RESEARCH COUNCIL OF ALBERTA

GEOLOGICAL DIVISION

MEMOIR 1

GEOLOGY OF THE McMURRAY FORMATION

PART III

GENERAL GEOLOGY OF THE McMURRAY AREA

by

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FOREWORD

The McMurray oil sand is one of the largest in-place reserves of oil in North America and as such it has received a great deal of attention from geologists and engineers. As it is essentially an "exhumed" oil field, it affords an excellent opportunity for geologists to examine an oil reservoir in outcrop.

During the summers of 1953, 1954 and 1955 a Research Council geological party was sent into the McMurray area with instructions to map the geology. This work—which was carried out by G. A. Collins—resulted in the compilation of a geologic map on a scale of four miles to one inch. In 1957 field work on the McMurray formation was resumed by M. A. Carrigy, the author of this report, who examined outcrops on the Clearwater and Athabasca Rivers from a boat and then proceeded to the tributary streams by helicopter to make a reconnaissance of pertinent outcrops. The section on the stratigraphy of the Beaverhill Lake formation was written by R. Green.

This report forms the third part of a series on the geology of the McMurray formation. The first two parts were published as Report 72 of the Research Council of Alberta and are entitled, "Foraminifera of the upper McMurray and basal Clearwater formations" and "Heavy minerals of the McMurray formation".

C. P. Gravenor,

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ILLUSTRATIONS

TABLES

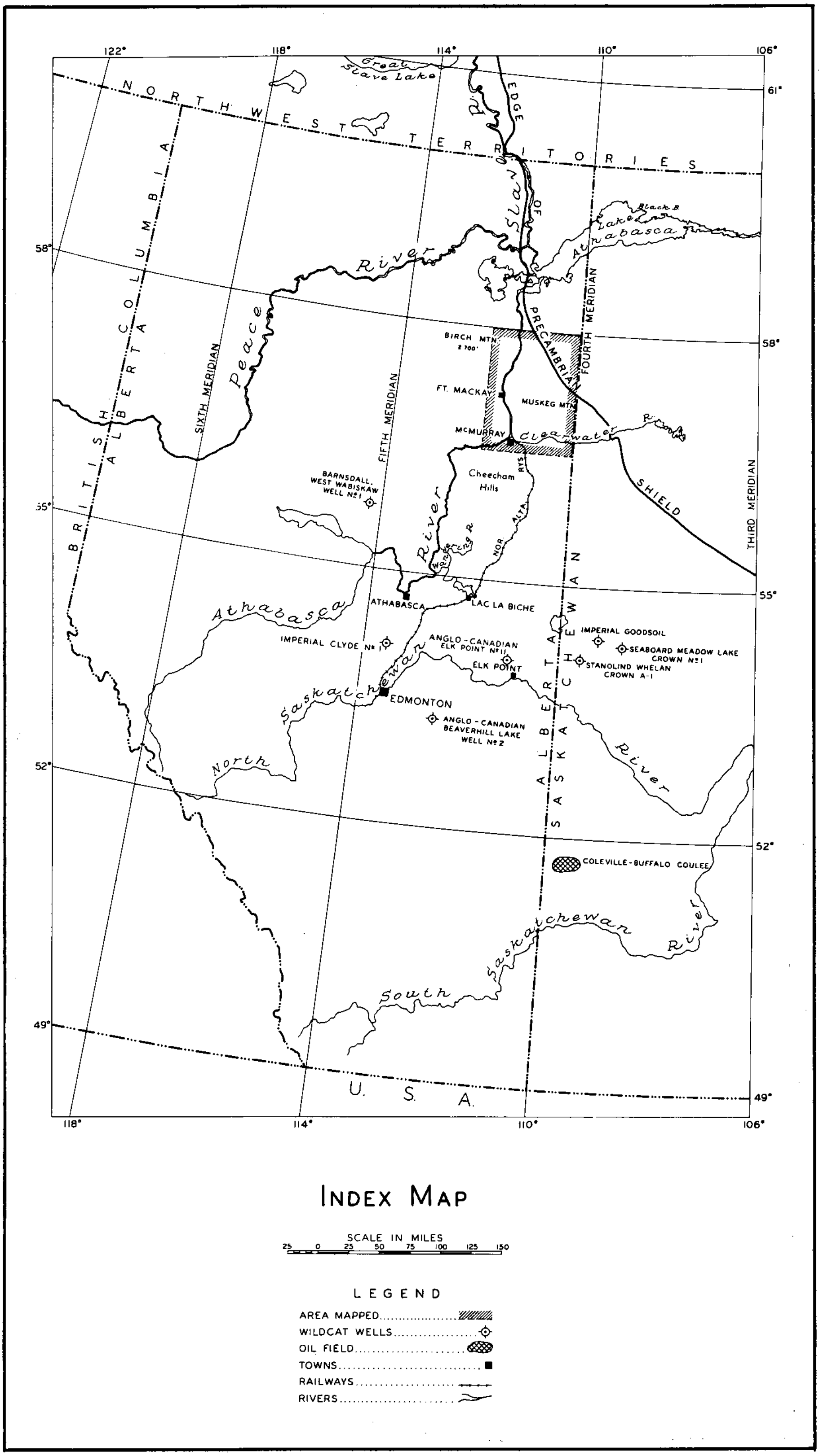

FIGURE 1. Index Map

CHAPTER I

Introduction

LOCATION AND ACCESS

This report describes the geology of an area located in the northeastern quarter of the Province of Alberta between latitudes 56 degrees 30 minutes and 58 degrees north and longitudes 110 degrees and 112 degrees west (Fig. 1 and map 26). In this area the Mesozoic strata which outcrop in the Athabasca River Valley hold the world's greatest known reserve of oil and the underlying Paleozoic strata contain notable deposits of halite and gypsum at moderate depth. Thus a description of the geology of the rocks which contain these valuable resources has considerable interest from the economic point of view.

Inferences about the geology of the McMurray area have been drawn from the information obtained from wildcat oil wells drilled in a contiguous area bounded by latitudes 55 and 59 degrees north and longitudes 110 and 114 degrees west. The literature on the regional correlation of the post-Precambrian strata in the area is reviewed and some modifications of the stratigraphic nomenclature are suggested.

The Town of McMurray can be reached by rail or air from the City of Edmonton. The rail service is provided by the Northern Alberta Railways Company and the air service by Pacific Western Airlines Limited.

PREVIOUS GEOLOGICAL WORK IN THE AREA

The early exploration of the Canadian north country was carried out by men who had a sound practical knowledge of natural science and they made many accurate observations of interest to subsequent workers in geology (and biology). However, the first writers to publish material of more than general interest to geologists were Meek (1868) and Macoun (1877). The first professional geologist to make the area the subject of a scientific report was Robert Bell of the Geological and Natural History Survey of Canada (Bell, 1884). His successor in the field was another officer of the Geological Survey, R. G. McConnell, whose report on the geology is the most comprehensive published until now (McConnell, 1893a). Both of these men were impressed by the size of the oil-sand deposits and were aware of their economic potential.

Federal Government activity in the area since the year 1900 has been the responsibility of the Mines Branch — the most notable field worker during this period was S. C. Ells whose topographic maps and carefully compiled reports have provided a reliable foundation for future economic development (Ells, 1914, 1926, 1932, 1936). Between the years 1942 and 1947 many wells were drilled through the oil sands to obtain reliable information on the subsurface extent of the deposits for the Federal Government. Most of this drilling was done in ground adjacent to oil-sand outcrops close to the Athabasca River. The results of this operation were presented in a Canada Mines Branch Report (Drilling and sampling of bituminous sands of northern Alberta, 1949, 3 vols.). A geological interpretation of the results of this drilling in the area most favorable for commercial development was made by Hume (1947).

K. A. Clark of the Research Council of Alberta has published much of geological and economic interest on the oil sands since the year 1921 (Clark, 1921, 1944, 1949, 1951, 1957b; Clark and Blair, 1927). Another contributor to geological knowledge of this area was J. A. Allan of the University of Alberta, whose work was concerned with the salt deposits of Paleozoic age beneath the Beaverhill Lake limestone at McMurray (Allan, 1920, 1924, 1929, 1938, 1943).

Many other geologists and engineers have visited the area and all have been impressed by the sight of the oil-cemented quartz sands of the McMurray formation. Much has been published by geologists regarding the source of this oil, but little agreement has been reached (see reports of the geological session of the Proceedings of the Athabasca Oil Sands Conference, 1951).

Since 1947 the exploration of the oil sands has been carried on by oil companies, hundreds of holes have been drilled through the oil sands but no official geological reports have been published.

MAPS AND SURVEYS

Topographic maps of the entire area are available on a scale of eight miles to one inch in the National Topographic Series. The four-mile sheets of this series, however, have been published only for the northern half of the area. Planimetric sheets on scales of one and two miles to the inch have been compiled from aerial photographs and are published by the Government of Alberta. An area of 1,260 square miles along the valley of the Athabasca River between townships 87 and 100 has been mapped on a scale of one-half mile to one inch with a contour interval of 20 feet by Ells (1926).

Under the survey system used in Alberta, the province is laid out in blocks six miles square. These subdivisions are known as townships. Each township is subdivided into 36 blocks one mile square called sections. Each section can be subdivided into 16 blocks, one quarter of a mile square, called legal subdivisions.

Townships are numbered consecutively from the southern border of the province northward, and at the northern boundary of every fourth township a base line is surveyed across the width of the province. The first base line coincides with the 49th parallel of latitude; other base lines are numbered consecutively in a northward direction. The location of a township relative to a meridian is called its range. Ranges are numbered consecutively in a westerly direction from the Fourth, Fifth and Sixth Meridians.

FIELD WORK

Geological field work in the McMurray area encounters two major problems. One is the presence of a blanket of glacial drift of Pleistocene age masking the underlying bedrock; the second is the occurrence of much

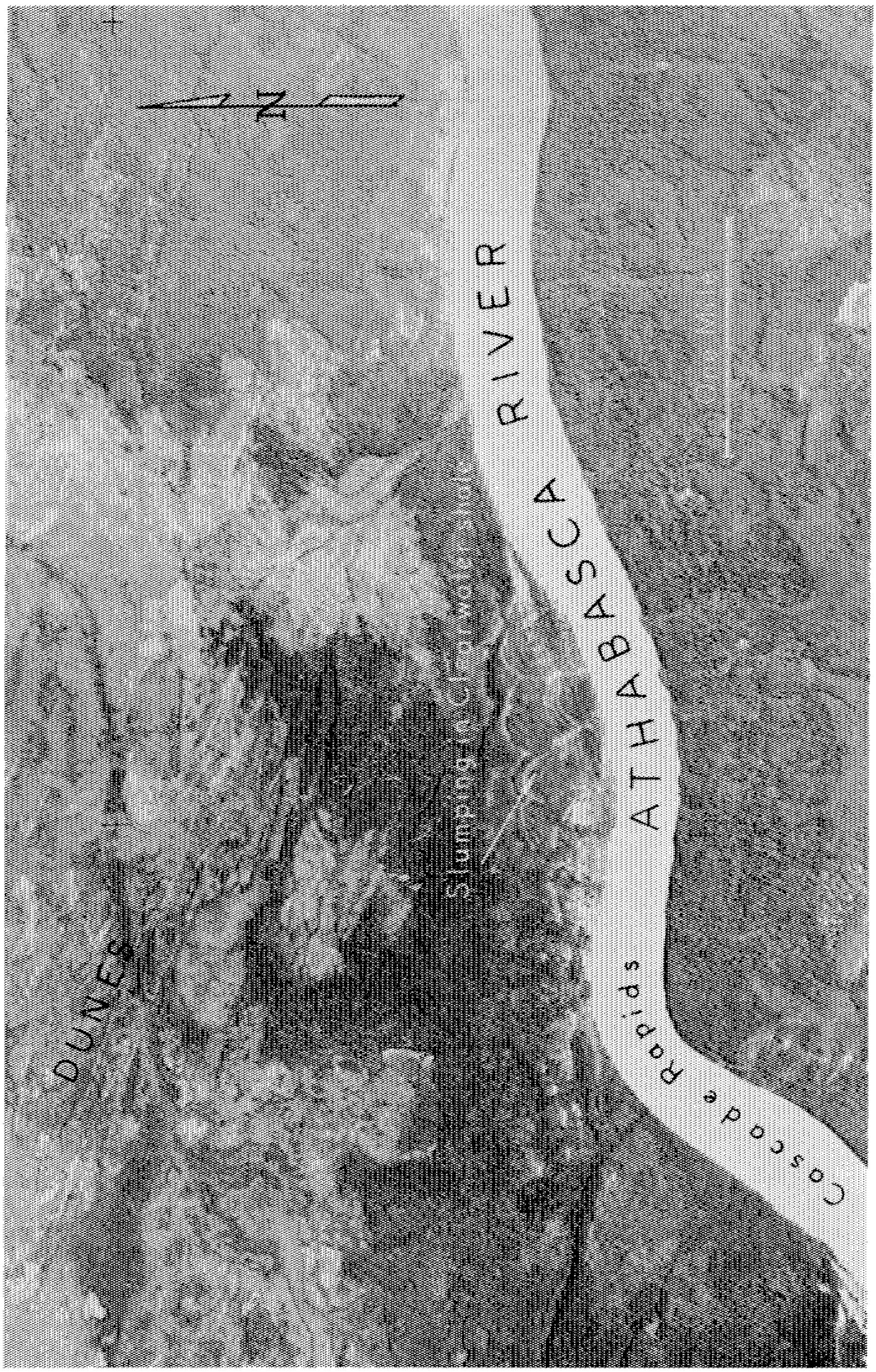

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PLATE 1. Vertical aerial photograph of the Athabasca River in Tp. 88, R. 11

large-scale sliding and slumping of the valley walls. Where whole cliffs have slumped, in many instances, the slip faces are not obvious from inspection on the ground. The slip planes, could, however, be detected on the vertical aerial photographs where they appear as a series of arcuate lines (plate 1). Slumping in the Clearwater River Valley has been extensive in the past but it is now largely stabilized by a thick cover of vegetation and thus outcrops of bedrock are scarce. Some useful exposures, however, were found in the valleys of the tributary streams — the Christina River, Cottonwood Creek*, Edwin Creek and High Hill River.

