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DEPARTMENT OF MINES AND RESOURCES

MINES, FORESTS AND SCIENTIFIC SERVICES BRANCH
BUREAU OF MINES

DRILLING AND SAMPLING
OF
BITUMINOUS SANDS OF NORTHERN ALBERTA

VOL. I

Results of Investigations
1942-1947

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PREFACE

The investigations covered in this report were undertaken by the Dominion Government primarily as a safeguard against the possible development in Canada during the war of a critical shortage of oil that would have greatly hampered the country's war effort. Previous work on the deposits by the Government, dating back to 1913, was mainly of a reconnaissance nature and the investigations reported herein marked the first systematic and concerted attempt by the Government to appraise the possibilities of the deposits.

Although the investigations did not lead to the production of petroleum products on a commercial scale, they have provided a much sounder basis than hitherto existed for an appraisal of the tonnages and grade of mineable material available and of the geological, engineering, and processing problems that are likely to be encountered when the time becomes opportune for the active and full-scale development of the deposits. The information contained in the report will doubtless prove to be a most valuable guide in such development.

The report is being published in three volumes: Volume I, results of investigations, 1942–47; Volume II contains detailed drilling and sampling records; and Volume III, cross-sections and plans of the areas drilled.

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OTTAWA, DECEMBER 2, 1948.

Drilling and Sampling of Bituminous Sands of Northern Alberta

INTRODUCTION

Early in 1942, with oil production from the Turner Valley area of Alberta showing signs of commencing to decline and Canada becoming increasingly dependent for petroleum upon foreign supplies, the Canadian Government decided that consideration should be given to the bituminous sands of Alberta as a possible source for the large quantities of aviation and motor gasoline and of fuel oil that were urgently required. A committee which investigated for the Department of Munitions and Supply reported its belief that the production of crude oil from the sands would be a practical project as a war measure, and, further, that the project would have more than a reasonable chance as a post-war commercial enterprise. The committee recommended the immediate planning of a 10,000-barrel per day mining and extraction plant to operate in the bituminous sand area, but found that, although large reserves of sands suitable for commercial operations apparently existed, no detailed work had been done to prove definitely that any one deposit fulfilled the conditions necessary for a large operation. It was regarded as necessary to drill and sample the more promising deposits thoroughly, to determine the location for a plant.

At the date of the investigation mentioned, the knowledge of the Alberta deposits of bituminous sands rested mainly upon the work of early drillers for oil, and of such organizations and companies as the Federal Mines Branch, Scientific and Industrial Research Council of Alberta, Abasand Oils, Limited, International Bitumen Company, and Consolidated Mining and Smelting Company of Canada, Limited. During the period 1897 to 1925 some forty holes exploring for oil had been put down in the Fort McMurray area, mostly to rather deep rock horizons, and of these approximately twenty encountered bituminous sand strata, according to available records.[1]

Although the records for a number of these holes give a fairly clear picture of the thickness of bituminous sands passed through, the drilling operations apparently did not include any sampling and assaying to establish the bitumen content of the sands. The field investigations of the Federal Mines Branch, conducted by S. C. Ells in various years between 1913 and 1931, contributed the locations of all major outcroppings of bituminous sands in the banks of Athabaska River and tributary streams over an area of 1,260 square miles topographically mapped.[2]

Furthermore, at many outcroppings Ells took samples that were assayed for bitumen content, but the average depth from which the hand-augered samples were taken did not exceed 4 feet.[3] Finally, the sampling by Ells included shallow pits, trenches, and shafts, and the first attempts by drilling to sample through entire thicknesses of bituminous sand strata. Of eight attempted deep holes in the years 1925 to 1928, one reached a depth of 237 feet and four exceeded depths of 100 feet.[4] The putting down of these holes was assisted by machine drills, but actual sampling was done by the hand-turning of augers. The 1928 work also included twelve hand-auger holes to depths as great as

[1]Ells collected logs and other data on these holes. *See* Mines Branch Report No. 632, "Bituminous Sands of Northern Alberta," pp. 21—29.

[2]Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 59, and maps accompanying report.

[3]Mines Branch, Dept. of Mines, Canada, Rept. No. 632, pp. 49—53.

[4]Mines Branch, Dept. of Mines, Canada, Repts. Nos. 694, 710, and Separate 710-1.

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30 feet.[1] The Scientific and Industrial Research Council of Alberta in 1924 assayed some two hundred and fifty samples of bituminous sands obtained from sinking a shaft to a depth of 45 feet in Horse River Reserve, near Fort McMurray, and from thirty-five widely separated outcroppings along Athabaska River and tributaries, at which trenches a few inches to a few feet in depth were excavated from top to bottom of exposures to obtain unweathered samples of sands.[2] In 1941, Abasand Oils, Limited, by means of hand drill-holes and some pits and trenches, sampled bituminous sand deposits in eight localities situated from 22 to 61 miles north of Fort McMurray. The Consolidated Mining and Smelting Company of Canada, Limited and the International Bitumen Company also carried out limited exploratory and sampling work. All of the sampling mentioned, together with sampling resulting from such quarrying operations as conducted by the Federal Mines Branch, McMurray Asphaltum and Oil Company, International Bitumen Company, and Abasand Oils, Limited, gave only "spot" information on the quality of the sands at locations here and there in the bituminous sands area, and the assays were mostly from material taken at exposures or from shallow depths. None of the work constituted the area-sampling to the bottom of deposits that would be necessary to establish reserves of good grade bituminous sand for a large enterprise. Both Ells and Dr. K. A. Clark of the Scientific and Industrial Research Council of Alberta pointed out the indications of great variability, both vertically and laterally, in the bituminous sands formation, the latter finding "no system to the succession of rich and lean bituminous sand beds" and that the formation "is composed of a haphazard assortment of lenses of variable material".[3]

Both investigators emphasized the need for careful prospecting of deposits as a necessary prelude to establishment of commercial enterprises. Evidently, a method of rapid machine drilling, capable of providing accurate core samples to the bottom of deposits and which would give information on overburden conditions, was needed to enable development of Alberta's bituminous sands. The investigating committee for the Department of Munitions and Supply recommended the commissioning of an organization properly equipped to thoroughly drill and sample promising deposits.

With the urgency for finding petroleum supplies for Canada's war effort as incentive, the Minister of Munitions and Supply, early in June 1942, commissioned The Consolidated Mining and Smelting Company of Canada, Limited to undertake certain investigations in regard to Alberta bituminous sands, including test drilling, to find a suitable deposit for a large oil plant having a capacity of around 10,000 barrels daily. Administration of the project was assigned to the Department of Mines and Resources. In the period July 29, 1942 to January 26, 1943, in addition to putting down various test pits and shallow augered holes, the company drilled twenty-one holes into or through the bituminous sands in the Wheeler Island and Steepbank River areas, contiguous to Athabaska River, north of Fort McMurray. These holes averaged 144 feet in depth and the season's work was notable for the types of power-drilling equipment given trials in efforts to evolve a machine-drilling method for rapidly and efficiently taking samples of bituminous sands from deep strata. All the efforts to accomplish power-drill sampling were unsatisfactory, and in the end the method employed to draw samples was the slow and tedious hand-augering one previously used by Ells; the cable and rotary drill rigs serving only for drilling through overburden, for handling rods, for reaming, and for setting of casing. It was found necessary to case the holes not only through overburden but through the bituminous sands, in order to shut off the numerous waterflows and enable

[1]Mines Branch, Dept. of Mines, Canada, Rept. No. 710, pp. 28—46; and Separate No. 710-1.

[2]Scientific and Industrial Research Council of Alberta: Fifth Annual report (1924); and Rept. No. 18, pt. 1, "The Bituminous Sands of Alberta", by K. A. Clark and S. M. Blair.

[3]Scientific and Industrial Research Council of Alberta; Rept. No. 18, pt. 1, p. 72.

samples to be withdrawn without the material for assay being washed from the augers. Drilling was expensive and the difficulties so great that not only were no samples obtained from lengthy bituminous sand sections of some holes but several holes were abandoned in the middle of bituminous sand strata because of broken augers. Nevertheless, some development pointing to possible improvement in drilling method took place towards the end of the drilling. Where waterflows were moderate it was found that if mud was introduced into the bottom of the hole the augered sample when withdrawn through it became encased in mud, which made an effective seal against waterwashing, so that upon scraping away the mud a dry, unaltered sample of the bituminous sands was disclosed. It was considered that investigation should be made of core drilling using a non-rotating core barrel and a mud-laden fluid to remove cuttings. Taking of core samples by such a method, if found practicable, was seen as likely to permit rapid drilling, and it was thought that the casing of holes might be eliminated owing to the expected action of the mud fluid in preventing caving.

The widely spaced holes put down by The Consolidated Mining and Smelting Company of Canada could be regarded as only exploratory or reconnaissance drilling. Based upon indications given by the drilling that a large tonnage of sands averaging about 12 per cent bitumen content lying under overburden of moderate depth could be outlined in the Steepbank River area, the company recommended that close-spaced drilling should be done in this area. It was also stressed that if a suitable deposit of sands averaging 15 per cent bitumen content could be found there would be a great reduction in the amount of sands to be mined and treated for a 10,000-barrel per day oil operation, and recommendation was made, therefore, that reconnaissance drilling should be continued.

In the spring of 1943 the work of drilling for a deposit of bituminous sands capable of supporting a large oil-producing industry was taken up as a direct activity of the Mines and Geology Branch. This drilling, which comprised both close-spaced and reconnaissance drilling, was continued with only brief interruptions until January 1947, and during the period two hundred and ninety-one holes were put down representing total drilled footage of 53,918 feet. As was anticipated, the recommended drilling in the Steepbank River area outlined there a large tonnage of bituminous sands of the expected grade; but this report will show, furthermore, that in the Mildred-Ruth Lakes area, where the final drilling took place, a larger tonnage was disclosed of sands of the hoped-for superior grade, and these sands have the added merit for mining that a lower ratio of overburden would have to be handled than in the Steepbank River area. The close-spaced drilling also included the outlining of certain smaller deposits of good grade bituminous sands in the Horse River Reserve near Fort McMurray.

The carrying out by the Mines and Geology Branch of such a large amount of drilling in less than 4 years with only two drills, and at times only one in operation, was made possible through early development of successful power core-drilling, using diamond drills and gel-mud drilling fluid. Although the holes went to a maximum depth of over 300 feet, and averaged 185 feet, casing was unnecessary except through the overburden. The drilling established new standards for reliability in the sampling of bituminous sands. Through the use of stationary core barrels and drilling mud, recoveries up to 100 per cent were made of dry, compact core that could be split for assay samples. The technique seldom lost more than a foot or two of core at any one place in a hole, and total core recoveries were usually from 93 to 98 per cent and only very occasionally under 90 per cent. The drilling was performed under contract by Boyles Brothers Drilling Company, Limited, of Vancouver, at very reasonable costs compared with the previous expense of hand-augered holes. After putting down a few initial holes by the previous hand-augering method, this firm quickly developed the technique for diamond drilling the bituminous sands and thus

opened a new vista with regard not only to accurate sampling and assays of the bitumen content of the sands but in regard to the logging of the holes to provide geological and other information on the strata penetrated.

The drilling was performed under constant supervision by field officers of the Mines and Geology Branch, who located the holes, made surveys for establishing collar elevations and for determining the position of the holes relative to land survey corners, and carried out such topographical mapping as was necessary for drawing cross-sections and determining overburden quantities. These engineers also logged the holes and split the cores, shipping half-cores to Ottawa, where the assays for bitumen content and the screen analyses of mineral content were carried out in the Division of Fuels, Bureau of Mines.

