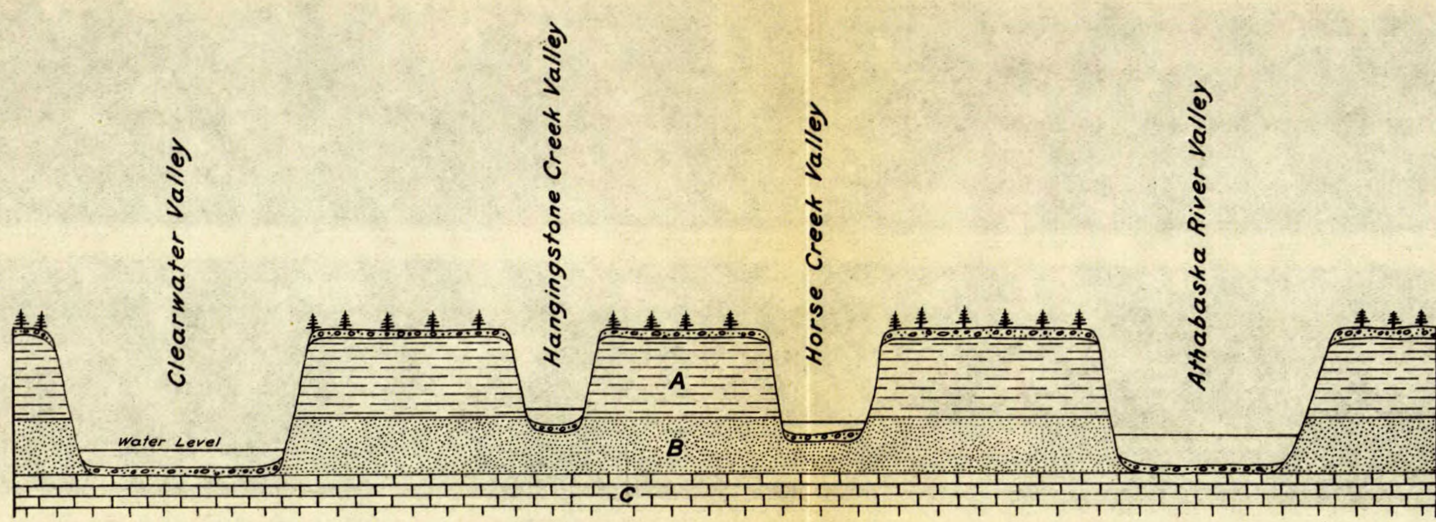

Fig. 1.

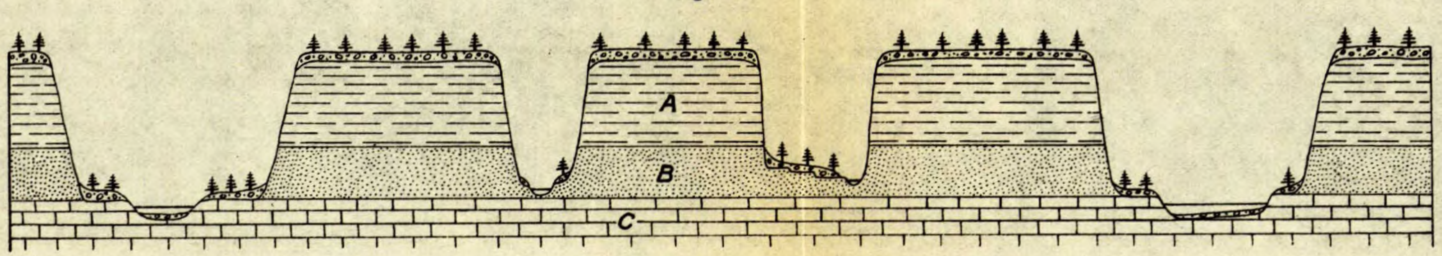

Fig. 2.

Fig. 1. Diagrammatic section E. and W. near McMurray

(A) Cretaceous Shales, Sandstones, etc. (B) Bituminous Sands. (C) Devonian Limestone. The presence of small areas of bottom lands along Horse creek, coupled with the fact that former erosion has not cut down to the Devonian Limestone, make it probable that occasional small deposits of Bituminous Sands with moderate overburden will be found in this valley.

Principal Exposures, Section 2. Athabaska River, North of McMurray.

Number.	Average exposed thickness of high grade.	Average exposed thickness of low grade.	Total exposed thickness bituminous sand.	Overburden.	Horizontal distance from foot of outcrop to point at which thickness of overburden is estimated.	Lower limit of bituminous sand, above or below water level.	Side of river.	Approximate length of exposure.	Miles north of Forks.	Remarks.
12 (a)	65		65	115	425	Above.	E.	4980	2	Between Poplar Island and McMurray, a, b, c, are equidistant sections along outcrop. It is difficult to estimate the thickness of commercial grade sand. The deposit is largely made up of impure partings of clay, etc., which to a great extent destroys its value.
(b)	30		30	165	570	"	"	"	3	
(c)			60	170	440	"	"	"	3	
13 (a)			90	100+	315	"	E.	3400	6	Opposite north end Big Poplar Island. Bituminous sand is mostly of low grade and much banded. From surface indications, the greater part of it is of no value.
(b)	30		30+	180	250	"	"	"	"	
(c)	40		40+	145	330	"	"	"	"	
(d)	60		60+	90	345	"	"	"	"	
14			80	110	520	"	"	600	11	Opposite Stony Island, the exposed part of this outcrop shows many impure partings. The lower part of this section may contain high grade material, but is obscured by talus pile 130 feet up the face. On surface indications this outcrop is of no value.
15			75	70+	625	"	"	3000	12	This exposure is largely covered by talus and drift, and the average content in bituminous sand apparently does not exceed 5%.
16 (a)			90	160	700	10′ above.	W.	1775	16	1½ miles below lower end Twin Islands. Surface indications at sections a and b show a low grade deposit of but little value.
(b)			50	205	575	" "	"	"	"	
17			35	15	125	5′ "	E.	300	24	Surface indications show material of low grade and of little value.
18			30	70+	250	?	"	250+	37	Surface indications indicate this to be of no commercial value.
19 (a)	20		65	75	315	?	"	1225	37½	Much of this exposure is obscured by talus and drift. Surface indications are promising.
(b)	30		60	55	545	?	"	"	"	
20			30	60+		?	"	1800	38	Material shows numerous partings of clays, etc., and surface indications do not indicate deposit of commercial value.
21 (a)	14		14	7	450	Sand.	"	900+	40	Surface indications promising.
(b)	16		16	5–8	450		"	"	"	Overburden light.
22			35	50+	350	Above.	"	180+	51½	Outcrop highly banded with interbedded impurities and is of little apparent value.
23			20	23	1010	At.	"	500	53	North of Pierre au Calumet creek. Highly banded. Surface indications indicate low grade material of little value.
24 (a)			30	65 110	1225 1575	Below.	"	1200 "	57½ "	Some interstratified partings, but surface indications promising.
(b)			35	60	950	"	"			
25	?	45	45+	70	550	?	"	600+	19	Opposite Tar island.
26			60	5–15	200		W.	5000	52	Just above mouth of Calumet river. Material much banded by impure partings and apparently of no commercial value.
27			70	10–20	300		"	500+	36	2 miles below mouth of Red river. Material much banded by impure partings From surface indications deposit is of no commercial value.

Horse Creek.

Horse creek, which enters the Athabaska river 1¼ miles above the Forks, was ascended for 13 miles. The average width near the mouth is 100 feet, which gradually decreases to 50-65 feet during the first 15 miles of its course. The course of the stream is very tortuous, and is marked by a continuous succession of light rapids. By means of poling and tracking, navigation with light canoes is possible at certain stages of high water, but with difficulty during periods of low water.

Outcrops of bituminous sand occur at intervals along Horse creek, for some 5¼ miles from the mouth. Beyond this, the stream was ascended for a distance of 8 miles, but no further indications of bituminous sand, either as float or in place, were seen.

Along the lower section of the river, eighteen exposed sections were examined. References to certain of these are given in table on page 18.

The difficulties in the way of surface transportation along Horse creek are those common to most tributary streams in the McMurray district. At alternate bends in the stream, where the current impinges against the banks, the possibility of heavy clay slides must be taken into consideration. Points opposite such cut banks are, however, usually low and free from the effects of slides. It would probably thus be possible to construct an aerial tramway that would cross and recross the creek. It would be necessary to operate such a tram by power, as the average grade of the creek does not appear to exceed 11 per cent.

In conclusion, it may thus be said that, along the first five miles of Horse creek, recurring exposures indicate the presence of a very large tonnage of bituminous sand. Much of this, judged by material seen in outcrops, and apart from grading of mineral aggregate, is of commercial grade; but probably not more than four or five outcrops are so situated as to permit of practical development. The areal extent even of these, is limited by the narrow and precipitous nature of the valley.

Principal Exposures along Horse Creek.

Number.	Average exposed thickness high grade material.	Average exposed thickness low grade material.	Total average exposed thickness bituminous sand.	Overburden.	Horizontal distance from base of outcrop to point at which thickness of overburden is estimated.	Lower limit of bituminous sand, above or below water level.	Side of creek.	Approximate length of outcrop exposed.
28			90	120	410	Above.	E.	500+
29			105	115	340	At.	E.	600+
30			105(?)	105(?)	370	At.	E.	400+
31	12		12+	11	225	Below.	E.	200
32			55+	75+	250	Below.	W.	225+
33			120	110	435	Below.	E.	.....
34	5–15		15+	4–12	225	Below.	E.	960
35	65	60	125	110	490	Below.	W.	.....
36	35		35	15	100	Below.	E.	485+
37	35		35+	25–130	500	Below.	W.	.....
38	20–70		20–70	25–100	250	Below.	W.	350+

[1] These figures must be regarded as approximations, and are intended merely to convey a general idea of extent of individual deposits and thickness of overburden. In many instances a small amount of stripping would expose an outcrop much larger than that indicated. Similarly, stripping of overburden would, doubtless, in many cases give a greater average thickness of bituminous sand.

Approximations of available tonnage[1] have, however, been made in the case of three of the more promising outcrops. It must be remembered that these approximations are based solely on the imperfect evidence of surface indications. To thoroughly prospect these deposits will require drills capable of passing through 10 to 60 feet of overburden and an equal thickness of bituminous sand. Any development work will presuppose extensive stripping.

Outcrop No. 4 occurs on the N.E. side of Horse creek, 1⅓ miles from the mouth. From elevations indicated by contour lines, and assuming the average thickness of bituminous sand to be 35 feet, the quantity available would be approximately 400,000 tons. To secure this tonnage of bituminous sand would require the removal of quite 150,000 cubic yards of overburden.

Figures such as the above must be considered as approximations, for, as pointed out elsewhere, only systematic and detailed exploration can furnish a basis for accurate calculation.

Outcrop No. 9 occurs on the west side of Horse creek, 2⅓ miles from the mouth. As is the case with other deposits on this creek, the exposed thickness of bituminous sand and of overburden varies widely within narrow limits, owing to the effect of erosion. Approximating averages, however, it appears that the deposit would furnish 550,000 tons of bituminous sand, involving the removal of 220,000 cubic yards of overburden.

Outcrop No. 11 is on the west side of Horse creek and 4⅔ miles from the mouth. The amount of bituminous sand available is estimated at 500,000 tons, necessitating the removal of 200,000 cubic yards of overburden. It may be noted that, in

[1] The following table indicates tonnage of bituminous sand for various areas and thicknesses. Specific gravity of bituminous sand taken as 1·75. Short tons of 2,000 lbs.

Thickness in feet	Tons on 1 acre.	Tons on 2 acres.	Tons on 3 acres.	Tons on 4 acres.	Tons on 5 acres.
1	2380	4800	7100	9500	11900
5	11900	23800	35800	47700	59600
10	23800	47700	71600	95400	119200
15	35800	71600	107300	143100	178905
20	47700	95400	143100	190800	238500
25	59600	119300	178900	238500	298200
30	71600	143100	214600	286200	357700
35	83500	166900	250400	333900	417400
40	95400	190800	286200	381600	477000
45	107300	214600	321900	429300	536600
50	119200	238500	357700	477000	596300

this as in the case of outcrops Nos. 4 and 9, the waste material can probably be disposed of without undue difficulty.

Clearwater River.

The Clearwater river, the largest tributary entering the Athabaska north of Athabaska Landing, was ascended for a distance of 18 miles. The width of the stream varies from 100 to 250 yards, and it is probable that by improving the channel at one point, scows of 100 tons burden could navigate it at almost all stages of water.

The valley of the Clearwater is somewhat larger than that of the Athabaska, although the river channel itself is smaller. Consequently the main slopes of the valley usually lie well back from the river; and for 20 miles above the mouth, only one exposure of bituminous sand is seen. At a point on the north shore, about one quarter of a mile west of the mouth of Hangingstone creek, the north slope of the valley swings out to the river, and the bituminous sand appears in the cut bank formed at this point. There is little doubt, however, but that deposits, obscured by forest growth and by drift, extend more or less continuously along both sides of the Clearwater valley for many miles above the mouth.

The one exposure (Number 39) here referred to, extends along the river bank for upwards of 1500 feet, disappearing east and west under the mantle of timber and drift. A ledge of Devonian limestone, nearly obscured by bituminous float, rises above the water a few feet, and above this, the maximum exposed thickness of the bituminous sand is 20 feet. An examination of the hillside at this point shows occasional pieces of bituminous sand float to an elevation of 115 feet. Above this point, overlying sediments and drift rise 65 feet to a terrace 500 feet wide, beyond which a further rise of 60 feet takes place.

In the section exposed, the bituminous content, as well as the grading of the mineral aggregate, show considerable variation, but at present it is impossible to express any opinion as to the probable value of the upper portion of the deposit. It should, however, be remembered that 2 miles to the northwest an extension of this bed, exposed in high cut banks along the Athabaska river, shows a material of which the average is below commercial grade and usually of little or no value.

Hangingstone Creek.[1]

Hangingstone creek is a swift, rapid stream, and enters the Clearwater river, 2 miles above the forks. The average breadth for 5 miles[2] above the mouth is 60-75 feet. At low water the stream is unnavigable for canoes, but at high water can be ascended only with considerable difficulty. Canoes taken overland could, however, probably be run down by competent canoemen at high and medium stages of water. A winter road leading from McMurray to Willow lake crosses the Hangingstone 1 mile above its mouth, and after keeping near that stream for over 5 miles diverges to the eastward. A foot trail follows along the high narrow ridge between Hangingstone and Horse creeks.

The deep, notch-like valley of Hangingstone creek is narrower than that of Horse creek, and the area of occasional bottom lands rarely reaches 5 acres. Consequently, as a rule, the sides of the valley rise almost from the water's edge, and heavy clay slides are frequent, particularly where fire has destroyed the forest growth.

Along the first 5 miles of the creek, bituminous sand outcrops at nearly every bend. One mile above the mouth, the lower limit of the deposit is near water level; but, owing to the rapid change in elevation in ascending the stream, the exposed thickness of the bituminous sand rapidly decreases. As the general elevation of the country on either side is well over 200 feet above water level, the significance of overburden, even near the mouth of the creek, is at once apparent. It is, however, possible, that future careful exploration and a study of surface topography may indicate points at which quarrying operations

[1] At the time of Mr. Ells' visit to Hangingstone creek in August, 1913, the water was unusually high owing to recent heavy rains. Owing to this fact a number of the lower lying ledges of bituminous sand were completely covered.

Mr. Ells has recently revisited Hangingstone creek at a time when the water was several feet lower, and has reported the presence of a number of these low lying outcrops. It is possible that further investigation of these exposures may prove them to be of considerable commercial value. *Dr. Eugene Haanel, Director of Mines Branch, July 14, 1914.*

[2] Distances noted on this stream are estimated.

may be successfully undertaken. The following sections of the more promising outcrops are of interest as illustrating certain general features.

Christina River.[1]

The Christina river, which enters the Clearwater 18 miles to the east of McMurray, was ascended a distance of 16 miles.[2] Along its lower course the average width is probably 400 feet, narrowing to less than 200 feet, at 15 miles from the mouth. Light rapids occur at frequent intervals during the first 10 miles, becoming almost continuous beyond this point. The average current is apparently not less than three miles per hour, and necessitates continuous poling and tracking. Canoes drawing 6″ to 10″ may ascend, except during stages of low water, but it is probable that light canoes may be taken up by skilful canoemen at almost any stage of water.

Along its lower course small areas of bottom lands give the valley a width of $\frac{1}{4}$–$\frac{1}{3}$ mile, which, however, rapidly decreases in ascending the stream. The general country elevation is probably between 250-300 feet above water level, and, as the breadth of the valley diminishes, depth of overburden and heavy clay slides become more and more controlling factors in considering the possible development of the various outcrops of bituminous sand. As in many other parts of the McMurray area, the effect of forest fires is marked, although small areas of spruce and poplar still remain in the valley bottom. Where fire has swept to the water's edge, the increased instability of the banks is at once apparent (Plate IV). Saline springs and small seams of lignite were noted at a number of points, but, of the latter, none appear to be of any significance.

Deposits of bituminous sand recur throughout a distance of 11 miles from the mouth of the river. For some 3 miles low-lying and typical Devonian limestones underlie the bituminous sand, but beyond this point the limestone disappears altogether.

[1] Formerly known as Pembina river.
[2] Distances noted on this stream are measured.

Principal Exposures along Hangingstone Creek.

Number.	Average exposed thickness high grade.	Average exposed thickness low grade.	Total exposed thickness bituminous sand.	Thickness of overburden.	Horizontal distance from lower limit of bituminous sand to point at which thickness of overburden is estimated.	Lower limit bituminous sand below or above water level.	Approximate length exposed section.	Side of creek.	Distance from mouth of creek.
40			130	45	325	Above.	350	S.E.	1 mile
41	50	75	125	65	350	Above.	600	N.W.	1¼ "
42	70	60	130	70	300	Near.		N.W.	1½ "
43	55	40+	95+	140	400	Below.	200	N.W.	2 miles
44	15	30	45	90	450	Below.	150	S.E.	2¼ "
45	30	35+	65+	95	500	Below.	200	N.W.	2½ "
46	15	40	55	120	400	Below.	125	N.W.	4¼ "

Topographically, the valley of the Christina river resembles that of Horse creek. Its course is, however, more direct and the small areas of bottom lands are consequently fewer. In all, 24 exposures of bituminous sands were noted, measurements being made of 7. Owing to heavy overburden, prevalence of clay slides, and the presence of impure partings in the bituminous sand itself, it was considered that the remaining 17 could be eliminated from further consideration.

As in the case of deposits elsewhere, the above figures must be considered as approximating to average conditions. Pending systematic and detailed prospecting, it is doubtful whether a more accurate estimate can be given. The data are, however, sufficiently accurate to demonstrate the serious feature that will be presented by stripping and the disposal of overburden.

In considering transportation along that portion of the Christina river examined, it is probable that better grades and a better alignment can be secured than on either Hangingstone or Horse creeks. Owing, however, to the unstable and often precipitous character of the banks, it is very doubtful if, even here, a surface line could be maintained within the valley itself.

Steepbank River.

Steepbank river is a swift shallow stream, and enters the Athabaska from the east, 21½ miles below McMurray. The width at the mouth is about 100 feet, narrowing to 80 feet at 17 miles.[1] For more than 15 miles a swift current and numerous rapids make tracking or poling imperative. The depth of the valley decreases from about 225 feet at 2 miles, to about 150 feet at 17 miles. A hunter's trail leaves the Athabaska at the mouth of the Steepbank, and follows up along the north shore as far as the forks.

For 5 miles from the mouth of the river, well bedded Devonian limestones, showing in places traces of bitumen,[2] undulate along the shores at elevations varying from 5 to 40 feet. Resting on the limestone, sections of bituminous sand are exposed on the outer bank at nearly every bend (Plate XVII), the higher

[1] Distances on this stream are measured.
[2] See footnote p. 34.

Principal Exposures along Christina River.