Another problem is the occurrence of mass flowage of the oil and sand down the cliff faces to the river level. Such flows commonly obscure the true contact between the Beaverhill Lake limestone and the McMurray formation.

GENERAL STRATIGRAPHY

The following table has been prepared to give a summary of the stratigraphy of the McMurray area.

Table 1: Stratigraphic Formations

System or Series	Formation or Group	Member	Lithology
Pleistocene and Recent			Glacial and post-glacial deposits of till, silt, and sand
	Erosional unconformity		
Cretaceous	La Biche		Shale
	Pelican		Sandstone
	Joli Fou		Shale
	Grand Rapids		Lithic sands and sandstones
	Clearwater		Shale and sandstone
		Wabiskaw	Sandstone, glauconitic
	McMurray	No. 3 (Upper)	Fine-grained quartz sands, oil-cemented, horizontally-bedded; fossiliferous (brackish-water fauna)
		No. 2 (Middle)	Medium-grained quartz sands, oil-cemented, lenticular beds of siltstone, shale, and coal; numerous beds of ironstone, cemented sandstone, vegetable remains, pyrite nodules
		No. 1 (Lower)	Conglomerate, detrital clays and shales, siltstone and coarse-grained sands; some wood, lignite, and coal

* This name is used locally to refer to the officially unnamed easterly-flowing creek which enters the Clearwater River at the 23rd base line in range 3.

System or Series	Group	Formation	Member	Lithology
		Erosional unconformity		
Devonian	Woodbend Group	Grosmont		Limestone reef
	Woodbend Group	Ireton		Shale and argillaceous limestone
	Woodbend Group	Duvernay		Brown limestone and shale
	Woodbend Group	Cooking Lake		Limestone
		Beaverhill Lake	Mildred	Grey-green and buff, argillaceous limestone
			Moberly	Grey-buff, mottled limestone
			Christina	Green-grey, calcareous shale
			Calumet	Clastic limestone
			Firebag	Argillaceous limestone
		Paraconformity		
		Slave Point equivalent		Buff-brown limestone and dolomite
		Paraconformity		
		Dawson Bay equivalent		Reddish siltstone with interbeds of dolomite and anhydrite
	Elk Point Group	Prairie evaporite		Halite, anhydrite, gypsum, and dolomite
	Elk Point Group	Methy (generally includes Elm Point equivalent)		Buff dolomite, reefal, argillaceous; and evaporitic and fossiliferous limestone
	Elk Point Group	Ashern equivalent		Green dolomitic claystone, and beds of anhydrite
		Paraconformity?		
		Meadow Lake equivalent		Red claystone, siltstone, and sandstones; arkose at base
		Erosional unconformity		
Paleozoic or Precambrian		Athabasca		Orthoquartzite
		Erosional unconformity		
Precambrian				Metasedimentary rocks intruded by granites and cut by diabase dykes

ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance given in the preparation of this report by the following people: G. A. Collins, who was in the field during the summers of 1953, 1954, 1955, compiled a geological map of the area and left valuable field notes and specimens; A. G. Swan, V. M. Sweetnam, A. W. Aunger, G. Archibald, F. Parkinson, R. Reeve, and R. N. Farvolden, all of whom assisted Collins in the field; Dr. K. A. Clark, Consultant to the Research Council, for his helpful discussion of the many problems encountered during this study; L. A. Bayrock, C. L. Bell, and R. Jull, who assisted the writer in the field; J. R. Pow, Chief Geologist, and M. Fuglem, Geologist, of the Oil and Gas Conservation Board, Calgary, who have been helpful in providing advice and assistance with this work; Dr. L. M. Clark of Pacific Petroleums Limited, Calgary, who made available copies of the Bear Oil Company well history logs; the Mobil Oil Company of Canada Limited who provided the core from Socony Vacuum Hole No. 27 which has now been set up as a subsurface type section for the McMurray formation.

Shell Oil Company of Canada, Limited, and Bailey Selburn Oil and Gas Company Limited supplied information regarding the location of some of the tracks and trails marked on map 26.

CHAPTER II

Geography

PHYSICAL GEOGRAPHY

Topography

Within the boundaries of the McMurray area there are elements of two of the major physiographic regions of North America: the Interior Plains and the Canadian Shield. The boundary between these two regions crosses the eastern border at 57 degrees 20 minutes north latitude and the northern border at 111 degrees west longitude. The Canadian Shield is underlain by rocks of Precambrian age and is found northeast of the boundary. The Interior Plains cover the remaining area and are underlain by rocks of Paleozoic and Mesozoic age. On the Plains two distinct surfaces can be distinguished; the lower or Second Prairie Level of Saskatchewan and Manitoba covers most of the area and is less than 1,000 feet in elevation. This surface slopes northward and gradually merges into the Canadian Shield in the vicinity of Lake Athabasca. Standing about 1,000 feet above this plain and joined to it by escarpments of moderate slope are the residuals of the High Plains of Alberta—Birch Mountain, Muskeg Mountain and Cheecham Hills. Incised into the Second Prairie Level Plain is the northerly-flowing drainage system of the lower Athabasca River.

The maximum relief in the drainage area of the lower Athabasca River is 2,000 feet. The minimum elevation of 699 feet is found in the north where the Athabasca River enters Lake Athabasca (Fig. 2). The maximum elevation of 2,700 feet occurs on Birch Mountain. The second order relief is provided by features formed by glacial erosion and deposition. The many shallow depressions thus formed are now lakes or muskeg.

Drainage

In Tp. 87, R. 17* the northward-flowing Athabasca River makes a right angle turn and flows eastward as far as McMurray where it is joined by a major tributary from the east, the Clearwater River. From McMurray it once again follows a northerly course through the McMurray area to Lake Athabasca. The tributaries of the Athabasca and Clearwater Rivers have their headwaters in the highland areas previously mentioned. Muskeg Mountain in the east gives rise to the southerly-flowing tributaries of the Clearwater River including the High Hill River, and the westerly-flowing tributaries of the Athabasca River—Steepbank and Muskeg Rivers. The northerly-flowing tributaries of the Athabasca and Clearwater Rivers—Horse, Hangingstone, and Christina Rivers—originate in the Cheecham Hills. The easterly-flowing tributaries of the Athabasca River—MacKay, Ells, Tar, Calumet, Pierre, and Eymundson Rivers—have their headwaters

*Unless otherwise stated, all range locations are west of the Fourth Meridian.

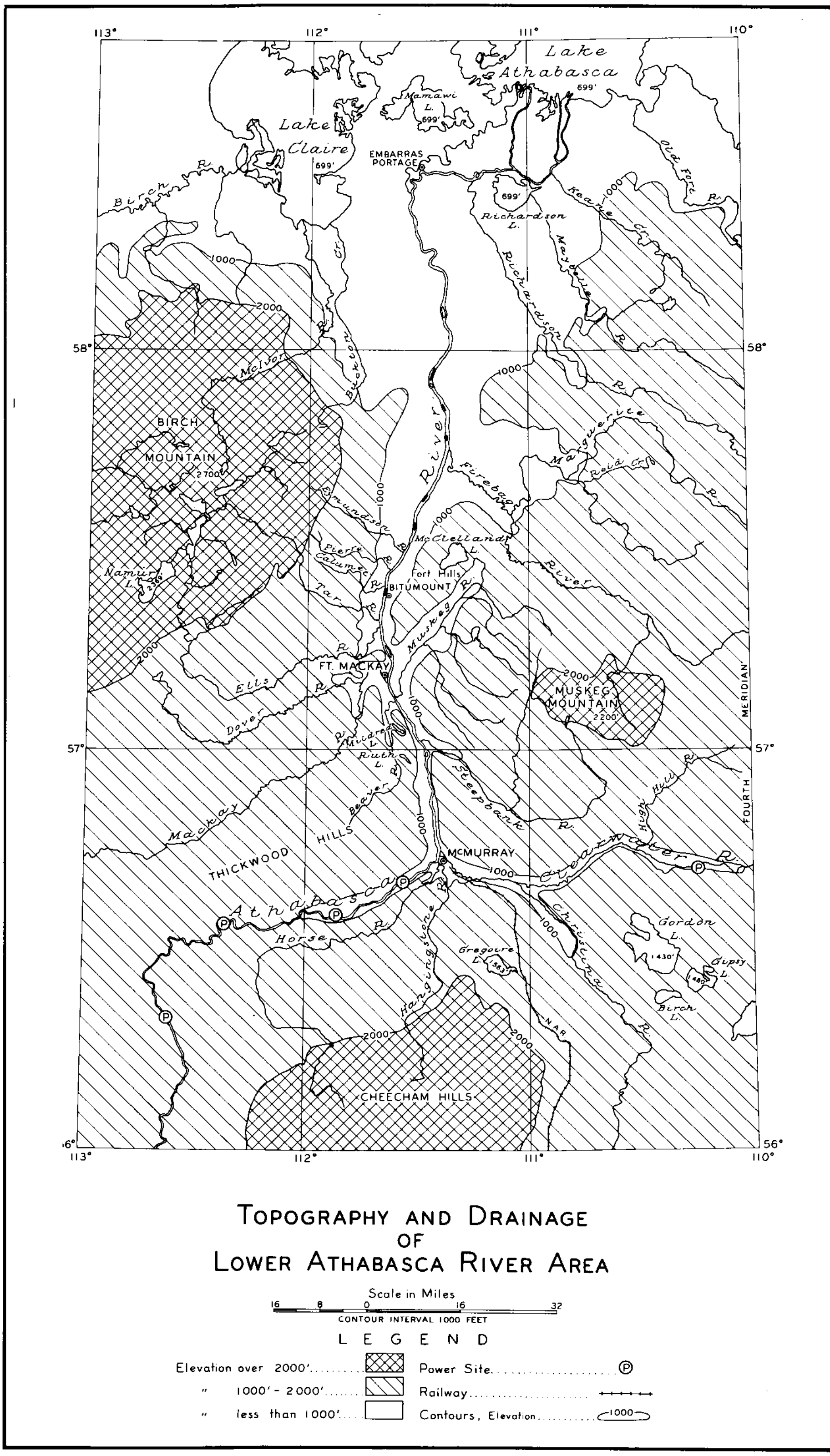


FIGURE 2. Topography and Drainage of Lower Athabasca River Area

in Birch Mountain. The Beaver River rises in the high ground south of Birch Mountain known as the Thickwood Hills. The Clearwater, Firebag, Marguerite, and Richardson Rivers flow into Alberta from Saskatchewan. This drainage system has been incised into the upland plain and the rivers now occupy deep trench-like valleys.

The major valley system of the area has a broad U-shaped cross-section and straight parallel walls free of spurs. At McMurray it is one mile wide and 250 feet deep. It runs westward from the Saskatchewan border along the 23rd base line and is occupied by the Clearwater River as far as McMurray where it turns northward. This north-trending section is occupied by the Athabasca River which breaks into the valley at McMurray (Fig. 3). The tributary stream valleys are V-shaped and river terraces are narrow and discontinuous.