CHRONOLOGICAL STATEMENT OF DRILLING OPERATIONS 1942 to 1947

July 29, 1942.	Drilling commenced by Consolidated Mining and Smelting Company of Canada, Limited, in Wheeler Island area.
August 21, 1942.	Drilling commenced by Consolidated Mining and Smelting Company, in Steepbank River area.
December 27, 1942.	Drilling in Wheeler Island area discontinued by Consolidated Mining and Smelting Company.
January 26, 1943	Drilling in Steepbank River area discontinued by Consolidated Mining and Smelting Company.
June 26, 1943.	Contract drilling by Boyles Brothers Drilling Company, Ltd., for Mines and Geology Branch, started in Steepbank River area.
November 29, 1943.	Drilling in Steepbank River area discontinued.
January 13, 1944.	Boyles Brothers commenced drilling for Mines and Geology Branch on Horse River Reserve, near Fort McMurray.
July 28, 1944.	Drilling program on Horse River Reserve completed.
August 22, 1944.	Boyles Brothers resumed drilling in Steepbank River area.
December 8, 1945.	Drilling program completed in Steepbank River area.
August 10, 1945.	Drilling commenced by Boyles Brothers for Mines and Geology Branch, in Muskeg River area.
July 24, 1946.	Drilling program completed in Muskeg River area.
March 15, 1946.	Boyles Brothers commenced drilling for Mines and Geology Branch, in Mildred-Ruth Lakes area.
January 24, 1947.	Drilling program in Mildred-Ruth Lakes area completed.

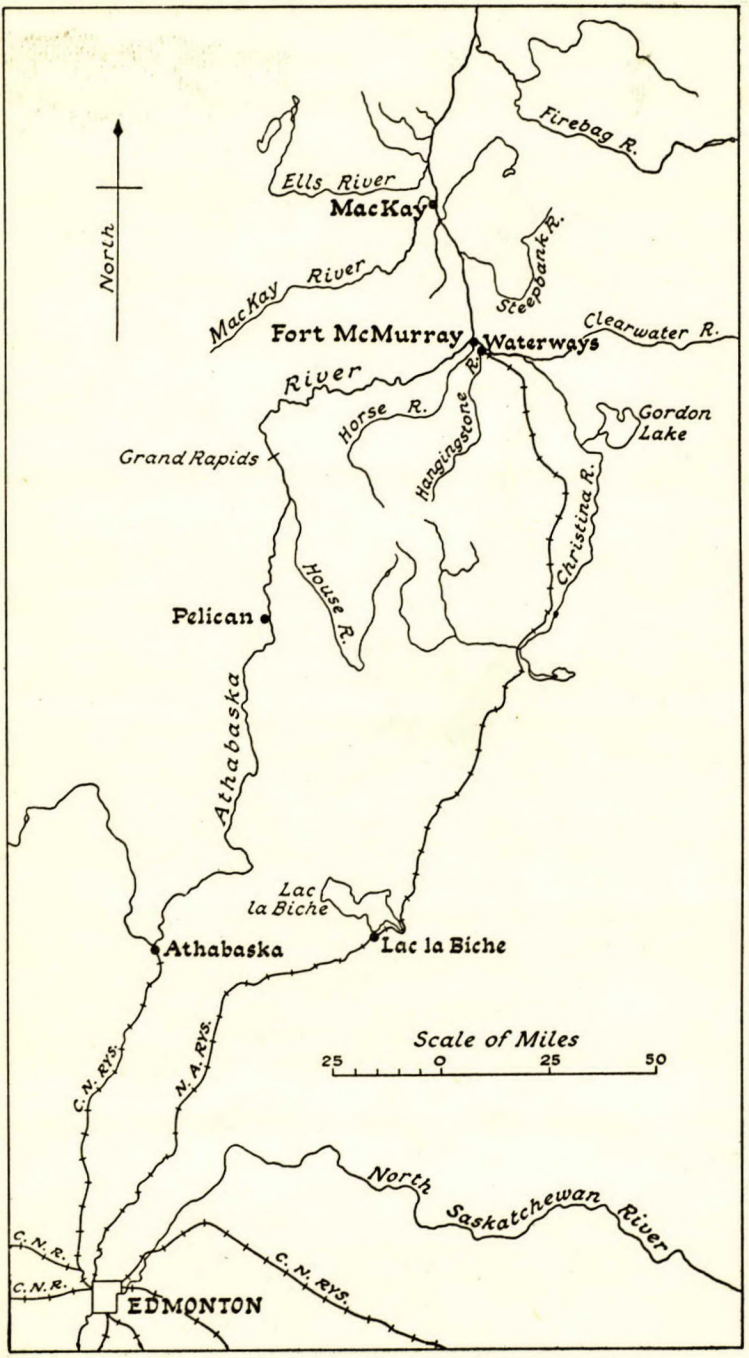


Figure 1. Key map showing the location of Fort McMurray in relation to Edmonton.

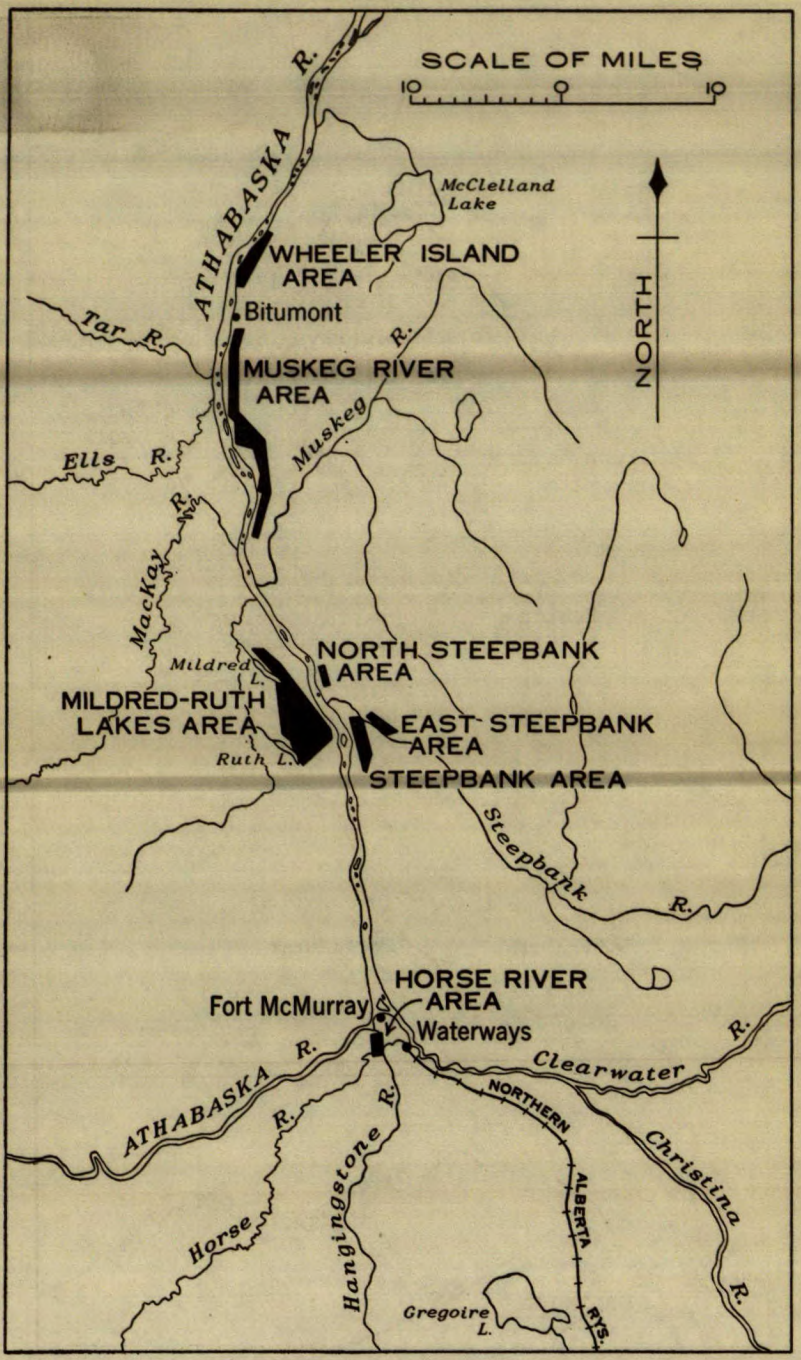


Figure 2. Key map showing in black the areas explored by drilling.

GEOLOGY OF THE BITUMINOUS SANDS AREA

(G. S. Hume)

LOCATION AND TOPOGRAPHY

The bituminous sands of northern Alberta occur in the general vicinity of Fort McMurray at the junction of the Athabaska and Clearwater Rivers, 300 miles north of Edmonton. This part of northern Alberta consists of a plateau area on which are extensive areas of muskeg and forests of poplar, spruce, and jack pine. Numerous poorly drained lakes occur on the upland areas, but the larger rivers and streams have cut steep-sided valleys up to 300 feet deep, and all tributary streams are deeply incised for some distance back from their outlets. At Fort McMurray the valley of Athabaska River is about a mile wide, and at a short distance above its mouth the Clearwater Valley narrows to about half a mile. The banks of both rivers are high, and numerous exposures of bedrock occur along their courses.

At Fort McMurray the Athabaska occupies about one-half of the mile-wide valley bottom and this continues for many miles northward, with the valley sides gradually decreasing in elevation toward river-level at the delta at Athabaska Lake. The river follows a winding course in the valley bottom, at one place impinging against one bank and forming river-cut cliffs and then becoming diverted to the other bank where cliffs of a similar type are formed. Thus the cliffs on the two sides of the river alternate with one another, and between the cliffs on each side of the river, and also alternating with one another, are long stretches of low-forested lands with heavy underbrush up to half a mile wide between the river and the valley wall. In the Fort McMurray area the river has cut to the Palæozoic limestones and for some miles north these are exposed 20 to 30 feet above the river-level. The surface of the limestones, however, broadly undulates, and, farther north, areas of limestone exposures alternate with others where obviously the limestone is below river-level. Where the river impinges sharply against the banks the limestones may be overlain by cliffs of bituminous sands up to 150 feet or more high, but elsewhere the flat areas in the valley bottoms are either at or close to the limestone level without any or only a relatively thin cover of bituminous sands. These are the areas that may be important as disposal sites in bituminous sand operations. In these low areas, in places, are former river meanders, some of them with ox-bow lakes or occupied by swampy land.

To the west and south of Fort McMurray, Athabaska River Valley is much narrower than to the north, and a short distance above the mouth of Horse River, a tributary that enters Athabaska River from the south, a limestone barrier in the river forms a rapid. The limestones, however, disappear below the river-level a short distance above Fort McMurray and higher formations in succession are exposed southwestward.

STRATIGRAPHY

The bituminous sands of the McMurray formation that outcrop for 118 miles along Athabaska River, from 42 miles above Fort McMurray to 76 miles below it, and on tributary streams within this area, are part of a succession of

Lower Cretaceous sediments resting on the Waterways formation of Upper Devonian limestones. The complete succession is as follows:—

Age	Formation	Thickness	Sedimentation
		Feet	
Lower Cretaceous.....	Pelican Shale	90	Dark marine shales.
	Grand Rapids	280	Upper part continental sandstone with thin coal seams and lower part concretionary marine sandstone.
	Clearwater	275	Grey and black marine shales with green sandstones.
	McMurray	225	Massive and crossbedded sandstones in places conglomeratic, interstratified with soft clay shales. Sands partly impregnated with bitumen. (Bituminous sands).
Upper Devonian.....	Waterways	490	Limestones and shaly limestones and greenish limy shales, 490 feet thick, resting on a succession of salt beds up to and exceeding 200 feet in thickness, of which the age is not positively known and which may be either Devonian or Silurian.

THE McMURRAY FORMATION

The McMurray formation was named by McLearn.[1] It consists of fine sands interstratified with clay and shale bands. It includes also thin bands of lignitic and carbonaceous materials and, in some places, beds near the base of the formation may be conglomeratic. Ells[2] reports that on Firebag River in section 5, township 98, range 7 "smooth rounded pebbles having a maximum diameter of 6 inches but with an average diameter of 2 inches are associated with bituminous sand strata". In places "the pebbles almost entirely replace the bituminous sand, forming a conglomerate cemented together with bitumen". Thus, this is a basal conglomerate, but it is only locally present. In other places clay occurs at the base of the McMurray formation, and clays may be interstratified with the bituminous sands in the McMurray formation.

The surface of the Devonian limestones was subjected to erosion prior to the deposition of Lower Cretaceous sediments and, in places, it consists of a finely brecciated limestone with grey and pink limestone fragments in a deeper red, calcareous clay matrix. In other places this may be replaced by grey limy clays grading downward into limestone beds. The bituminous sands in some localities rest directly on these Devonian clays or on the limestones themselves, but in other places there is present a few feet of non-calcareous and semi-refractory clay usually with some gritty material. These may rest directly on and in sharp contact with the limestones. For this reason and also due to the fact that at slightly higher stratigraphic levels similar clays are interstratified with the bituminous sands, these non-calcareous clays are considered to belong to the McMurray formation and are thus not the same age as the calcareous clays that resulted from weathering and that in places lie on the brecciated re-cemented surface of the Waterways formation. An example of a basal McMurray clay

[1]McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1916, pt. B, p. 147.