Number.	Average age exposed thickness high grade.	Average age exposed thickness low grade.	Total average exposed thickness bituminous sand.	Thickness of overburden.	Horizontal distance from lower limit bituminous sand to point at which thickness of overburden is estimated.	Lower limit of bituminous sand whether above or below water level.	Approximate length of exposed section.	Distance from mouth of river.	Side of river.	Remarks.
47	25	55	80	65—80	400	Above.	1200+	$2\frac{1}{2}$ m.	N.E.	Some narrow clay partings in bituminous sand
48	..	..	75	125	900	Above.	600+	$5\frac{1}{4}$ m.	N.E.	Interbedded sandstones, aggregating 85 feet.
49	20		20	110	600	Below.	200	$6\frac{1}{3}$ m.	S.W.	
50	..		120	115	800	Obscured.	1200+	$6\frac{2}{3}$ m.	N.E.	Some narrow clay partings in the bituminous sand.
51	..		100	175	1200	Obscured.	1300	$7\frac{3}{4}$ m.	N.E.	
52	12		12	160	1000	Below.	1200	$9\frac{1}{4}$ m.	N.E.	
53	..	..	110	85	750	Below.	250	9 m.	S.W.	Some clay partings.

grade and more homogeneous, underlying the dryer and more banded material. In ascending the stream, and, following the disappearance of the limestone, the sections of bituminous sand also gradually begin to disappear, so that beyond mile 10, little except low grade material remains exposed above water level. Of 26 separate outcrops seen, 9 of the more promising are noted below.

Based on surface indications, the deposits of bituminous sand on Steepbank river may be considered quite as promising as those seen on any other stream in the McMurray district (Plates XXII, XXIV). Owing to the sandy and gravelly character of much of the overburden, there is a general absence of the heavy clay slides so frequently met with on some of the other streams. Such a consideration is of importance in considering possible development and transportation within a narrow valley.

Muskeg River.

The Muskeg river enters the Athabaska from the east, 31 miles below McMurray. Its width near the mouth is 100 feet, decreasing to 60 feet at 5 miles and to 30 feet at 16 miles.[1] Throughout this distance the stream is navigable for canoes at high and medium stages of water. At low water it is navigable only in parts. The first 6¼ miles consists of a series of rapids, necessitating continuous and sometimes difficult poling or tracking. An Indian portage trail, about 1¾ miles in length, leaves the Athabaska 2 miles below the mouth of the Muskeg river, and meets that stream at the head of the swift water. In ascending the Muskeg, it will generally be found advisable to use this portage, though in descending, the rapids may readily be run with light canoes. Above the head of the portage, the stream presents no difficulties, although easy poling is occasionally necessary. From mile 8 to mile 18, the current does not exceed ½ mile per hour, the stream winding through a wide, low-lying and swampy area.

Leaving the Athabaska river, both rubbly and massive limestone ledges 10-75 feet high outcrop for nearly 5 miles,

[1] Distances on this stream are measured.

Principal Exposures along Steepbank River.

Number.	Average exposed thickness high grade.	Average exposed thickness low grade.	Total average exposed thickness bituminous sand.	Overburden.	Horizontal distance from water's edge to point at which thickness of overburden is estimated.	Lower limit of bituminous sand.	Side of river.	Approximate length of outcrop.	Distance from mouth of river. Miles.	
54			90	15–20	300	20′–40′ above water level.	N.E.	400	2	Shows much banding due to narrow partings of clay, etc.
55 (a)			160	20	250	15′–20′ above	S.W.	800	2	Outcrop shows much banding and does not appear so favourable as others farther up river.
(b)			180	15	250		"	"	"	
56	70	100	170	25	300	At.	N.E.	275	3	Low grade is highly banded, but high grade is of good quality.
57			30–70	10–90	325	10′ above.	S.W.	625	3¼	Material good and conditions relatively favourable.
58	70	80	150	40	300	Near.	S.W.	200	5	
59	75	80	155	20	300	Near.	N.E.	300+	5½	
60	12		12	8	200	Below.	S.W.	300	5¾	
61	75	60	135	20	250	Below.	N.E.	500	10	
62			120	25	300	Below.	S.W.	425	12	Outcrop shows much banding.

and at a number of places, show small percentages of bitumen along bedding and joint planes.[1]

Occasional small deposits of bituminous sand also occur along the Muskeg river, but from surface indications none of these is of commercial value. The most promising (No. 63) occurs in the northwest bank, $1\frac{1}{4}$ mile above the head of the portage, and extends along the stream for quite 400 feet (Plate XXV). The average thickness is 15 feet, overlaid by a thin capping of quartzite. Although in this deposit occasional rich bands contain 10-12 per cent of bitumen, the average content of the whole face, based on surface samples, is much lower. The grading of the mineral aggregate also shows wide variation within narrow limits.

On the north bank and some 2 miles from the mouth a deposit of clay[2] separates the bituminous sand from the underlying limestone. Owing to the stage of the river, the extent of this deposit could not be determined.

Pierre au Calumet Creek.

The Pierre au Calumet is a rapid creek 6 feet to 10 feet wide, which enters the Athabaska from the east, 53 miles below McMurray. It flows through a shallow valley 300 feet wide at the mouth and 25 feet to 50 feet deep, but its present erosive power is insufficient to form cut banks. Its average fall is probably quite $1\frac{1}{2}$ per cent, and, $3\frac{1}{2}$ miles from its mouth, the valley merges in a wide swampy area in which the stream takes its rise.

Although moss and forest growth reach to the water's edge, at three points within 1 mile of the mouth, small exposures of bituminous sand in place may be found. In each instance the material is lean and of a low grade, being similar to the main outcrop on the Athabaska, one half mile to the northwest. In no case is the material as exposed at the surface, of commercial value, although weathering due to surface water and other causes, has doubtless caused a deterioration.

[1] See footnote page 34.
[2] See Appendix VII.

Firebag River.[1]

The Firebag river, which rises in the low-lying Muskeg mountains, is the most easily navigable of the streams flowing through the area examined. It has an average width near the mouth of 300 feet, which decreases, within the first 23 miles, to 150 feet. During this distance, four light rapids, none of which necessitate portaging, occur. The average summer current is from 3 to $3\frac{1}{2}$ miles per hour, but, with the exception of 3 or 4 miles near the mouth, the shores are suitable for tracking. The country immediately along the river is gently undulating, with no relief higher than a few feet. Sandy jack pine knolls, with intervening areas of muskeg, are frequent, but the greater part of the original forest growth has been destroyed by fire.

The river has eroded its valley to a depth of 125-150 feet, cutting through lacustral sands, clays, and glacial till. At four points along the first 23 miles, minor folds in the Devonian limestones also appear, crossing the river and occasioning light rapids. At one other point on the south shore, between the first and second of these rapids, a low-lying ledge of limestone outcrops for upwards of 150 feet. At this point fragments of limestone coated with bitumen,[2] and up to 5 lbs. in weight, were found. Although none of this rock was seen in place at this point, the appearance of the float indicates a source in the immediate vicinity. At three points, springs strongly charged with sulphuretted hydrogen gas, were noted.

The Firebag river was not ascended farther than 23 miles, since considerations affecting transportation will, for some time to come, preclude the possibility of mining development. Thin, low grade beds of bituminous sand, very limited in extent, and apparently of no commercial value, are, however, reported[3] near the forks, 25 miles above the junction with the Athabaska.

It is probable that in this direction the bituminous sands do not extend much beyond the Firebag river, though the north-

[1] Distances estimated.
[2] See footnote p. 34.
[3] Mr. D. B. Dowling, referring to the Firebag river, in Vol.VI, p. 22, A.G.S.C. Annual Report, says: "At the forks of the stream the limestone is followed by the black sandstone holding tar, but this is here represented by beds only a few feet thick, so that it probably does not extend much farther to the east."

ern limit of the Dakota sand itself is uncertain. So far as any commercial value is concerned, the northern boundary of the bituminous sand lies quite 15 miles to the south of the Firebag.

Calumet River.

The Calumet river enters the Athabaska from the west 53 miles below McMurray. The river valley near the mouth is 150-200 feet deep, and, during the first 2 miles, attains, in places, a width of ⅓ mile. The stream, seldom more than 15 feet wide, rises rapidly during the first 4 miles. Beyond this point, the valley broadens out, and the stream flows with sluggish current, from a southerly direction, through a swamp and muskeg country.

The slopes of the valley during the first 2 miles[1] are thickly wooded, and one outcrop only of bituminous sand is seen. On the south side, 1 mile above the mouth, a cut bank, 80 feet high and 200 feet long, exposes low-grade material, highly banded with interstratified partings of clay and 'dry' sand. Three miles from its mouth, the valley narrows to 300 feet, and is, apparently, about 60 feet deep. For 1 mile beyond this point exposures of bituminous sand are frequent. The material is, however, similar to that seen nearer the river mouth, and appears to be of no commercial value.

A hunter's trail leaves the Athabaska river near the mouth of the Calumet, and follows along near the north bank of the latter stream for more than 3 miles.

Tar River.

Tar river is a rapid stream, 25 to 40 feet wide, which enters the Athabaska from the west, 48 miles below McMurray. For ½ mile[2] from its mouth its course winds through a low-lying, well timbered river bottom, but beyond this point a rapid rise takes place, resulting in a continuous series of light rapids for 7 miles. From here on, the river valley broadens out into a for wide spruce swamp, in which the river takes its rise. Except

[1] Distances on the stream are estimated.
[2] Distances on this stream are measured.

for half a mile near the mouth, the stream is not navigable for canoes.

At $1\frac{3}{4}$ miles from the mouth, a cut bank, upwards of 100 feet high, exposes the first bituminous sand, and during the next 4 miles other exposures, of varying thickness, occur. In all of these exposures, however, the material is of a low grade and highly banded character; and although the overburden is, in some instances, light, none of the outcrops seen, can be considered of commercial value.

A hunter's trail on the north side parallels the stream at a distance of $\frac{1}{8}$–$\frac{1}{4}$ mile, and may be followed for quite 6 miles.

Moose River.

The Moose river enters the Athabaska from the west, 47 miles below McMurray. Its average width near the mouth is about 150 feet, narrowing at 16 miles[1] to 100 feet. The stream is navigable for light canoes at medium stages of water, although a swift current and frequent light rapids necessitate continuous poling or tracking.

The valley of the Moose is for the most part narrow, with banks rising 150-200 feet. At a number of points, however, changes in the course of the river have resulted in the formation of occasional lateral basins and low-lying areas, which may prove of importance should development of the bituminous sand be undertaken here. An Indian trail from McKay meets the Moose at a point above the more difficult of the rapids; and between this point and the mouth—a distance of about 14 miles—17 outcrops of bituminous sand were noted. Limestone in place was seen at one point, about $7\frac{1}{2}$ miles from the mouth. Here, what may be the crest of an anticline, extends along the north shore of the river for several hundred feet, attaining a maximum elevation of 8 or 10 feet above water level.

In general, the bituminous sand exposed along the stream below the first forks, is low grade and of a distinctly banded nature. This corresponds with the character of material exposed along the lower part of Tar river to the north, and on the Athabaska immediately to the northeast and east. Again,

[1] Distances noted on this stream are measured.

beyond mile 8, a similar deterioration in the quality of material exposed is noticeable (Plate XXVII). If, therefore, deposits of commercial value are not found along that section of the river between the first forks and mile nine, all other deposits on the Moose may be eliminated from further consideration. Sections of eight of the most promising outcrops were measured, and conditions are probably fairly well represented in the table, page 33.

From the above sections, it is evident that certain of the outcrops along the Moose river between mile 4 and mile 8 are of sufficient promise to warrant further detailed exploration. As on other streams of a similar character, transportation within the valley itself, will present difficulties. Owing, however, to lighter overburden causing fewer clay slides, the maintenance of a line would not be so difficult as on most of the other tributaries of the Athabaska river.

It may be added that some 7 miles from the mouth and in the north bank, a deposit of clay separates the Dakota sands from the Devonian limestone.[1] The extent of this deposit was not determined, but it appears to have a thickness of quite 8 feet and outcrops for a distance of over 150 feet.

McKay River (Little Red River).

The Little Red river,—now known as the McKay river,—is the third largest of the tributaries entering the Athabaska north of McMurray. Its width near the mouth is about 200 feet, gradually narrowing to 125 feet at 10 miles, and at 18 miles to about 100 feet. At 13½ miles[2] from the mouth, the main branch, Willow creek, enters from the northwest.

Throughout the first 16 miles, a two to three mile current necessitates continuous tracking or poling. At highest stages of water, tracking is probably quite impossible, as the water is heavy and the narrow beaches covered. At medium and low stages of water, tracking and poling are, however, feasible. About 27 miles from the mouth, paddling becomes possible, with indications of comparatively easy navigation for some distance beyond.

[1] See Appendix VII.
[2] Distances noted on this stream are measured.

Principal Exposures along Moose River.

Number.	Average exposed thickness high grade material	Average exposed thickness low grade material	Total average exposed thickness bituminous sand.	Thickness of overburden.	Horizontal distance from foot of outcrop to point at which thickness of overburden is estimated.	Lower limit of bituminous sand, above or below water level.	Approximate length of outcrop.	Side of river.	Miles from mouth of river.	Remarks.
64 (a)			80	80	500	Below.	1600	S.E.	$6\frac{1}{2}$	Thickness of strata difficult to determine, owing to drift and talus.
(b)			70	95	350	"	"	"	"	
(c)			75?	90	300	"	"	"	"	
65	40	10	50	15	250	"	550	N.W.	$6\frac{1}{2}$	
66 (a)			80	10	200	Below.	900	S.E.	$6\frac{1}{2}$	
(b)	40		40	120	550		900	"	$6\frac{1}{2}$	
67	20		20	15	600	Above.	700	N.W.	$6\frac{3}{4}$	Quality good and but few impure partings.
68			70	10—80	570	?	500	N.W.	7	Quality good and fairly free from impure partings.
69			40	10	225	Below.	400	N.W.	8	General quality good, but frequent impure partings.
70	12		12	10	200	Below.	500	S.E.	$8\frac{1}{2}$	Apparently homogeneous and fairly free from impure bands.
71			120	10	200	At.	400	N.W.	9	Exposed surface of bituminous is highly banded.

The river flows through a narrow valley, marked by precipitous slopes and high cut banks. At 3 miles from the mouth, the average depth of the valley is not less than 200 feet, decreasing to 100 feet within the next 15 miles. The surface of the country on either side is gently undulating with sandy knolls and frequent areas of swamp and muskeg, and with small shallow ponds and lakes. In places within the valley, a fair growth of spruce and poplar is found, but most of the country has been burned over, and is now covered by second growth.

For 14 miles above the mouth, the usual well-bedded grey and buff highly fossiliferous Devonian limestones are seen (Plate XXVIII). These strata rise and fall in a series of minor folds, sections with a maximum height of 90-100 feet being thus exposed.[1]

Above the limestones, sections of bituminous sand are exposed at bends throughout the first 22 miles (Plate XXVIII). In places differential denudation has eroded the softer bituminous sands leaving the limestone as a terrace. In such cases the bituminous sand will nearly always be found at a little distance back from the river, though usually obscured by moss and forest growth. As noted elsewhere, the richer portion of the bituminous sand in nearly every case, directly overlies the limestone, while the upper portions of the beds become leaner and more banded with interstratified clays and dry sands. Thus, when the limestones, apparently dipping to the southwest, disappear near mile 14, the exposed sections of bituminous sand thereafter become lower, until finally, at mile 22, only the upper or banded zone remains above water level.

In all, some twenty-nine exposures of bituminous sand were seen, and of these, nine were examined in some detail. The remaining twenty were not considered of sufficient importance to warrant further attention.

It is probably safe to say, that, based on surface indications, some of the above outcrops represent deposits of commercial

[1] At a number of points on the McKay, Muskeg, and Steepbank rivers, as well as elsewhere, bitumen was observed associated with the Devonian limestones. This bitumen is apparently derived from the overlying bituminous sands. Where the limestone is of a rubbly nature, or where shattering has accompanied the development of a line of weakness in the more massive strata, fragments of rock have become more or less heavily coated. Instances where the bitumen has entered vesicles in the rock were also noted. The writer does not consider that any of these can be properly classed as true bituminous or asphaltic limestone.

value. Transportation to the Athabaska presents the usual difficulties met with along the valleys of streams of this character.

Minor Streams.

If workable deposits are not found along any of the 13 rivers and creeks that have been thus briefly referred to, it will be useless to look elsewhere in the McMurray district. Nevertheless, a considerable number of smaller tributaries,—some little more than mere brooks,—were noted in this area. Typical examples of these are Chadwick creek and Annes creek, both of which enter the Athabaska just below McMurray.

Small streams such as these, not having any great erosive power, have a rapid rise, and usually reach the general country level within 2 or 3 miles of their junction with the Athabaska. Consequently the vertical dimensions of sections of bituminous sand exposed near their mouths, quickly decrease with the rapid change in the elevation in ascending the streams. Moreover, although valleys of such creeks are usually mere notches with no areas of bottom lands, the effect of clay slides is apparent wherever fire has removed the forest growth. If actual excavation work were commenced, along any of these slopes, the effect of such slides would be so increased as probably to prohibit operations altogether.

Principal Exposures along McKay River.

Number.	Average exposed thickness high grade.	Average exposed thickness low grade.	Total exposed thickness bituminous sand.	Thickness overburden.	Horizontal distance from shore to point at which overburden is estimated.	Lower limit bituminous sand above or below water level.	Approximate length of outcrop.	Side of river.	Distance from mouth of river.	Remarks.
72			40	10	300	110′ above.	700	S.	¾	
73			65	10	300	60′ above.	350	S.	2	Numerous interstratified bands of clay, etc.
74			120	10	550	55′ above.	700	N.	2½	Shows considerable variation in per cent of bitumen and in grading of mineral aggregate.
75			140	60	875	Above.	400	N.	7½	
76			25	40	400	5′ above.	1200	S.	8	Float and talus prevent accurate observations.
77			60	20	325	25′ above.	400	S.	9	
78			80	75	500	10′ above.	550	N.	10	
79			40	50	400		150+	N.	12	
80			30	20	300		500	N.	13	

APPENDIX I.

CLASSIFICATION OF BITUMINOUS SUBSTANCES.

Hydrocarbons in gaseous, liquid, and solid forms, have a wide geographical distribution, and are found throughout nearly the whole range of geological strata from the Laurentian to the most recent members of the Quaternary. In considering the various attempts that have been made toward a classification of hydrocarbons and allied substances, the difficulty of establishing hard and fast lines is at once apparent.

In the following classification by Herbert Abraham,[1] bituminous sand is classified as a solid siliceous asphaltum.

[1] Paper presented at the Eighth International Congress of Applied Chemistry, New York, Sept., 1912.

BITUMINOUS SUBSTANCES.

- NATURAL
  - BITUMENS
    - Gaseous
      - Natural gas
      - Marsh gas
    - Liquid or semi-liquid
      - Petroleums
        - Paraffin base
        - Asphaltic base
        - Mixed
      - Malthas ("mineral tar")
    - Solid
      - Mineral waxes
        - Ozokerite (ceresine)
        - Montan wax
        - Hatchettite
      - Mineral pitches
        - Asphalt (um)
          - Pure or fairly pure
          - Calcareous
          - Siliceous
          - Earthy
        - Asphaltites
          - Gilsonite
          - Glance pitch
          - Manjak
          - Grahamite
  - PYRO-BITUMENS
    - Solid
      - Occur fairly pure
        - From asphalts
          - Wurtzilite (elaterite)
          - Albertite
          - Impsonite
        - From vegetable growths
          - Peat
          - Lignite
          - Bituminous coal
          - Anthracite
      - Mineral matter predominates
        - Bituminous schists
        - Bituminous shales
- ARTIFICIAL
  - ANIMAL ORIGIN
    - From bones — Bone tar and bone-tar pitch
    - From fats — Fatty acid pitches ("stearin pitch")
  - VEGETABLE ORIGIN
    - From vegetable oils — Fatty acid pitches ("stearin pitch")
      - Stearin pitch ("candle tar")
      - Stearin-wool pitch
      - Wool-fat pitch ("wool pitch")
      - Palm-oil pitch
      - Cottonseed-oil pitch
      - Cotton-oil-foots pitch
    - From saps of coniferae — Resin pitch
    - From wood and roots of coniferae — Pine tar and pine-tar pitch
    - From hard woods (*e.g.*, oak, maple, birch and beech) — Wood tar and wood-tar pitch
  - MINERAL ORIGIN
    - From petroleum
      - Water-gas tar and water-gas-tar pitch
      - Sludge pitch
      - Petroleum asphalt (petroleum pitch)
      - Blown (oxidized) petroleum asphalt
    - From malthas — Asphalt (um)
    - From ozokerite, etc. — Paraffin, etc.
    - From peat — Peat tar and peat-tar pitch
    - From lignite — Lignite tar (brown-coal tar) and lignite-tar pitch
    - From bituminous coal
      - Coal tar and coal-tar pitch
      - Coke-oven tar and coke-oven tar pitch
      - Blast-furnace tar and blast-furnace-tar pitch
      - Generator-gas tar and generator-gas-tar pitch
    - From elaterite — Elaterite pitch
    - From bituminous shales — Shale oil and shale-oil pitch

APPENDIX II.