Many of the names given geographic features by the early explorers and settlers in the McMurray area have been found to be unsatisfactory because of duplication in other parts of Alberta. Therefore, the Canadian Board on Geographical Names has had to revise many of the names for rivers which have appeared in the older publications (see table 2).

Table 2: Names of Rivers in the Lower Athabasca Drainage System

Approved name	Name used in previous publications
Athabasca River	La Biche, Elk, Athabaska
Clearwater River	Pelican, Swan, Clear Water
Christina River	Pembina River
Horse River	Horse-trail Creek
Steepbank River	Steep Bank River, Dugout Creek
MacKay River	Red River, Little Red River
Ells River	Moose River
Calumet Creek	Wolf Creek
Marguerite River	Cree River
Richardson River	Jackfish River

Climate

The climate of the McMurray area is similar in almost every respect to that of the central plains of the Province of Alberta. The normal winter temperatures are very low, and the snowfall is light. The normal summer is pleasantly warm with occasional thunderstorms and rainy periods. The climatic data obtained at weather stations situated in the Town of McMurray and the City of Edmonton are tabulated below.

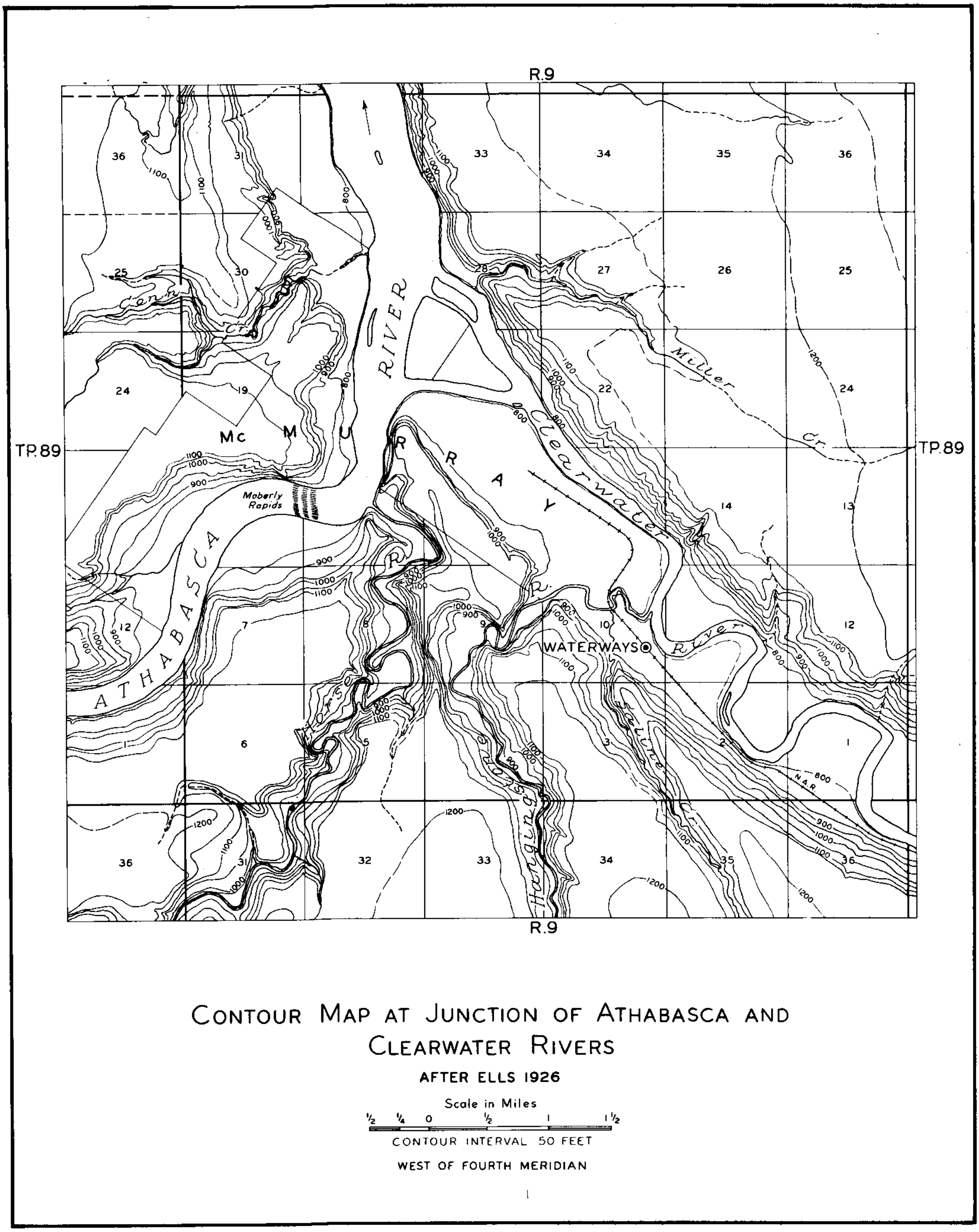


FIGURE 3. Contour Map at Junction of Athabasca and Clearwater Rivers

Table 3: Standard 30-year (1921-50) Normals of Temperature and Precipitation for the Town of McMurray and the City of Edmonton

(Data from figures published by the Provincial Bureau of Statistics in "Alberta Facts and Figures, 1954")

A: Temperature (°F)

Station	Minimum Recorded	Maximum Recorded	January Mean Daily		July Mean Daily	
			Maximum	Minimum	Maximum	Minimum
McMurray	—60	99	4	—17	76	47
Edmonton	—55	102	17	—1	75	51

B: Precipitation (inches)

Station	Mean Annual Precipitation	Mean Annual Snowfall	Mean Monthly Precipitation			
			April	May	June	July
McMurray	16.32	47.2	0.77	1.39	2.11	3.08
Edmonton	17.62	52.9	1.10	1.82	2.97	3.11

Table 4: Frost Data for McMurray and Edmonton

(from Alberta Facts and Figures, 1954)

Station	Period of observation (years)	Mean Date		Frost-free Period		
		Last in Spring	First in Fall	Mean (days)	Longest (days)	Shortest (days)
McMurray	7	June 21	August 6	46	87	X
Edmonton	60	May 29	September 6	100	144	44

Vegetation

Muskeg, slough, and swamp growth cover a large part of the area on the Second Prairie Level Plain. In the river valleys and on well-drained hillsides heavy growths of poplar, spruce, and jack pine which contain merchantable lumber are common.

Much of the natural vegetation has been destroyed by recurrent forest fires. Following these fires a dense regrowth of poplar and jack pine appears in most places after a few years. Ells reported in 1932 that if fires were not controlled the greater part of the area would eventually turn into a desert. This observation was still applicable to the area in 1957. A forestry crew from the Provincial Department of Lands and Forests is stationed at McMurray and lookout towers are located in Tp. 90, R. 12 and Tp. 94, R. 6.

ECONOMIC AND HUMAN GEOGRAPHY

Transportation and Communications

A single-track railway linking Edmonton with Waterways at the head of navigation on the Mackenzie River System was completed in 1917 by the Alberta and Great Waterways Railroad Company. This service is now operated by the Northern Alberta Railways Company which provides freight and passenger service. The rail terminal is at Waterways, three miles southeast of McMurray, but the end of steel is at the depot of Northern Transportation Company Limited on the Clearwater River between the two settlements. At this depot freight is transferred from rail to barge for shipment north to points along the Mackenzie River System or the Arctic Coast. Navigation on the Athabasca River at McMurray officially begins on April 25 and closes on October 20. The shipping season averages 178 days in length but may be considerably shorter as in 1957 when the Edmonton Journal reported that the navigation season opened on June 11 and closed on October 21. During 1957, 144,932 tons of freight* was moved north from McMurray by Northern Transportation Company Limited and McInnes Products Company Limited.

Water travel within the area is possible during the summer months (June through September) by canoes and small boats powered by outboard motors. The Clearwater River and the Athabasca River west of McMurray have many stretches of fast water and rapids which to be successfully negotiated require skill and familiarity. These rivers should not be used without the services of a reliable guide. By poling and tracking at medium stages of water the tributary streams can be ascended in canoes. The distance that can be travelled varies from a few miles to tens of miles depending on the stream and the type of boat used. The only river navigable by larger craft is the Athabasca north of McMurray.

Pacific Western Airlines Limited runs a scheduled passenger and express service between Edmonton and McMurray. The airport is situated southeast of the settlement and is 12 miles distant by road. The Federal Department of Transport operates radio beacon and weather service as well as normal airport facilities. The runway is hard surfaced and is 5,400 feet in length (Alberta Facts and Figures, 1954). Smaller wheeled and float planes are available for charter from McMurray Air Service Limited at McMurray. Helicopters cannot be hired locally.

No highway connects settlements within the area with the provincial network but winter roads have been cleared by oil companies from Athabasca Town and Wandering River, near Lac la Biche, to McMurray (Ellison, 1957).

Winter roads and trap-line trails penetrate most of the hinterland. As many of these trails cross areas of muskeg and deadfall they are not

*Reported by the Royal Commission on the Development of Northern Alberta, Edmonton, 1958.

suitable for travel during the summer months. The absence of natural fodder and potable water precludes the use of pack-horses throughout most of the area.

Contact with other regions can be made by post or telegraph. All first-class mail is carried by air. A dial telephone system at McMurray and Waterways was connected to the Alberta Government Telephones network during 1958. Telegraph services are operated by the Northern Alberta Railways and the Department of Transport.

Radio contact with field camps and river traffic in the area is also maintained by the Department of Transport at McMurray.

Settlement

There are three settlements within the area—McMurray, Waterways, and Fort MacKay. The largest of these, McMurray, is situated near the confluence of the Athabasca and Clearwater Rivers. The combined population of the McMurray* and Waterways settlements in 1956 was 1,110 persons. A rural population** of 879 persons in the vicinity of the settlements makes a total of 1,989 persons. Settlement near the confluence of the Clearwater and Athabasca Rivers began about 1790 with the establishment of a Northwest Company trading post there to deal in furs (Voorhis, 1930). This became a Hudson's Bay post in 1821 when the two companies amalgamated. It was later abandoned, and then rebuilt about 1875. Now, several trading stores handle general merchandise. Liquid fuels and oils can be purchased from at least two oil company depots.

A small Hudson's Bay Company trading post is located at Fort MacKay, 35 miles north of McMurray. The trade is mostly with local Indians and few perishable foods are stocked.

Indian Reserves***

The Federal Government has set aside three areas for the use of the Indians. The largest of these has an area of 2,261 acres and is situated at the junction of the Christina and Clearwater Rivers, 18 miles east of McMurray. In 1958 two families were living on this reserve. Another reserve with an area of 256.8 acres is situated on the east bank of the Athabasca River in Tp. 94, R. 11. No Indians were living on the reserve in 1958 but 102 were settled on the west bank of the Athabasca River in the vicinity of the Hudson's Bay Company trading post at Fort MacKay. A third reserve of about 2,000 acres is located on the east bank of the Athabasca River in Tps. 102 and 103, R. 9. This is a part of a larger reserve

*The Alberta Department of Municipal Affairs recognizes only one town, McMurray.

**See Report of the Royal Commission on the Development of Northern Alberta.

***The information on the Indian Reserves in the McMurray area was supplied by officers of the Indian Affairs Branch of the Federal Government in Edmonton.

which covers an area of 52,398 acres in the Athabasca River Delta. Separate population figures are not available but the total Indian population on the whole reserve was 782 in 1958.

Water Power

The Royal Commission on the Development of Northern Alberta (1958) has estimated that 1,615,000 horsepower in potential hydro-electric power are available in the drainage system of the lower Athabasca River near McMurray. The locations of some of the possible future power-generating sites are given in tables 5 and 6 and are shown on figure 2.

Table 5: Undeveloped Water Power Available at Various Sites on the Athabasca River near McMurray

(extracted from the Report of the Royal Commission on the Development of Northern Alberta, 1958)

Site	Full Supply Level (feet above sea level)	Maximum Head (feet)	Continuous Plant Output (kilowatts)	Installed Turbine Capacity (horsepower)
Grand Rapids Tp. 84, R. 17	1,420	203	93,300	378,000
Unnamed rapids in Tp. 87, R. 15	1,217	137	81,000	305,000
Crooked Rapids Tp. 87, R. 12	1,080	168	97,000	365,000
Mountain Rapids Tp. 88, R. 10	912	92	62,700	223,000
			Total	1,271,000

Table 6: Undeveloped Water Power Available at Various Sites on the Clearwater River near McMurray

(extracted from the Report of the Royal Commission on the Development of Northern Alberta, 1958)

Site*	Natural Head (feet)	Ordinary Six-month Flow (second-feet)	Horsepower Available
Cascade Rapids	16	1,120	2,000
Le Bon Rapids	31	1,120	3,900
Big Stone Rapids	7	1,120	900
Aux Pins (4 miles below Whitemud Falls)	21	1,120	2,700
Whitemud Falls	41	1,120	5,200
		Total	14,700

*All localities are in Tp. 89, Rs. 1 and 2.