[2]Ells, S. C.: Bituminous Sands of Northern Alberta, Mines Branch, Dept. of Mines, Canada, Rept. No. 632 (1926), p.17.

deposit may be cited from section 17, township 91, range 9, about 2 miles north of Stony Island on the east side of Athabaska River. Here, 10 feet of clay occurs above and in sharp contact with the Devonian limestones. Above the clay there are 1 or 2 feet of grit with pebbles mostly the size of peas but up to three-quarters of an inch in diameter. This pebble zone is overlain by bituminous sands. In another area on section 18, township 95, range 11, on the west side of Athabaska River, about 12 miles north of Muskeg River, a clay bed 15 feet thick, similar to the basal clays on section 17, north of Stony Island, is overlain and underlain by bituminous sands with which thinner clay beds are interstratified. In drilling the bituminous sands in various areas clay beds are commonly present in all localities, but there is a wide variation even locally in the number and thickness of clay beds present. In the Horse River area at the Abasand plant, about 3 miles south of Fort McMurray, the bituminous sands are underlain by 22 feet of clay resting directly on Devonian limestones. This clay is considered to belong to the McMurray formation, although actual proof is lacking.

In drilling the bituminous sands, clay beds are present in all areas. In the Mildred-Ruth Lakes area some of these were clay shales containing foraminifera and hence of marine origin. This shows that there are marine shale interfingerings into the bituminous sands and since, from the drilling done to date, it appears the sands are becoming less abundant to the west and the clays and shales more predominant the inference is that the interfingers of marine shale are from the west.

The mode of deposition of the bituminous sands has always presented an intriguing problem. The large-scale crossbedding present in some areas has been interpreted as the foreset beds of a delta. It is apparent also that, if as indicated by the drilling done to date the sands are disappearing westward and are being replaced by shales in that direction, the sand for the McMurray formation originated from the east or from what is now the Precambrian Shield. Thus, the McMurray formation is regarded as a deltaic or a shoreline deposit laid down on the edge of the Precambrian Shield and, in the area north of McMurray, largely disappearing to the west in a relatively short distance, although extending as a widespread thin deposit on top of the Devonian limestone possibly into the Peace River area, where sandy beds in a similar stratigraphic position occur. It is uncertain how far the equivalents of the basal McMurray formation should be extended to the south. Oil of a type similar but lighter in gravity than that from the bituminous sands is being produced in the Vermilion, Wainwright, and Lloydminster areas of Alberta and Saskatchewan, and it is known that the Lower Cretaceous in these areas consists of an alternation of marine and non-marine sediments similar to conditions in the Fort McMurray area. The inference, therefore, has been that there is a direct relationship between the sediments of the two areas with the assumption that part of the equivalents of the McMurray formation may extend outward for long distances. The stratigraphic position of the oil-bearing beds in the Vermilion, Wainwright, and Lloydminster areas, however, is more suggestive of a correlation with the Grand Rapids sandstone than with the McMurray formation. This belief is supported by evidence from the Athabaska area, where oil and gas production has been found in the Grand Rapids formation, and by the fact that the upper part of the Grand Rapids formation contains thin coal beds similar in stratigraphic position to thin coal seams that occur in east-central Alberta above the productive oil sands. Thus until a better correlation of the various parts of the Lower Cretaceous is established between the Fort McMurray area and east-central Alberta it does not

seem possible to determine the extent of the McMurray formation sand. It is obvious, though, that most of the thickness of McMurray formation sands present in the general vicinity of Fort McMurray rather rapidly thins out to the west and south, and hence the conclusion that most of the deposit is shoreline or deltaic still is justified.

In any deltaic deposit where sands are being deposited it is obvious that the offshore sediments laid down in the sea at the same time would be marine shales. According to the character and amount of materials available for deposition the boundary between the sands and shales would oscillate backward and forward at different periods, thus accounting for the interfingering of marine shales in the sand deposits. It is unknown but thought unlikely that all the clay bands in the bituminous sands were formed in this way, and as only a few shale bands have actually been identified as marine, and in appearance these are somewhat different to the ordinary clay bands, it is inferred that the two are unrelated in origin. Most of the clay bands in the bituminous sands are, therefore, considered to be flood deposits of silt and clay originating from the same source as the sands themselves and alternately deposited with them. This, then, accounts for the wide variations locally in the character of the bituminous sand deposit, since well-washed sands may have been deposited in one place, while at the same time silts and clays were being laid down in areas of more quiescence immediately adjoining. It is the areas of sands relatively free of clay which in general are the beds that contain the richest bituminous sands, and hence their distribution and size of deposit will be of major importance in any mining operations that may be undertaken.

STRUCTURE

The Devonian surface shows a considerable local relief within a relatively small area. This is important in relation to the thickness of bituminous sand beds present. In the Steepbank area where drilling in some holes commenced in the lower part of the Clearwater shales and thus, where the thickness of the bituminous sands could actually be determined between the base of the Clearwater formation and the top of the Devonian, it was found that the McMurray formation is less thick over limestone knobs and ridges than it is over limestone valleys. This proves conclusively that the limestone surface was quite irregular at the time of the beginning of the deposition of the McMurray formation, but it is not known how much of this irregularity should be ascribed to pre-Cretaceous erosion and how much to pre-Cretaceous folding of the limestone beds. It seems obvious that both were present. In the Mildred-Ruth Lakes area, 20 miles north of Fort McMurray, where the limestone as determined by drilling has a relief of as much as 165 feet there is also some evidence, although by no means conclusive, to support the contention that there may be some local post-Cretaceous folding. No definite key horizons are present in the bituminous sands in the Mildred-Ruth Lakes area whereby all wells can be definitely correlated, and as no overlying Clearwater shales are present there is no bed above the limestone surface that can be used for structural control. The regional southwest dip that is shown by the succession of outcrops of higher formations to the southwest on Athabaska River is obviously post-Cretaceous deformation, but this regional warping of the Cretaceous beds should not be confused with local folding which, if present in the Mildred-Ruth Lakes area, might have a very considerable bearing on the methods used in the bituminous sands operations that eventually may be undertaken. It is unlikely that local Cretaceous folding, if present, will be proved until individual bituminous sand beds can be traced over considerable areas by extensive workings.

ORIGIN AND CHARACTER OF THE BITUMEN

The origin and character of the bitumen in the bituminous sands has been discussed in a report "Results and Significance of Drilling Operations in the Athabaska Bituminous Sands"[1] as follows:—

"McConnell[2], who saw these deposits in the early days when the Devonian in Ontario had been shown to have a rich oil content, expressed the opinion that the oil came from the Devonian. This conclusion had been followed by Sproule[3] and has found considerable support from others. The writer, however, for many years has expressed the opinion that the oil could, and probably did, originate in the Lower Cretaceous beds themselves, and this view has been strongly supported by Ball[4], who had a very extensive experience in dealing with the bituminous sands. Ball expressed the opinion that the oil 'originated in its present location' and strongly emphasized the 'near source' by rejecting various other hypotheses that have from time to time been postulated by way of explanation. The discovery of bitumen beds interstratified in the Mildred-Ruth Lakes deposit can hardly be explained other than by a near source, especially if it is agreed, as Ball has strongly maintained, that the oil is not a residual product left by evaporation and oxidation of lighter oil but is 'a young oil that has never been geologically gently cracked or decomposed into lighter or heavier fractions'. The evidence for this is quite convincing, for the bitumen, as now found, cracks at abnormally low pressures and temperatures in comparison with residuums which, as pointed out by Ball, it resembles 'in appearance, viscosity, and specific gravity'.

"If the near source for the oil is accepted, it seems not too difficult also to accept a possible origin related to the occurrence of dark marine shales, which are now known to interfinger the bituminous sands, presumably from the west, where marine conditions must have existed contemporaneous with the deposition of the McMurray sands. This infers that shore lines were present, and if proof of this is needed it would seem to be provided by the occurrence of lignite and conglomeratic beds in samples from some of the wells in the Mildred-Ruth Lakes area. In hole B22, for example, coal occurs at a depth of 111 to 112 feet and it has been reported in other holes. Also 'gravel' was reported in hole B19 at a depth of 152 feet and pebbles up to half an inch in diameter occur in conglomeratic beds within the McMurray formation, apart from basal beds. These shore-line conditions, therefore, might readily be regarded as favourable for the collection of source materials for oil, although the difficulty seems to be the generation of such large volumes of oil as are necessary without any direct evidence or actual knowledge of source materials. It has been shown[5] that there is more than sufficient organic material present in some sediments, both ancient and recent, to account for all the oil present in some rich oil fields, but the time and conditions necessary to bring about the formation of oil has been the subject of much discussion.[6]

"From the occurrence of the bitumen beds in the Mildred-Ruth Lakes area it would appear that, if the bitumen originated in Lower Cretaceous time, its formation is contemporaneous with the deposition of the sediments with which it is interstratified. Also, if such is the case, the bitumen for all the bituminous sands probably originated under similar conditions.

"Ball[7] has pointed out that the 'oil', as he refers to it, 'is not a pore-space filling, but is present as a film around each grain of sand', and Link, in the discussion of Ball's paper, has drawn attention to the fact that the sand has a film of water[8] inside the oil. Thus, if wet sand grains received a coating of bitumen during deposition from a nearby oil source, some of the difficulties of explanation for the migration of the bitumen into the deposit after its formation are avoided. Such an explanation might also help, although perhaps very inadequately, to explain why the sands, when deposited on top of the bitumen beds, did not penetrate much farther into them than seems to have been the case. If the sands were bituminous sands at the time of deposition they might readily form a somewhat coherent mass on deposition and thus only penetrate the bitumen for a limited depth. Such a condition might be aided by stages of relatively fast sedimentation, but, even so, it seems hard to believe that the bitumen from any bitumen beds that may have formed would not be squeezed out by the weight of overlying sediments. The bitumen itself, during deposition, can hardly be thought of as much less fluid than at present or it would not have spread into flows, as it

[1]Hume, G. S.: Can. Inst. Min. and Met., vol. 50, pp. 318-320 (1947).

[2]McConnell, R. G.: Geol. Surv., Can., Ann. Rept., vol. 5, p. 32D (1890-91).

[3]Sproule, J. C.: Bull. Amer. Assoc. Pet. Geol., vol. 22, No. 9, pp. 1133-1152 (1938).

[4]Ball, Max. W.: "Athabaska Oil Sands, Apparent Example of Local Origin of Oil"; Bull. Amer. Assoc. Pet. Geol., vol. 19, No. 2, pp. 153-171 (1935). *Also* "Development of Athabaska Oil Sands"; Can. Inst. Min. and Met., Trans., vol. 44, pp. 58-91 (1941).

[5]Trask, D. Parker, and Patinode, H. Whitman: "Source Beds of Petroleum"; Amer. Assoc. Pet. Geol., 1942.

[6]*See* "Problems of Petroleum Geology"; Amer. Assoc. Pet. Geol., 1934.

[7]Ball, Max W.: Amer. Assoc. Pet. Geol., vol. 19, No. 2, p. 159 (1935).

[8]*See also* Clark K. A.: "Hot Water Separation of Alberta Bituminous Sand"; Can. Inst. Min. and Met., Trans., vol. 67, p. 257 (1944).

seems to have done. It is possible, of course, that the temperature of formation was lower than at present, although, as heat is thought by many geologists to aid the formation of oil from source materials, this suggestion only adds a further difficulty of explanation.