BITUMINOUS SANDS AND SANDSTONES AS A PAVING MATERIAL.

Bituminous sands have, for a number of years, been used in the construction of various classes of pavements in the United States. As pointed out elsewhere, the principal sources of supply at the present time are in Kentucky, Oklahoma, and California. The extent to which the material has been used, appears to have been determined to a considerable degree by the fixing of freight charges. Apart from this consideration, political interests and the somewhat questionable methods peculiar to the asphalt paving industry itself, should also be borne in mind.[1]

From personal observation in various cities and towns in the United States, the writer believes that pavements constructed largely from bituminous sands have been satisfactory. Certain of these pavements have been subjected merely to the comparatively light traffic of residential streets, while others have been tested under severe traffic conditions. On the other hand, many pavements laid with bituminous sand have proved unsatisfactory.

From a consideration of the successes and the failures that have resulted from the use of bituminous sand rock, the writer would, in the strongest possible manner, emphasize one conclusion. It is, that the most careful study should be given to its chemical, but more especially to its physical; character, as a preliminary step to actual attempts at paving.[2] To handle our Canadian bituminous sand in a haphazard manner, either

[1] In the preface to the second edition of his book entitled "Asphalts, their Sources and Utilizations," Col. T. Hugh Boorman comments on this aspect of the paving industry as follows:—"In the immense amount of treatises and papers on bituminous construction presented before conventions, engineers' associations and colleges, it is lamentable to find how few can be received as from unbiased sources. This is the day of astute advertising, and in addition to their regularly paid employes, such as consulting engineers, chemists and salesmen, the large corporations subsidize to an immense extent the daily and technical press so that the unsuspecting layman seeking information on asphalt, is apt to be misled through statements of merits of individual brands of asphalts, emanating from such clever salesmen with their various titles ranging from college professors to daily news reporters. The most flagrant advertising dodge was that of an asphalt company who offered a premium of $100 to be awarded to the highway college student who produced the best treatise on asphalt."

[2] Small slabs, composed largely of Alberta bituminous sand, were laid in Calgary and in Edmonton by Mr. J. H. Russel. The slabs in Edmonton—laid in the fall of 1911—are about 5′ x 5′, are laid on concrete in the concrete sidewalk, and are thus surrounded on all sides by concrete. As a pioneer effort this work has its value. As an illustration of the real importance that should attach to the bituminous sand as a paving material, the writer considers that these squares are of but little significance.

through failure to intelligently appreciate its true nature, or through lack of proper manipulation, will simply be to court failure and serious financial loss. The writer considers that the construction of one or more types of experimental pavement, will prove to be the most satisfactory method of actually determining the real value that should attach to bituminous sand from the Alberta deposits.

At various times during the past few years, the adaptability of bituminous sand as a paving material has been adversely criticised by well informed men. The following expressions of opinion by municipal engineers who have had experience with this class of rock, are, therefore, of interest at the present time. In citing these opinions, the writer is thoroughly aware that there exists more or less variation between the bituminous sand rock from California and that from the Province of Alberta. Nevertheless, as much of this criticism has been in the nature of a sweeping condemnation of bituminous sand rock in general, certain of the opinions are herewith submitted.

(Letter No. 1).

"Your inquiry as to our experience in the use of bituminous sandstones has been received and given careful attention. The sandstone used in Oakland is all from the Santa Cruz Quarries (Plates LI and LIII) operated by the City Street Improvement Co. of San Francisco. Oakland used the material in its natural state intermittently for some fifteen years with varying results. Its use was abandoned in 1907, but resumed in 1911, in a different form. Since 1911 we have used this material in the construction of about one and one-half miles of street with uniformly satisfactory results. However, the material is not used in its natural form, but modified by the addition of suitable sand and stone dust to produce a mixture conforming closely to the ideal composition of a standard asphalt pavement.

"The first street constructed with this material in Oakland was built about twenty-two years ago and is in excellent condition today. This street has had a steady stream of light traffic, but is not a portion of a thoroughfare. Another street laid in 1898 has carried a reasonably heavy traffic from the time of its construction, and is now one of our main business streets. The pavement on this street had no repairs until last year, when about two and one-half per cent. of the surface was renewed. Additional repairs are now being made to about the same amount. Other streets have given equally good service, while still others have been a failure from the time of their construction. This variation in service leads us to believe that the material is capable of making a satisfactory street surface, and that faulty manipulation is responsible for the failures. Investigation along these lines has shown that where the material has failed its composition corresponds very closely to that of reported failures of other asphaltic material in other cities; that is, the mesh composition or the bituminous content is unbalanced. Pavements that have given us good service, have shown a fairly balanced mixture. It appears that the product as mined does not have the proper composition and comes in several grades. We believe that we have overcome these difficulties by mixing two grades of sandstone, modifying the mixture by the addition of sand and stone dust, and analysing the product from day to day, to enable us to make further modifications as may seem necessary. It is the general opinion of inspectors and others who observe the product that appears on the street from day to day that the resulting pavement is even better than that obtained with the artificial mixture of California asphalt, sand and stone dust. It seems to be more adhesive, tougher and more dense. Pending a more definite determination of these claims, I am not prepared to give the material any preference over the ordinary artificial mixture, but I do believe that it is as good.

"Our experience in Oakland with bituminous sandstones is limited to this particular product. Other sandstones may not give good service from the nature of their composition or through lack of proper manipulation. It has taken many years to discover the proper method of using this particular sandstone.

In view of the advance in knowledge of asphaltic materials in the past few years it should not take so long to discover the value of a new field opened at this date. However, the first work done with material from a new field should be in small quantities until the value of the product is determined by trial and the proper method of manipulation is developed. I might suggest that failures in the early work might be due as much to the method of manipulation as to the character of the material.

(*Signed*) **Walter N. Frickstad,**
Asst. Supt. of Streets,
Oakland, Cal."

Approved:—
(*Signed*) Percy F. Brown,
Superintendent of Streets
and Ex-officio City Engr.
Feby. 2, 1914.

(Letter No. 2).

"In reply to your letter of January 24, 1914, regarding bituminous rock pavements laid in San Francisco, will say that I find them to be very satisfactory. We have some streets of this material that have been down many years which are still in an excellent condition.

"It must be understood, however, that the natural bituminous rock cannot be handled in a haphazard manner. The material is seldom mined in a condition that is suitable for paving purposes, and in such cases where the run of the mine has been laid on the street, the resulting pavements have been of service only in those sections where the traffic is very light. In instances where the rock has been subjected to heavy duty and has survived for many years, it has been found by inspection that some selection of rock has been exercised or an after treatment used, which, in either case, provided a mixture approaching the recognized standard in asphalt paving practice.

"On this account the present method of handling the bituminous rock is vastly different from that prevailing several years ago. The rock from the different strata of the mine is now selected and shipped so that a proper grading of materials can be made at the mixing plant. The resulting product is now one that is remarkable for its uniformity, and all the pavements that have been laid under this system, during the last four years, promise to give as good service as the original ones they are patterned after.

(*Signed*) **M. M. O'Shaughnessy,**
City Engineer,
San Francisco, Cal."

San Francisco,
Jan. 30, 1914.

(Letter No. 3).

"In answer to your communication relative to the bituminous deposits in the vicinity of Santa Barbara, would say that in my opinion an excellent pavement can be made from this material if it is properly treated.

"The material here consists of some beach and some bank sand, a rather soft lime rock and sea shells composing the coarse aggregate, and all being bonded together with an asphaltic base bitumen. The sand and asphalt vary greatly in quantity even with each batch, consequently each batch requires special treatment. Some of the bitumen will contain more light oils than others and require longer heating than do those containing a less amount of the light oils. The grading of the sand, too, is always different one batch from another, so to successfully use the material from the natural bituminous deposits for the construction of a good pavement requires considerable study and experience.

"In the year 1888 this city laid about two miles of pavement made from the natural bitumen. This pavement did not wear well in places, due, undoubtedly, to careless treatment and preparation; though in other places it wore well. In 1898 about one-half of this pavement was removed and replaced with a refined sheet asphalt pavement. The pavement that was not removed is still in use, and most of it is in very good condition.

"In short, I would say that, from my observation and experience, I believe, with proper treatment, as good a pavement can be made with the material from natural deposits of bituminous lime rock or sand stone as can be laid with the use of refined asphalt.

(*Signed*) **Eldon A. Garland,**
City Engineer,
Santa Barbara, Cal."

Santa Barbara,
Feby. 11, 1914.

The bituminous rock used in San Francisco and in Oakland is from quarries near Santa Cruz. Detailed reference to the nature of this material will be found in the appendix on "Bituminous Sandstone."

Mr. Clifford Richardson, in his book entitled "The Modern Asphalt Pavement," writes as follows:—

"*Santa Cruz Bituminous Sands.*—The quarries of bituminous sand near the summit of the Empire ridge, facing the Bay of Monterey and the Pacific Ocean, are of very large extent. The individual strata are very variable in composition. . . . .

"The bitumen which these sands contain, is in the form of maltha, much of it readily staining the hands when the sands are handled. It hardens on heating with a loss of the lighter oils and a reduction in the percentage of bitumen to a point which makes it possible to produce a surface mixture which will withstand traffic.

"It will be noted that the grading of these sands is sufficiently fine and that they contain a certain amount of 200-mesh material.

"The streets which have been paved with the Santa Cruz bituminous sands in San Francisco have been only fairly satisfactory. They have required large repairs which, however, are readily made by reheating the material, but there is now a tendency to abandon this form of asphalt pavement, and to construct surfaces from properly graded sand combined with filler and a suitable pure bitumen."

The letter of the City Engineer of San Francisco, cited above, explains the cause of such failures and indicates that under the practice now followed with these bituminous sands, they promise to be as satisfactory as the artificial material.

In his well known book,[1] entitled, "Street Pavements and Paving Materials," Mr. Geo. W. Tillson, Consulting Engineer to the Borough President, Borough of Brooklyn, City of New York, states, "Some bituminous limestone has been found in this country (United States) as well as a sandstone-bearing asphalt, and also in California beds of sand which contained asphalt, and of which many of the early California pavements were made. These pavements were laid in a very crude manner, with but little knowledge of the material or of the subject, and a great many of them failed in a short time, as might have been expected. These failures, however, should not have been charged up to California asphalt or to asphalt pavements, as experience has demonstrated that with the proper treatment, a good pavement can be laid with this material."

As an illustration of the necessity of proper manipulation, an interurban road, with which the writer is familiar, between Santa Barbara and Carpinteria, Cal., may be mentioned. This road is subjected to varied traffic conditions, including a large volume of fast automobile travel, as well as heavy caterpillar-tread traction machines and trucks having a capacity of from 2 to 5 tons. No wide tire ordinance is in force.

Different sections of this road were laid by different contractors and, although practically the same bituminous sand was used throughout, the contrast between the various sections of the completed work is marked. Thus where the bituminous sand had not been heated sufficiently to drive off the lighter oils, the surface was rutted. Where the material had been overheated the surface was very hard and showed considerable evidence of flaking. When the material had been properly handled the results appeared to be excellent.

[1] Page 264.

APPENDIX III.

EXTRACTION OF BITUMEN FROM BITUMINOUS SANDS AND SANDSTONES.

In addition to the present recognized application of certain varieties of bituminous sands and sandstones to street paving purposes, other possible uses[1] for extracted bitumen in various branches of engineering and construction will at once suggest themselves. Among these a few may be mentioned, as: floorings for many classes of buildings—such as mills, hospitals, schools and skating rinks—foundations that will absorb vibration and jar, as in electric power plants, or where heavy gravity or steam hammers are used; flooring, lining and damp courses for cellars, reservoirs, etc.; for fireproofing roofs; for insulation or preservation of various kinds of pipes; for heavy and waterproofing paints; and as a source of asphaltic oils (*for road preservation*) by sprinkling or "penetration" methods. These and many other possible uses presuppose, in the case of the Alberta deposits, an efficient extraction of bitumen from the siliceous mineral aggregate. It is held by many engineers that the bitumen which, in this class of deposit, owes its present form to a process of natural distillation, possesses qualities superior to those of bitumens derived through the artificial distillation of petroleum.

At various localities in the United States during the past twenty years, the commercial extraction of bitumen from bituminous sands and sandstones and from bituminous limestones has been attempted. Although the construction of such plants has involved an expenditure of many hundreds of thousands of dollars, accurate information regarding details of operation and of actual results are difficult of access.[2] The following

[1] "Twenty Years' Practical Experience of Natural Asphalt and Natural Bitumen." Delano. Pub. by E. and F. N. Spon, London, 1893.

[2] Asphaltum Refining, by Hans A. Frasch, Vol. VII, Mineral Industry.

Apparatus for treating rock asphalt, U.S. Patent No. 722,500, March 10, 1903. Application made by J. S. Downard and B. A. Ralason.

Extraction of bitumen using naphtha as solvent. U.S. Patent No. 581,546.

Extraction of bitumen using petroleum and benzine as solvent. U.S. Patent No. 617,226, granted to A. S. Cooper.

Extraction of bitumen using solvent in steam-jacketed tanks. U.S. Patent Nos. 617,712 and 655,430, granted to A. F. L. Bell.

Extraction of bitumen from bituminous sand rock. U.S. Patent No. 655,416, granted to Jacob Philippi.

Refining methods used by Tar Springs Asphalt Co., Tar Springs, Okla., from Mines and Mining, March, 1903.

Asphalt Mining and Refining in Oklahoma, by W. R. Crane, in Engineering and Mining Journal, Dec. 17, 1903.

13th Report of the State Minerologist (1895-96), California State Mining Bureau.

very brief reference to a matter that will eventually be of real moment to those who seriously undertake the development of the Alberta deposits of bituminous sands, is based, in part, on the writer's personal investigations in Oklahoma and California, and, in part, on what is believed to be reliable information gathered indirectly from various sources.

Generally speaking, commercial extraction in the past has been attempted by the use of solvents—principally carbon disulphide, and the lighter petroleum distillates—and by the use of hot water and steam. Of the first two solvents, carbon disulphide is more expensive and more volatile, while the escaping fumes are a menace to the health of employees. In actual commercial practice, however, it appears that neither the use of naphtha nor of carbon disulphide has been successful. Apart from attendant danger from fire and explosions, there is a serious loss in the solvent employed.[1] Such a loss, due in part to evaporation and in part to failure to fully recover the solvent from the extracted bitumen, will, at times, probably aggregate nearly 15 per cent.

The results when hot water and steam have been used have been more encouraging.[2] A fairly rapid and comparatively inexpensive separation has been possible, but in actual commercial practice the extraction has not been sufficiently complete. Summarizing all evidence available to the writer, it appears that, as at present understood, the use of hot water or steam, or a combination of the two, will not give a commercial extraction of more than 60 per cent of the bitumen contained in average bituminous sand-rock. In attempting to secure a higher percentage extraction, a disproportionate increase in cost will probably result. The following constitutes only a partial list of companies which, during recent years, have attempted extraction in the United States:—

Litho Carbon Company, operated at Cline, Uvalde Co., Texas, about 1896. Rock treated, bituminous limestone, carrying 10-13 per cent bitumen.

[1] There appears to be no doubt that there will always be more or less loss in the solvent. Probably in a well designed plant, this can be reduced to a minimum.

[2] It should be remembered that certain bitumens, owing to their gravity, cannot be handled by the hot water process. This was so, for instance, in the case of the Sisquoc asphalt deposit, operated by the Alcatraz Company in California. In this instance there was no alternative but to extract by means of other solvents, that adopted by the Alcatraz Company being a light distillate of petroleum.

Uvalde Asphalt Company, operated at Cline, Uvalde Co., Texas, about 1898. Rock treated, bituminous limestone, carrying 10-13 per cent bitumen.

California Petroleum and Asphalt Company, operated at La Patera, Ventura Co., Cal., about 1890. Rock treated, bituminous shale carrying 60 per cent bitumen.

Alcatraz Asphalt Company, operated at Alcatraz, Cal., about 1902, on bituminous sand-rock carrying 10-16 per cent bitumen.

Tar Springs Refining Company, operated about 1902 at Tar Springs, Okla., on bituminous sandstone, carrying 10-14 per cent "asphaltum" and 20-30 per cent heavy oils—largely petrolene.

Pacific Oil & Asphalt Company, ceased experimental operations in Santa Barbara county, and in San Francisco about 1903. Rock treated, bituminous sandstone, carrying 12 per cent bitumen.

Conical Company, operated at Woodford, Okla., in 1898, on bituminous sandstone, carrying 8-10 per cent bitumen. Operations hampered by insufficient working capital.

Southern Asphalt Company, operated at Woodford, Okla., in 1906, on bituminous sand-rock, carrying 9-11 per cent bitumen.

Continental Company, operated near Ardmore, Okla., on bituminous sand-rock, carrying 10-12 per cent bitumen.

Snider Asphalt Company, operated near Ardmore, Okla., on 10-12 per cent bituminous sand-rock.

American Mineral Wax Company, operated at Ardmore, Okla., 1910, on bituminous sand-rock, carrying 10-12 per cent bitumen.

So far as the writer is aware, no plants for the extraction of bitumen from bituminous sand-rock have been in operation in the United States during the past three years. In one or two instances the precise cause or causes for discontinuing operations are somewhat obscure, or else are difficult to interpret correctly. It appears, however, that failure to secure a successful commercial extraction of bitumen from bituminous rock has, in the past, been due to one or more of the following causes:

Unperfected mechanical operation of plants, resulting in imperfect separation; limited capacity and output, resulting in overhead charges being unduly high.

Local conditions, including high transportation and mining costs; selection of bituminous rock not adapted to extraction processes; legitimate trade competition from other satisfactory paving materials (as petroleum residuum).

Trade competition not based on normal commercial conditions, i.e., rate cutting by a stronger competing company.

Shortage of funds at critical periods, particularly during experimental stage of operation. Unsound financial methods.

Fires and explosions, chiefly due to inflammable nature of solvents used, and to the installation of open instead of closed distillation apparatus.

It is thus safe to say that, even apart from the actual merits of any of the processes that have been used, the extraction of bitumen from bituminous sand-rock has not met with commercial success. Nevertheless, in view of the various factors that must be taken in to account in considering past attempts, it is difficult to say whether, under the most favourable conditions, commercial extraction may or may not be feasible. Meanwhile, those who may care to attempt extraction on a commercial scale and under conditions prevailing in northern Alberta, will have available the results of many years' elaborate and often costly experimentation, on which to base their efforts. Further, it should be remembered that, owing to freight and other charges on imported asphalts, extraction in Alberta would be on a much more favourable basis than has, for example, been the case in California, where competing residuum[1] can be sold at a very low figure.

[1] Present prices of imported asphalt (99% pure) at Edmonton are \$27-\$34 per ton. At San Francisco, Cal., the same material may be had at considerably less than half this cost.

APPENDIX IV.

BITUMINOUS SANDSTONES.