CHAPTER III

Precambrian Rocks

Rocks of Precambrian age outcrop in Alberta to the north and east of a line drawn from the southwest corner of Lake Athabasca to near where the Clearwater River crosses the Alberta-Saskatchewan border. In the area mapped for this report (map 26) Precambrian metamorphic and igneous rocks are exposed in the vicinity of the Marguerite and Richardson Rivers. The sedimentary Athabasca formation outcrops in the northeast corner of township 103, ranges 1 and 2 (Blake, 1956).

Ells (1932) and Sproule (1951) reported what they believed to be bosses of Precambrian quartzite in township 94, range 10 between the Muskeg and Athabasca Rivers. Drilling* in this area has revealed similar silicified sandstone beds within the McMurray formation. Microscopic examination of thin sections of the rock has shown it to be silicified quartz sand. It is underlain by Devonian limestone and is probably Jurassic or Lower Cretaceous in age.

In the loop of the Marguerite River, in townships 100 and 101 and ranges 3 and 4, the basement complex is composed of a series of metasedimentary rocks striking north 40 degrees west. These have been intruded by granites and granite gneisses which in turn have been cut by quartz, pegmatite and aplite veins, and diabase dykes. The petrography of this suite of rocks is similar to that of the Tazin series described by Hale (1954) from the Black Bay area of northern Saskatchewan, where uranium mineralization is extensive. No radioactivity anomalies were detected with a geiger counter on traverses near the loop of the Marguerite River.

Although Precambrian rocks do not outcrop elsewhere in the area mapped they have been penetrated by a number of wildcat wells. The well locations and type of rock encountered have been reported by Burwash (1957) (See also table 7 and Fig. 4 of this report). He identified a single rock type, a calc-alkali-granite, whose apparent age varies from 1,270 (plus or minus 80) to 1,770 (plus or minus 120) million years. He has included the Precambrian rocks of this region in the Athabasca (Churchill) province of the Canadian Shield.

A structure contour map of the Precambrian surface (Fig. 4) indicates that considerable local relief is superimposed on a southwesterly regional slope of about 30 feet to the mile. For example, a knob on the basement surface is present under Draper where the Precambrian rocks were encountered in Alberta Government Salt Well No. 2 at an elevation of 25 feet above sea level. Under McMurray six miles to the north, the Precambrian rocks were encountered in Bear Rodeo No. 1 well at an

*Drilling and sampling of bituminous sands of northern Alberta; Can. Mines Branch Rept. 826, Vol. 2, p. 379-471.

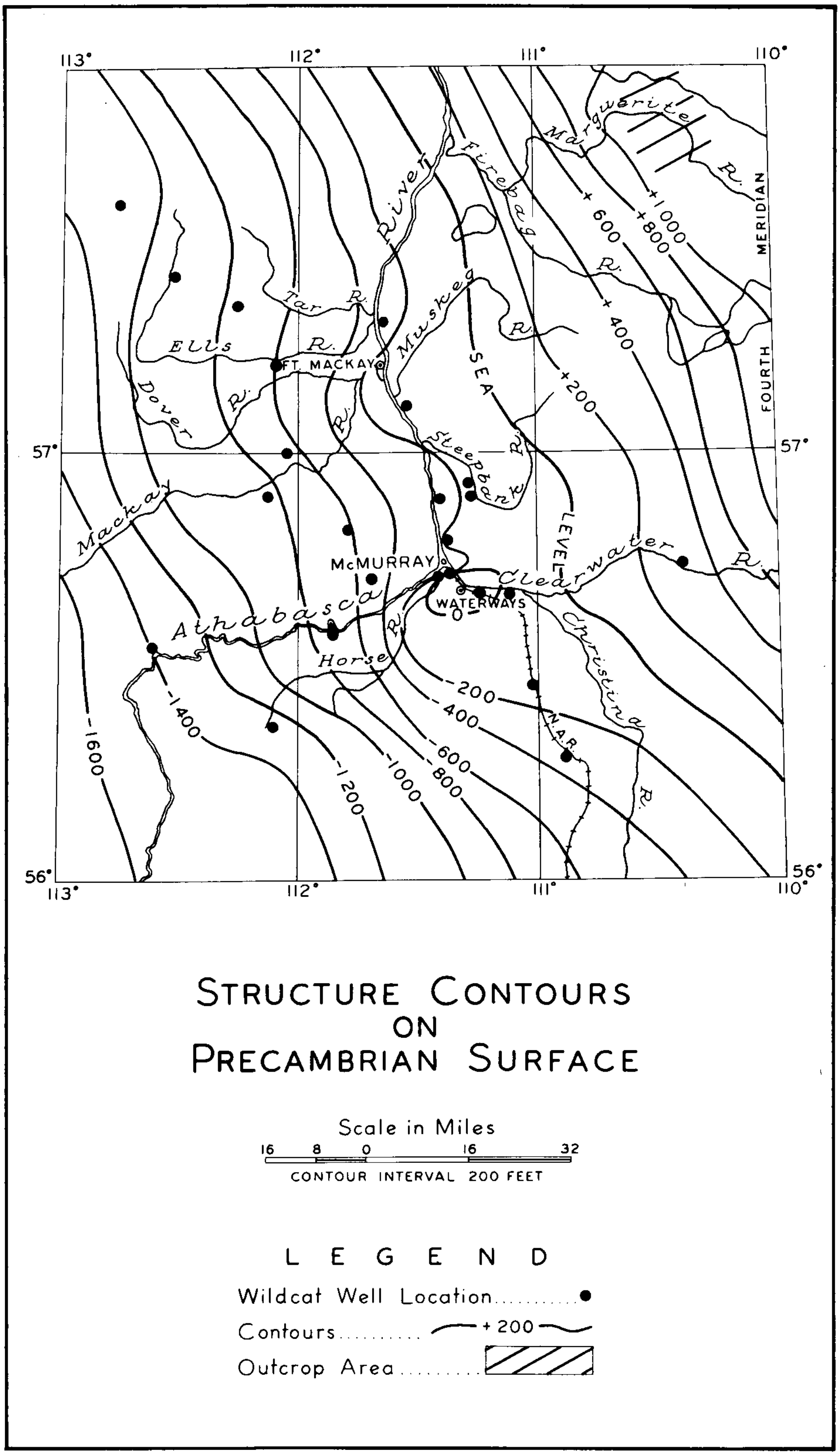


FIGURE 4. Structure Contours on Precambrian Surface

elevation of 308 feet below sea level. An indication of the basement structure and topography can be gleaned from a study of the preliminary maps of an aeromagnetic survey of the area published by the Geological Survey of Canada on a scale of one inch to one mile** (Garland and Bower, 1959).

Table 7: List of Wells Drilled to Precambrian Basement in Northeastern Alberta in the Vicinity of McMurray

(compiled from publications of the Alberta Oil and Gas Conservation Board)

Name of Well	Location				Elevation (feet)	Total Depth (feet)	Elevation of Precambrian Surface (feet)
	Lsd.	Sec.	Tp.	R.			
Richfield Oil Corporation et al. Corner Lake	6	8	81	8	not available	3322	not available
Richfield Oil Corporation et al. Cottonwood 2-23	2	23	82	5	K.B. 1546	1989	not available
Richfield Oil Corporation et al. Divide 6-36	6	36	82	12	not available	3545	not available
Bear McMahon No. 1	11	15	84	6	1535	1903	—362
Richfield Oil Corporation et al. Telegraph 10-12	10	12	85	14	K.B. 1861	3141	—1280
Bear Westmount No. 1*	14	9	86	7	1622	1793	—150
Bear Vampire No. 1*	7	28	87	12	1540	2304	—759
Bear Biltmore No. 1*	7	11	87	17	1440	2865	—1416
Richfield Oil Corporation et al. Buffalo Creek 14-3	14	3	87	18	K.B. 1686	3337	—1650
Alberta Government Salt Well No. 2†	5	32	88	8	810	789	+25
Bear Westmount No. 2*	9	36	88	8	837	936	—71
Richfield Oil Corporation et al. Brulé Rapids 6-28	6	28	88	16	K.B. 1800	3028	—1250
Weymarn No. 1		16	89	3	800	495	+300
Bear Rodeo No. 1*	8	20	89	9	817	1142	—308
Northern Alberta Exploration No. 2*	NE ¼	16	89	9	817	1405	—322
Amerada Mink Lake S.T.H. - 1	7	21	89	11	K.B. 1496	2005	—600
Amerada Mink Lake S.T.H. 4	6	21	90	12	K.B. 1745	2333	—580
Baysel Steepbank 13-16	13	16	91	8	K.B. 1439	1568	—129
Baysel Steepbank 15-29	15	29	91	8	K.B. 1319	1438	—119
Bear Rodeo No. 2*	5	17	91	9	804	1064	—259

**Geol. Surv. Can. (1956 - 1957); Geophysics Papers Nos. 305 - 358, 407 - 422, 437 - 469.
*Well log description in appendix A
†Well log description in appendix B

Name of Well	Location				Elevation (feet)	Total Depth (feet)	Elevation of Precambrian Surface (feet)
	Lsd.	Sec.	Tp.	R.			
Amerada Mink Lake S.T.H. 5		14	91	14	K.B. 1560	2414	—844
Amerada Mink Lake S.T.H. 6	11	28	92	13	K.B. 1556	2217	—657
Bear Vampire No. 2*	4	32	93	10	793	883	—82
Baysel Birch Hills	9	34	94	14	K.B. 1379	2000	—612
Athabasca Oils Ltd. No. 1*	8	2	96	11	816	1130	—289
Regent Birch Hills 12-30	12	30	96	14	K.B. 2052	2724	—668
Regent Birch Hills 3-16	3	16	97	16	K.B. 2180	3070	—875
Regent Birch Hills 2-7	2	7	99	17	K.B. 2425	3532	—1099

*Well log in appendix A

CHAPTER IV

Paleozoic Rocks

GENERAL DISCUSSION

Beds of detrital sand which overlie the Precambrian basement below the surface of most of northern Alberta have been called "granite wash" (Sproule, 1956). A thin layer of "granite wash" is common at the base of the sedimentary sequence in the McMurray area. These beds are overlain by strata which were included in the Elk Point formation by McGehee (1949) and Crickmay (1954). The Bear Rodeo No. 1 well drilled in the McMurray settlement exhibits a typical section of Paleozoic strata for the McMurray area and the following general discussion refers to this well (see appendix A for well log). The basal beds, 137 feet thick in this well, correspond to members 5 to 9 of the Elk Point formation of Crickmay (1954). Lithologically they consist of claystone which grades in places to siltstone and sandstone containing some gypsum and anhydrite. They are green at the top and red at the bottom. Overlying these beds are 24 feet of green dolomitic claystone (member 4 of Crickmay, 1954) and 10 feet of anhydrite. The 35 feet of coarse fragmental limestone overlying member 4 is considered to be equivalent to the Elm Point formation in Saskatchewan because the lower 5 feet contains *Atrypa arctica* Warren (Crickmay, 1954). Greiner (1956) when defining the Methy formation was unable to separate the Elm Point formation equivalents from the Methy formation and thus this limestone bed, together with 34 feet of dolomitized limestone and 43 feet of dolomite, make a total thickness of 112 feet for the Methy formation strata in this well. Overlying the Methy formation is the Prairie Evaporite formation. It is represented by 269 feet of strata containing beds of halite, anhydrite, gypsum, and dolomite. In other wells these beds have been reduced in thickness by solution, and as a result some post-depositional collapse has taken place in the overlying Beaverhill Lake limestone (Figs. 5 and 7). On top of the Prairie Evaporite are 98 feet of strata starting with a thin persistent siltstone layer which is overlain by beds of anhydrite, silty claystone, and limestone (member 1 of Crickmay, 1954). This was regarded by Crickmay (1954) as the equivalent of the Dawson Bay formation and "Red Beds" found in the same stratigraphic position in Saskatchewan and Manitoba.

The Dawson Bay formation is overlain by a 5-foot bed of brown limestone believed to be the equivalent of the Slave Point formation. Above this bed are the strata of the three lower members of the Beaverhill Lake formation, which total 440 feet in thickness. The only available complete section of the Beaverhill Lake formation is that cored in Bear Biltmore No. 1 well. It was discussed in detail by Belyea (1952) and Crickmay (1957).