"In connection with the suggestion that the bitumen in the bituminous sands and bitumen beds originated and was deposited contemporaneously with the McMurray formation, it is interesting to note that the McMurray sands along Clearwater river eastward from the mouth of Cottonwood creek, twenty-five miles east of McMurray, to and beyond the Alberta-Saskatchewan boundary, are not impregnated[1] with bitumen, although there is no obvious difference in the character of the sediments in impregnated and unimpregnated sands. It may also be significant that, at the eastern boundary of the bituminous sands on Cottonwood creek, the upper only, and not the lower, beds are impregnated with bitumen. Such a condition as described above might be explained if the bitumen were being formed close to, and at the margin of, a strand line that was on the western edge of the alluvial fan or deltaic deposit, but which, as the interfingering of marine shales proves, was transgressing or receding at various stages of deposition. Such a conception would be in harmony with interstratified bitumen beds on or near the west edge of the deposit, as in the Mildred-Ruth Lakes area, where the amount of bitumen formed might be in excess of that which could be adsorbed by the sand grains. On the other hand, the absence of bitumen in the sands of the east side of the deposit might be explained by the lack of bitumen due to the absence of source materials associated with marine conditions. If this is the explanation, it emphasizes the near source for the bitumen in relation to the position in which it was deposited, and, as Ball has convincingly shown that the oil is relatively little altered from its original state, migration for any distance would seem improbable. Also, as the bitumen is a coating separating the sand grains rather than a pore-space filling, it would appear it was adhering to the sand grains when these were deposited."

SIZE OF BITUMINOUS SAND DEPOSIT

Various opinions have been expressed as to the size of the bituminous sand area. The difficulty is to know how far to extend it beyond its outcrops. In a well drilled in 1897 at Pelican, 80 miles southwest of Fort McMurray, heavy oil called maltha by Dawson[2] was encountered in beds that are undoubtedly the equivalents of the McMurray formation which in that area are 70 feet thick. Due to the regional southwest dip the McMurray formation, the base of which is exposed at Fort McMurray, disappears below the level of Athabaska River 42 miles upstream and from there, southwestward, higher formations successively appear as outcrops on the river banks. The result is that at Pelican the top of the McMurray formation is at a depth of 750 feet. There is no information to show how much of the 70 feet of McMurray formation in the Pelican area is impregnated with bitumen. As has already been pointed out the McMurray sands along Clearwater River eastward from the mouth of Cottonwood Creek, 25 miles east of McMurray to and beyond the Alberta-Saskatchewan boundary, are not impregnated with bitumen although there is no obvious difference between the impregnated sand west of Cottonwood Creek and the unimpregnated sands east of it. Thus, from McMurray eastward there is a width of 25 miles of impregnated sands, but in the area of Cottonwood Creek, according to Sproule,[3] only the upper sands of the formation and not the lower ones are impregnated with bitumen. Thus the bituminous sands, which in the Mildred-Ruth Lakes area reach a maximum thickness of 224 feet, thin out to a wedge-shaped edge 25 miles eastward from Fort McMurray where the formation is 180 to 200 feet thick and all more or less impregnated with bitumen.

Without much further drilling it is impossible to arrive at a satisfactory conclusion regarding the areal extent and average thickness of the bituminous sands. To the west of McMurray the regional southwesterly dip carries the bituminous beds below higher formations and the extent of the concealed beds is a matter of speculation. Ells[4] conservatively estimated that "the area underlain

[1]Sproule, J. C.: Geol. Surv., Canada, unpublished manuscript.

[2]Dawson, G. M.: Geol. Surv., Canada, Ann. Rept., vol. 10, p. 19A (1897).

[3]Sproule, J. C.: Geol. Surv., Canada, unpublished manuscript.

[4]Ells, S. C.: "Some Economic Aspects of the Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Rept. 735, p. 11 (1934).

by bituminous sands is not less than 1,500 square miles and the total areal extent of the deposit is probably very much larger"; whereas Ball[1] states that "the saturated sands underlie at least 10,000, probably 20,000 and possibly 30,000 square miles", but the area in which "the sands are accessible and mineable is probably less than 20 square miles". In the Mildred-Ruth Lakes area it was calculated that for an area of 3 square miles where drilling was done there may be as much as 224,000,000 barrels of bitumen to the square mile. This area is relatively rich and the sands are also relatively thick. This may, therefore, represent approximately a maximum content, but in view of the size of the deposit it is not difficult to arrive at an estimate of 100 billion to 250 billion barrels as has been so widely quoted.[2] The fact that only a small part of this is readily accessible, as Ball points out, still leaves an enormous volume that can be recovered by ordinary mining methods.

[1]Ball, Max W.: Bull. Amer. Assoc. Pet. Geol., vol. 19, No. 2, p. 158 (1935).
[2]Pratt, Wallace E.: "Oil in the Earth"; Univ. of Kansas Press, p 41 (1943).

WHEELER ISLAND AND STEEPBANK RIVER AREAS

SUMMARY OF EXPLORATION IN 1942

(The Consolidated Mining and Smelting Company of Canada, Limited.)

INTRODUCTION

Commencing July 19, 1942, The Consolidated Mining and Smelting Company of Canada, Ltd., at the request of the Dominion Government, carried out exploration for mineable deposits of bituminous sands in the McMurray area. Based on exploration carried out by the Mines Branch, the Research Council of Alberta, Abasand Oils, Limited, and The Consolidated Mining and Smelting Company in previous years, two areas were chosen that showed:

(a) Indications of a large tonnage of a good grade of bituminous sand with low clay content.

(b) Shallow overburden.

(c) Adequate tailing disposal areas.

These were the Steepbank area, 24 miles below McMurray, and the Wheeler Island area, 56 miles below McMurray, both on the east bank of Athabaska River.

All previous drilling had been done using augers, and as the time for experimentation was limited this method was adopted although it had serious defects and was costly. To get through overburden a Keystone and Hillman churn drill was used and three diamond drills were employed to power-auger the holes through the tar sand to the underlying limestone. Holes were drilled at half-mile centres and by January 26, 1943, eleven holes had been completed at Wheeler Island, exploring an area of 1,400 acres, and ten holes at Steepbank, exploring an area of 900 acres.

DRILLING TECHNIQUE

Auger drilling had serious defects due to breakage of augers in the holes, short pulls resulting in an average advance of 5·0 feet per shift, and the necessity of working always in a dry hole. Experimentation with various types of augers showed little improvement, but using mud in the hole enabled a satisfactory sample to be obtained even though the hole was full of water. Some tests were made with an "N"-size, non-rotating core barrel using water as a circulating medium, but they were not successful.

However, results of these tests permitted the following conclusion:

> "This method has possibilities if a larger diameter core barrel were used and the cuttings removed with a mud-laden fluid. The heavier liquid would probably remove the coarse cuttings more efficiently and also prevent them from backing up into the core barrel whenever water pressure fell off. The mud would help protect the core from water-washing and, also, if the hole was kept full of liquid, casing might not be necessary."

Auger drilling speeds varied from 2·1 feet to 6·3 feet per shift for holes up to 200-foot depth. The holes had to be cased throughout, using 6-inch casing through overburden and 4- to $2\frac{1}{4}$-inch flush joint casing through the tar sands. Casing had to be kept close to the bottom of the hole to prevent salting of the sample by overlying material and to cut off water inflows. The lowest core recovery from the sampled sections was 60·9 per cent, but the average for all the holes was 90 per cent.

Winter drilling presented no problem, except the necessity of keeping the tar on the rods from freezing. The drills were housed, and to pull the rods a "rat hole" was drilled so that the deckman handled the rods within the drill shack.

WHEELER ISLAND AREA

This area includes parts of sections 18, 19, 29, 30, and 32, township 97, range 10, and parts of sections 13 and 24, township 97, range 11. It is situated 56 miles, by river, below McMurray, Alberta, and consists of a low river bench, 1,400 acres in area, on the right bank of the river, immediately below the lease of the International Bitumen Company. The bench varies in elevation from 760 feet near the river to 820 feet at the inside, and in width from a mile wide at Fort Creek to less than a quarter mile wide, 3½ miles north. Susan Lake occupies a small depression in a muskeg area on the east side of the bench.

The first exploration in this area was in 1918 when the Northland Oil Syndicate drilled two wells near Wheeler Island. In 1938 The Consolidated Mining and Smelting Company carried out a trenching program and sank three shafts in the northern part of the bench; and in 1941 Abasand Oils, Limited drilled some shallow auger holes along the river bank.

Between July 29 and December 27, 1942, The Consolidated Mining and Smelting Company drilled eleven holes at 2,500-foot centres for a total footage of 1,682·8 feet. Only a single line of holes was drilled in the northern part where the bench narrowed. Seven test pits were also sunk through the overburden.

Overburden varies from 12 to 43 feet in depth, consisting of 7 to 20 feet of glacial boulders and gravel underlain by 8 to 32 feet of lean oil sand. The bituminous sand formation varies from 35 to 78 feet in thickness and is underlain by limestone and carbonaceous shale.

The limestone bedrock varies from an elevation of 620 feet at the south end of the property to 680 feet at the north end and outcrops at river-level 5 miles downstream. Overlying this uniformly dipping limestone surface is a ridge of residual clay that outcrops opposite Wheeler Island, rises 30 feet above river-level, and apparently extends across the centre of the area in an east-west direction. Except for the area on top of this ridge the limestone is overlain by 30 feet of black carbonaceous shale, which appears to thicken at the south end of the area to form the entire McMurray formation above the limestone.

The greatest thickness of the McMurray formation drilled was 170 feet, and east of the bench the formation appears to be overlain by the recent sand deposits that form the Old Fort Hills. The drilled thickness of 170 feet is probably the true thickness of the McMurray formation in this area.

The bituminous sand of possible mineable grade is divided into two blocks, one lying to the south of the residual clay ridge, and the other a mile to the north separated by low-grade oil sand up to 70 per cent of −200-mesh material. The south block is 4,000 feet wide and 6,000 feet long, and the north block 1,400 feet wide and 4,600 feet long. The tonnage available as indicated by the widely spaced holes is estimated as: 99,200,000 tons assaying 13·0 per cent bitumen and 26·7 per cent −200-mesh material, overlain by 49,700,000 cubic yards of overburden. The ratio of bituminous sand to overburden is 1 to 0·73.

Overburden and tailing disposal areas are available in the channel between Wheeler Island and the mainland, or on the areas underlain by low-grade bituminous sands, until mining has advanced sufficiently to permit returning the tailings to the mined-out areas.

STEEPBANK AREA

This area includes parts of sections 17, 19, 20, 29, and 30, township 92, range 9. It is situated 21 miles below McMurray on the right bank of the river and includes the ridge lying between the Steepbank and Athabaska Rivers.

Elevations vary from 770 feet at river-level to 1,080 feet at the top of the ridge that rises to the general level of the plateau. Facing Athabaska River is a bench with an elevation of 920 feet that varies from 500 feet to 1,500 feet in width and extends for 2 miles along the front of the ridge. Below this is a broad river flat, ½ mile in width, extending northwards to the Steepbank River's outlet and underlain by flat-dipping limestone.

In 1907, A. Hammerstein drilled an oil well in section 19 and obtained a lease on 3 square miles of oil lands in this area. In 1915, S. C. Ells sampled the outcrops along Steepbank River for the Mines Branch; and, in 1924, the Alberta Research Council re-sampled these exposures. In 1941, Abasand drilled three auger holes along the Athabaska River; and between July 19, 1942 and January 26, 1943, The Consolidated Mining and Smelting Company drilled twelve holes totalling 1,445 feet, of which three were abandoned, due to auger breakage, before reaching the base of the sands, and two were drilled through the gravel overburden only. These holes were drilled at 2,000-foot centres exploring a wedge-shaped area, 6,000 feet wide at the south end and tapering to 2,000 feet wide, 2 miles north near the mouth of Steepbank River, with an area of 900 acres.

Seven hand-auger holes were also drilled and twenty-one test pits sunk to get through weathered tar sands.

The McMurray formation in this area is overlain by glacial boulders and gravel, which together with shale or lean bituminous sand form the overburden material. The overburden varies from 5 to 15 feet on the river bench facing Athabaska River to a maximum of 104 feet on the high ridge between Steepbank and Athabaska Rivers. The sands have a thickness of 45 to 94 feet on the bench and up to 119 feet on the ridge, where probably the entire original thickness is still present.

The underlying limestone surface dips southwest at 60 feet to the mile, but trending north 30 degrees east across the area is a depression in the limestone that may be either structural or an erosion feature on the limestone surface. This depression is filled in by sand with fairly high −200-mesh material. Locally, coarse sand or gravel lies at the base and directly on the limestone. Above this is a lens of well-sorted sand with a thickness of 80 feet, and continuous throughout the area drilled. Overlying this is a sand high in clay with a low bitumen content.