At the present time bituminous sands are, commercially, unavailable in Canada. In parts of Europe, however, and particularly in the United States of America, deposits of this material have been operated for many years.[1] In view of the interest which deposits in the McMurray district are now attracting, a brief reference to occurrences in the United States is given herewith. These notes are based in part on information acquired by the writer in Kentucky, Oklahoma, and California, and, in part, on information secured from other sources.[2]

It appears that in the United States, at the present time, there are recognized at least sixty-two separate deposits of bituminous sand. Of these, sixteen are in Kentucky, fifteen in Oklahoma, and twenty-four in California, the remaining seven being in Missouri, Utah, and Texas. The bituminous content of these deposits ranges from 3 to over 20 per cent, a fair average being probably about 10 per cent. At the present time, owing

[1]**Production of Asphaltum and Bituminous Rock in the United States (tons of 2000 lbs.)**

States.	1911			1912		
	Tons	Value	Per ton	Tons	Value	Per ton
Bituminous Rock.		$	$		$	$
California........	27507	89,264	3.25	35637	88,621	2.50
Kentucky........	13831	54,980	3.70	......	....	....
Oklahoma........	......	....		10969	44,428	4.05
Texas	......	....		6435	19,626	3.05
Utah	......	....				
Total..........	41338	144,244	3.50	53041	152,675	2.87
Asphaltum.						
California........	177690	2,202,490	12.40	213694	2,097,782	9.85
Oklahoma........	53566	325,976	6.09	54748	296,945	5.40
Utah	......	....	.....	.....	....	....
Texas	55826	786,785	14.05	88097	1,384,640	15.75
Total..........	287082					

In addition to the above, the imports of asphalts and bitumens into the United States in 1912 were 194,775 tons valued at $4.72 per long ton.

[2] 22nd Annual Report, U.S. Geol. Survey, Vol. I.
Bulletin No. 8, Oklahoma Geol. Survey.
Mineral Industry, Vols. 1 to 22.

to various causes, the majority of these deposits are not being operated, although nearly all have at various times been opened up to some extent. The thickness of many of these beds in Kentucky and in Oklahoma does not exceed 10 to 15 feet. In California, however, a number of beds are of greater thickness; that formerly operated by the Alcatraz Company in the Los Alamos district attaining in places a thickness of over 100 feet.

Apart from the percentage content of bitumen and the hardness of the rock itself, nearly all American deposits of bituminous sand with which the writer is acquainted bear a general resemblance to those of the McMurray district. Generally, the compactness of the rock appears to vary with the grading of the sand; and, with the removal of the cementing bitumen, the quartz grains fall apart. It is also noticeable, as in the McMurray district, that the richer material frequently constitutes the lower part of the impregnated strata, and that in many cases there is a close physical resemblance between the impregnated mass of sandstone and an oil pool as at present understood. The passage from richer to poorer zones is gradual to moderately sharp, though at times faint traces of bitumen are also found extending into the overlying sandy shales. Seepages of bitumen from outcrops are common to exposures of nearly all deposits in Canada and in the United States. In the case of the former deposits, the feature presented by the presence of interbedded clay partings is more marked. As in the McMurray district, variation in the grading of the mineral aggregate is also frequently met with. In such cases it has been found feasible to combine material from two or even three sections of a deposit, the resulting mixture giving the required grading.

Geologically,[1] the bituminous sands of Kentucky, Oklahoma, and of California, occur in widely separated horizons. In Kentucky the deposits occur principally as a part of the Chester Series of the Lower Coal Measures. In Oklahoma, they are found in the Ordovician and in the Trinity sands at the base of the Lower Cretaceous. In California, however, the deposits of asphalt and of bituminous rock are confined to formations of the Miocene and particularly associated with the Monterey shales

[1] 22nd Annual Report, U.S. Geol. Survey, Vol. I.

and sandstones that occur immediately above. It thus appears that, in their geological horizon, certain deposits in Oklahoma, most nearly correspond to the bituminous sands of the McMurray district.

Of the quarries being operated in the United States at the present time, three are here referred to for purposes of comparison. From these, large shipments of bituminous sand have been made, and it is claimed that pavements constructed by the use of this material, have proved quite satisfactory.

No. 1. Rock creek, Oklahoma.[1] The product consists of subangular grains of sand, cemented by a solid asphalt pitch, having the penetration of ordinary asphalt cement. It is used to furnish the solid pitch for paving mixtures.

Bitumen soluble in CS_2	7·80%
Character of bitumen, semi-solid, sticky, ductile.	
Specific gravity, 25° C.—25° C.	1·017
Penetration, 100 g. 5 sec. 25° C.	61·0
Loss at 163°—5 hours	3·48%
Consistency of residue, penetration as above	29·0
Bitumen soluble in 86° B. paraffin naphtha	22·44%
Fixed carbon	10·36%
Mineral matter	4·93%

Grading of mineral aggregate,—

Retained on 50 mesh sieve	0·2%
" " 80 " "	9·8%
" " 100 " "	14·3%
" " 200 " "	45·1%
Passing " 200	30·6%

Character of mineral aggregate—very fine sand with rounded grains.

No. 2. From near Dougherty, Oklahoma.[1]

The product consists of angular to subangular grains of sand, loosely cemented by a soft maltha. It is used as the softening agent or flux for harder pitches.

[1] Bulletin No. 8, Oklahoma Geological Survey.

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Bitumen soluble in CS_2	6·77%
Character of bitumen, sticky, viscous fluid	
Specific gravity, 25° C.—25° C.	0·991%
Loss at 163° C.,—5 hours	6·13%
Consistency of residue, too soft for penetration test.	
Bitumen, insoluble in 86° B. paraffin naphtha	11·15%
Fixed carbon	6·95%
Mineral matter	0·81%

Grading of mineral aggregate,—

Retained on 30 mesh sieve	0·0%
" " 50 " "	1·3%
" " 80 " "	40·0%
" " 100 " "	39·5%
" " 200 " "	18·6%
Passing " 200 " "	0·6%
	100·00

In competition with other asphalts, the product from the above quarries has been shipped 450 miles by rail. The average selling price of Oklahoma bituminous sand-rock, in 1912, was approximately $3 f.o.b. place of shipment.

No. 3. The following is a laboratory report on the bituminous rock of a portion of the Santa Cruz deposit owned and operated by the City Street Improvement Co. of San Francisco, California.

In competition with barrelled petroleum residuum at $9[1] per ton, the product from this quarry has been shipped 200 miles by rail. The average selling price per ton of the bituminous sand-rock during 1912 and 1913 was $3.50 f.o.b.

Specific gravity 77° F. dry material	1·0162
Penetration at 77° F.	93

[1] Of this amount probably $2.50 represents cost of barrelling.

Chemical Characteristics.

Dry Substance,—	
Loss at 325° F. for 5 hours	3·7%
Penetration of residue	32
Character of residue	Smooth.
Bitumen soluble in CS_2 air temp.	99·0%
Organic matter insoluble	0·6%
Inorganic matter insoluble	0·4
	100·0
Malthenes,—	
Bitumen soluble in 86% naphtha (Commercial)	79·1%
Bitumen soluble in 62% naphtha (Commercial)	89·6%
Carbenes,—	
Bitumen insoluble in carbon tetrachloride	0·1%
Bitumen yields on ignition.	
Fixed Carbon,—	
Loss at 325° F. of original rock.	
50 grams of coarse bituminous rock lost	0·75%
Per cent of bitumen in sand	16·40%
Loss on heating, per cent of total bitumen	4·50
Grading of mineral aggregate,—	
Soft rock lower strata.	
Bitumen	13·42%
Passing 200 mesh sieve,	4·02
Retained on 200 mesh sieve	4·32
" " 100 " "	7·28
" " 80 " "	31·36
" " 50 " "	11·12
" " 40 " "	17·68
" " 30 " "	8·00
" " 20 " "	2·48
All passing 10 " "	

Hard rock upper stratum,—

Bitumen					15·70%
Passing 200 mesh sieve					8·86
Retained on 200 mesh sieve					36·40
"	"	100	"	"	24·00
"	"	80	"	"	12·28
"	"	50	"	"	1·44
"	"	40	"	"	0·60
"	"	30	"	"	0·28
"	"	20	"	"	0·20
All passing		10	"	"	

As the above deposit is probably one of the most important in the United States, and as the material somewhat resembles that from certain of the outcrops in the McMurray district, the following detailed reference may be of interest. It is taken from an article written by Mr. J. R. Price, C.E., for the California Journal of Technology, Aug. 1913:

"On the slope of the Coast Range mountains in the County of Santa Cruz, about 8 miles northwesterly from the City of Santa Cruz, are located the bituminous sandstone deposits, owned and operated by the City Street Improvement Company of San Francisco. The formation is a Miocene or Monterey shale and bituminous sands. The deposit has an elevation of 800 feet above sea level. There are three distinct layers or strata of saturated sands. The lower stratum has a depth of 8 feet. Above this is a layer or stratum of fine sand 8 feet in depth impregnated with 2 to 3 per cent of bitumen. Above this stratum of sand is a deposit of splendidly saturated sand containing about fourteen per cent of pure bitumen. Its depth is no less than 32 feet. Its sands are partially graded and consist of those retained on the coarser meshed sieves. Upon this great mass of bituminous sand rock rests a shale deposit of a diatomaceous character. This shale cap is from 40 to 60 feet in depth. Immediately over it is a deposit of excellent bituminous sandstone containing from 16 to 18 per cent of pure bitumen and about 82 to 84 per cent of fine siliceous sand, all or nearly all, passing the 50 mesh screen. The average depth of this deposit is 25 feet. We have, therefore, in this mine three strata aggregating a thickness of 64 feet............................

Method of Mining.

"The Miocene shale cap is removed by blasting and scraping. Where the shale has been cleared away, the bituminous sandstone is moved by the use of powder. Augers are used to bore holes, having extension rods very much like the well boring auger.......... When a hard rock or substance is encountered that cannot be removed with the auger, a churn drill is used to pass through the hard material, after which the auger is again used. The hole is bored until the sand deposit is reached, upon which the bitumen rests, or to the shale bed........ After being broken down, the material is loaded into wagons, transported 3 miles to railroad and then reloaded on cars to be shipped to points for use.

Character of the Material.

"The bituminous sandstone breaks very easily with a quick blow, making a very clean fracture, but when warmed by the heat of the sun, becomes very elastic and difficult to handle.

"In order to make use of this material it is necessary to disintegrate and thoroughly mix it. Heat appears to be the best medium.

"The material, as it is extracted from the earth, is not in the very best condition for a stable pavement. It contains nearly all the ingredients required for such purposes, but not in the correct proportion.

"The most satisfactory combination of asphalt and mineral aggregate for a standard pavement has been determined by actual trial. For sheet asphalt it may be stated as follows:—

"Asphalt soluble in bi-sulphide of carbon	10½%
Mineral aggregate,—	
Stone dust passing the 200 mesh sieve	13 %
Sand passing the 80 and rejected by 200 sieve	26 %
Sand passing the 50 and rejected by 80 sieve	23½%

Sand passing the 30 and rejected by 50 sieve........................	19 %
Sand passing the 20 and rejected by 30 sieve........................	5 %
Sand passing the 10 and rejected by 20 sieve........................	3 %

"A combination of asphalt, stone dust and sand having the proportions above stated is believed to be the best mixture that can be made for a first class pavement. The voids in this mixture have been reduced to 2½ per cent and usually do not exceed 8 per cent. The object of the classification of the material as above is to reduce the voids in the final mixture to a minimum, at the same time fitting the sands together in the most compact manner possible. The nature of the material necessarily involves some impossibilities and therefore it is not to be presumed that the formula above can, at all times, be complied with. Therefore, all specifications allow a margin on each side of the standard in order that we may be able to lay pavements. The maximum and minimum limits are given in all first class asphalt specifications. It should be the aim, however, to approach as closely as possible the standard formula.

"The pure bitumen in the asphalt must be of the proper quality, that is, it must be adhesive, cohesive and ductile at ordinary temperature. The method of distillation of the asphalt is all important. It is better to have asphalt distilled under a slow heat and moderate temperature than at high degrees of heat which changes the hydrocarbons, producing a surplus of asphaltenes.

"The long life of samples of bituminous sandstone pavements extracted from the Santa Cruz deposits, is sufficient evidence in itself to forever refute the contention, if any, against the quality of the asphalt from this source. . . . .

The Mineral Aggregate.

"The mineral aggregate consists of almost a pure siliceous sand and dust. The sands are not of the sphere shaped class but are semi-spheroidal, exposing surfaces upon which similar ones will rest without slipping.

"The dust passing the 200 mesh sieve varies in quantity from 2 to 8 per cent but is quite regular in each class of sand-rock. It is extremely fine grained material forming an impalpable powder unacted on by water and one of the greatest essential parts of the mineral aggregate. It is extremely difficult to filter out the asphalt from the sand-rock, with a solvent, due entirely to the presence of this peculiar marine deposit. It is of a more minute character than any stone dust prepared by artificial grinding and is therefore the *one* filler required in a mineral aggregate to make it impervious to water when combined with the asphaltic cement. It forms a part, and a very important one, of a thoroughly graded mineral combination beginning with the coarser sands and passing down the different sized materials to infinity, or a particle of stable material so small that a most powerful magnifying glass is required to even see, without measuring, its possible dimensions.

Grade of Sands.

"The sands contained in the two lower strata of the deposit are practically confined to those passing the ten mesh and rejected by the 80 mesh sieves. The occurrence is reasonably regular in all parts of the mine. In the upper stratum from 75 to 80 per cent of the sands pass the 50 mesh sieve, about 12 per cent being retained on the 80 mesh sieve, the remainder passing this sieve and 7 to 10 per cent passing the 200 mesh sieve. The sands in the upper stratum are extremely regular, no change worthy of note having been discovered from the time of its early use to the present date.

"The bituminous sand-rock is loaded at the mine into wagons hauling five to eight tons to the railroad station at Godola. Here it is transferred to the cars and shipped to all points where the freight rates will permit. Its competitor is Oil Asphalt obtained from the distillation of crude petroleums.

Preparation for Use.

"The material is shipped to a convenient point where it is to be laid. To make it a mixture for a standard sheet asphalt, it must be disintegrated and mixed so that each part will take its place in the final mix. This is done in what is known as the Torpedo Mixer. It is introduced into the revolving conical shaped drum with the proper proportion of each class of sand, stone dust and such other materials as are necessary. An oil burner in a fire box beneath the drum supplies the heat, the drum revolving on rollers at the speed of about 12 to 14 revolutions per minute. Inside the drum a worm extends the whole length of the same, requiring 10 to 15 minutes of time for the material to pass from the entrance to the exit. The drum motion is reversible and when revolving in one direction it unloads and in the opposite direction it tends to throw the material back on itself. All during this operation the material is constantly disintegrating and mixing the same as cement concrete in a rotary mixer. Mixing paddles assist the operation."

APPENDIX V.

PROSPECTING BITUMINOUS SAND.

The following notes may prove of value to those undertaking the prospecting of bituminous sand for the first time. Since at present all equipment required in prospecting in the McMurray district must be secured before leaving Athabaska, and since work must be carried on at least 250 miles from the base of supplies, rather more detail is given than would otherwise be deemed necessary.

The necessity of carefully and systematically prospecting any area of bituminous sand as a preliminary to actual development is, of course, obvious, and until this has been done it is impossible to definitely express an intelligent opinion regarding the value of a deposit. Incidentally, it may be noted that a certain degree of danger attends such work. During warm weather, large and small masses of bituminous sand flake off and fall from exposed faces, and after rains, heavy slides of loosened material are frequent along the more precipitous outcrops. The following are among the more important conditions to be considered.

(a) *Overburden.* Even a casual consideration of the measurements of sections given elsewhere, will indicate the importance that will attach to this feature, since everywhere the bituminous sand is overlaid to some extent. In certain cases, gravels and clays, in others, stratified sandstones, shales and occasional thin quartzites constitute the overburden; while, in many instances, low grade bituminous sand must also be classed as overburden, and removed as such. Moreover, contour maps of small areas in the vicinity of eleven of the more promising outcrops indicate wide variation in surface elevations, often within narrow limits.

Types of Machines, etc.

Types of machines for proving depth and character of overburden are well known, and require little comment. A simple churn drill that is being used extensively in connexion with prospecting work on the iron ranges of Minnesota, is, however, here briefly referred to (Fig. 4). Such a drill is found to be satisfactory in determining depth of overburden when the material consists of sand, gravel, and clays. As illustrated in Fig. 4, the three members of the head frame, which is 30 to 40 feet high, consist of two squared legs, about 5″ x 6″, and a heavy ladder: the latter being of service in connexion with necessary work about the upper part of the rig. Light poles, spiked to the ladder and legs, carry plank scaffolding. A 1¼″ hemp rope, supports the casing, drill, etc., also operates the 250 lb. hammer used in driving the casing. This rope runs over an 18″ shieve placed in the upper end of the ladder, and from thence passes around a capstan as shown in Fig. 4. In driving the casing, or in operating the drill, an attendant checks or loosens the rope, and thus controls the height and frequency of the drop of the hammer.

The casing used is 3″ heavy wrought iron, lengths being usually about 20 feet. Wash rods of 1¼″ wrought iron are passed down through the casing, and carry a bitt at the lower end. In driving the casing a T coupling is usually screwed to the upper end in order to prevent damage by the hammer. By means of a 6 foot bar clamped about the casing, a slow turning movement is given, which tends to prevent binding.

In commencing a hole, the casing is first driven down until it no longer sinks easily. Water is then pumped down through the wash rod, and passes out through small holes in the faces of the bitt. This water mixes with the material churned up by the bitt, and, rising through the casing, overflows at the casing head. Here the material from the hole is either wasted or run into settling boxes, for further examination. It may be noted that in soft ground, such as sand, a bitt is not required, the water merely flowing through the lower open end of the wash rod. Usually the casing is easily driven after the wash rod. In tough clay, however, it is often desirable to first spring the hole with 60% dynamite. Boulders when encountered are also shattered by the use of dynamite, rods and casing first being drawn up a sufficient distance. After passing through the over-

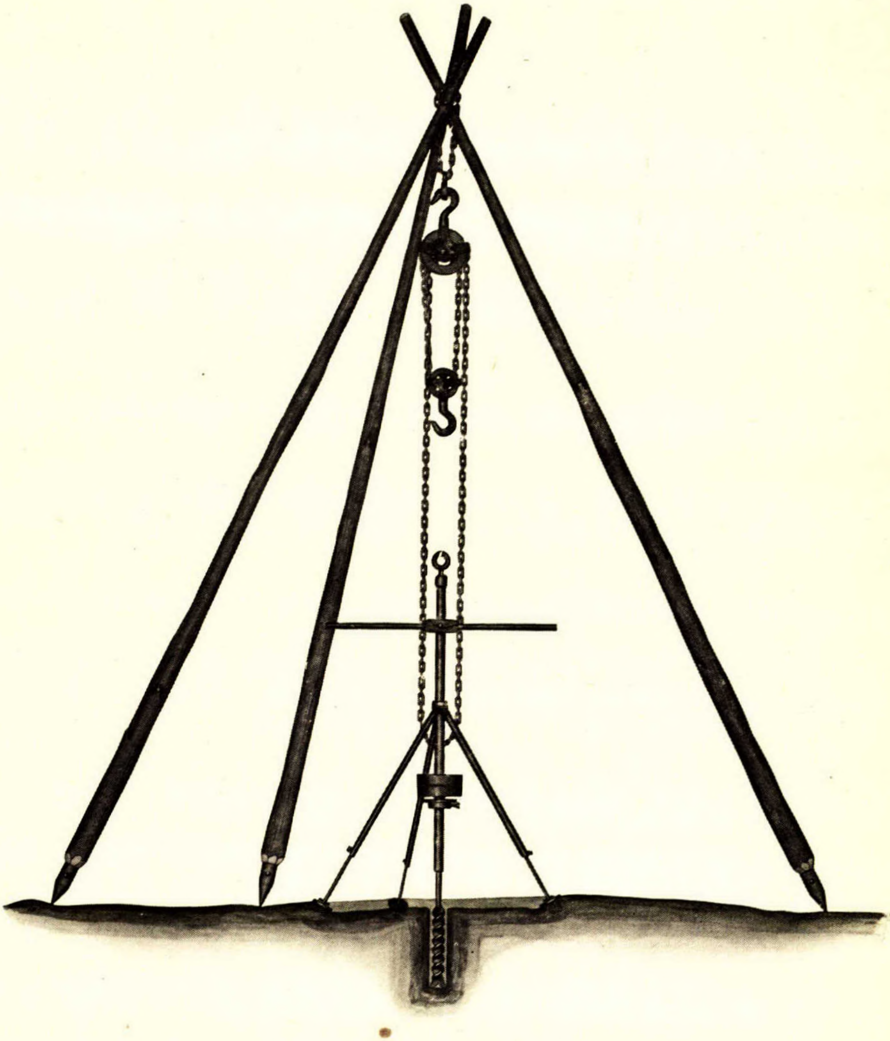

Fig. 4. Arrangement of auger for boring Bituminous Sand

burden, holes may be continued, in the case of bituminous sand, by means of an auger, or other suitable appliance.