The term "Elk Point" as used by Crickmay (1954) and by the Alberta Oil and Gas Conservation Board includes the strata between the base of the Meadow Lake formation equivalent and the top of the Dawson Bay formation equivalent. In Saskatchewan the lower limit of the Elk Point group is placed at the base of the Ashern formation and the upper limit at the top of the Prairie Evaporite formation (Baillie, 1953).

DESCRIPTIONS OF FORMATIONS

Meadow Lake Formation Equivalent

The name "Meadow Lake" was introduced by Van Hees (1956) to describe a series of evaporites and red beds found below the Ashern formation in the Meadow Lake area of Saskatchewan. Van Hees correlated these beds with members 5 to 9 of the Elk Point strata in east-central Alberta as defined by Crickmay (1954). Crickmay (1954) established the correlation between the Elk Point strata in east-central Alberta and the strata beneath the Beaverhill Lake formation in the vicinity of McMurray. It now seems desirable to use the name "Meadow Lake" to describe members 5 to 9 of Crickmay's Elk Point formation in the McMurray area. Thus in Bear Rodeo No. 1 well, which was drilled in the McMurray townsite, the 137 feet of strata overlying the Precambrian rocks have been assigned to this formation. In the McMurray area the strata of this formation commonly contain a basal bed of "granite wash", arkosic pebblestone or red sandstone, which grades upward into siltstone and claystone with beds of gypsum, anhydrite, and chert. A 34-foot thick bed of red sandstone with rounded quartz grains was found in the Bear Biltmore No. 1 well overlying the Precambrian rocks. Outcrops of a feldspathic sandstone have been found underlying the Methy formation on the Clearwater River at Contact Rapids in Saskatchewan. Sproule (1951) believed these beds to be an extension of the Athabasca formation.

The Meadow Lake formation in Saskatchewan consists of evaporites and red beds. In the interval 2,004 to 2,290 feet in Seaboard Meadow Lake Crown No. 1 well (Lsd. 13, Sec. 31, Tp. 61, R. 15, W. 3rd Mer.) the formation has been described by Van Hees (1956, p. 34). The uppermost 76 feet of strata are composed of interbedded anhydrite, evaporitic dolomite, and granular limestone. These overlie 200 feet of red dolostones and marlstones with white anhydrite patches, and red shale with floating rounded quartz grains and some glauconite. The basal bed is 10 feet thick and consists of anhydrite overlain by fine- to coarse-grained red sandstone with argillaceous cement and angular to rounded, clear to frosted grains. Thick beds of halite have been recorded in this formation in Stanolind Whelan Crown A-1 well (Lsd. 10, Sec. 2, Tp. 59, R. 24, W. 3rd Mer.) and Imperial Goodsoil well (Lsd. 8, Sec. 11, Tp. 62, R. 22, W. 3rd Mer.) (Buller, 1958). Van Hees (1956) was of the opinion that these beds were Lower Devonian in age. Fossils having a recorded generic range of Middle Silurian (Niagaran) to Lower Devonian have been found in them (Buller, 1958, p. 44) but insufficient paleontological data are available at present to give a more precise age to these strata.

Ashern Formation Equivalent

The relationship of the Meadow Lake and Ashern formations in Saskatchewan has been clarified by Buller (1958). Crickmay (1954) regarded the lower members (4 to 9) of his Elk Point formation in Bear Rodeo No. 1 well to be equivalent to the Ashern formation, but Van Hees (1956) suggested that the term be confined to member 4 only. In the McMurray area the name "Ashern formation equivalent" has been applied to the green fossiliferous shale or claystone strata, overlain by beds of shaly to silty dolomite with some anhydrite and chert. This formation cannot always be differentiated with certainty from the underlying Meadow Lake formation equivalents. The Ashern formation equivalent is 113 feet thick in Bear Rodeo No. 2 well, but in Alberta Government Salt Well No. 2 it is only about 19 feet thick. In Saskatchewan the Ashern formation consists of an upper green calcareous shale and a lower dark-red to chocolate calcareous silty shale (Buller, 1958). This formation is considered to mark the beginning of marine sedimentation of Middle Devonian times in the Elk Point basin in Saskatchewan.

Elm Point Formation Equivalent

The Elm Point formation outcrops in southwestern Manitoba in the Manitoba shelf area where it is a thin-bedded microgranular limestone carrying *Atrypa arctica* Warren (Baillie, 1953, p. 20). Belyea (1952) suggested that the 71 feet of brown cherty dolomite found between the depths of 2,589 and 2,660 feet in Bear Biltmore No. 1 well were equivalent to the Elm Point formation. This observation was supported by Crickmay (1954) who also stated that the lower part of his member 3 of the Elk Point formation was the equivalent of the Elm Point formation.

The "Elm Point formation equivalent" in the McMurray area has been differentiated from the Methy formation on the basis of lithology and the presence of *Atrypa arctica* Warren. It is represented by 71 feet of the dark-brown cherty dolomite in Bear Biltmore No. 1 well, 70 feet of dolomite in Bear Rodeo No. 2 well, 35 feet of coarse fragmental limestone in Bear Rodeo No. 1 well, and 106 feet of dolomitic limestone in Bear Westmount No. 1 well. Generally, however, these strata have been included in the Methy formation (Greiner, 1956). They were not recognized in the logs of Bear Vampire No. 1 well, Alberta Government Salt Well No. 2, or Bear Vampire No. 2 well.

Methy Formation (Nauss, 1950)

The name "Methy dolomite" was first used in a paper by Nauss (1950), but designation of a type section and detailed lithological descriptions were not made until 1956 (Greiner, 1956).

The Methy formation outcrops along the Clearwater River in Saskatchewan and as far west as the western boundary of range 2 in township 89 in Alberta. At Cascade Rapids on the Clearwater River the dolomite is hard, buff-colored and porous. Stromatoporoid, coral, and algal reefs, mostly less than one to two feet thick, are found in certain beds. Most of the porosity in the dolomite has been atributed to recrystallization, and the vugs in the reef facies have been filled with secondary calcite. Sulfides are not widespread in occurrence nor are they of economic importance, but galena was found in the Methy formation at Whitemud Falls (Tp. 89, R. 1), where it filled a small cavity in the rock formed as a result of dolomitization of organic remains.

The top and base of the Methy formation are nowhere exposed in the same outcrop section, but in the McMurray area, well records show a thickness variation from 113 to 227 feet (Greiner, 1956, p. 2058).

In age the Methy formation is Middle Devonian (Erian); faunas from Whitemud Falls and Contact Rapids, identified by Crickmay (1954) and Warren (in Greiner, 1956) indicate that it can be correlated with the Presqu'ile dolomite of the Great Slave Lake area and with the Winnipegosan dolomite of Manitoba (Greiner, 1956, p. 2078).

The Prairie Evaporite Formation (Baillie, 1953)

"Prairie evaporite" was the term used by Baillie (1953, p. 40) to describe the upper salt beds of the Elk Point group type section. The thickness of the formation in the McMurray area has been modified by solution of halite and this has caused some deformation of the overlying Beaverhill Lake strata. Its thickness is proportional to the amount of halite now remaining; it is greatest (697 feet) in Bear Biltmore No. 1 well and least (104 feet) in Bear Westmount No. 1 well.

Features which are probably solution breccias have been recorded in this formation in Bear Westmount No. 2 well. The structure contour map on the upper surface of the Elk Point evaporites *sensu lato* (Fig. 5) illustrates collapse structures. The Prairie Evaporite formation in the McMurray area is composed of dolomite, anhydrite, gypsum and halite.

Dawson Bay Formation Equivalent

Baillie (1953, p. 26) proposed that the term "Dawson Bay formation" be used to describe the lowest strata of the Manitoba group in Saskatchewan and Manitoba. The lower limit was placed at the base of the red and green argillaceous zone (Second Red Bed) which overlies the Elk Point strata. Member 1 (Crickmay, 1954) has been correlated with the Dawson Bay formation and the overlying First Red Bed of the Manitoba group (Van Hees, 1956). The equivalent of Crickmay's member 1 has been recognized in the lithological logs of most of the deep wells drilled in the McMurray area where the maximum thickness measured was 98 feet in Bear Rodeo No. 1 well. The lower limit has been placed at the base of a thin persistent siltstone bed overlying anhydrite at the top of the Prairie Evaporite. The overlying strata consist of interbedded reddish dolomite, anhydrite, shales, siltstone, and silty limestones.

Walker (1957) has proposed giving group status to the Dawson Bay formation in Saskatchewan.

Slave Point Formation Equivalent

The five feet of thin-bedded buff-brown limestone and dolomite, from 1,683 to 1,688 feet in the Bear Biltmore No. 1 well, were considered to be the Slave Point equivalent by Crickmay (1957, p. 10). This bed is represented by four feet of buff dolomitic limestone in Industrial Minerals Salt Well No. 1 (490 to 494 feet), by six to seven feet of interbedded shale, limestone and dolomite in Industrial Minerals Salt Well No. 3 (513-520 feet), and by five feet of dark-brown and buff limestone and dolomitic limestone in Alberta Government Salt Well No. 1 (497 to 502 feet). Both MacDonald (1947) and Crickmay (1957) noted that this unit was bounded by paraconformities. Belyea (1952, p. 44) included these limestones and dolomites in the basal limestone unit of the Beaverhill Lake formation. The Slave Point formation has been recognized during recent drilling in the western part of the area, and it apparently thickens rapidly to the northwest. The formation is reported to be 56 feet thick in Amerada Mink Lake S. T. H. 5, 60 feet thick in Amerada Mink Lake S. T. H. 6, and 122 feet in California Standard Mikkwa well No. 12-23 (Oil and Gas Conservation Board Weekly Reports, 1958).

No fossils have been found in this thin unit in the wells at McMurray, but Crickmay (1957, p. 10) recorded *Atrypa* aff *A. independensis* Webster and *Ambothyris* sp. in the Bear Biltmore No. 1 well.

The limestone unit of the Slave Point formation of Law (1955, p. 1941) in the Hay River area probably is the stratigraphic equivalent of this thin unit of the McMurray area. Warren (1957, p. 2) noted that the Firebag member of the Beaverhill Lake formation with the *Lingula* cf. *L. spatulata* fauna lies on the Slave Point formation in the Hay River area. Law (1955, p. 1949) recognized the Slave Point limestone unit in the Barnsdall et al. West Wabiskaw No. 1 well and Belyea (1952, Fig. 3) correlated this unit in the Wabiskaw well with those dolomites and limestones in the Bear Biltmore No. 1 well which include Crickmay's Slave Point equivalent.

Warren (1957) correlated the Slave Point formation with the lower part of the Manitoba group, which includes the Dawson Bay formation. The correlations made earlier in this report place the Dawson Bay formation equivalent beneath the Slave Point formation in the McMurray area.

Beaverhill Lake Formation

General Discussion. The limestones and calcareous shales which outcrop on the Clearwater and Athabasca Rivers were noted by many of the early travellers who passed through the region. Dr. John Richardson traversed the area in 1819 and again in 1825, and was the first to describe the strata (Richardson, in Franklin, 1828). Richardson travelled down the lower Athabasca River again in 1848 and made additional examinations of the limestone and shale outcrops along the river banks (Richardson, 1851).

More detailed descriptions were given by Macoun (1877), Bell (1884), McConnell (1893a), and Ells (1932), but introduction of a formal name for the Devonian limestones was not made until 1933 (Warren, 1933, p. 149). Warren proposed the term "Waterways formation" for "the limestone and shale on the Athabasca River, carrying the Portage fauna and correlative with the Simpson shale on the Mackenzie River". At that time the lower boundary of the formation was placed at the top of the "gypsum beds" and the upper boundary at the pre-Cretaceous erosion surface.

The "Waterways" is called a formation, but as defined is more strictly a stage term—"limestone and shale . . . carrying the Portage fauna". As its definition is based primarily on the presence of a characteristic fauna, "Waterways" should not be used as a rock-stratigraphic term.