To the outer limits of the area explored the tonnage available indicated by the widely spaced holes is: 178,500,000 tons assaying 11·7 per cent bitumen and 21·3 per cent −200-mesh material overlain by 65,600,000 cubic yards of overburden, or a ratio of oil sand to overburden of 1 to 0·54. Taking only the higher grade material or that under low overburden on the bench, the tonnage is 101,000,000 assaying 13·0 per cent bitumen and 19·0 per cent −200-mesh material overlain by 32,800,000 cubic yards of overburden, or a ratio of oil sand to overburden of 1 to 0·49. If lean bituminous sand assaying 6·8 per cent bitumen and 36·9 per cent −200-mesh material could be treated, the overburden would be reduced to 8,600,000 tons and the ratio of oil sand to overburden would be 1 to 0·13.

Included in this higher grade is 13,000,000 tons assaying 14·2 per cent bitumen and 12·5 per cent −200-mesh material under 5 feet of leached sand overburden.

There is an adequate tailing disposal area on the large flat along Athabaska River, near the mouth of Steepbank River.

CONCLUSIONS AND RECOMMENDATIONS

From "Final Report on Exploration—March 10th, 1943":

1. "A method of core drilling using a mud-laden fluid to remove cuttings should be investigated. Taking a core sample would permit rapid advance and the mud fluid would prevent caving of the hole, thus doing away with casing."

   (NOTE:—This method was used by Boyles Brothers later, in 1943 drilling.)

2. "It is recommended that exploration be continued in the Steepbank area even though other areas are investigated at the same time. The possibilities that a more favourable deposit will be found are not particularly encouraging."

3. "To further prove the estimated tonnage at Steepbank would require drilling at 1,000-foot centres a total of twenty-two holes with an estimated footage of 3,000."

   (NOTE:—The Dominion Government did this work in 1943, and extended the work to the south.)

4. "The drilling is widely spaced and tonnage and grade estimates are merely indicative of the possibilities."

5. "Practically all exploration for oil sands in the McMurray area has been based on areas where the outcrops showed good grade oil sand and where the overburden is not excessive. Due to the resistance of tar sand to erosion, the exposures frequently have the more clayey material concealed. This is well shown at Wheeler Island, where the outcrops showed only good grade oil sand."

From "Report on possible areas for further exploration—Nov. 20, 1942":

6. "The areas most promising for preliminary exploration, i.e. holes spaced at one-mile centres, are:

   1. North of Steepbank River.
   2. Mildred Lake area.

   These are both within 25 miles of McMurray and offer as good chances for tonnage as the present Steepbank area, as well as having adequate disposal areas."

MAIN STEEPBANK RIVER AREA

INTRODUCTION

The bituminous sands of northern Alberta lie within the basin of the Athabaska River, with all exposures within a radius of 80 miles of Fort McMurray. The extent of the deposit is not known with any certainty, though exposures found along the valleys of the Athabaska and its tributaries indicate an approximate length of 115 miles and a width of 55 miles. That part of the deposit that is of practical significance at the present time lies from Fort McMurray northward along Athabaska River for 65 miles. The potential economic importance of the bituminous sands has been known for many years, but it is only recently that by improved drilling methods sufficient data have been secured, on which to base estimates of grade and tonnage in any particular area.

Between 1913 and the Second World War the Dominion Government carried out reconnaissance mapping of the whole area, and also did a small amount of exploratory drilling by hand-augering methods. This work focused attention on a number of locations for possible commercial development, one of the most favourable of which was that known as the Steepbank area, some 20 miles north of Fort McMurray.

During the Second World War, when the necessity of securing greater oil reserves in Canada became apparent, the Dominion Government decided on a more intensive program of exploratory drilling. In 1942, it was arranged by the Minister of Munitions and Supply that The Consolidated Mining and Smelting Company of Canada should commence this drilling program, and from August 1942 to January 1943 some 3,000 feet of drilling was completed, of which 1,445 feet was done in the Steepbank area. In 1943 the Mines and Geology Branch of the Department of Mines and Resources took over active direction of the investigation and a contract was let to Boyles Brothers Drilling Company. This company commenced drilling operations in June of that year and a greatly improved drilling technique was rapidly developed. Except for a 6-month period in 1944, drilling was continuous at Steepbank until, by July 1945, Boyles Brothers had completed ninety-five holes with a total footage of 17,482 feet. On the information obtained from the drill cores, estimates of grade and tonnage have been based.

LOCATION

The Steepbank area is located where Steepbank River enters the Athabaska from the east, some 20 miles north of and downstream from Fort McMurray: that part covered in this report lies in township 92, within the triangle formed by the junction of the two rivers. The end of steel is at Waterways, 3 miles east of Fort McMurray. Transportation by shallow-draught river boats and scows is available for approximately 5 months during summer and autumn, and during winter, river ice can be used by trucks and tractor trains for from 2 to 3 months with safety. If necessary, land haulage could be developed between Steepbank area and Waterways, but would have to overcome the difficulties of a 400-foot descent into the valley of Clearwater River and the crossing of that stream.

TOPOGRAPHY

The region in general is plateau-like, having an elevation of 1,100 to 1,200 feet above sea-level, and into this plateau-like upland Steepbank and Athabaska Rivers have cut their valleys, the Athabaska Valley being much older than that of the Steepbank. River terraces have been formed and series of from two to three benches are not uncommon along the Athabaska. Although all of the

area lying between the Athabaska escarpment and Steepbank River is known to be underlain by bituminous sand, over most of it the thickness of overburden is very considerable. On the river terraces, however, much of this overburden has been eroded and the decreased thickness would obviously prove a favourable factor in any attempt to recover the bituminous sands by open-pit mining methods.

To the east the terraces give way to the undisturbed upland, which has a glacial till cover of varying thickness. To the west is the Athabaska Valley bottom-land, only 10 to 25 feet above high water, which is for the most part poorly drained swamp partly covered with timber. This bottom-land would be an ideal tailings disposal area of large acreage, and it is one of the attractive features of the Steepbank area as a location for a mining and separation plant.

BITUMINOUS SAND

The bituminous sands of the Steepbank area form part of the McMurray formation of Lower Cretaceous age. They were laid down on an old erosion surface of Devonian limestone and are conformably overlain by sandstone and shales of the Clearwater series, most of which have been eroded in the cutting of Athabaska Valley. The McMurray formation varies considerably in thickness over comparatively small areas: drill-holes that pierced it from top to bottom at Steepbank show thicknesses of from 50 to 215 feet.

The bituminous deposits are made up of beds of unconsolidated sand, silt, and clay impregnated to a varying extent with a very viscous asphaltic oil or, more properly, bitumen. The sand beds show much crossbedding and lensing and were apparently water-lain under deltaic conditions. Clay and silt occur in the deposits as thin partings or as prominent beds, and close interbedding of sand, silt, and clay is common. The sand particles generally are of 50-mesh size and smaller with the amount of material finer than 200-mesh varying from a few per cent to high percentages. These particles consist mainly of quartz, but as much as 5 per cent may be of such minerals as mica, rutile, ilmenite, tourmaline, zircon, spinel, garnet, and pyrite. Lignitic material is of common occurrence in parting planes. Concretionary pyrite does not seem to be common at Steepbank, but clay ironstone bands frequently occur near the top of the McMurray formation.

Normal, good grade bituminous sand freshly taken from a deposit is an aggregate of black, glistening, bitumen-coated, rounded grains of sand. It is free from any cementing material other than bitumen. It has a strong petroliferous odour but does not exude any liquid petroleum. On exposure to the atmosphere it gradually hardens and loses its glistening lustre and most of its odour. The lower grade sands—those assaying less than 10 per cent bitumen—lack the lustre of the higher grade material, and the colour varies from dull black to light brown as the bitumen content decreases, though colour alone is not a safe gauge of percentage composition.

The bitumen content of the deposits varies, mainly with variation of silt and clay content, though bands of low-grade sand containing no clay frequently occur, particularly in the upper beds. As a general rule, a sand becomes silty or clayey in nature as the content of material passing the 200-mesh sieve exceeds 20 per cent: under these conditions the bitumen content becomes lower, and the water content increases. In individual samples of the better grade material the contained bitumen rarely exceeds 18 per cent by weight. The sand in samples of that quality is usually characterized by uniformity of grain size and it would appear that such sand, having the maximum of pore space, has attained in 18 per cent bitumen content the limit of bitumen adsorbability. It follows

that the more diversity there is in grain size and shape, and the less the available pore space, the lower will be the percentage of adsorbed bitumen. Therefore, a high proportion of clay intermingled with good grade sand will considerably lower the average grade in any given section of the deposit.

Although the better grade sands range from 14 to 18 per cent bitumen, the estimate chart, in Volume III of this report, shows average values below these figures. The difference in grade is due to the fact that, for such a large tonnage, considerable low grade had to be included, and the presence of clay layers containing little or no bitumen has had a diluting effect on the large tonnage blocked out. Factors that influence the grade for a large tonnage are: (1) the adsorption capacity of the beds involved; and (2) the number and size of the clay beds present. At Steepbank the bitumen values have been fairly well established: on the order of magnitude of 167 million tons the average grade is 12·96 per cent, and of 298 million tons the average grade is 11·96 per cent.

EXTENT OF DIAMOND DRILLING AND METHODS USED

Prior to the summer of 1943 all exploratory drilling had been done by hand-augering methods, which had never been satisfactory as to speed of drilling, condition of the recovered material, and accuracy of samples for analysis. It was thought that core drilling by diamond-drill methods would be impracticable because of the leaching action of water used for lubricating the bit. However, this difficulty was successfully overcome by the use of a gel mud suspension as a lubricating medium instead of water. The technique is based on standard diamond-drilling practice with ordinary diamond-drill equipment slightly modified. The drilling time was speeded by 700 per cent over augering methods, but more important was the condition of the core as recovered. Practically no separation of bitumen or bitumen contamination of the core takes place through the action of the drilling fluid, so that results of analyses are much more dependable. The core, as removed from the inner tube and placed in partitioned boxes, accurately represents the character and original position of cored materials. From such samples it is possible to obtain an accurate idea of the grain size; the uniformity of grain size; and the thickness and distribution of the fine-grained clays, which lower the over-all grade of the bituminous sands.

The drilling during 1942 and 1943 was of an exploratory nature, the main purpose being to locate possible commercial deposits and to obtain overburden ratios. In 1944, after exploratory drilling in the southerly part of township 92 had disclosed only low-grade sand with high clay content, a program of closely spaced drilling was carried out in the more northerly part of the area for the purpose of blocking out tonnages and establishing average grade. This program was completed in July 1945. Some drilling was done subsequently to the east of Steepbank River, where a body of good grade sand was disclosed, though the overburden was shown to be rather heavy. Data obtained by this drilling are not ready for inclusion in this report, but locations of the drill-holes are shown on the plan accompanying Volume III.

A topographical survey of the area was made during the course of the drilling in 1944-45, and the plan accompanying Volume III of this report was prepared from the data secured, on a scale of 1 inch to 400 feet. Proposed holes were located on parallel range lines spaced at regular intervals. The holes were drilled in the field at locations previously spotted on the map. In certain cases proposed holes were eliminated, as it became known that the overburden ratio or percentage of clay to be expected would be too great. In this way deposits of

bituminous sands that hold possibilities for commercial development were definitely delineated. Particulars of the drilling, exclusive of that to the east of Steepbank River, are shown in the following table:

Date	Number of holes	Drilled by	Total feet
Aug. 1942—Jan. 1943	12	Cons. Min. and Sm. Co.	1,445
June 1943—Dec. 1943	18	Mines and Geol. Branch	3,348
July 1944—July 1945	77	Mines and Geol. Branch	14,134
	107		18,927

The north-south extent of the drilling was from range 28 at the north to range 13 at the south, or a distance of $4\frac{1}{2}$ miles. The maximum width encompassed by the drilling, exclusive of that to the east of Steepbank River, was 4,200 feet. The average dimensions of the blocked-out deposit are 14,000 by 3,000 feet.