A rig such as the above can be operated by two men, though a crew of three will get better results. In favourable ground 30-50 feet of hole per day can be driven.

A 10 H.P. engine[1] similar to that shown in Fig. 4, weighs about 1400 pounds, and a 20 H.P. boiler about 3,000 pounds. These are easily capable of sinking and casing holes to a depth of 150 feet. Moving with stone boat and wagon, and setting up, need, therefore, present no serious difficulty. The total cost of boiler, engine, pump, pipe, tools, etc., should not exceed $1,200. Such equipment may usually be purchased second hand at a somewhat lower cost.

Any decisions regarding the larger question of subsequent stripping and disposal of waste will, of course, depend, in each individual case, on results of borings, and on local conditions. Since removal of overburden on a large scale will constitute an important feature in connexion with development in practically all parts of the McMurray field, a brief reference to this feature of preliminary work will be of interest.

Under conditions prevailing in the McMurray area, overburden can be removed and wasted by any of the following methods: viz., mechanically operated drag line scrapers, steam shovel outfit, or by hydraulicking. Each of these methods, under favourable conditions, has proved its efficiency. The writer knows of an instance in California where a hard shale rock is being moved and washed by drag line scraper at a cost of not over 9c. per cubic yard, apart from the charges for breaking down the rock itself. On the Cayuna range[2] in Minnesota, using heavy Bucyrus shovels, sandy overburden has recently been removed at a cost of about 8c. per cubic yard. Steam shovel and scraper methods are, however, so well known as to require no comment.

During the past two years, removal of overburden, by means of hydraulicking has been successfully undertaken near Riverton, Minn.[3] Water under a pressure of 50 pounds is directed through

[1] Built by West Clyde Iron Works, Duluth, Minn.
[2] Pennington Mine, Crosby, Minn.
[3] Somewhat similar methods have also been adopted in connexion with the removal of overburden from phosphate deposits in Florida.
Method there used and results obtained are outlined in an article on "Florida Phosphate Practice" by J. A. Barr, in Mining and Metallurgical Journal, Dec. 1912, p. 265.

4″ nozzles of hydraulic guns[1] against the material to be broken down. At the property in question the water is delivered from the nearby lake through about ¼ mile of 12″ spiral rivetted, No. 16 wrought iron pipe.

From the face, the water sluices sand, gravel, and boulders down a 3½ to 5 per cent slope into a shallow sump 3 to 4 feet in depth. From the sump, the material is sucked up by a heavy specially designed No. 12 belt driven Morris Centrifugal Sand Pump,[2] and discharged through a line of 12″ spiral rivetted, wrough tiron pipe.

Although the pump has a 12″ suction, and a 12″ discharge; and although capable of handling solids up to 10″; in actual practice, a coarse screen is used which prevents anything over 4″ or 5″ diameter entering the suction pipe. The pump and motor together with a resistance to facilitate control under varying load, are housed on a heavy wooden platform, having a floor area about 16 × 30 feet. When commencing operations, a small sump is provided, either by taking advantage of some natural depression in the surface of the ground or by actual excavation. At the outset, six[3] columns, made up of short sections of heavy 3″ casing are driven to bed rock. Heavy clamps secured to these columns support wooden cradles or sills on which the main platform rests. As excavation proceeds, the platform is lowered by chain and blocks or other suitable means; short lengths of the several columns being removed when no longer required. Finally, the platform itself reaches almost to bed rock, when its position is changed to new ground, as circumstances may require.

A unit such as the above, and using electric driven pumps, requires 2 to 3 attendants only. With one gun operating continuously—24 hours per day—against a face 30 to 60 feet high, it will break down, sluice and discharge through a pipe line up to 70,000 cubic yards per month. Indeed, the through put is controlled by the working capacity of the sand pump, since a 4″ hydraulic gun operating under conditions such as the above, will readily break and sluice over 75,000 cubic yards per month.

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[1] Built by Joshua Hendy Iron Works, San Francisco, Cal.
[2] Built by Morris Machine Co., Boldwinville, N.Y.
[3] It is probable that 8 columns would prove an advantage as giving greater stability and freedom from vibration.

Under ordinarily favorable conditions, the cost of breaking down, handling, and discharging the material at the end of a 1,500 foot pipe line, is well under 7 cents per cubic yard. At the Rowe Mine, Riverton, Minn., a hydraulic installation, similar to that described above, has been successfully handling material consisting largely of sand, with an aggregate of clay, gravel, and boulders, varying in amount up to 20 or 30 per cent of the whole. In the event of the clay forming a larger proportion of the whole, even more favorable results should be obtained.

In the handling of large yardage, and under conditions approximating to those at the Rowe Mine, the hydraulic unit has distinct advantages over the steam shovel. The first cost of such a unit complete will probably not exceed $8,000 as against $60,000 or $70,000 for a steam shovel equipment; while in efficiency and speed the hydraulic methods also shows marked superiority.

At the Rowe Mine, as already noted, all material is sluiced down to a central sump, and thence discharged by centrifugal pump and pipe line at a point several hundred feet distant from and at an elevation considerably above, the pump itself. It is quite probable that topographic conditions governing certain of the outcrops of bituminous sand in the McMurray district may be such as to obviate the necessity for much of this pumping, and that, in some cases, the waste material can be handled simply by the use of hydraulic guns, and by sluicing. If such is found to be the case, the estimate of cost per cubic yard given above, would, of course, be very considerably reduced.

A recent modification introduced at the Rowe mine, substitutes a flat car for the usual heavy platform, the entire equipment being mounted on a flat car. The suction pipe connected with the sand pump overhangs that side of the car from which the material is to be taken. A small sump, not exceeding 3 feet in depth, is excavated by hand, and the giant operated against the adjacent bank, as usual.

In cases where a unit can be operated in this manner, the advantages are marked; since the entire plant can be moved to a new location several hundred feet distant, and excavation recommenced the same day. The car carries the machinery well, and affords a sufficiently stable platform.

(b) *Variation in thickness of bituminous sand.* Owing to the general uniformity of elevation of underlying limestones, and to the undisturbed condition of much of the overlying strata, when present, the thickness of bituminous sand in any deposit within a reasonably limited area will probably be fairly uniform. The outcrops are, however, often partially concealed by drift and talus piles, which will necessitate extensive excavation before accurate measurements can be made. Frequently a portion of a bed extends below water level, in which case boring must also be resorted to.

(c) *Variation in quality of bituminous sand.* Variation in per cent of bituminous content, grading of mineral aggregate, percentages of sulphur, etc., will be met with, often within narrow horizontal and vertical limits. Such features can only be determined by systematic sampling to the full depth of the deposit to be excavated. Two methods may be adopted, each of which will be found applicable under different conditions.

1. In sampling an exposed face, it is probable that the best results can usually be had by blasting out a vertical section. Care should be taken that such a section exposes bituminous sand in place, for, especially under heavy overburden, the effects of slips may extend several feet into the banks. Such slips are not always easy to detect, since disturbed bituminous sand, even under its own weight, will resolidify in such a manner as to leave no surface indication of any disturbance. In one instance the writer exposed a section 65 feet high, by excavating the whole face to a depth of 5 to 8 feet. Although at first the material appeared to be in place, it was afterwards considered to be all a part of one large slip.

In connexion with excavation such as the above, holes are most easily sunk by means of a special auger.[1] The shank of this auger is $\frac{7}{8}''$ steel, the auger itself being 2″ in diameter, with seven turns to the foot. The cutting edges are drawn to a chisel edge, $2\frac{1}{2}''$ diameter, and nearly at right angles to the stem. The boring rods for holes up to 20 feet deep are of 1″ steel, and 10 or 12 foot lengths, jointed by means of sleeve couplings, have been found convenient. In order to secure a downward pressure,

[1] These augers may be obtained from Messrs. Baker and Hamilton, 4th and Brennan streets, San Francisco.

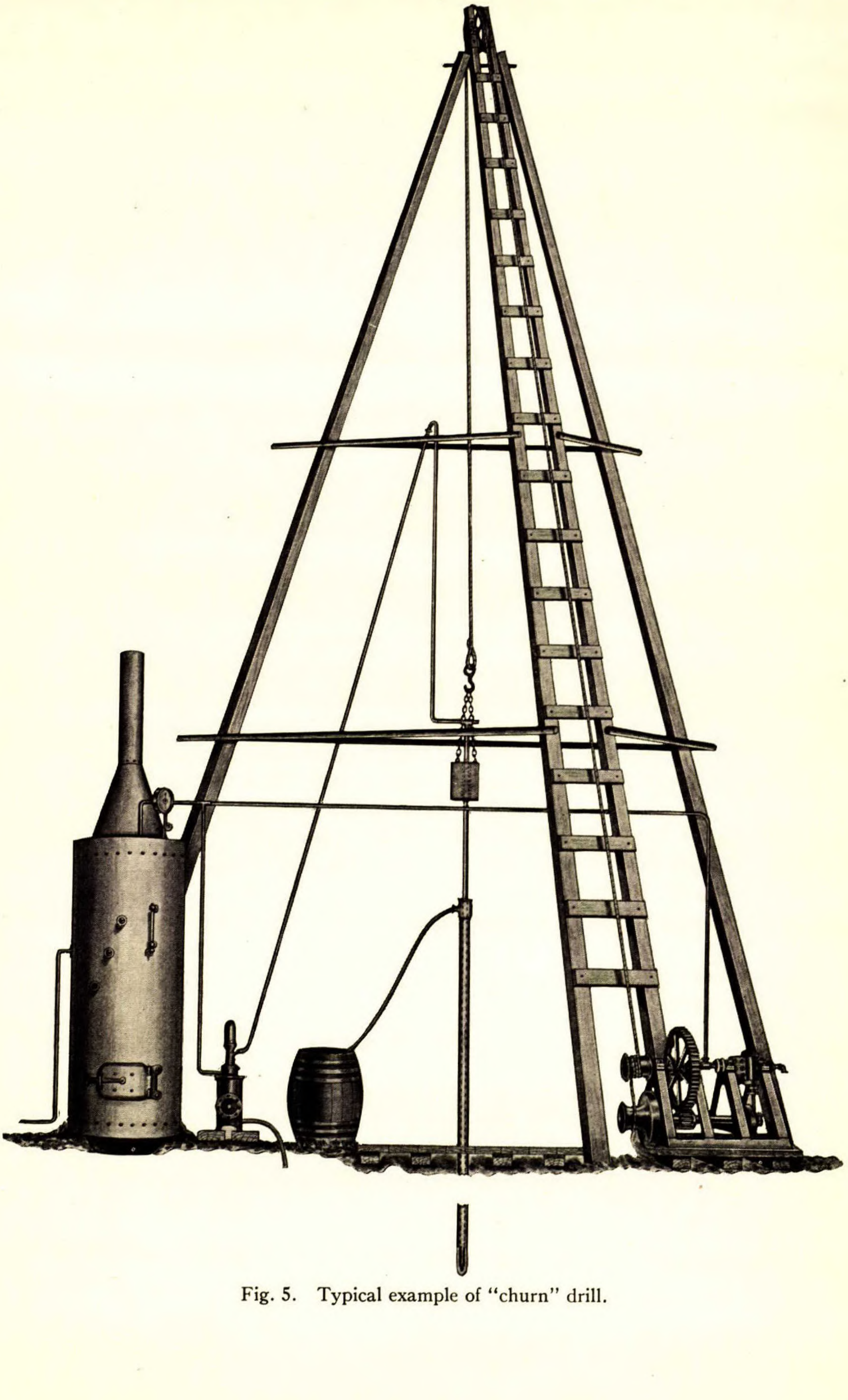


Fig. 5. Typical example of "churn" drill.

circular movable weights, slotted at the side, are supported by a collar, held in place by set screws. The brake handles, 2 or 4 in number, may be held in place either by a chuck or simply by a set screw. If a set screw is used, the drilling rods must, of course, be flattened at intervals. A light adjustable tripod and collar is suggested, since considerable care is required in holding the rods at any desired angle. In order to prevent the points of the tripod from sinking into the soft bituminous sand during warm weather, thin, flat, circular metal plates may be used as indicated. In boring, it is found necessary to lift the auger at frequent intervals, in order to clear the hole. A block, suspended from a triangle of rough iron-shod poles, is, therefore, suggested for this purpose. A circular leather collar, loosely fitted about the auger shaft, will prevent dirt and borings from entering the hole when the auger is lifted. A suggested arrangement for such a rig is indicated in Fig. 5. Difficulty is often experienced in boring, especially in passing through the richer beds, and all parts should be made to stand a total pressure on the brake handles of 600 pounds. The occasional use of small quantities of distillate in the hole is often essential in order to 'cut' the bitumen and prevent the auger sticking. Boulders or hard stratum are passed through by using a churn drill.

Whenever possible, it is obviously desirable that the bottom of the hole reach bed rock or other hard stratum. Before loading, the holes should be sprung, half a pound of 60 per cent dynamite being used to every 25 pounds of black powder subsequently charged. Near the city of Santa Cruz, Cal., the City Street Improvement Company operates an extensive quarry in bituminous sandstone,[1] somewhat similar to much of the material of the McMurray district. At this quarry the holes, after springing, are usually loaded with 175 pounds of black powder, a charge that will throw from the face from 280-300 tons of bituminous sandstone.

2. In prospecting at points where overburden is heavy, some type of light drill may be used to reach the upper limit of the bituminous sand. Beyond this, a rig similar to that shown in Fig. 5 should be used, but with the greater depth heavier rods will be required.

[1] See Appendix IV.

Finally, the following list includes the more important articles that will be required by the prospector:

Excavating tools, etc.—Shovels (long and short handles), mattocks, pick axes (extra strong), crowbars, sledges (8 lb.).

Drilling tools, etc.—Augers, drill steel, portable forge.

Explosives, etc.—Black powder, 40 per cent or 60 per cent dynamite, caps, fuse, battery for firing.

Miscellaneous tools, as: stilson, pipe, nut, chain and monkey wrenches, stocks and dies, cold chisels, pincers and pipe tongs, files.

Equipment for rough carpenter work, as: brace and bitts, hammers and nails, chisel, saws, axes, grindstone.

Miscellaneous: rope, spare set screws, gasoline, friction top sample cans, with capacity of about 20 cubic inches. Carrying boxes for all small tools and for sample cans.

Interstratified partings. In many outcrops of bituminous sand a banded structure is seen. This is due to the presence of interstratified partings of 'dry' (unimpregnated) clays, sands, lignitic particles, etc., which vary in thickness up to 4 and even 12 inches. During rainy weather, this banded structure cannot be readily distinguished in the wet face, but immediately on drying, the interstratified bands stand out.

Along the upper surfaces of these impervious bands, bitumen tends to collect, forming zones of greater enrichment. Consequently, such partings, in beds of otherwise rich bituminous sand, can nearly always be detected during warm weather by horizontal lines of seepage. The effect of such bands is also seen in the manner of weathering. Where strong and persistent partings occur, roughly rectangular masses of bituminous sand detach themselves (Plate VIII). When such partings are almost or wholly absent, a distinctly typical, somewhat conchoidal cleavage, roughly parallel with the face, is set up, owing to weight of overburden and to the effect of the heat. (Plate XXIV). When overburden is light, this parallel flaking off is less noticeable. In considering the probable value of any deposit for paving purposes, the desirability of accurately determining the percentages in which interbedded clays and lignitic particles are present is obvious.

A banded structure frequently persists throughout a complete vertical section, and it is unfortunate that homogeneous bituminous sand, when present, nearly always underlies this inferior material.

APPENDIX VI.

NAVIGATION, TRANSPORTATION AND COMMUNICATION.

Practically all summer travel and transportation between Athabaska, McMurray, and Chippewyan is by the Athabaska river. In winter, land trails via Lac la Biche and House river are used to some extent.

During the season of navigation, and depending on stage of water and individual requirements, steamers operated by the Hudson's Bay Company, gasoline launches operated by private parties, scows or canoes may be used.

The Athabaska is the second largest tributary of the Athabaska-Mackenzie system. It rises in the Rocky mountains, near Mount Brown, and, during a course of quite 600 miles, extends through six degrees of latitude. The river usually opens at Athabaska about the end of April and closes between the 8th and 12th of November. At McMurray the date for opening of navigation is usually between April 20th and May 1st, and the date of closing between November 1st and 15th. The discharge, as measured at Athabaska on September 18th, 1911, was 28,783 cubic feet per second.

At Athabaska the width of the river is 1485 feet, gradually increasing to 3010 feet at McMurray. The average current has never been determined, but in July it is probably about 3 to 4 miles per hour. During average seasons the river is navigable in May, June, July, August and first part of September by stern wheel steamers, drawing 2½ feet, and with a cargo capacity of 125 tons. These steamers operate as far as House river, at which point passengers and freight for McMurray and other northern points are transferred to scows operated by the Hudson's Bay transport. During the season of navigation, canoes and scows may be used at practically all stages of water. Careful discrimination should be exercised in deciding which of the above means of travel will best meet individual requirements. Information regarding transportation by steamer and Hudson's Bay Company's transport, may be secured from the Company's agent at Athabaska.

Flat bottomed river scows of various capacities, may also be secured at Athabaska. Thirty-five foot scows, carrying 5 tons cargo, sell for about $100, while fifty foot scows, carrying 10 tons, sell for $125 to $140. Wooden and canvas canoes can be secured at Edmonton, and nearly always at Athabaska.

To men thoroughly familiar with the handling of canoes in swift water, and who will exercise the usual precautions in approaching rapids, canoeing on the Athabaska need present no serious difficulties. All others should secure the services of competent rivermen. If, however, a scow be selected as the means of transport, the services of a competent bowsman and steersman should be secured. A 10 ton scow usually carries a crew of 4 men. Apart from the bowsman and steersman, average canoemen can be depended on to complete the crew.

Competent guides and canoemen may nearly always be secured at Athabaska during the month of May. At other times difficulty is often had in securing suitable men.

The following table has been compiled from the most accurate surveys at present available, distances being measured along the middle of the Athabaska river. Data on descent and length of rapids are very approximately correct, being taken from the report of Mr. L. Denis, of the Dominion Commission of Conservation.

	Miles.	Side taken by canoes.	Side taken by scows.	Total descent.	Length of rapid.
ATHABASKA to					
La Biche river.....	38				
Calling river	48				
Swift current	64				
Pelican wells	115				
Pelican river......	117½				
Pelican rapid......	119	right	left or right	12′	2 miles
Stoney rapid	124			5	⅓ mile
Rapid	131			8′	2 miles
Rapid du Joli Fou (includes Driftwood, Major and Wheel rapids) ..	142	either	either	9′	1¼ miles
House river.......	152				
Grand rapid and head of island ...	162	portage	right	44′	⅘ mile

Continued.