If attempts are made to use "Waterways formation", then several problems arise. In 1933, little drilling had been carried out to the west of the McMurray area, and description of the upper limit of the Waterways formation as an erosion surface (Warren, 1933, p. 149) was satisfactory. When the Bear Oil Company wells (Bear Biltmore No. 1 in particular) were drilled in 1948 and 1949, there arose the problem of where to draw the upper limit of the "Waterways formation" in the subsurface, as this limit could no longer be considered as an erosion surface. By the original definition the formation includes limestones and shales correlative with the "Simpson shale" on the Mackenzie River. The upper boundary of the Simpson shale as defined by Crickmay (1957) is the base of the lowest coquina containing *Eleutherokomma reidfordi* Crickmay—the base of the *Eleutherokomma reidfordi* zone. In the Bear Biltmore No. 1 well the base of this zone is at 724 feet (Crickmay, 1957), 126 feet above the base of the Ireton formation. Strictly, on the basis of correlation, this is where the top of the "Waterways formation" should be placed, and thus the formation includes the Beaverhill Lake formation, the Cooking Lake formation, and the lower strata of the Ireton formation. The Waterways probably should be defined as a limestone and green-grey shale sequence and its upper limit placed at the base of the brownish shale succession of the Duvernay-Ireton strata, thus including only the Beaverhill Lake and Cooking Lake formations. Even if so defined, the term "Waterways formation" is losing much of its usefulness as a result of more precise definition of subsurface rock-stratigraphic units (Imperial Oil, 1950; Belyea, 1952; Crickmay, 1957).

It is recommended that the term "Waterways" should be used with stage connotation only and, as originally defined, covering the range of the "Portage fauna" in Western Canada. Usage in this manner will permit a general equating of the stage with the Finger Lake stage of the New York Devonian succession (Cooper, 1942). The Waterways stage contains the following faunas or zones of Warren and Stelck (1956):

Buchiola retrostriata (Von Buch)
Eleutherokomma leducensis Crickmay
Eleutherokomma hamiltoni Crickmay

Allanaria allani (Warren)
Lingula cf. *L. spatulata* Vanuxem
Caryorhynchus castanea (Meek)

In the Bear Biltmore No. 1 well on the basis of the correlation made with the type section of the Beaverhill Lake formation by Belyea (1952), the five members of the "Waterways formation" established by Crickmay (1957) constitute subdivisions of the Beaverhill Lake formation. The upper and lower limits of the Beaverhill Lake formation in the vicinity of McMurray are well established (Belyea, 1952; Crickmay, 1957) and the name "Beaverhill Lake" is used here as the rock-stratigraphic term to include the limestones and shales of the Waterways stage in this area.

Distribution. The Beaverhill Lake formation is exposed along the banks of the Athabasca River and many of its tributary streams in the McMurray area. On the Firebag River the Beaverhill Lake formation outcrops in Sec. 2, Tp. 100, R. 8 and as far upstream as Sec. 9, Tp. 99, R. 7. The river has not cut deeply into the Devonian strata and no thick sections were observed. Rapids in the Firebag River are generally indicative of neighboring outcrops. The limestones are characteristically grey and thin bedded with shaly limestone interbeds. Greenish shale and shale debris are found at the mouth of the Marguerite River and in only a few other places. The limestone is well-jointed and commonly fractured; some of the joints and fractures are filled with bitumen. For example, an isolated exposure of the limestone is found in Sec. 1, Tp. 98, R. 7, where an anticline in the Beaverhill Lake formation outcrops over a distance of some 200 feet. The strata are very thin bedded, light-grey to grey-green mudstones, with joints and shattered zones sealed with hardened bitumen.

To the east of the last-mentioned outcrop Devonian strata were not found, but boulders of Devonian limestone and dolomitized reef, some of which are oil-stained, were found in the till and glacial outwash as far upstream as the centre of Tp. 96, R. 3.

On the Marguerite River isolated outcrops of the Beaverhill Lake formation were found as far upstream as Sec. 25, Tp. 99, R. 7 where the river changes direction abruptly from southeasterly to westerly. Limestone boulders were found in some rapids farther upstream. Such boulders were observed along the Marguerite River short distances above and below its confluence with Reid Creek (Sec. 18, Tp. 100, R. 5, and Sec. 13, Tp. 100, R. 6, respectively), less than one mile west of outcrops of Precambrian rocks. These limestone boulders have probably come from nearby outcrops.

The northernmost Devonian limestone on the Athabasca River outcrops in extensive low benches along the river banks in Tp. 99, R. 10 and in the northeast quarter of Tp. 98, R. 10. In Sec. 15, Tp. 98, R. 10 a low arch of limestone one-quarter of a mile wide is exposed on the east bank of the river.

Fossiliferous limestone forms a cliff on the west bank of the Athabasca River several hundred yards north of the mouth of the Pierre

River (Secs. 30 and 32, Tp. 97, R. 10). This cliff is referred to in several reports as the Pierre au Calumet locality. The upper surface of the limestone is 50 feet above water level and is covered by white clay. This outcrop is on the northern rim of the Bitumount basin (Figs. 5, 7 and 10).

Outcrops of the Beaverhill Lake formation were found on the Athabasca River about two miles north of Fort MacKay (Sec. 31, Tp. 94, R. 10; Sec. 36, Tp. 94, R. 11; Sec. 6, Tp. 95, R. 10). These are the northernmost exposures of an almost continuous outcrop belt which extends upstream into Tp. 87, R. 12 and up the Clearwater River into Tp. 89, R. 3. Devonian strata outcrop on the Ells River in Sec. 21, Tp. 95, R. 11, and small Devonian outcrops were found also on the MacKay River (Sec. 19, Tp. 94, R. 11; Sec. 3, Tp. 95, R. 11).

PLATE 2. Anticline in Beaverhill Lake formation on east side of Athabasca River near Fort MacKay, Tp. 94, R. 11

The Beaverhill Lake formation outcrops extensively between the Athabasca and the Muskeg Rivers in township 94; the outcrops on the Muskeg River extend from the mouth upstream into Sec. 33, Tp. 94, R. 10. Most of the McMurray strata has been eroded from many of these outcrops and Pleistocene deposits rest directly on the Devonian limestone.

From the Muskeg River southward to the vicinity of McMurray Town the pre-Cretaceous erosion surface almost parallels the bedding of the limestone, and lies at an elevation of from 800 to 900 feet. Almost continuous outcrops of the Beaverhill Lake formation were observed on the east bank of the Athabasca River between the mouths of the Muskeg and Steepbank Rivers, where small domes are developed in the limestone. On the Steepbank River the Beaverhill Lake formation is exposed for only one and one-half miles above the river month.

Detailed Description of Members. The basal unit of the Beaverhill Lake formation in the McMurray area is the Firebag member (Crickmay, 1957, p. 7) which is 170 feet thick in the Bear Biltmore No. 1 well (which contains the type sections of all five members) and consists of calcareous shales and argillaceous limestones, with a thin layer of fragmental limestone at the base. Crickmay (p. 11) considers that the following zones—apparently more strictly teilzones — are present, in ascending order: — *Atrypa independensis* (2 to 3 feet thick), *Lingula spatulata* (46 feet thick), and *Eleutherokomma impennis* (122 feet thick). The two lower zones are approximately equivalent to Warren and Stelck's (1950) *Lingula* cf. *L. spatulata* biozone, and the *Eleutherokomma impennis* teilzone is included within Warren and Stelck's *Allanaria allani* biozone.

In the Beaverhill Lake formation in the Imperial Clyde well (Belyea, 1952, Fig. 3) the dominantly shaly Firebag member is recognizable and is probably the Bh. 2 unit of Belyea (1957).

The Calumet member (Crickmay, 1957) in its type section comprises 102 feet of fine-grained and clastic limestones. In the wells around McMurray the member consists of buff and grey-buff mottled and argillaceous limestones. It carries the fauna of teilzone Q of Crickmay—*Stropheodonta costata* Owen and *Spinocyrtia capax* Hall—and lies within the *Allanaria allani* biozone of Warren and Stelck. This member is probably equivalent to the Bh. 3 unit of Belyea (1957).

In the Bear Biltmore No. 1 well the 90 feet of green-grey calcareous shale and argillaceous limestone above the Calumet member were termed Christina member (Crickmay, 1957). Along with the other members this unit is recognizable in the type section of the Beaverhill Lake formation (Bh. 4 of Belyea, 1957). The Christina member constitutes Crickmay's teilzone P [*Allanaria* sp. and *Eleutherokomma* cf. *E. jasperensis* (Warren)].

In its type section the Christina member is overlain by 200 feet of buff and grey-buff, mottled and argillaceous limestones — the Moberly member (Crickmay, 1957). Limestones of the Moberly member outcrop around the Town of McMurray. The upper 80 feet of the member constitute the *Eleutherokomma hamiltoni* zone of Crickmay (1957) and Warren and Stelck (1950). The lower 120 feet constitute Crickmay's *Allanaria allani* teilzone and the upper part of the *Allanaria allani* biozone of Warren and Stelck.

The term Mildred member was used by Crickmay (1957) to describe the uppermost strata of the Beaverhill Lake formation; in its type section it is composed of 140 feet of green-grey and buff argillaceous limestones and calcareous shales. The teilzone of *Eleutherokomma killeri* is coextensive with this member, as is the lower portion of the *Eleutherokomma leducensis* biozone of Warren and Stelck.

With regard to paleontological zonation it is evident that detailed correlations are frequently being attempted on incomplete paleontological data, and by incorrect usage of such data. The teilzone, or local range of a taxonomic unit, is considerably smaller than the biozone, or total range of a taxonomic unit. For instance, the species *Eleutherokomma jasperensis* (Warren) is recorded from the middle of the Beaverhill Lake formation

(Crickmay, 1950), the Maligne formation (Taylor, 1957), the Cooking Lake formation (Warren and Stelck, 1956) and the upper Cooking Lake formation (Belyea, 1955); *Eleutherokomma leducensis* Crickmay is recorded from the basal Duvernay formation (Crickmay, 1950; Belyea, 1955), from the Beaverhill Lake formation (Warren and Stelck, 1956) and from the Maligne formation (Taylor, 1957). Therefore the biozone of *Eleutherokomma jasperensis* extends from the middle of the Beaverhill Lake formation to the upper part of the Cooking Lake formation, and the *Eleutherokomma* cf. *E. jasperensis* zone of Crickmay in the middle of the Beaverhill Lake formation of the McMurray area is a teilzone. Similarly the biozone of *Eleutherokomma leducensis* extends from the top of the Moberly member of the Beaverhill Lake formation into the lower part of the Duvernay formation, and Crickmay's *E. leducensis* zone is also a teilzone.

The local stratigraphic ranges of the species (i.e. the teilzones) are controlled in part by ecologic factors and thus in different areas the species may be present at different stratigraphic levels and in different sequence within the biozone. In the Beaverhill Lake formation in the McMurray area paleontological zonation and lithology are closely related. This relationship indicates ecological control of species ranges.

On the basis of biozone correlation the lower Beaverhill Lake formation in the McMurray area (*Lingula* cf. *L. spatulata* zone) is correlated with the lower "Flume" formation of the Kakwa Lake area. The middle and upper Beaverhill Lake formation (*Allanaria allani* and *Eleutherokomma hamiltoni* zones) is considered to be equivalent to the Flume formation of Taylor (1957).

Formations of Woodbend Group

The name "Woodbend formation" was given by the staff of Imperial Oil (1950) to a sequence of limestones and shales overlying the Beaverhill Lake formation. It consists of three lithological members, the Cooking Lake, the Duvernay, and the Ireton. Warren (1951) suggested that these members were sufficiently distinct to warrant formation status; a formal proposal to this effect was made by Belyea (1955), and it now seems to be generally accepted (Taylor, 1957; Andrichuk, 1958).

The Bear Biltmore No. 1 well, drilled in Tp. 87, R. 17, passed through 527 feet of Woodbend strata. A detailed description of the core recovered from this well was made by Belyea (1952). The Cooking Lake formation conformably overlies the Mildred member of the Beaverhill Lake formation and is composed of 137 feet of grey-buff, fossiliferous calcarenite, containing numerous minute brown spores, and some ooliths. The Duvernay formation was not recognized by Belyea, who stated (p. 19) that Ireton-type beds rest directly on the Cooking Lake formation. The Ireton formation is represented by interbedded greenish-grey shale and limestone units totalling 345 feet in thickness. Ostracodes from the Ireton formation in the Bear Biltmore No. 1 well were described by Loranger

(1954a). An erosion remnant of a reef, consisting of dolomitic limestone with scattered fossil fragments, was found in this well directly beneath the Cretaceous-Devonian unconformity and was correlated with the Grosmont formation by Belyea (1952).