ESTIMATES OF GRADE AND TONNAGE

There are twenty-three range lines traversing that part of the Steepbank area that contains bituminous sands of possible commercial grade. The number of holes drilled on or near each range line varies from three to five. Vertical sections were made on each range line, and the logs and core analyses of the holes were graphically plotted. In this way the results of each hole were shown in relation to the results of others in the same range. Average assay values were calculated for each range section and areas that included bituminous sand of required grades were determined by means of a planimeter. Volumes between the ranges were calculated, as were the average grades for these volumes.

In making the estimates, as it is not yet known just what percentage of bitumen in a given body of sand would constitute commercial grade, two limits were set. The first was for 12 per cent bitumen or better, and the second for 10 per cent bitumen or better, with a separate set of calculations for each. The main assumptions used in calculating tonnages were: (a) 15·5 cubic feet (0·574 cubic yard) of average overburden equals one ton, and (b) 16·0 cubic feet of bituminous sand equals one ton. The bituminous sand is more or less homogeneous; as the voids are filled with bitumen its density could be expected to approximate that of water-filled sand, and laboratory tests on core samples of varying bitumen content have indicated that bituminous sand in place has a specific gravity of 2·0, equal to 125 pounds a cubic foot. The overburden, on the other hand, is composed of about one-third barren sand and two-thirds clay, and on a dry basis it would have a specific gravity of slightly less than 2·0. However, some allowance must be made for natural moisture and it is considered that the factor of 15·5 cubic feet to the ton gives a reasonably close estimate of the overburden tonnage.

As shown in the estimate chart,[1] the 12 per cent or better material available in the Steepbank area lies in two bodies: these are separated by a body of lower grade material and total 167,680,000 tons averaging 12·958 per cent bitumen. The estimated tonnage of 10 per cent or better material, including the higher grade bodies, is 297,779,000 tons averaging 11·96 per cent bitumen.

[1] See Volume III, p. 2, Steepbank River Area Section.

RESULTS

The results attained by the program of drilling in the Steepbank area may be summarized as follows:

(1) A reliable drilling technique for coring bituminous sand deposits has been developed.

(2) A large-sized deposit of bituminous sand has been indicated and the grade of a large tonnage has been determined.

(3) A bituminous-sand-to-overburden ratio of better than 2 to 1 has been established for a large tonnage.

CONCLUSIONS

(1) *General*

(a) Individual beds of sand possess a definite limit of bitumen adsorbability, determined by grain size and shape: though sands having the same grain size do not always have the same bitumen content.

(b) The bitumen content of the sands has been found to vary greatly in short distances either vertically or horizontally: in general, the better grade material is found in the lower beds.

(c) The occurrence of clay partings interbedded with good grade sand is the principal factor in reducing average bitumen values.

(2) *Steepbank Area*

(a) The tonnage indicated at the close of 1945 is sufficient to supply a plant having a capacity of 10,000 tons a day for 40 years, treating material with a bitumen content of 12 per cent or better.

(b) A favourable plant site with an adequate tailings disposal area lies immediately west of the deposit of bituminous sand.

Steepbank River Area

Tonnage Estimates: 1945

A 12% Plus

—	Bituminous sand,* tons	Grade, per cent bitumen content	Overburden,** tons	Ratio: bituminous sand to overburden	Average length, feet	Average width, feet	Acreage, acres
North body.....	69,817,000	13·043	27,527,000	2·6 : 1	3,800	2,200	197
South body.....	97,863,000	12·896	38,377,000	2·6 : 1	5,400	2,600	323
Total.....	167,680,000	12·958	65,904,000	2·6 : 1			520

B 10% Plus (Includes the 12% Plus)

Total.....	297,779,000	11·96	117,135,000	2·5 : 1	14,000	3,000	945

*Calculated on the basis of 16·0 cu. ft. to 1 ton.

**Calculated on the basis of 15·5 cu. ft. to 1 ton.

EAST OF STEEPBANK RIVER AREA

INTRODUCTION

The main area of bituminous sands identified with Steepbank River lies immediately south of the junction of that river with the Athabaska. This area was explored by systematic diamond drilling during the years 1943 to 1945 inclusive, and a large tonnage of good grade (12 to 13 per cent) bituminous sand was developed. When this drilling program was completed in July 1945, other areas near at hand that showed favourable indications were considered as possible locations where diamond drilling might develop further bodies of good grade sands. Directly to the east of the main Steepbank area, across Steepbank River, there are a series of prominent exposures of bituminous sand along the river escarpment that are almost vertical in places and over 100 feet in height. Thickness of overburden, as exposed along these sheer banks, appears light. Because of the possibility that the body of good grade bituminous sand in the main Steepbank area might be found to extend considerably to the east, it was decided to put down a series of diamond drill-holes east of Steepbank River. Eighteen holes were drilled, over a linear distance of almost 2 miles, during the period August 14 to December 8, 1945.

LOCATION

The area explored extends along the top of the escarpment on the east side of Steepbank River. The most northerly hole was drilled at a point 2½ miles in a straight line from the mouth of the river, or 4 miles measured along the river course, and the others continued in a southeasterly direction. The drilling was done in the southeast quarter of section 29, the southwest quarter of section 28, and the north half of section 21, township 92, range 9, west of the 4th meridian.

TOPOGRAPHY

Steepbank River has cut a deep valley through the fairly level plain that extends eastward from Athabaska River. Adjacent to the area drilled, the river-level is some 250 feet below the elevation of the plain. The river meanders through the valley-bottom, which averages 1,000 feet in width, and the banks on both sides rise steeply to the plains above. The elevations of the escarpments on both sides of the river are about the same. There is a gradual rise in elevation on the upland plain to the east.

EXTENT OF DRILLING

The first hole drilled in this area, No. 115, showed 142 feet of bituminous sand averaging 12·2 per cent bitumen content, with a comparatively light overburden. This was very encouraging, but results of the next hole, No. 155, drilled 1,750 feet to the northwest were very poor. Drilling was, therefore, continued to the south and east of hole No. 115, holes being widely spaced at approximately 1,200 feet, to hole No. 163 in section 22, where, southeasterly, progress was stopped owing to thickness of overburden encountered. Subsequently, more closely spaced holes were put down to fill in sections where results from earlier holes were good.

ESTIMATES OF TONNAGE AND GRADE

From parallel sections drawn on the map (accompanying Volume III), through those of the eighteen holes that showed the best results, it was possible to outline two bodies of good grade sand, 2,400 feet apart, separated by a volume of low-grade sand. The main assumptions used in calculating tonnages were: (a) 15·5 cubic feet (0·574 cubic yard) of average overburden equals one ton; and (b) 16·0 cubic feet of bituminous sand equals one ton.

West Body

Estimates of the west body were based on results from eleven holes, through which it was possible to draw six sections. On each section there were two holes spaced on an average of 700 feet apart. The estimates can, therefore, be considered as developed tonnage.

Estimates from Vertical Sections

Bituminous sand	38,000,000 tons
Grade	12·3 per cent
Overburden	21,100,000 tons
Ratio: bituminous sand to overburden	1·8 to 1
Area covered by estimates	92 acres

East Body

There were only three holes on which to base tonnage estimates in this section, and the results can be considered only as inferred tonnage. The quality, grade, and depth of the bituminous sand in each of these three holes were consistently good, however, and the assumption appears justified that closer spaced drilling here would develop a much larger tonnage of better than average grade.

Estimates from Vertical Sections

Bituminous sand	20,000,000 tons
Grade	13·5 per cent
Overburden	13,300,000 tons
Ratio: bituminous sand to overburden	1·5 to 1
Area covered by estimates	43 acres

East of Steepbank Area

Tonnage Estimates: 1946

	Bituminous sand, tons	Grade, per cent bitumen content	Overburden, tons	Ratio: bituminous sand to overburden	Acreage
West body	38,000,000 (Developed)	12·3	21,100,000	1·8 to 1	92
East body	20,000,000 (Inferred)	13·5	13,300,000	1·5 to 1	43
Total	58,000,000	12·7	34,400,000	1·68 to 1	135

NORTH OF STEEPBANK RIVER AREA

INTRODUCTION

From 1942 to 1945 extensive drilling of bituminous sands was carried out by the Dominion Government in the area immediately south of the junction of Steepbank and Athabaska Rivers, which is 22½ miles north of and downstream from Fort McMurray. On completion of this drilling program attention was given to the exploration of other areas where preliminary investigation had indicated the possible existence of substantial bodies of bituminous sands under light overburden. One of these was the area immediately north of Steepbank River. The occurrence of outcrops of bituminous sand on the Athabaska River escarpment, the comparative regularity of the escarpment, and the level nature of the upland plain to the east were favourable factors, and a reconnaissance program of four holes was initiated, provision being made for further drilling if results should justify extension of the program. The results obtained in the four holes, however, were not considered sufficient justification for further work in their immediate vicinity. The drilling was carried out by Boyles Brothers Drilling Company, under the supervision of a Mines and Geology Branch engineer, during the period July 12 to July 25, 1945.

LOCATION

The area explored extends along the Athabaska River escarpment from the northwest quarter of section 1, township 93, range 10, to the northeast quarter of section 11 in the same township, a distance of approximately 1 mile. The most southerly hole, R-3, is about 1½ miles north of the south of Steepbank River. Locations of the drill-holes are shown on the map accompanying Volume III of this report.

EXTENT OF DRILLING

The four holes, R-1, R-2, R-3, R-4, were all drilled from the top of the Athabaska escarpment, at approximately the same collar elevation and spaced from 1,600 to 2,000 feet apart. The total footage drilled was 547 feet. Holes R-2, R-3, and R-4 went to 121 feet, 116 feet, and 128 feet, respectively, but hole R-1 went to 182 feet before reaching the residual clay that overlies the Devonian limestone. Bituminous sand was cored in all holes, though the amount in hole R-3 was negligible; however, the presence of clay beds varying in thickness from a few inches up to 50 feet discouraged any idea of extending the drilling beyond the reconnaissance stage.

RESULTS

As was anticipated, the overburden in the area was found to be very light. On the other hand, the overall grade of the bituminous sand, as indicated by the drill-hole logs, is relatively low and the amount of interbedded clay is excessive.

HORSE RIVER RESERVE AREA

INTRODUCTION

In 1913 the Dominion Government commenced investigations of the bituminous sands of northern Alberta. Early in these investigations the quality of the exposures found along Horse River, near its junction with Athabaska River, had caused this area to be regarded as one of the most promising for development. The Dominion Government, therefore, having decided that certain bituminous sands areas should be reserved for the advantage of the National Parks of Canada, made reservation in 1915 of an area of 581 acres on Horse River. This area has become known as Horse River Reserve. In 1930, the Minister of the Interior entered into an agreement with Mr. Max W. Ball to mine the bituminous sands on 100 acres of the reserve. A subsequent agreement entered into between the Minister of Mines and Resources and Abasand Oils, Limited, assignees of Mr. Ball, leases to that company the mining rights on 100 acres of the reserve and provides that upon the performance of certain covenants the company may obtain a lease of the bituminous sands mining rights for the whole of the reserve.

In 1943, when the procuring of oil supplies for the necessities of the Second World War was a matter of grave concern, the Dominion Government decided to provide funds for remodelling and expanding the plant of Abasand Oils, Limited, on Horse River Reserve and for operation of the plant as an experimental or pilot plant to determine whether the mining and treatment of bituminous sands could be of assistance in meeting Canada's oil emergency. Under an agreement entered into with Abasand Oils, Limited, the properties and mining rights of that company were placed under the control of the Government.

In view of the Government's financing of the Abasand Oils' operation and the need for definite knowledge of the bituminous sand reserves available for immediate and future plant operations, it was decided that previous assumptions as to the volume and grade of bituminous sands on Horse River Reserve, based on test-pitting and other minor exploratory operations, should be checked by diamond drilling. Fortunately, during drilling operations conducted in 1943 in the Steepbank area north of Fort McMurray, a satisfactory method of core drilling, using diamond-drill equipment, had been developed.

On January 13, 1944, drilling commenced on Horse River Reserve under a contract with Boyles Brothers Drilling Co., Ltd., of Vancouver, and between that date and July 28, 1944, forty-eight vertical holes with a total footage of 6,601 feet were put down. The drilling was initially concerned with determining the tonnage and grade of bituminous sands in the pit area adjacent to the Abasand plant, and was later extended with a view to finding the most readily accessible deposits of good grade bituminous sands within reasonable distance of the plant. No attempt was made to determine the total volume or tonnage of bituminous sands lying within the boundaries of Horse River Reserve, and much of the reserve, particularly in the southern end, remains undrilled. Although the drilling gave indications that the unexplored sections may contain large tonnages of bituminous sands, the additional deposits would be composed of lower grade sands to some extent, and mining of these additional deposits would involve such thicknesses of overburden as to render them of no immediate interest.