	Miles.	Side taken by canoes.	Side taken by scows.	Total descent.	Length of rapid.
Little Grand......				10′	2 miles
Rapid	166			10′	½ mile
Pt. La Biche rapid.	168			10′	2 miles
Little Buffalo river.	181				
Brûlé rapid	187	right	right	8′	½ mile
Boiler rapid.......	207	right	middle to left	25′	3 miles
Middle rapid......	210	right	left	20′	1½ miles
Long rapid........	213	right	left	28′	3 miles
Crooked rapid.....	219	right	left	13′	1½ miles
Rock, or Stoney rapid	222	right	left	12′	1½ miles
Little Cascade rapid	226	left	right	10′	2 miles
Big Cascade rapid.	228	left	right	7′	1 mile
Mountain rapid	237	left to right	left to right	8′	1 mile
Moberly rapid.....	142	right	left	3′	¼ mile
Fort McMurray ...	244				

	Miles.		Miles.
Fort McMurray to		Moose river	47
Steepbank creek	21	Tar river..............	48
Saline lake...........	26	Calumet river	53
Beaver creek	30	Firebag river..........	87
Muskeg river	31	Point Brûlé	94
McKay river (Red river)	34		
Fort McKay	35	Chipewyan	177

Under present arrangement, (March, 1914), mails for McMurray leave Athabaska on the first Monday of each month, and are due to arrive at McMurray not later than the following Saturday, in summer, and not later than the following Monday, in winter. Returning, the courier leaves McMurray on the second Monday of each month, in summer, and the second Tuesday, in winter.

A telegraph line from Athabaska to McMurray is now being constructed by the Dominion Government. In January, 1914, 58 miles of line had been completed.

APPENDIX VII.

ANALYSES[1] AND CONCLUSIONS.

At a number of points in the McMurray district, samples of bituminous sand were taken. Analyses of certain of these are given herewith. It is not claimed that such samples accurately represent the outcrops from which they are taken, since to secure such representative samples would have necessitated extensive boring and excavation, not possible in the eight weeks available during the past season's work. It is, however, considered that the samples represent average high grade bituminous sand from the various outcrops. Consequently, although no final conclusion regarding the merit of any individual outcrop can be stated at present, nevertheless, the analyses furnish a basis for the comparison of samples taken over a wide area, as well as a general indication of the character of the bituminous sand itself.

A fairly complete analysis is given of one sample of typical bituminous sand. In the case of the other samples, only such results are given as will best illustrate the general character of the material, such as grading of mineral aggregate and per cent of contained bitumen.[2]

Analysis of Sample (No. 11) from east bank Athabaska river, one half mile south of McMurray.

1. Crude bituminous sand,—

Specific gravity 25°C/25°C..........	1·75
Moisture	1·3%
Bitumen soluble in CS_2	18·5%
Sand	80·2

Characteristics of Sand.

The sand consists, for the most part, of clear quartz grains. In form the grains are most irregular, varying from sharply angular to oval water worn shapes. Judging from

[1] Analyses by S. C. Ells.

[2] From present information the writer believes that the physical character of the contained bitumen does not vary greatly over a considerable area; but further, and more detailed investigation will be necessary before this can be definitely asserted.

the grading of the sand, the bulk of which ranges from 40 to 80 mesh, the greater part may be considered as originating as shore deposits. The following is an analysis of sand combined from samples taken from six representative outcrops:—

SiO_2	95·50%
Al_2O_3	2·25
CaO	0·50
Fe_2O_3	0·35
MgO	0·23
Less loss on ignition	1·50
Total	100·33

At present all plate and window glass[1] used in Canada is imported. In the case of sand extracted from the Alberta bituminous deposits, the percentage of iron would prohibit its use in the manufacture of plate glass; while even for window glass the presence of mica, clay and feldspar, would probably necessitate mechanical purification. For either purpose the grading of the sand is such that grinding would have to be resorted to. Bottle glass is largely manufactured in eastern and western Canada and for this purpose the Alberta sand would prove suitable. For sand lime brick the extracted sand should also prove satisfactory.

These remarks are based on the analysis noted above. It is probable, however, that analyses of a number of samples of sand, even if taken from the same deposit, would show a considerable variation. It should, moreover, be remembered that any value the extracted sand may have, will depend on a clean separation of sand and bitumen. In all attempts that have been made up to the present time, to extract bitumen from bituminous sands or sandstones on a commercial scale, a clean separation, such as would be required, has not been found practicable.

Until actual prospecting has been undertaken, it will be

[1] Report on the non-metallic minerals used in Canadian manufacturing industries, by H. Fréchette. Mines Branch Report No. 305.

impossible to express an intelligent opinion as to the probable commercial significance of the extracted sand from any outcrop. It is expected that during the next twelve months sand extracted from the Alberta bituminous sands will be carefully tested in order to actually determine to what uses it is best adapted.

2. Extracted bitumen[1],—

Specific gravity, 25°C/25°C	1·018
Fixed carbon	7·23%
Sulphur	4·85%
Bitumen soluble in 76° naphtha	82·8%
Bitumen soluble in 88° naphtha	78·2%
Carbenes	trace.
Ash[2]	trace.
Saturated compounds in 88° naphtha solution	39·6%
Unsaturated compounds in 88° naphtha solution	60·4%
Stickiness	4881·0
Penetration at 115° F.	Too soft
" " 77° F. (100 grams. 5 sec.)	" "
(100 grams, 1 sec.)	9·0 mm.
Penetration at 32° F. (100 grams, 5 secs.)	2·5 "
Ductility at 77° F.	100 cm. +
Volatile 160° C.—5 hours (Using New York testing oven)	11·2%
Volatile 205° C.—5 hours (Using New York testing oven)	14·2%
Volatile 250° C.—4 hours (Using New York testing oven)	18·8%

FRACTIONAL DISTILLATION TEST.

A number of samples of the extracted bitumen were subjected to distillation until coked. The apparatus used was that recommended by the American Society for Testing Materials

[1] All extractions by use of CS_2.
[2] Fine mineral matter not removed by extraction.

but heat was applied by means of a hot air bath instead of direct heating from below only.

The average total percentage of oil thus distilled, including all fractions, is 69 per cent of the original bitumen. The coke residue is equivalent to 23·7 per cent of original bitumen. The remaining 7·3 per cent represents uncondensed fractions, losses in apparatus, etc.

Analysis of coke,—

Volatile	6·5%
Ash	2·0%
Fixed Carbon	91·5%
	100·0

The general fractions have been grouped as follows:—

Fractions	Temperature	Amount of oil	Sp. gr.	Par-affine scale	Unsaturated (polemerized using 37 normal H_2SO_4)
1st	0°C.—110°C.	2·5 c.c.	0·85	....	......
2nd	110°C.—275°C.	73·0 c.c.	0·88	0·29%	30%
	(Chiefly between 250° C. and 275°C.)				
3rd	300°C.—330°C.	17·5 c.c.	0·91	0·09	40·9%
4th	330°C.—360°C.	2·5 c.c.	0·96	....	......

3. Characteristics of residual bitumen after heating.	165°C. 5 hours.	205°C. 5 hours.	250°C. 4 hours.
Specific gravity, 25°C./25°C.	1·021	1·025	1·028
Fixed carbon	8·99%	10·77%	12·33%
Sulphur	None	None	None
Carbenes	Trace	Trace	Trace
Fusing temperature	106°F.	114°F.	125°F.
Penetration at 115° F.	too soft	too soft	too soft
" " 77° F. (100 grams 5 secs.)	26·2 mm.	12·2 mm.	5·8 mm.
Penetration at 32°F. (200 grams 1 minute)	10·5 "	5·3 "	2·4 "
Ductility at 115°F	100 cm.+	100 cm.+	34·5 cm.
" " 77°F	100 cm.+	99 cm.	45·0 cm.
Tensile strength at 115°F.			0.3 kgs.
" " " 77°F.			1.5 "
" " " 32°F.			25.5 "

Residual bitumen derived from heating extracted bitumen for 4 hours at 250° C. was further heated for 7 hours at 165° C. and at 205° C. with the following results:—

Loss, 165° C., 7 hours ....0·26%
Penetration ....5·5 mm.
Character of residue ....smooth.

Abridged Analyses of Other Samples of Bituminous Sand from the McMurray District.

Test number.	Passing Mesh.									Per cent contained bitumen
	Source	200	100	80	50	40	30	20	10	
11	Athabaska river.......	2	11	54	16	10	5	2		14
12	" "	6	54	25	13	.	.	.	.	15
12	" "	7	77	14	2	.	.	.	.	16
15	" "	24	64	9	3	.	.	.	.	17
15	" "	3	38	19	40	.	.	.	.	9
16	" "	9	33	11	47	.	.	.	.	12
21	" "	3	5	1	8	7	15	33	27	15
21	" "	4	26	11	48	3	2	3	3	20
22	" "	11	70	14	5	.	.	.	.	12
47	Christina river........	3	6	8	12	14	45	12	.	11
49	" "	3	15	11	70	1	.	.	.	14
52	" "	2	35	12	51	.	.	.	.	17
52	" "	4	34	16	46	.	.	.	.	15
39	Clearwater river	4	14	14	48	9	7	4	.	14
43	Hangingstone creek....	3	22	9	51	9	4	2	.	15
31	Horse creek...........	5	38	8	47	2	.	.	.	16
32	" "	5	47	16	32	.	.	.	.	16
33	" "	5	36	14	45	.	.	.	.	15
34	" "	10	33	19	37	1	.	.	.	17
35	" "	4	27	11	56	2	.	.	.	9
35	" "	7	77	5	11	.	.	.	.	17
36	" "	4	40	5	51	.	.	.	.	16
36	" "	5	39	27	29	.	.	.	.	11
37	" "	3	35	15	57	.	.	.	.	13
38	" "	5	42	18	35	.	.	.	.	11
38	" "	4	30	18	47	1	.	.	.	16
73	McKay river..........	2	49	26	22	.	.	.	.	16
74	" "	6	25	16	40	4	9	.	.	13
64	Moose river...........	6	75	18	1	.	.	.	.	15
67	" "	8	53	19	20	.	.	.	.	16

Continued

Test number.	Passing Mesh.									Per cent contained bitumen.
	Source.	200	100	80	50	40	30	20	10	
63	Muskeg river	7	10	1	27	20	16	10	6	9
54	Steepbank river	3	8	2	25	16	20	16	9	14
55	" " "	7	4	1	12	10	17	27	22	16
56	" " "	2	4	1	42	22	13	9	4	17
58	" " "	5	33	2	43	7	4	2	3	16
59	" " "	3	14	2	72	5	5	1	.	16
61	" " "	7	10	1	27	20	16	10	6	8

Test numbers in marginal column correspond to numbers of tabulated exposures noted elsewhere in report.

In addition to the above analyses, a number of briquettes of varying composition as regards per cent of bituminous sand, clean sand, and flux, were heated and moulded under a pressure of 2 tons per square inch. Certain of these briquettes gave fairly satisfactory results when subsequently tested, but further experimental work is required before definite conclusions can be stated.

For purposes of comparison, the following data concerning certain well known natural asphalts are given:—

1. Trinidad asphalt-cement,—
   Dow penetration at 77° F. (100 grams, 5 secs.) 50
   Fusing temperature ....113° F.
   Susceptibility factor............. 45·2
   Ductility at 115° F.............. 15·0
   " " 77° F.............. 21·5
   " " 32° F. .... 1·0
   Tensile strength at 115° F. ...... 0·25 kgs.
   " " " 77° F. ...... 0·75 "
   " " " 32° F. ...... 15·0 "
2. Bermudez asphalt-cement,—
   Dow penetration at 77° F. (100 grams for 5 secs.)............ 50
   Fusing temperature ....113 F.°
   Susceptibility factor 53

Ductility at 115° F.	17·5 cms.
" " 77° F.	17·0 "
" " 32° F.	0·0 "
Tensile strength at 115° F.	0·50 kgs.
" " " 77° F.	1·10
" " " 32° F.	14·0

For purposes of comparison, certain standard specifications governing asphalt cement and grading of mineral aggregate for sheet asphalt pavements are noted below, and furnish an indication of requirements for such work.

Mineral aggregate.	Light traffic mixture.	Medium traffic mixture.	Heavy traffic mixture.
	%	%	%
Pass 8 mesh and retained on 10 ...	0—5	None	None
" 8 " " " " 40 ...	10—45	"	"
" 10 " " " " 40 ...	....	10—35	10—30
" 40 " " " " 80 ...	20—55	20—55	20—55
Total passing 80 mesh..........	18—45	....	....
Pass 80 mesh and retained on 200....	....	10—30	13—30
Pass 200..........................	10—18	12—18	13—20
Bitumen	9·5—12	9·5—12·5	10—12·5
Penetration of asphaltic cement......	60—75	50—65	40—55

CONCLUSIONS.

a. Mineral aggregate. It is unnecessary to emphasize the importance that attaches to the character, but especially to the grading, of the sand in any sheet asphalt pavement. A consideration of the grading of sand in a number of samples noted above, indicates that in this respect much of the Alberta material is unsatisfactory. It is, however, possible that a further and more detailed investigation of individual deposits will show that a combination of material from two or more localities will result in a satisfactory grading of the aggregate. This procedure has been adopted in making use of the deposits of bituminous sand near Santa Cruz, Cal., and at Carpinteria, Cal. This lack of uniformity in the mineral aggregate of the bituminous sand constitutes probably its greatest drawback as a suitable paving material.

b. Percentage of contained bitumen. In general, the percent of asphalt cement required in various classes of bituminous road construction, ranges from 6 to 12. The average per cent of bitumen contained in samples of Alberta bituminous sand examined is about 15. Of this amount 15-17 per cent will be lost in necessary preliminary heating. On such a basis the bituminous content actually available in the anhydrous sand will thus be reduced to 12-13 per cent.

It is not uncommon for paving contractors to attempt to work up old paving material, as taken from the streets, and, by the addition of further bitumen, use it a second time. Generally speaking, it is believed that such efforts have not proved successful. It is, however, quite possible to soften such partially worn asphalt in properly constructed steam heated tanks. The material is then transferred to a regular asphalt mixing machine where such bitumen as may be required is added. In the case of 12-13 per cent bituminous sand, it would evidently be a much more difficult matter to materially reduce the percentage of bitumen by the addition of fresh sand. If, however, the mixer used be furnished with sufficient power and the sand itself be preheated, the desired reduction could doubtless be effected.

In considering the possible use of such machines, the number of units that would be required at once suggests itself. It appears that what is usually known as a one-thousand pound batch—one mixer full—of the regulation artificial mixture for sheet asphalt, is required in laying 5 square yards of sheet asphalt topping 2″ thick when compressed upon the street. In order, therefore, to enable a contractor to lay 1250-1500 square yards of pavement per day, it is evident that a large number of such mixers, involving high labour cost, would be required. Indeed it appears that specially designed machines will have to be constructed before Athabaska bituminous sand can be seriously considered as a paving material.

c. Nature of contained bitumen.

1. Penetration. Before it can be successfully adapted to sheet asphalt work, the bitumen contained in the Alberta sand

will require a very considerable modification. The penetration of the extracted bitumen is much too high and constitutes the dominant feature in considering its value as an asphalt cement. In the laboratory this feature can be sufficiently modified by proper heating and fluxing. Whether this will be found practicable when undertaken under conditions governing actual paving construction, can best be determined under conditions more nearly approaching those of commercial work.

In the laboratory a sample of the extracted bitumen was heated for 4 hours at 250° C., and then gave a penetration of 52. Another sample heated for 5 hours at 205° C. showed a modified penetration of 112. Each of these penetrations indicates an asphalt cement quite suitable for certain classes of paving work. On the other hand, it must be remembered that, to effect a similar modification of the bitumen while still incorporated in the sand aggregate, would require a much greater expenditure of heat. The total heat thus required could be somewhat reduced by the addition of a percentage of a suitable hardening flux. Moreover, the introduction of steam into the bituminous sand as a feature of the heating process would still further reduce the actual temperature required by lowering the distillation temperatures of the lighter fractions. To determine such considerations is of importance, and further laboratory work will be required before complete data can be made available.

2. Susceptibility factor.[1] After being modified by heat treatment until a penetration of 52 has been attained, the bitumen derived from the Alberta bituminous sand is less susceptible to changes in temperature than either Trinidad or Bermudez asphalt cements, the susceptibility factor of the first being 36·5, as against 42·5 for the Trinidad cement, and 53·0 for the Bermudez cement.

3. Ductility. The ductility of the asphalt cement for the Alberta bituminous sand at a penetration of 52, is correspondingly greater at 115°, 77° and 32° F., than that of either the Trinidad or Bermudez cements, with the possible exception of the ductility at 32° F., which is slightly greater in the case of the Trinidad cement.

[1] The susceptibility factor is equal to the difference in hardness at 32° and at 115° F., divided by the fusing temperature and multiplied by 100.

4. Effect of subsequent heating on 58 penetration bitumen.

As giving some indication of the liability of the cements to change on heating, and to harden on use, the second heating of the penetration residual bitumen is of interest. Refined Trinidad Lake asphalt when heated for 7 hours at 165° C. shows a loss of 1·1 per cent. When heated 7 hours at 205° C. the loss is 4·0 per cent.

It is here unnecessary to discuss considerations presented by sulphur, paraffin scale, naphtha solubility, fusing temperature, etc., since the analyses available indicate that none of these will constitute unfavourable features.

In view of the variety and widely differing specifications under which bituminous roads and pavements are now constructed, considerable laboratory experimentation will be necessary before it can be stated to what class of bituminous road construction, if any, the bituminous sands of Alberta are best adapted.

Meanwhile, it is evident that either in its soft condition, or when reduced to the hardness of an asphalt cement, the bitumen from the bituminous sand would make an excellent binder, either in the internal or surface treatment of roads. This and other possible uses, depending on a successful extraction process, need not be discussed at the present time. It furnishes, however, a further indication of the value and importance that would attach to the development of such a process.

Mr. A. D. St. John, Ch. E. of New York city, has furnished the writer quite recently with certain information relative to a process[1] for the conversion of bituminous sands into wearing surface mixtures. As his process refers especially to sands whose bituminous content, as in the case with the Alberta material, is of a comparatively soft nature, an outline is given herewith.

"The conversion of bituminous sands into wearing surface mixtures is brought about by hardening the bitumen present; i.e., reducing its penetration.

The hardening is accomplished by partly removing the more volatile hydrocarbons present, and partly through oxidation of some of the bitumen, substantially as follows:—

[1] Patents applied for.

The sand is introduced into a suitable apparatus, mixed with an oxidizing agent, such as MnO_2, Fe_2O_3, or similar substance, and heat applied. When a proper temperature is attained (about 200° C.), water is introduced into the mixture, with stirring, and replaced from time to time as it is volatilized. A current of air may be blown across the surface to remove steam and vapors.

Under these conditions the oxidizing agent combines chemically with some of the bitumens present, and hardens them. The water is rapidly converted into steam, and serves the double purpose of breaking up the solid mass of sand so that each particle is separated from the others, thus opening up an exit for the lighter portions to distil through and escape (the whole mass swells up), and at the same time gives a steam distillation; i.e., the partial pressure of the steam removes an equivalent pressure from the bitumens, in effect lowering the boiling point—preventing burning in two ways.

I. The water uses surplus local heat in volatilizing.

II. The same temperature will distil a greater amount of the bitumens, on account of the lowering of the boiling points.

This result cannot be accomplished satisfactorily by merely introducing steam, as the sand will remain in lumps and open only in spots to permit the steam to escape."

In the McMurray district, there is thus a very large body of bituminous sand, the prospecting and development of which will be confined to stream valleys. The following constitutes a summary of the outcrops noted by the writer:—

Name of stream.	Distances through which exposures recur.	Number of separate outcrops noted.
Athabaska river.........	105 miles	55 outcrops
Horse creek	6 "	32 "
Hangingstone creek......	6 "	11 "
Clearwater river.........	1 mile	1 outcrop
Christina river	9 miles	31 outcrops
Steepbank river	13 "	35 "
Muskeg river	7 "	4 "
Calumet river	3 "	8 "
Tar river	6 "	7 "
Moose river	13 "	25 "
McKay (Red) river	16 "	38 "
	"	"
	185 "	247 "

Only after careful exploration by means of adequate equipment can the true value of any deposit be affirmed. Nevertheless, owing to heavy overburden and lack of uniformity in the quality of bituminous sand, it is probable that quite 80 per cent of the exposures may be eliminated from further consideration at the present time. Considerations affecting transportation will still further reduce the remaining number. Certain of the outcrops should, however, lend themselves to development on a commercial scale.