LITHOLOGY OF THE PALEOZOIC ROCKS

Apart from the layer of detrital sediment at the base of the sequence, the Paleozoic rocks consist of evaporites and organic carbonates with minor amounts of sediment of terrigenous origin. Evaporites in the Elk Point group include dolomite, anhydrite, gypsum, and halite. The purity of these deposits has been noted by Allan (1921, 1943) who made a detailed study of the cores obtained from the salt wells of the Alberta Government and Industrial Minerals Limited. Thick beds of salt were analysed and found to be over 95 per cent sodium chloride; the impurities consisted of thin seams of pure anhydrite (table 9). Potassium salts have not been found in any of the cores from the McMurray area (Allan, 1943). Two samples of the dolomitic limestones of the Methy formation have been analysed chemically (table 8) and were found to contain 59.2 and 62.8 per cent of calcium carbonate and 34.14 and 32.01 per cent of magnesium carbonate, respectively. Two samples of the Moberly member of the Beaverhill Lake formation were collected and on analysis were found to contain 93.4 and 95.25 per cent calcium carbonate and 1.11 per cent and 1.54 per cent magnesium carbonate respectively.

Table 8: Chemical Analyses of Some Paleozoic Carbonate Rocks

(Analyses by Provincial Analyst, Edmonton)

Sample No.	**1**	**2**	**3**	**4**
Silica	1.66	3.60	0.30	1.64
Iron oxide	0.21	0.51	1.03	0.84
Alumina	1.28	0.51	1.49	2.19
Calcium oxide	53.33	52.30	33.12	35.17
Magnesium oxide	0.53	0.73	16.32	15.30
Ignition loss	42.74	42.32	46.26	43.30
$CaCO_3$ $MgCO_3$	95.25 1.11	93.41 1.54	59.20 34.14	62.80 32.01

1. North bank, Clearwater River at junction with Athabasca River. Beaverhill Lake formation.
2. Clearwater River exposure, north bank, on 23rd Base line, Rs. 5, 6, W. 4th Mer. Beaverhill Lake formation.
3. Whitemud Falls, Clearwater River. Methy formation.
4. Contact Rapids, Clearwater River, Saskatchewan. Methy formation.

The non-carbonate content of a sample of grey, crinoidal, Beaverhill Lake limestone collected from an outcrop on the Clearwater River about two miles west of the Christina River mouth was found to consist mainly of a boxwork of needle-like crystals of iron sulfide (marcasite) which had partially replaced the fossils. A small percentage of fine-grained angular quartz was also present. Dolomite from Methy Portage contained similar acid-insoluble residues.

Table 9: Chemical Analyses of Some Paleozoic Evaporite Rocks

(from Alberta Government Salt Well No. 1, after Allan (1921)
(See Appendix B for well log)

Halite

Sample No.	1	2	3
Insoluble in water	0.24	0.46	0.30
Sodium chloride	94.78	98.46	96.53
Calcium sulfate	4.74	0.90	2.78
Potash	0.00	0.00	0.00
Magnesia	0.00	0.00	0.00
Ignition loss	—	—	0.18
Total	99.76	99.82	99.79

Anhydrite and Gypsum

Sample No.	4	5	6
Calcium oxide	32.81	35.27	37.04
Magnesium oxide	5.14	0.24	0.12
Ignition loss	2.72	9.02	3.01
Sulfuric anhydride (SO_3)	58.11	49.16	54.62
Sodium chloride	—	0.58	1.02
Siliceous residue	1.02	5.20	4.02
Total	99.80	99.47	99.83

1. Rock salt, depth 648 - 662 feet.
2. Transparent rock salt, depth 650 feet.
3. Rock salt with anhydrite lenses, depth 645 feet.
4. Gypsum and anhydrite. Interbedded in a shale, depth 534 feet.
5. Anhydrite, depth 665 feet.
6. Coarse granular anhydrite, depth 681 feet.

Beds of argillaceous limestone, and calcareous shale bands have been observed in the Beaverhill Lake formation but chemical and mineralogical examination of these rocks has not yet been attempted.

FAUNA OF THE PALEOZOIC ROCKS

The stratigraphic distribution of the fauna in the Devonian strata above the Elk Point group is given in Appendix C of this report.

STRUCTURE OF THE PALEOZOIC STRATA

Beds of the Elk Point group and older formations apparently have remained relatively undisturbed since they were laid down. At the time of their deposition initial dips were negligible or very slight towards the west. The present dip is to the southwest at a small angle and is roughly parallel to the slope of the Precambrian surface. The Methy formation, however, does not follow the minor undulations in the basement topography, because the depressions had been largely filled by sediment of the Meadow Lake and Ashern formations. The dip of the Devonian strata steepens considerably south of Bear Westmount No. 1 well. The strata above the evaporite beds have been disturbed more than those below, therefore the structures observed in the higher beds such as domes and basins in the Beaverhill Lake formation (plate 2) could have been caused by solution of water-soluble evaporite beds in the Elk Point group (Figs. 5 and 6). Saline springs are common throughout the area and are today bringing to the surface soluble salts from below the Beaverhill Lake limestone (see section on underground water). Continuing solution activity along a northwest-trending fault (Fig. 5) would account for the apparently anomalous post-Cretaceous folding observed in the vicinity of Bitumount. Where the evaporites have not been dissolved, as in Bear Biltmore No. 1 well, the attitudes of the Beaverhill Lake and overlying Woodbend strata are the same as that of the Methy formation. Hume (1947, p. 310) suggested that the local domes and basins in the Beaverhill Lake formation were due to volume changes accompanying the hydration of some anhydrite in the Prairie Evaporite, Belyea (1952) has suggested that the structures are due to local thickening of the salt and doming in the overlying strata in the vicinity of the Bear Biltmore well.

Post-Beaverhill Lake activity along a fault in the Precambrian basement has been postulated (geological cross-section A-A, Fig. 6) to account for the outcrop of the Calumet member of the Beaverhill Lake formation on the Athabasca River in Sec. 30, Tp. 97, R. 10. A vertical component of movement on this fault of 200 feet accounts for the observed displacement in the Beaverhill Lake formation, and post-Cretaceous collapse of a further 200 feet due to solution of water-soluble strata accounts for the structure called the Bitumount basin (Figs. 5 and 7).

An alternative explanation, to the fault, is that a thickening of approximately 200 feet in the Prairie Evaporite formation occurs northeast of the proposed fault line.