LOCATION

The Horse River Reserve, as shown on the map accompanying Volume III of this report, comprises the north half of section 5 and the east half of section 8, less legal subdivision 16 and that part of legal subdivision 1 lying east of Horse

River, in township 89, range 9, west of the 4th meridian. The area of the reserve is approximately 581 acres. At its nearest point the reserve is about 1½ air miles southwest of the town of Fort McMurray, which is located at the junction of Clearwater and Athabaska Rivers. By road the plant of Abasand Oils, Limited, in the north end of the reserve, is about 3 miles from Fort McMurray, and about the same distance from Waterways, the terminus of the Northern Alberta Railways line from Edmonton.

TOPOGRAPHY

Horse River flows through Horse River Reserve in a deep trough-like valley and joins Athabaska River about half a mile north of the north boundary of the reserve. A narrow ridge, the top of which lies approximately along the east boundary of the reserve and 300 feet above Horse River, separates Horse River and Hangingstone River Valleys. To the west of Horse River the side of the valley rises some 350 feet in one-quarter to one-half mile to the edge of tableland. The stream that eroded Horse River Valley had an effective erosive force considerably less than that of Athabaska River, which cut completely through the bituminous sands and into underlying Devonian limestone: consequently, the floor of Horse River Valley is mostly made up of bituminous sand. The Horse River of today is a relatively small, meandering stream and in receding to its present channel has left a series of residual areas of bituminous sand. It was primarily to explore these residual areas, containing good grade bituminous sands under relatively light overburden, that the drilling program was carried out.

EXTENT OF DRILLING

Most of the forty-eight holes drilled were located within Horse River Reserve, a few being located just outside its boundaries. In general, drilling was restricted to the valley-bottom and the lower parts of adjacent slopes. However, five holes were put down on the summit of the east ridge between Horse and Hangingstone Rivers, where outcrops indicated the possible existence of a good body of bituminous sand under light overburden, but results from all five holes showed prohibitive overburden and very low-grade bituminous sands with a large amount of clay.

ESTIMATES OF TONNAGES AND GRADE

On the map accompanying Volume III of this report the valley-bottom areas explored by drilling have been indicated by the letters "A", "B", "C", "D", "E", "F", and "M". In each of these areas sufficient drilling has been completed to provide information from which reliable estimates could be made of the grade (bitumen content) and tonnages of the contained bituminous sands, and also of the overburden that would have to be stripped to accomplish mining of the sands. The main assumptions used in calculating tonnages were: (a) 15·5 cubic feet (0·574 cubic yard) of average overburden equals one ton; and (b) 16·0 cubic feet of bituminous sand equals one ton. Laboratory tests on core samples of varying bitumen content have indicated that bituminous sand in place has a specific gravity of approximately 2·0, equal to 125 pounds a cubic foot. The density of overburden was arrived at by estimating the proportionate amounts of clay and sand of which it is composed and making some allowance for natural moisture; this estimation led to the assumption that the weight of overburden in place is slightly greater than that of the bituminous sand.

Detailed descriptions of the areas and pertinent estimates follow; area "E", adjacent to the Abasand open pit, is placed first, and the others in order of their

north to south location. The estimates given relate to the parts of each area, shown in green on the map accompanying Volume III, that contain available good grade sands under comparatively light overburden.

Area "E"

Area "E" is immediately adjacent to the separation plant of Abasand Oils, Limited. From an open pit here all the sands treated to date in the successive periods of plant operation have been mined. Seven holes were put down to the east of the open pit, and an eighth hole on the flats to the southeast. The seven holes showed the average thickness of bituminous sand to be 36 feet, underlain by a clay bed averaging 22 feet in thickness. The eighth hole, showing only 10 feet of bituminous sand, indicated that a good thickness of sand is not to be expected in that direction. The tonnage given in the estimates is exclusive of material remaining in the open pit.

Estimates from Vertical Sections

Bituminous sand	330,000 tons
Grade	16·3 per cent
Overburden	98,000 tons
Ratio: bituminous sand to overburden	1·4 to 1
Area covered by estimates	3·30 acres

Area "F"

Area "F" adjoins the north boundary of Horse River Reserve and is directly west of the Abasand plant area. On the opposite side of Horse River from the plant, a prominent exposure of bituminous sand rises steeply from the water's edge to a height of about 75 feet. Six holes were drilled in this area, all of which showed good grade bituminous sand; in four of them, however, the good grade sand was found to be overlain by a prohibitive thickness of overburden and low-grade sand. Tonnage estimates, therefore, have been calculated only for that part of the area which is on the slopes of the escarpment, where the sand-to-overburden ratio would appear to be practicable for mining. The available tonnage is further limited by the north boundary of the reserve.

Estimates from Vertical Sections

Bituminous sand	245,000 tons
Grade	15·5 per cent
Overburden	178,000 tons
Ratio: bituminous sand to overburden	1·4 to 1
Area covered by estimates	1·65 acres

Area "D"

Area "D" lies on the opposite side of Horse River immediately south of the Abasand plant area. It merges on the south with area "M", the boundary being set at the section where the overburden begins to exceed the assumed limits of practicability for mining. This factor was also considered in limiting the westerly extent of the area for tonnage computation purposes, as shown on the map accompanying Volume III of this report. Area "D" contains a considerable tonnage of good grade sand, much of which is covered by relatively light

overburden. It is close to the separation plant, and adjacent flat land lying within a bend of the river affords a convenient disposal area for overburden.

Estimates from Vertical Sections

Bituminous sand	1,535,000 tons
Grade	15·8 per cent
Overburden	1,102,000 tons
Ratio: bituminous sand to overburden	1·4 to 1
Area covered by estimates	10·19 acres

Area "M"

Drilling in area "M" has shown some good grade sand along the lower slopes of the valley, but the overburden is so heavy that no estimate of tonnage is justified.

Area "C"

Area "C" is situated in a narrow tongue of land enclosed by a meander of Horse River. Three holes were drilled here, results of which indicated a small tonnage of good grade bituminous sand.

Estimates from Vertical Sections

Bituminous sand	240,000 tons
Grade	15·5 per cent
Overburden	207,000 tons
Ratio: bituminous sand to overburden	1·2 to 1
Area covered by estimates	5·97 acres

Area "B"

From the standpoint of indicated tonnage, area "B" is the most important in the reserve. It is a narrow neck of steeply rising land between two elbows of Horse River: on each side of this neck, along the river banks, there are prominent exposures of bituminous sand. Six holes were drilled in this area, results of four of which enter into the computation of tonnage estimates.

Estimates from Vertical Sections

Bituminous sand	2,100,000 tons
Grade	13·6 per cent
Overburden	1,348,000 tons
Ratio: bituminous sand to overburden	1·7 to 1
Area covered by estimates	11·39 acres

Area "A"

This is the most southerly area drilled in the reserve. It resembles area "B" in topography, but it is considerably smaller in extent. Tonnage estimates were based on results of two drill-holes.

Estimates from Vertical Sections

Bituminous sand	802,000 tons
Grade	13·0 per cent
Overburden	415,000 tons
Ratio: bituminous sand to overburden	1·9 to 1
Area covered by estimates	4·13 acres

Summary

The following tabulation of the estimates given above shows the total tonnages for the six areas and overall averages of grade (bitumen content) and of bituminous-sand-to-overburden ratio.

Area	Bituminous sand, tons	Grade, per cent bitumen content	Overburden, tons	Ratio: bit. sand to overburden	Acreage
"A"	802,000	13·0	415,000	1·9 to 1	4·13
"B"	2,100,000	13·6	1,348,000	1·7 to 1	11·39
"C"	240,000	15·5	207,000	1·2 to 1	5·97
"D"	1,535,000	15·8	1,102,000	1·4 to 1	10·19
"E"	330,000	16·3	98,000	3·4 to 1	3·30
"F"	245,000	15·5	178,000	1·4 to 1	1·65
TOTAL	5,252,000	14·5	3,348,000	1·6 to 1	36·63

MUSKEG RIVER AREA

INTRODUCTION

Exploratory drilling of the bituminous sands of northern Alberta was undertaken by the Mines and Geology Branch of the Department of Mines and Resources in 1942. At that time, the main object of the war project was to develop quickly a large tonnage of sand with an average bitumen content sufficiently high that its utilization might be practicable, using known methods of separating the bitumen. The drilling during the years 1942 to 1945 was successful to the extent that a large tonnage of sands averaging 12 to 13 per cent bitumen content was developed in the Steepbank River area. It was not known whether this material was of as high a grade as could be expected to occur in quantity.

Following completion of the Steepbank program, it was decided to explore the possibilities in other areas along Athabaska River where surface reconnaissance work in earlier years had indicated the presence of bodies of good grade sand. The bituminous sands, considered in their entire extent, cover a large territory. Experience gained during 3 years of drilling, however, had shown that in many areas where favourable surface indications were present factors existed, such as too great a depth of overburden, too much clay, or too low a bitumen content, that precluded any possibility of commercial exploitation. Because of this, it was decided that in searching for other bodies of good grade sand it would be advisable to proceed with a program of reconnaissance drilling, putting down widely spaced holes. If any of these holes should indicate a favourable cross-section, development drilling with holes more closely spaced could be carried out later.

LOCATION

One of the areas chosen for reconnaissance drilling lies along the east bank of Athabaska River in townships 94 and 95, range 10, and township 96, range 11, west of the 4th meridian. The southerly end of the area drilled lies 3 miles north of the mouth of Muskeg River, or 35 miles north of Fort McMurray. Drilling started on August 10, 1945, and by July 24, 1946, fifty-three holes aggregating 8,452 feet of drilling had been put down in a 15-mile belt extending from section 30, township 94, range 10 to section 30, township 96, range 11, along the east bank of the Athabaska. Most of the holes were drilled less than 1 mile from the river, though three of them were located nearly 1½ miles inland. The following sections are those within which drilling was done:

Sections	30, 31	Township	94;	W. of	4th	Mer.
"	5, 8, 9, 17, 19, 20, 30, 31	"	95;	"	"	"
"	1, 12, 13, 24, 30	"	96;	"	"	"

TOPOGRAPHY

Along the southern half of the area under consideration, the escarpment rises steeply from the east shoreline of the Athabaska to a height of 140 feet. Farther north, the rise is gradual until the plateau is reached. This plateau is generally flat, with some swamp and muskeg. There are no deep valleys extending eastward from the river as occur in the vicinity of Steepbank River, some 15 miles to the south.

EXTENT OF DRILLING

Drilling commenced in section 31, township 94, and the first seven holes were drilled southerly at intervals of one-quarter mile along the north-south centre line of sections 31 and 30. The results from all these holes were very poor and drilling in this direction was discontinued.

The drill was then moved to section 8, township 95, where holes M-8 to M-17 inclusive were drilled at a spacing of from 1,400 to 2,000 feet. Results in this locality proved more encouraging especially those of hole M-8 which indicated a bitumen concentration at three horizons. Consequently, a pattern of more closely spaced holes was decided, to complete cross-sections of the earlier drilling. Holes M-18 to M-25, supplementary to the others, were drilled so that the distances between holes was from 700 to 900 feet. Holes M-26, M-27, and M-28 were located farther to the east, for additional information on the limestone contour.

Reconnaissance drilling was continued in a northerly direction with holes located arbitrarily at quarter-section corners. Holes M-29 to M-54, inclusive except for M-53, which was not drilled, were put down in this manner. The last and most northerly hole drilled, M-54, was located at the west quarter of section 30.

RESULTS

As stated earlier, all the drilling in this area was considered as reconnaissance work except in section 8. In this locality, results from widely spaced holes appeared to justify closer drilling. Twenty-one holes in all were drilled here, through which five sections were drawn. When the results from these holes were considered in the light of the graphical sections, however, it was found impossible to correlate bands of good grade sand in one hole with those in another. Though some holes contained sections of bituminous sand of a very good grade, these were overlain or separated by bands of clay to such an extent that any attempt to form an estimate of tonnage or grade would be useless.