The present application of bituminous sand-rock is limited to its use as a paving material. The value of the Alberta product for such a purpose can best be demonstrated by actual experimental paving construction. Meanwhile it appears that if the development of the Alberta deposits of bituminous sand is possible, success will largely depend on making no false move in the first place, and in having no "lost motions" in operating the quarry itself.

A process that can be successfully adapted to an efficient commercial extraction of the bitumen from the sand aggregate, would prove of very considerable value in any attempts that may be made to utilize these deposits of bituminous sand. After considering the many attempts at such extraction that have been made during the past twenty years, the writer does not know of any instance where the outcome has proved a commercial success. It appears, however, that under favourable conditions the development of a successful extraction process may be possible.

Meanwhile, the discovery of petroleum fields in western Canada will have a direct bearing on any proposed development of the Alberta deposits of bituminous sand.

Besides the deposits of bituminous sand, beds of clay have been briefly referred to as outcropping on the Moose and Muskeg rivers. Samples of these and other clays were submitted to Mr. Joseph Keele of the Geological Survey. Through the courtesy of Mr. R. W. Brock, Deputy Minister of Mines, the following results of Mr. Keele's examination have been forwarded to the writer.

It may be noted that the clays secured were merely small surface samples. It is therefore possible that samples which will more nearly represent the true nature of the clays, and which have not become contaminated by seepages from overlying bituminous sand, may prove to be of more satisfactory character. During the coming field season larger and more representative samples of these clays will be secured.

"The samples were too small in size to allow of complete determinations concerning their working and drying qualities but they appear to be free from the drying defects so common to the Western Cretaceous clays.

"These clays are of the stoneware type, being exceedingly plastic, and burning to a light coloured dense body at cone 5, while they retain their shape without softening when fired to much higher temperatures. Their most serious defect is due to the presence of asphaltic carbon, which renders the safe burning of wares made from them a difficult process. Nos. 190 and 191 appear to be free from this impurity, as far as could be told from the small samples, and these clays would be valuable for many purposes.

"Owing to their position under heavy overburdens, and the remoteness from transportation at which these deposits occur, it is doubtful if they can be included in the economic resources of the region, at least for some time to come.

"Lab. No. 189. Mottled light red clay from north bank of Firebag river, $\frac{1}{4}$ mile above first rapid.

"This is a very plastic and rather sticky clay. It burns to a red vitrified body at cone 3, but the shrinkages are rather high. It fuses about cone 10. This clay may be suitable for the manufacture of sewer pipe."

"Lab. No. 187. Dark grey, nearly black clay underlying bituminous sand on Moose river.

"This clay is very plastic, fine grained, and smooth. It works up rather stiff and slightly sticky. Dries very slowly with a drying shrinkage of 6·5 per cent. This clay contains such a large percentage of asphaltic carbon, that it is very hard to burn without swelling, unless burned very slowly during the oxidation stage. The density of body, due to the extreme fineness of grain, interferes with the expulsion of carbon, so that the oxidizing process of this clay is tedious.

"The clay burns to a light red colour at the lower temperatures, and to a buff or grey at higher. It vitrifies about cone 5, and is fused at cone 20.

"This clay is of the stoneware type, but the carbon it contains is a detriment.

"Lab. No. 188. From east bank of Athabaska river, $\frac{1}{3}$ mile above McMurray, Alberta.

"A dark grey clay, exceedingly plastic, and smooth, smelling strongly of asphalt when damp.

"It burns to a light red colour at a low temperature, becoming grey when heated up to cone 5 or thereabouts.

"It fuses at cone 16.

"Owing to its fineness of grain, and the fact that it contains a certain percentage of asphaltic carbon, this clay is very hard to burn. It could not be used unless a certain amount of it were calcined, ground, and added to the raw clay. This would improve its working, drying, and burning qualities.

"Lab. No. 190. From point on N.W. shore of Muskeg river, between head of portage and mouth of river.

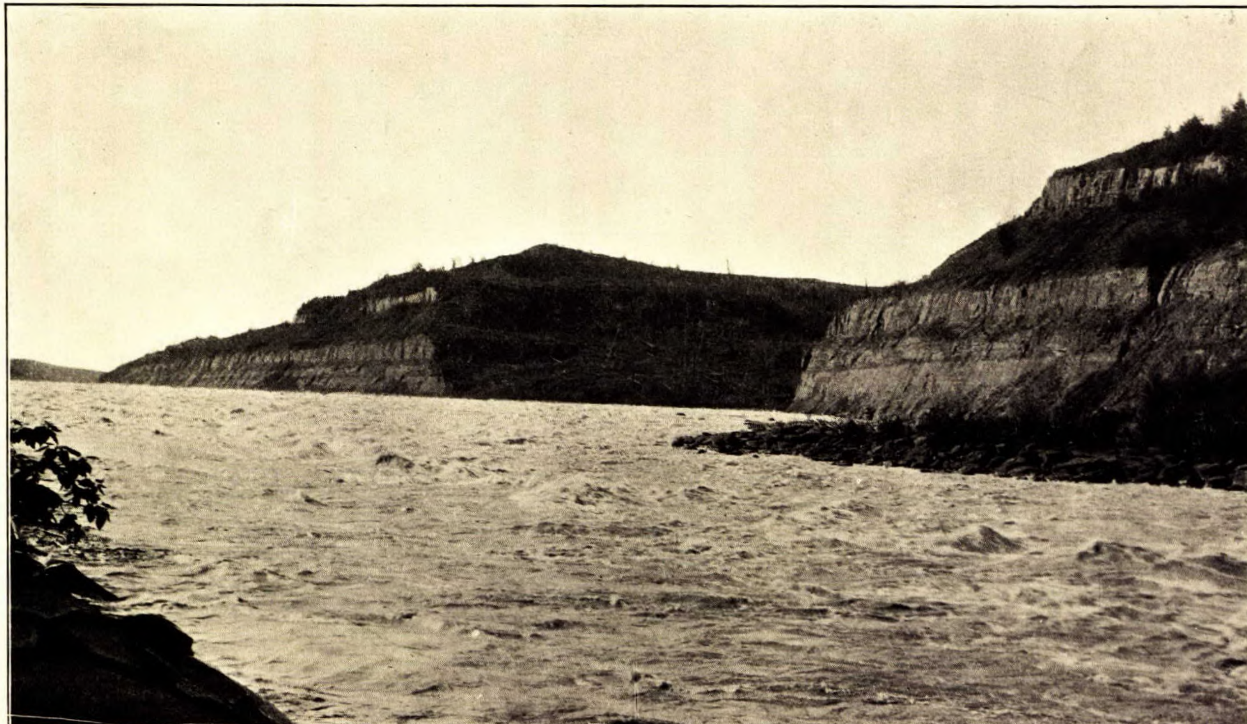
"A light grey, very plastic clay, with good working and drying qualities. It burns to a cream coloured, dense, steel hard body at cone 3, with a total shrinkage of 9 per cent, and softens when heated up to the temperature of cone 27. This is a good example of a stoneware clay, and is also a fire clay. It is the most refractory clay at present known to occur in the Province of Alberta.

"Lab. No. 191. From Moose river, interbedded between bituminous sand and Devonian limestone.

"Dark grey, very plastic, smooth, fine grained clay of the stoneware type. Burns to a salmon coloured dense body at cone 3, with rather high shrinkage, and fuses at cone 18.

Summary.

"These four samples of clay are alike in many of their physical characteristics, and appear to occur in the same geological horizon—viz., underlying the tar sands, on the Athabaska river, and its tributaries. They are very fine grained sediments, and low in fluxing impurities, No. 190 being exceptionally so, hence they are more refractory than any of the Cretaceous clays from the southern part of the Province."

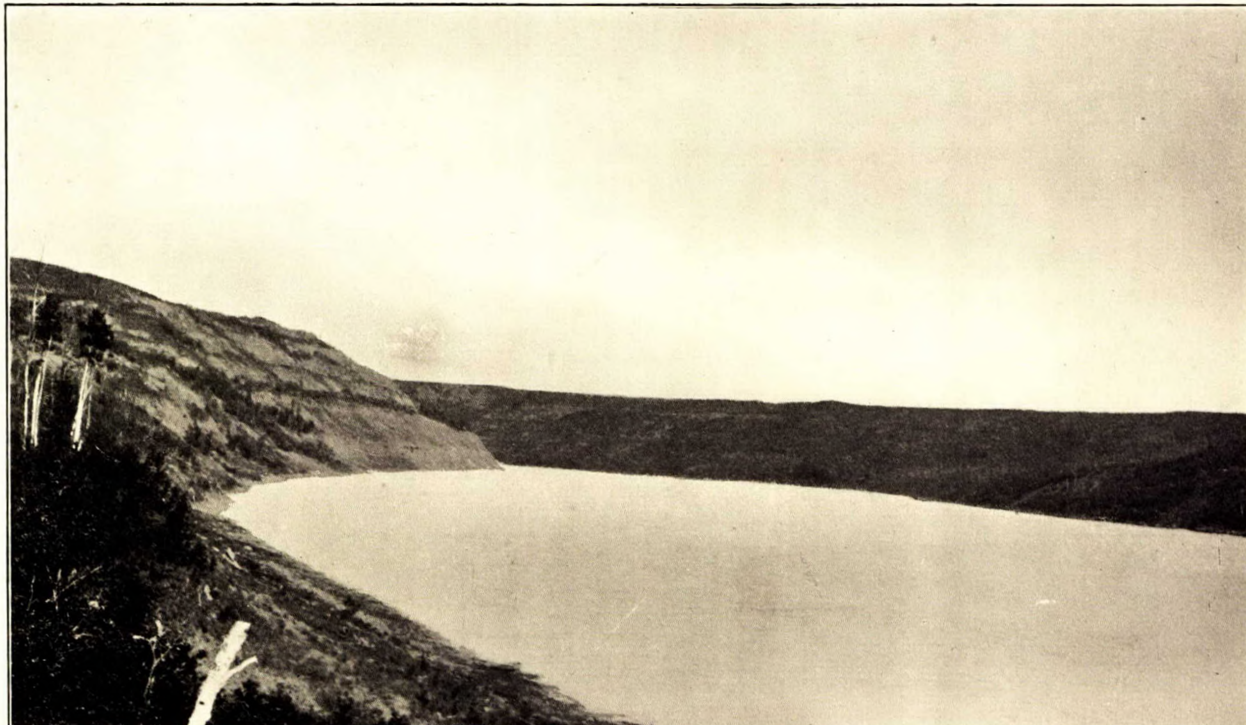


Grand rapids, Athabaska river: showing Grand Rapids sandstone, and effects of differential denudation.

Typical scenery on Christina river, illustrating effects of differential denudation and broken nature of ground common along tributary streams.

Typical exposure Grand Rapids sandstone, at Grand rapids, Athabaska river, showing spherical concretions.

Typical bank on Christina river, 14 miles from mouth, illustrating effects of clay slides. The effect of such slides is intensified where forest growth has been removed by fire.



View illustrating general character of Athabaska valley, near Cascade rapids. Height of banks, over 450 feet, bituminous sand exposed along the foot.

Exposure on west side Athabaska river, just above Crooked rapids, illustrating banded structure typical of much of the lower grade bituminous sand. The actual overburden is very light.

Exposure on east side Athabaska river, just below Mountain rapids. Although the bituminous sand here attains a thickness of over 150 feet, the overburden is very heavy.

Exposure on east side Athabaska river at Crooked rapids, illustrating the angular cleavage and weathering typical of lower grade deposits of bituminous sand-rock.

Exposure on east side Athabaska river, ½ mile below mouth of Pierre au Calumet. This illustrates a bed of bituminous sand under light overburden.

Exposure on west side Athabaska river at foot of Crooked rapids. This illustrates a bed of bituminous sand under heavy overburden. (The bituminous sand nearly reaches the top of the lowest terrace, and is underlaid by well-bedded Devonian limestones).

Exposure on west side Athabaska river, 2 miles north of Calumet river, illustrating general character of the dryer and lower grade banded outcrops of bituminous sand.

Typical example of clay slide. Such slides are common along all streams where overburden above the bituminous sand attains any considerable thickness.

Exposure on west side Athabaska river, 20 miles south of McMurray. Exposed thickness of bituminous sand 90 to 95 feet. Depth of overburden 180 to 415 feet.

Exposure on east side of Athabaska river, 43 miles north of McMurray. In descending the river, the thickness of overburden gradually decreases.

Typically terraced bank on Athabaska river. The bituminous sand lies at the base and is obscured by clay slides. The difficulty of working a deposit so situated is evident. Height of bank 320 feet.

Exposures on east side Horse creek, $2\frac{1}{3}$ miles from mouth. On the right is seen one of the typical residual deposits of bituminous sand found at times under light overburden within loops of the present stream. On the left (where the stream has impinged against the side of the main valley) is seen the full thickness of the bituminous sand under heavy overburden.

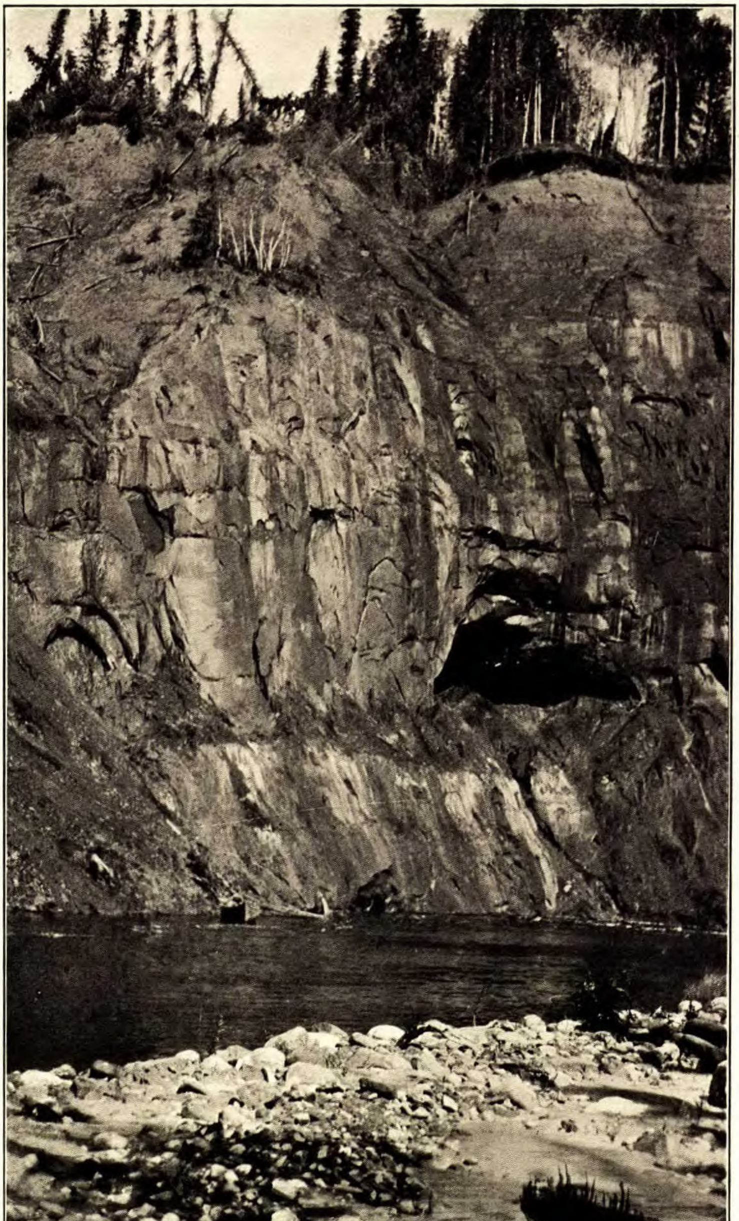
Exposure on north side Steepbank river, 2 miles from mouth, showing low grade and banded bituminous sand, overlying well stratified Devonian limestone.

Typical exposure of bituminous sand in north bank of Horse creek, three-quarters of a mile from the mouth. Approximate thickness bituminous sand 90 feet; thickness of overburden, 400 feet from edge of creek, is 120 feet.

Exposure on east side of Hangingstone creek, 3½ miles from mouth: showing outcrop of bituminous sand under a comparatively light overburden.

Exposure on west side of Hangingstone creek, $1\frac{1}{4}$ miles from the mouth. Total exposed thickness bituminous sand, 125 feet, much of which is, however, low grade material.

Exposure in northeast bank of Christina river, 10 miles above the mouth. The bituminous sand at this point underlies a small area of river bottom land, and consequently has a comparatively light overburden.



Exposure on north side of Steepbank river about 3½ miles from mouth, illustrating typical massive structure and cleavage common to high grade deposits of bituminous sand.

Exposure on east side of Athabaska river, 3 miles below McMurray, illustrating typical banded character of many of the lower grade deposits of bituminous sand.

Exposure on north side of Steepbank river, $3\frac{1}{3}$ miles from mouth, illustrating typical massive structure and cleavage of many of the high grade deposits of bituminous sand.

Exposure in north bank of Muskeg river, 5 miles from mouth, and about 1 mile above head of portage trail. Material at outcrop is of a comparatively low grade, but overburden is light.

Exposure on north side of Moose river, 8 miles from mouth, illustrating banded structure, typical of many of the outcrops of lower grade bituminous sand. Thickness of exposed section, 40 to 140 feet.

Exposure on north side of Moose river, 9 miles from mouth. The upper part of this section is low grade and practically worthless. The lower part contains some bituminous sand of good quality. Total thickness of exposed section, 135 feet.

Typical section in north bank of McKay river, 5 miles from mouth. At the base are well-bedded, highly fossiliferous Devonian limestones, the upper strata being rubbly. Above the limestones are dry and banded bituminous sandstones of no value. Total thickness of section, 170 feet.

Exposure on south side of McKay river, three-quarters of a mile from the mouth. Thickness of bituminous sand, 40 feet. Depth of overburden, 10 feet.

Outcrop of bituminous sand under light overburden on west side of Moose river, 6·7 miles from mouth.
Cretaceous clay interbedded between the bituminous sand and Devonian limestone here exposed.

Outcrop of bituminous sand on west side of Hangingstone creek. The lower one-third of the cut bank is high material but the remainder is low-grade and overburden. This illustrates well the significance of overburden over a large part of the McMurray area.

Outcrops on west side of Moose river, 5·6 miles from mouth, showing bituminous sand under light overburden.

Outcrop on west side of Moose river, 7·5 miles from mouth, illustrating false bedding in the bituminous sand.

PLATE XXXIV.

PLATE XXXV.

Outcrop on Horse creek 1-8 and 2 miles from mouth. The upper view illustrates outcrop with massive high-grade bituminous sands at base, while the lower shows an outcrop of banded and worthless material. These two outcrops of the same bed are but 2,000 feet apart, the change in character or material being probably due to a local syncline which causes high-grade material to disappear below the creek level.

Outcrop on west side of Horse creek, 4 miles from mouth: showing massive bituminous sand under light overburden.

Outcrop on west side of Hangingstone creek, 2·6 miles from mouth: showing low ledge of massive bituminous sand under light overburden.

Outcrop on east side of McKay river, 5·2 miles from mouth; showing bituminous sand under light overburden.

Outcrop on west side of McKay river, 8·6 miles from mouth: showing low-grade banded material over high-grade bituminous sand.

Weathered bank of clay on McKay river, 26·1 miles from mouth.

Outcrop on west side of Horse creek, 1·5 miles from mouth: showing residual deposits of bituminous sand under light overburden.

Outcrop on east side of Horse creek, 1·5 miles from mouth: showing residual deposits under light overburden.

Outcrop on west side of Steepbank river, 5·6 miles from mouth: showing residual deposit under light overburden.