The drilling in the northern part of this area, where holes were put down at quarter-section corners, was unproductive except for four holes: M-45, M-46, M-47, and M-48, in sections 1 and 12, township 96, range 11. Results from these four holes, drilled at half-mile spacing and covering $1\frac{1}{2}$ miles of territory, were good enough as regards both grade and overburden ratio, to indicate the possibility that a considerable tonnage of good grade sand might be developed through further drilling.

CONCLUSIONS

Results from the test drilling of this 15-mile stretch of bituminous sands along the Athabaska in the vicinity of Muskeg River have demonstrated that this area, with the exception of that part covered by reconnaissance holes M-45 to M-48, can be eliminated from consideration as a potential economic source of bitumen. Formerly, superficial examination had indicated that there possibly would be a large tonnage of good grade sand here. There are several other similar areas along the Athabaska that have been assumed to contain large tonnages of good grade bituminous sand, but until the soundness of this assumption has been proved by diamond drilling, the total potential of the Athabaska bituminous sands, often expressed in millions of barrels of oil, remains questionable. For this reason it is considered that the comparatively negative results of the drilling covered in this report are an important contribution to the forming of a true picture of the bituminous sands as an economic resource.

MILDRED-RUTH LAKES AREA

INTRODUCTION

From the middle of 1943 to the middle of 1946, diamond drilling of selected bituminous sand areas of northern Alberta was carried on continuously. This work, which followed some reconnaissance drilling in Wheeler Island and Steepbank River areas performed in 1942 by The Consolidated Mining and Smelting Company of Canada for the Dominion Government, was done under the direction of the Mines and Geology Branch of the Department of Mines and Resources. The drilling could be described as being in three stages: reconnaissance, exploration, and development. The spacing of holes was determined by immediate results in any given locality. By the middle of 1946, five areas had been drilled with varying results and conclusions as to the possibilities in each area. These have been dealt with in separate reports under the following headings:

1. Steepbank River Area
2. Horse River Area
3. East of Steepbank River
4. North of Steepbank River
5. Muskeg River Area

When plans for the 1946 drilling program were under consideration, the Mildred-Ruth Lakes area was also considered a favourable location for reconnaissance drilling. A series of widely spaced holes was laid out and drilling in this area was commenced in March 1946 and continued until all drilling of the bituminous sands was discontinued in January 1947.

LOCATION

The centre of the Mildred-Ruth Lakes area lies some 22 miles north of Fort McMurray, along the west bank of Athabaska River, opposite the mouth of Steepbank River and just below Tar Island. The area drilled is 8 miles in length and averages 2 miles in width. This area lies on the opposite side of the Athabaska and about 1 mile farther north than the main Steepbank area that was drilled in 1942-45.

TOPOGRAPHY

The area takes its name from the two shallow lakes, Mildred and Ruth, on the upper plateau, lying approximately 4 miles apart and 1½ to 3 miles west of Athabaska River. The central or main area drilled lies between the two lakes and 1½ miles from the river.

The top of the escarpment, which roughly parallels the river bank, is about 1 mile inland. At this point the plain above the escarpment is relatively flat, at an elevation of 1,000 to 1,080 feet, and consists of boulders and sand ridges and muskeg areas. The slope from the top of the escarpment to the river is quite steep, falling 200 feet in less than half a mile, then becoming fairly level ground at 800 feet. The elevation of the river here is approximately 780 feet above sea-level.

EXTENT OF DRILLING

When drilling commenced in March 1946, very little was known about this area. It was favourably regarded because of its proximity to the Steepbank area where previous drilling had disclosed a large tonnage of good grade sands, and because exposures along the escarpment revealed that relatively shallow overburden could be expected.

A series of widely spaced reconnaissance holes was planned, beginning south of the southern end of Ruth Lake and extending northward for some 8 miles to a point 1 mile beyond the north end of Mildred Lake. On the map accompanying Volume III, showing the hole locations, the numbering of the earlier holes indicates the order in which they were drilled.

The first four holes, drilled east and north of Ruth Lake, gave very poor results, but hole B-5 showed 133 feet of good grade sand under moderate overburden and was the first indication that the area might contain a valuable deposit of bituminous sands. The proposed reconnaissance holes, up to B-14, were drilled in the numerical order at locations planned. This completed the reconnaissance stage of drilling along the 8-mile belt.

Of this preliminary drilling, holes B-5 and B-13 gave the best results. It was, therefore, decided to concentrate exploration drilling within sections 27, 28, 33, and 34, in the vicinity of these holes. A pattern of holes, numbered B-15 to B-32, was laid out at quarter-section corners and exploration drilling of this definite area was continued.

Hole B-15 gave extraordinary results, for it encountered concentrations of bitumen in five beds or pockets ranging in thickness from 4 to 21 feet with an aggregate thickness of 57 feet. This was the first hole in which bitumen concentration in such quantity had been encountered in the core drilling of the bituminous sands. The next hole to contain bitumen concentrations was B-17, drilled northeast across a quarter-section from B-15. In B-17, there are eight beds or pockets aggregating 48 feet in thickness, with the thickest and thinnest being 12 and 3 feet respectively. Since these were the first two holes to contain bitumen concentration, and since the elevation of the top of the upper bed of bitumen in each case is almost the same (887 and 888 feet) it was thought at that time that the bitumen beds would be fairly uniform and would show some relationship from hole to hole. When drilling had progressed up to the completion of hole B-32, eight holes had been found to contain bitumen concentrations in varying amounts. There was, however, no apparent relationship or continuity of the bitumen beds from hole to hole.

Up to this time, all the holes had been drilled at a minimum spacing of one-half mile. It was thought that closer drilling might provide some evidence of the lateral extent of the bitumen beds encountered in each hole. Therefore, a further series of holes was planned for this area, numbered B-33 to B-64, located at one-quarter- and one-eighth-mile intervals and interspaced among the holes already drilled. Of these thirty-two holes, nineteen encountered bitumen concentration varying in amount from two thin layers aggregating 8 inches in hole B-41 to an aggregate thickness of 30 feet 9 inches in hole B-53.

The drilling results in the Mildred-Ruth Lakes area had now indicated that there existed here a large body of good grade bituminous sand, further enriched by beds or pockets of bitumen concentrations. Possibilities that this area extended farther south still existed. Consequently, nine more holes, located at quarter-section corners and numbered B-65 to B-73, were drilled southeast of the main area. The results of these fulfilled expectations and greatly increased the potential tonnage. It was also found that as drilling progressed southerly, the ratio of bituminous sands to overburden became greater.

When drilling operations were completed in the Mildred-Ruth Lakes area in January 1947, seventy-three holes had been drilled over an area that was roughly 8 miles long and 2 miles wide. Of these, forty-eight holes were concentrated in an area of $2\frac{1}{2}$ square miles. The southerly nine widely spaced holes

increased the favourable area of bituminous sands to 4½ square miles. The remaining sixteen reconnaissance holes gave poor results and eliminated the territory to the north and west of the developed area.

METHOD USED FOR DETERMINING GRADE AND TONNAGE

The various steps taken to obtain an estimate of the developed tonnage of better grade bituminous sands (close drilling) and of inferred tonnage (widely spaced drilling) are summarized below:

(a) The depths of bituminous sands of holes comprising each section were plotted to scale on the section sheet.

(b) The average assay of the area between two holes on the section was calculated by multiplying the depth of bituminous sands by its grade for each hole and dividing the sum for both holes by the sum of the depths of bituminous sands.

(c) The assay of area to the right or left of each end hole in a section was taken as the average assay of that hole.

(d) The areas were obtained by means of a planimeter. (The location of the hole is the left line of each hole as shown on the section sheets).

(e) The average assay of the bituminous sands in the whole section was obtained by adding the areas multiplied by their respective assays and dividing by the sum of the areas.

(f) The volume of bituminous sands between two sections was obtained by adding the areas of each section, multiplying by the distance between sections, and dividing by two.

(g) The average assay of the bituminous sands contained between two sections was obtained by multiplying the area of each section by its assay, adding the results, and dividing by the sum of the areas.

(h) The tonnage of bituminous sands was obtained by dividing the volume in cubic feet obtained in *(f)* by 16; for overburden the factor 15·5 was used. The following were the assumptions:

1 ton overburden = 15·5 cubic feet

1 ton of bituminous sand = 16·0 cubic feet

All assays of bitumen concentrations were arbitrarily reduced to 18 per cent bitumen content in calculating the average assay of a hole.

ESTIMATES OF GRADE AND TONNAGE

The *developed* tonnage of bituminous sands amounts to 587,824,000 tons averaging 13·4 per cent bitumen. The overburden on this tonnage is 261,067,000 tons, giving a ratio of bituminous sands to overburden of 2·3 to 1.

The *inferred* tonnage of bituminous sands amounts to 574,841,000 tons averaging 13·8 per cent bitumen. The overburden on this tonnage is 183,922,000 tons, giving a ratio of bituminous sand to overburden of 3·1 to 1.

The total developed and inferred tonnage of the Mildred-Ruth Lakes area is, therefore, 1,162,665,000 tons of bituminous sands averaging 13·6 per cent bitumen. The total overburden covering this bituminous sands area amounts to 444,989,000 tons, giving a total ratio of bituminous sands to overburden of 2·6 to 1.

CONCLUSIONS

(a) A large body of more than a billion tons of bituminous sands has been indicated, lying under moderate overburden. The estimates indicate a bitumen content in this deposit of better grade sands amounting to approximately 900,000,000 barrels, or sufficient, at 90 per cent recovery, to operate a 20,000-barrel per day plant for more than 100 years. When it is considered that appreciable thicknesses of bitumen concentration were found in many holes and that high assays of such sections were reduced to 18 per cent bitumen content for calculations of grade, it would appear that the estimate is conservative. Sections of the area should be found to have much higher average bitumen content than the estimate.

(b) The southerly limit of good depths of better grade bituminous sands, lying under moderate overburden, does not appear to have been reached by the drilling.

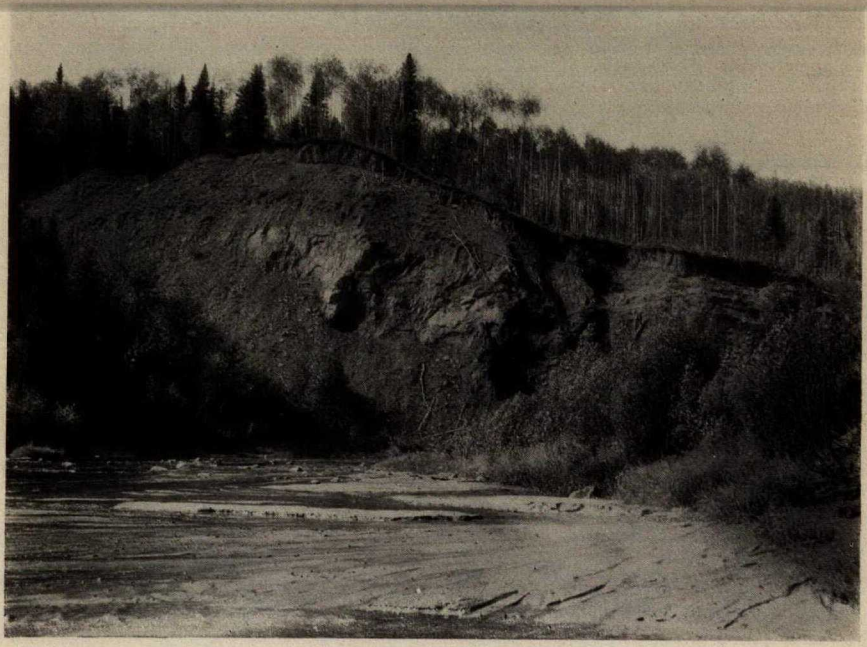
PLATE I

A. Blasting bituminous sand at plant of Abasand Oils, Limited, McMurray, Alberta.

B. Abasand plant, McMurray, Alberta.

PLATE II

A. Drilling in the Steepbank area, Alberta.



B. Outcrop of bituminous sand.

PLATE III

A. Winter transportation in the Steepbank area, Alberta.

B. River transportation in the Steepbank area, Alberta.

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Canada, mines branch reports.
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