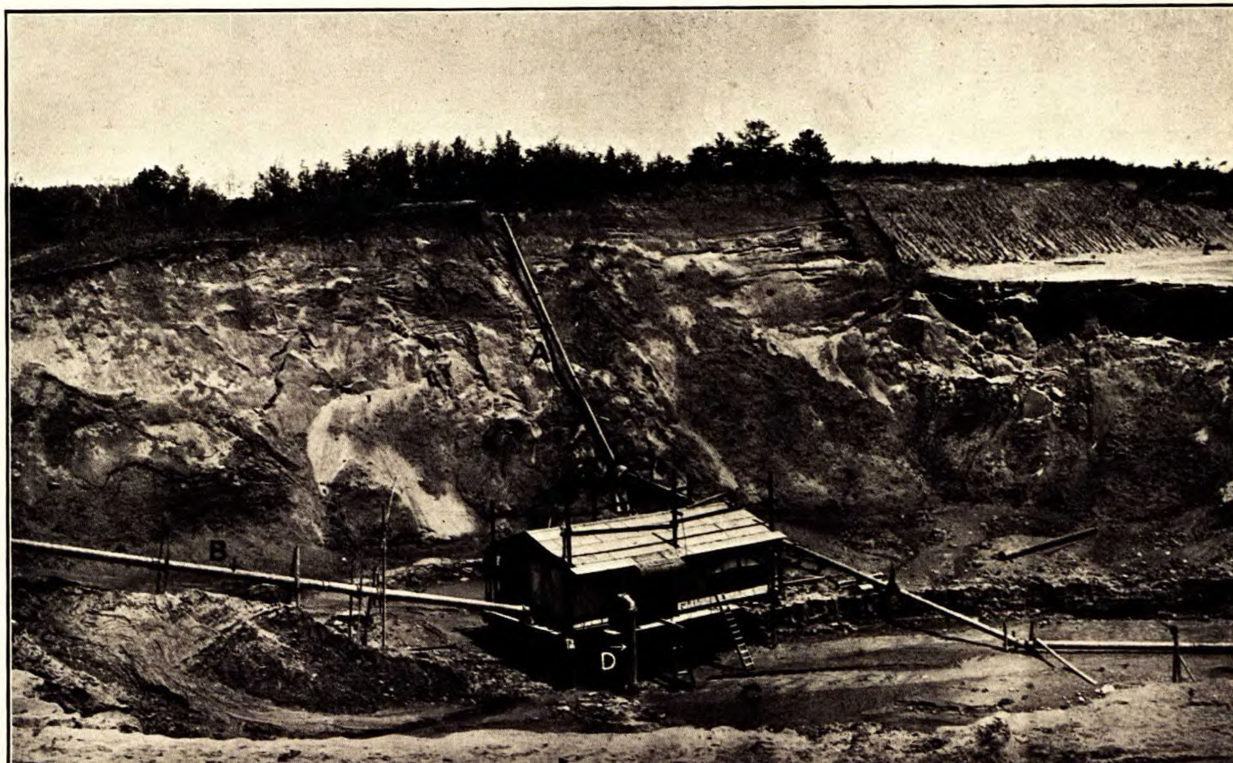
Outcrop on west side of McKay river, 21·2 miles from mouth: showing residual deposit of bituminous sand under light overburden.

Outcrop on east side of Horse creek, 2·9 miles from mouth: showing residual deposit of bituminous sand under light overburden.

Outcrop on west side of Horse creek, 4 miles from mouth: showing residual deposit of massive bituminous sand under light overburden.

Rowe mine, Minnesota. General view illustrating hydraulic removal of overburden and showing water supply pipe, discharge pipe, and hydraulic gun.

Rowe mine, Minnesota. Illustration of general arrangement of plant for removal of overburden by hydraulic stripping. (A) Water supply pipe to hydraulic gun. (B) Sump. (C) Discharge pipe leading from centrifugal pump. (D) Housed platform suspended from columns driven to bed-rock and carrying centrifugal pump and motor.



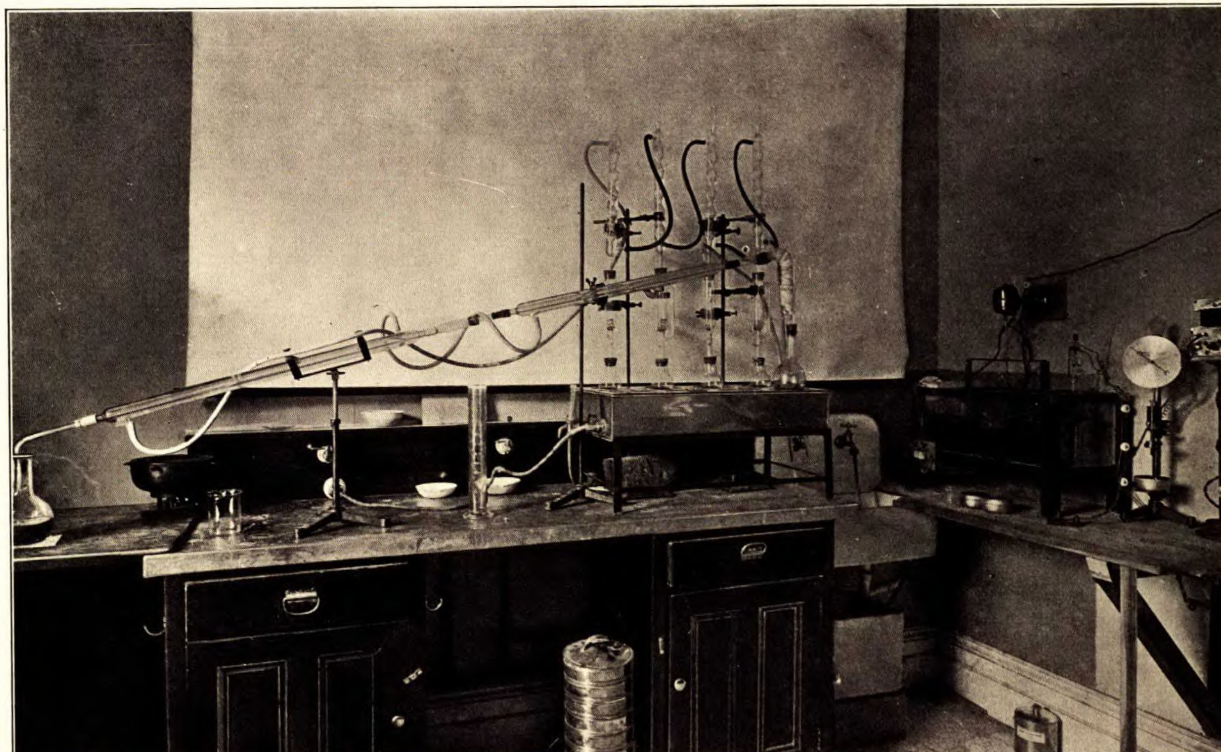
Hydraulic stripping at Rowe mine, Minnesota. (A) Water supply pipe to hydraulic gun. (B) Discharge pipe from centrifugal pump. (C) Sump. (D) Suction pipe connected with centrifugal pump.

Typical quarry of bituminous sand-rock, operated by Wadsworth Stone & Paving Co., at Asphalt, Ky., U.S.A. Average thickness of bituminous rock 12 to 14 feet. Overburden consists of earth, loose rock and sandstone of average thickess of 10 feet.

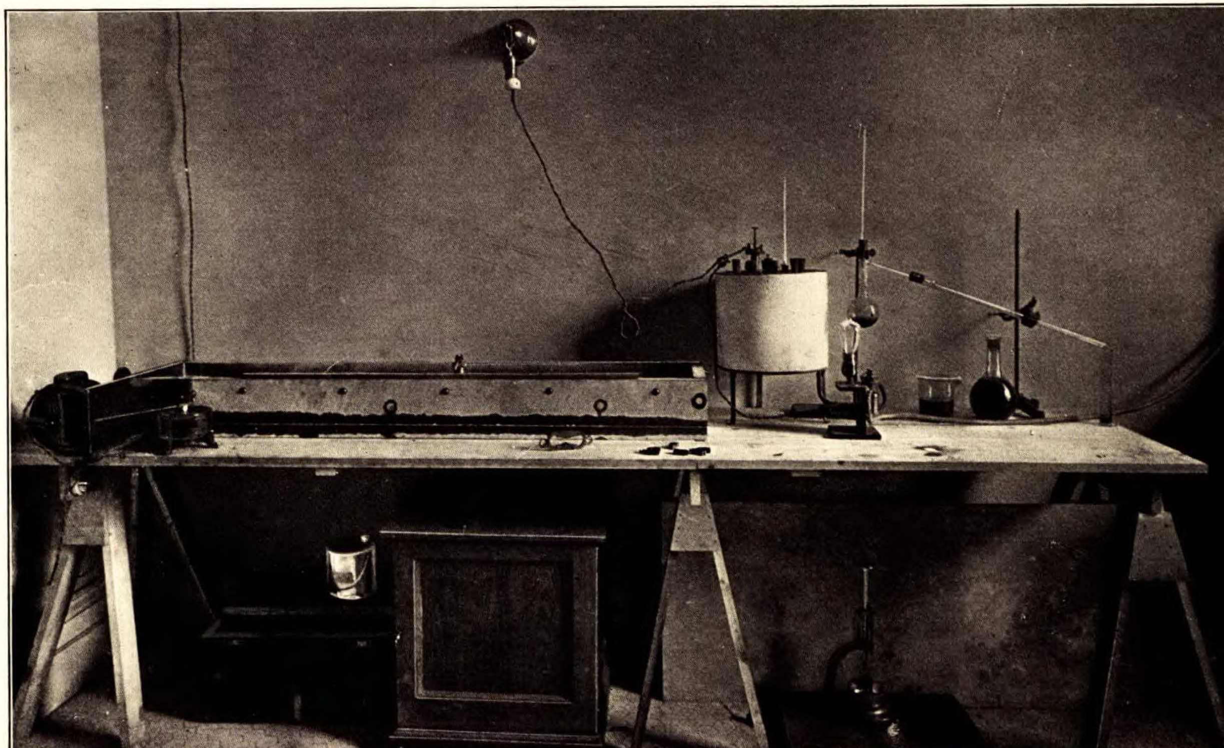
Typical quarry of bituminous sand-rock operated by City Street Improvement Co., near Santa Cruz, Cal., U.S.A. Average thickness of bituminous rock about 60 feet. Overburden consists of hard, Monterey shales, 40-60 feet in thickness.

Quarry of soft bituminous sand near Carpinteria, Cal., U.S.A. The bituminous sand is 10 to 15 feet in thickness, overlaid by 8 to 10 feet of earth. The bituminous sand is excavated in a series of steps, heated spades being used in this work.

General view of quarry of bituminous sand-rock, operated by the City Street Improvement Co., near Santa Cruz, Cal. Average thickness bituminous sand-rock 60 feet. Overburden, hard shales 40-60 feet in thickness. Shipments from this quarry for year ending April 31, 1913, were 32,853 tons.



Extraction apparatus; condenser for recovery of solvent; and electrically controlled penetrometer and time control.



Electrically controlled ductility machine; New York Laboratory type of oven; and flask and condenser for distillation.

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DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER: R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS.

1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.D., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A. and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores, and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

†4. Rapport de la Commission nommée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba: manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E. 1905. (See No. 118.)

†11. Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

† Publications marked thus † are out of print.

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate —by W. R. Ingalls, M.E., 1905.

†16. *Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

†18. Graphite: its properties, occurrence, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposits of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

21. Summary report of Mines Branch, 1907–8.

22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side) and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907–8.

25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

26a. French translation: The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a. The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

†28a. French translation: Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on —by Fritz Cirkel. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908. Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep, Peat Expert.

* A few copies of the Preliminary Report, 1906, are still available.
† Publications marked thus † are out of print.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

56. French translation: Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907–8.*

†31. Production of cement in Canada, 1908.
42. Production or iron and steel in Canada during the calendar years 1907 and 1908.
43. Production of chromite in Canada during the calendar years 1907 and 1908.
44. Production of asbestos in Canada during the calendar years 1907 and 1908.
†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.
46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories of the Department of Mines, 1906–7–8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analysis of oil-shales—by H. A. Leverin, Ch.E.).

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron ore deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

† Publications marked thus † are out of print.

†71. Investigation of the peat bogs, and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled 'A solution of the peat problem,' 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second edition, enlarged).

81. French translation: Chrysotile-asbestos, its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E.

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma. E., and others.
 Vol. I—Coal washing and coking tests.
 Vol. II—Boiler and gas producer tests.
 Vol. III—
  Appendix I
   Coal washing tests and diagrams.
 Vol. IV—
  Appendix II
   Boiler tests and diagrams.
 Vol. V—
  Appendix III
   Producer tests and diagrams.
 Vol. VI—
  Appendix IV
   Coking tests.
  Appendix V
   Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A

Note.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

†79. Production of iron and steel in Canada during the calendar year 1909.
†80. Production of coal and coke in Canada during the calendar year 1909.
85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

† **Publications marked thus † are out of print.**

90. Proceedings of conference on explosives.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Second edition.)

93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

100a. French translation: The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911; containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Fréchette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph. D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1910.*

- †114. Production of cement, lime, clay products, stone, and other structural materials in Canada, 1910.
- †115. Production of iron and steel in Canada during the calendar year 1910
- †116. Production of coal and coke in Canada during the calendar year 1910.
- †117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

† Publications marked thus † are out of print.

149. French translation: Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

154. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

155. French translation: The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

156. French translation: The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

169. French translation: Pyrites in Canada: its occurrence, exploitation, dressing, and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

180. French translation: Investigation of the peat bogs, and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

195. French translation: Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

196. French translation: Investigation of the peat bogs and peat industry of Canada, 1909–10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second Edition, enlarged.)

197. French translation: Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

198. French translation: Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

201. The mineral production of Canada during the calendar year 1911. Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

202. French translation: Graphite: its properties, occurrence, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

219. French translation: Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

226. French translation: Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224.)

230. Economic minerals and mining industries of Canada.

231. French translation: Economic minerals and mining industries of Canada.

† Publications marked thus † are out of print.

233. French translation: Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.
259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.
†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.
†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.
257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.
†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

264. French translation: Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. French translation: Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

290. French translation: Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

316. The production of coal and coke during the calendar year 1913. Bulletin on by John McLeish, B.A.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products, and Manufacturers of lime; copies of the lists may be obtained on application.

† Publications marked thus † are out of print.

IN THE PRESS

179. French translation: The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

204. French translation: Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

263. French translation: Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. v. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

285. Summary report of the Mines Branch, 1913.

287. French translation: Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. French translation: Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. French translation: Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

308. French translation: An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—

Vol. I—Coal washing and coking tests.
Vol. II—Boiler and gas producer tests.
Vol. III—
Appendix I
Coal washing tests and diagrams.
Vol. IV—
Appendix II
Boiler tests and diagrams.

309. The physical properties of the metal cobalt, Part II. Report on —by H. T. Kalmus, B.Sc., Ph.D.

314. French translation: Iron ore deposits, Bristol mine, Pontiac county, Quebec. Report on—by E. Lindeman, M.E.

315. The production of iron and steel during the calendar year 1913. Bulletin on—by John McLeish, B.A.

317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. By John McLeish, B.A.

319. General summary of the mineral production of Canada during the calendar year 1913. By John McLeish, B.A.

320. Annual report of the mineral production of Canada during the calendar year 1913. By John McLeish, B.A.

322. Economic minerals and mining industries of Canada. (Revised Edition).

MAPS.

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet = 1 inch. Summary report, 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet = 1 inch. Summary report, 1905. (See Map No. 186.)

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet = 1 inch. Summary report, 1905.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet = 1 inch.

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet = 1 inch.

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12, concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet = 1 inch.

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30).

*37. Survey of Alfred peat bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet = 1 inch. (Accompanying report No. 47.)

Note.—1. Maps marked thus* are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

*49. Magnetometric survey of Western Steel Iron claim, at Sechart, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet=1 inch. (Accompanying report No. 47.)

*53. Iron ore occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron ore occurrences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) (Out of print).

†57. The productive chrome iron ore district of Quebec—by Fritz Cirkel. (Accompanying report No. 29.)

†60. Magnetometric survey of the Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet=1 inch. (Accompanying report No. 67.)

†61. Topographical map of Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet=1 inch. (Accompanying report No. 67.)

†64. Index map of Nova Scotia Gypsum—by W. F. Jennison. (Accompanying report No. 84.)

†65. Index map of New Brunswick: Gypsum—by W. F. Jennison. (Accompanying report No. 84.)

†66. Map of Magdalen islands: Gypsum—by W. F. Jennison. (Accompanying report No. 84.)

†70. Magnetometric survey of Northeast Arm iron range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet = 1 inch. (Accompanying report No. 63.)

†72. Brunner peat bog, Ontario—by A. v. Anrep.

†73. Komoka peat bog, Ontario—by A. v. Anrep.

†74. Brockville peat bog, Ontario—by A. v. Anrep.

†75. Rondeau peat bog, Ontario—by A. v. Anrep.

†76. Alfred peat bog, Ontario—by A. v. Anrep

†77. Alfred peat bog, Ontario: main ditch profile—by A. v. Anrep.

(†72–†77: Out of print.)

†78. Map of asbestos region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile = 1 inch. (Accompanying report No. 69.)

†94. Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General map of Canada, showing coal fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†96. General map of coal fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—by Dr. J. B. Porter.)

†97. General map showing coal fields in Alberta, Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter.)

†98. General map of coal fields in British Columbia. (Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological map of Austin Brook iron bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet = 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Brook iron bearing district—by E. Lindeman. Scale 400 feet = 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet = 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog, Ontario—by A. v. Anrep. (Accompanying report No. 151.)

*119-137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles = 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles = 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles = 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron bearing district, Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet = 1 inch. (Accompanying report No. 110.)

†146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles = 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains = 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet = 1 inch. (Accompanying report No. 145.)

†152. Map showing the location of peat bogs investigated in Ontario—by A. v. Anrep.

†153. Map showing the location of peat bogs investigated in Manitoba—by A. v. Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. v. Anrep.

†158. Transmission peat bog, Manitoba—by A. v. Anrep.

†159. Corduroy peat bog, Manitoba—by A. v. Anrep.

†160. Boggy Creek peat bog, Manitoba—by A. v. Anrep.

†161. Rice Lake peat bog, Manitoba—by A. v. Anrep.

†162. Mud Lake peat bog, Manitoba—by A. v. Anrep.

†163. Litter peat bog, Manitoba—by A. v. Anrep.

(Accompanying report No. 151.)

†164. Julius peat litter bog, Manitoba—by A. v. Anrep.

†165. Fort Francis peat bog, Ontario—by A. v. Anrep.

(Accompanying report No. 151.)

†166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles = 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mile = 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†173. " Crean Hill mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†174. " Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus* are to be found only in reports.
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†176. Geological map of Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont townshio, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity; Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184).

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†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey, vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet = 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway —by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1912. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E. Lindeman, 1912. Scale 200 feet = 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet = 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet = 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
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†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet=1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet=1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet=1 inch. (Accompanying report No. 303.)

†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles=1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles = 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

†221. Dawson mining district, Yukon. Scale 2 miles = 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles=1 inch. (Accompanying report No. 230.)

†239. Index map of Canada, showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs. Scale 100 miles = 1 inch. (Accompanying report No. 245.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles=1 inch. (Accompanying report No. 245.)

†242. Map, Grand River deposits, Ontario. Scale 4 miles=1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles=1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet=1 inch. (Accompanying report No. 254.)

Note.—1. Maps marked thus* are to be found only in reports.
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†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet=1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet =1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet=1 inch. (Accompanying report No. 254.)

†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet =1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom, 1903. Scale 200 feet=1 inch.

†268. Map of peat bogs investigated in Quebec—by A. v. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

†270. Small Tea Field peat bog, Quebec " "

†271. Lanoraie peat bog, Quebec " "

†272. St. Hyacinthe peat bog, Quebec " "

†273. Rivière du Loup peat bog " "

†274. Cacouna peat bog " "

†275. Le Parc peat bog, Quebec " "

†276. St. Denis peat bog, Quebec " "

†277. Rivière Ouelle peat bog, Quebec " "

†278. Moose Mountain peat bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles=1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles=1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties, New Brunswick. Scale 1 mile=1 inch. (Accompanying report No. 291.)

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†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles = 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles =1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan and Manitoba. Scale 35 miles=1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles=1 inch. (Accompanying report No. 291.)

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles=1 inch. (Accompanying report No. 291.)

†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia. Scale 200 feet=1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia. Scale 200 feet=1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia. Scale 200 feet=1 inch.

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Address all communications to—

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