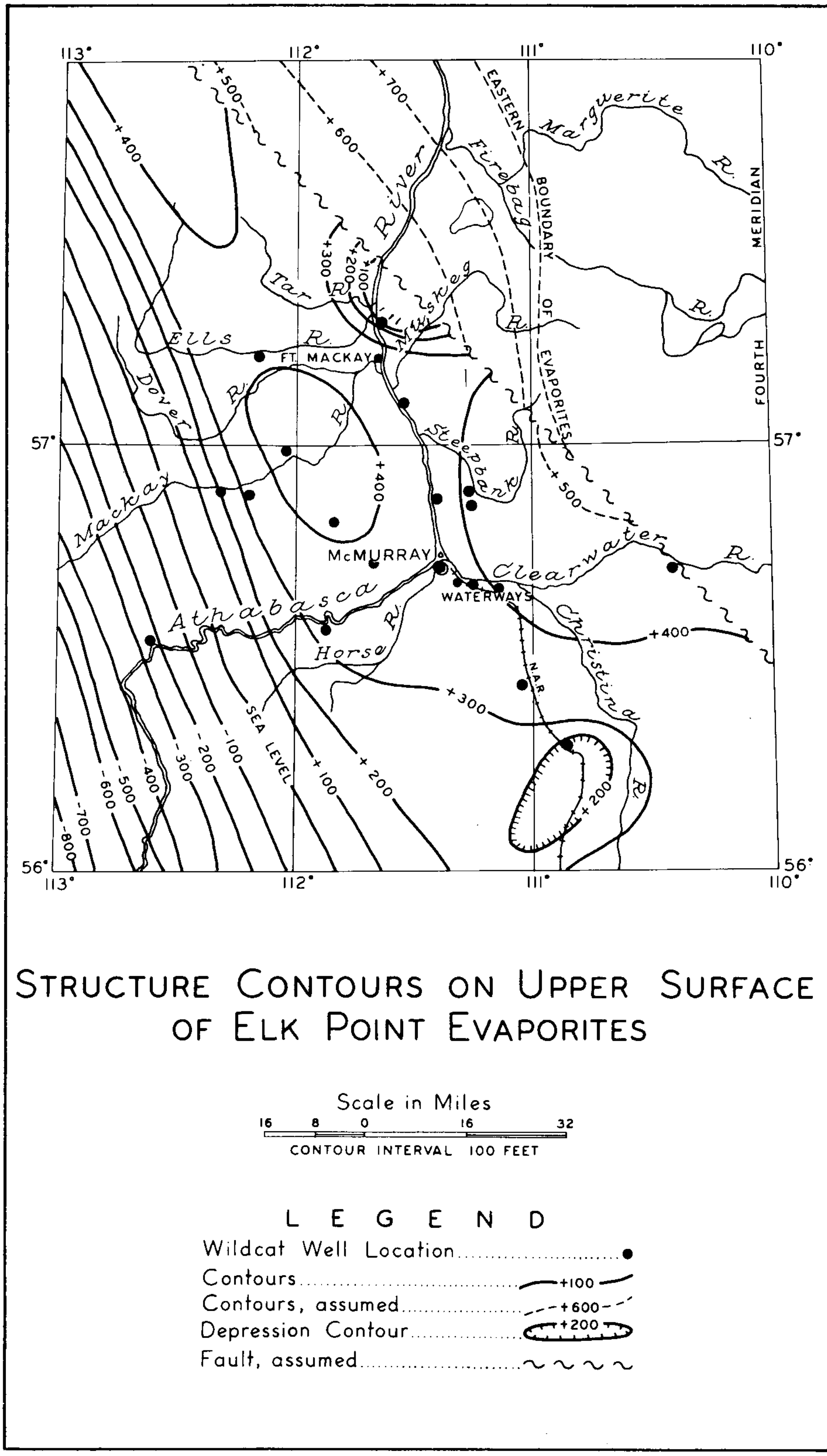


FIGURE 5. Structure Contours on Upper Surface of Elk Point Evaporites

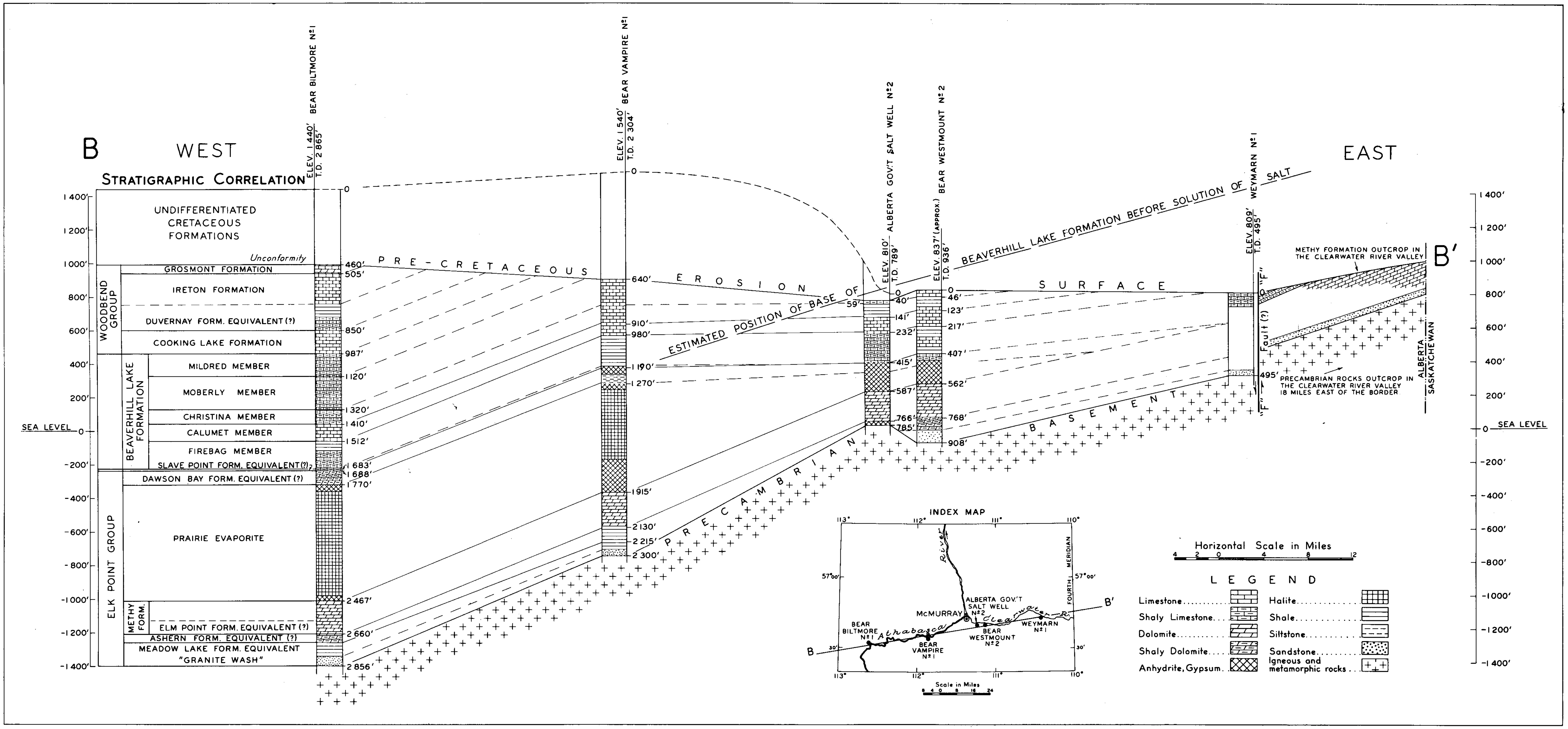


FIGURE 6. Geological Cross Section B-B' of Paleozoic Strata

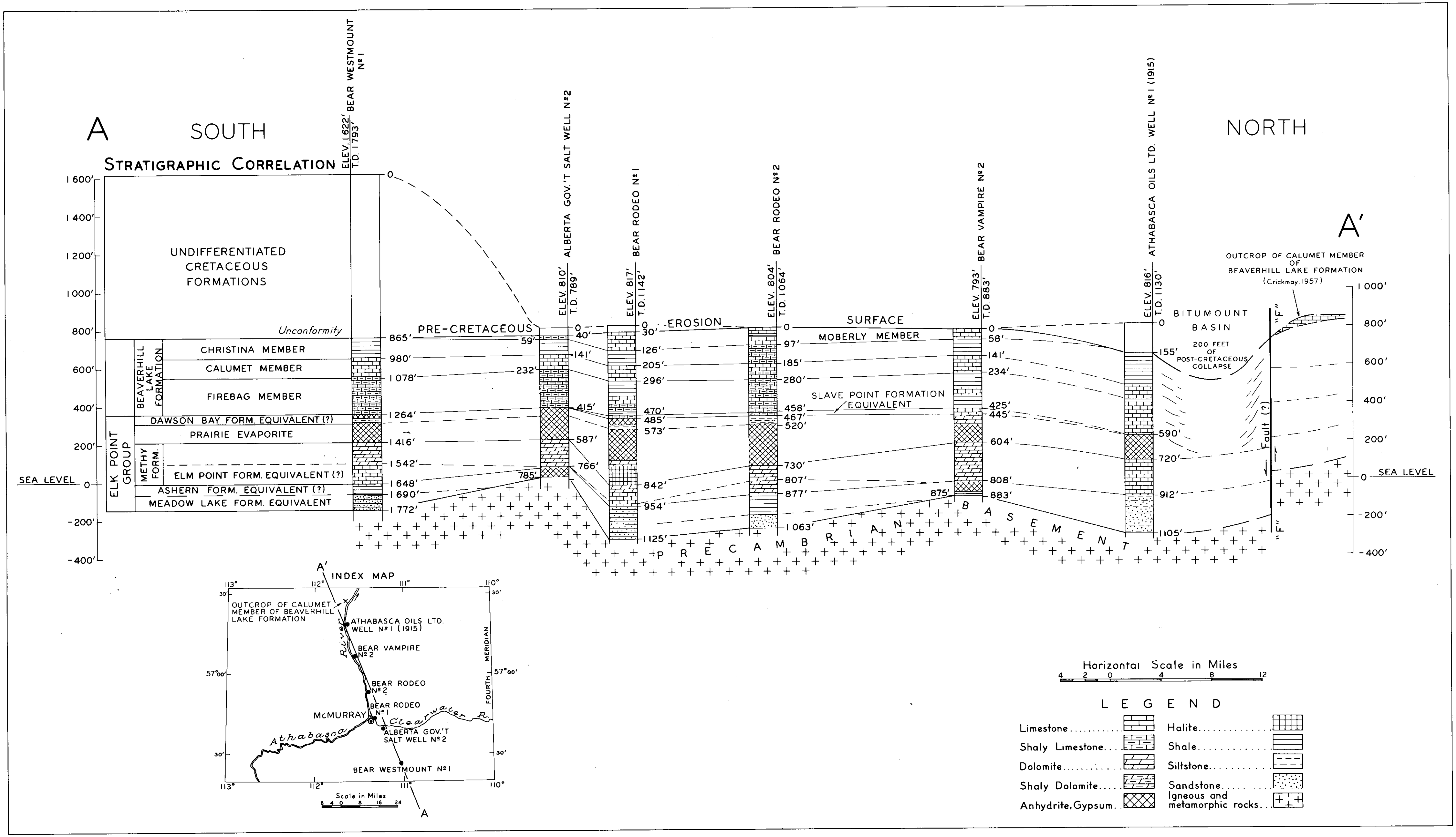


FIGURE 7. Geological Cross Section A-A' of Paleozoic Strata

THE POST-DEVONIAN, PRE-CRETACEOUS EROSION SURFACE

There is a major break in the stratigraphic sequence in the McMurray area between the Devonian and the Lower Cretaceous strata. During this interval of time the rocks in the area were probably subjected to several periods of sub-aerial erosion. The McMurray formation was deposited on the last of these erosion surfaces.

The Beaverhill Lake-McMurray unconformity has been exposed by recent erosion in the valleys of the lower Athabasca River system. The present stream profiles of the lower Athabasca and Clearwater Rivers are now controlled by the pre-Cretaceous erosion surface and thus give close approximations to vertical sections of the basin of deposition for McMurray formation sediments. The structure contours on the limestone surface (Fig. 10) have a similar form to the structure contours on the top of the underlying evaporite strata (Fig. 5). This leads to the suggestion that this pre-Cretaceous depression developed on the Devonian limestone is the result of the solution and removal of underlying water soluble strata. If this hypothesis is correct, then the sediments of the lower McMurray formation need not be related to a transgressing sea in early Cretaceous times.

The nature of the pre-Cretaceous surface varies. Where the contact between the Cretaceous strata and the Devonian limestone can be observed in outcrop on the Athabasca and Clearwater Rivers and their tributary streams south of township 96, there is no angular unconformity and the surface of contact undulates gently reflecting the structure of the Devonian strata. The amplitude of the waves is of the order of 50 to 100 feet and the wave length of one-half to one mile. Generally the crests of the domes rise above the river level and the floors of the basins fall below river level, but borings in Tp. 96, Rs. 10 and 11 have shown that a depression, the Bitumount basin, exists where the elevation of the Devonian surface is mostly less than 500 feet. Such a feature calls for explanation. In Tp. 95, R. 9 what is apparently an old steep-sided drainage channel has been outlined by drilling; it is suggested that the pre-Cretaceous drainage was originally across what is now the Bitumount basin and that some of this water found its way downward through a collapse, solution pipe, or fault plane, and dissolved the underlying evaporites causing the development of a collapse topography on the surface of the limestone. It is apparent from the structures observed in the overlying Cretaceous formations that solution and collapse has continued into post-Cretaceous times and may still be in progress. Much of the area still remains to be drilled; discovery of more collapse topography is to be expected. An analogous situation exists in beds of equivalent age in the Coleville-Buffalo Coulee area in Saskatchewan. Reasoner and Hunt (1954) have attributed the structures observed in the Cretaceous formations there to collapse of the surface due to leaching of salt and anhydrite from the underlying Potlach evaporite beds. Walker (1957) has suggested at least three periods of major solution in central and southern Saskatchewan, and considered that collapse structures may be common in strata overlying beds of the Elk Point group.

CHAPTER V

Mesozoic Rocks

DESCRIPTIONS OF FORMATIONS

McMurray Formation (McLearn, 1917)

General Discussion. The oil sands were noted in the journals of many of the early explorers — Mackenzie, Franklin, Richardson, and others. Since their discovery they have been the subject of many scientific reports: Bell (1884, 1908), McConnell (1891, 1893a, 1893b), Ells (1915a, 1926, 1931, 1932, 1936), McLearn (1917), Clark and Blair (1925, 1927), Clark (1949, 1951, 1957b), Ball (1935), Sproule (1938, 1951), Hume (1947, 1951a), Williams (1949), Falconer (1951), Kidd (1951), Link (1951a, 1951b), Gussow (1956), Mellon (1955, 1956), and Mellon and Wall (1956).

The oil sands were believed by Richardson (in Franklin, 1828) and Isbister (1855) to overlie the Devonian limestones conformably and were thus correlated with the Marcellus shale of the New York Devonian sequence. Meek (1868) was doubtful of the correlation made by Richardson and Isbister, but believed most of the oil sands to be Devonian in age and to represent the Chemung group of the New York Geological Survey. Bell (1884) recognized that the sands were not Paleozoic but Mesozoic in age and that the contact with the limestone was unconformable. McConnell (1891, 1893a) correlated the oil sands with the "Dakota" sandstones of Cretaceous age in Manitoba and Minnesota.

McLearn (1917) proposed the name McMurray for the oil-impregnated sands overlying the limestones on the lower Athabasca River, but did not make an attempt to date the formation. The lower sands of the outcrops were found to contain much wood in a good state of preservation and specimens were identified by I. M. Bailey as *Xenoxylon* sp., *Sciadopitys,* and *Keteloeria.* He believed them to be representatives of a Jurassic flora (Ells, 1931). On the basis of a brackish-water molluscan fauna, Russell (1932) correlated the upper beds of the formation with the Lower Cretaceous portion of the Blairmore group, and McLearn (1932, 1945), using the *Astarte natosini* fauna, correlated the uppermost McMurray strata with the lower Luscar formation of west-central Alberta. Mellon and Wall (1956) described a brackish-water foraminiferal suite from the upper part of the McMurray formation. This suite was calibrated with key ammonites of early Middle Albian age. As no satisfactory faunas have yet been found in the lower continental beds their age is uncertain.

Definition. The McMurray formation was defined by McLearn (1917, p. 147) as follows:

> The top is placed at the base of a bed of green sandstone, in places somewhat argillaceous, immediately below which the sands of the McMurray appear carrying a small invertebrate fauna of freshwater origin. The formation is prevailingly arenaceous and of rather coarse grain, the uppermost part lies horizontal and varies from massive to thick-bedded, but is never thin-bedded. The remainder and greater part of the formation is, in many places, cross-bedded on a very large scale with the beds dipping from 5 to 40

degrees. This part may be bedded above by intercalation of argillaceous sandstone or finer sandstone beds with the coarser sandstone, but is always massive below. Sometimes conglomerate and more rarely clay or shale are found at the very base.

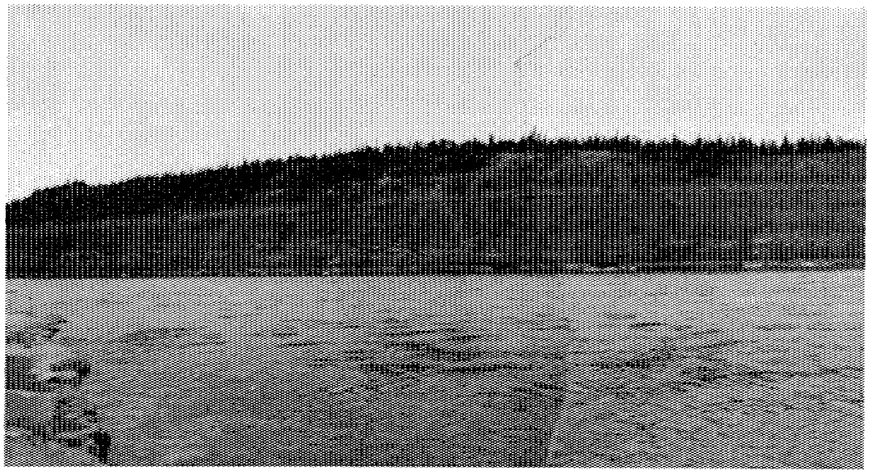


PLATE 3. McMurray formation at Crooked Rapids on the Athabasca River (Tp. 87, R. 12)

Distribution. The McMurray formation outcrops on the Athabasca River from Tp. 87, R. 14 to Tp. 98, R. 10, and on the Clearwater River from the Saskatchewan-Alberta border to its junction with the Athabasca River at McMurray. On the Athabasca River above McMurray it thins out to the west against a hill on the pre-Cretaceous erosion surface. This hill reaches an elevation of 1,000 feet in the vicinity of Brulé Rapids (Tp. 87, R. 17). On the Clearwater River near the Saskatchewan border at Whitemud Falls roughly 60 feet of clean white McMurray sandstone are exposed in the valley wall at an elevation of over 1,000 feet. The formation was traced six miles east tof the Saskatchewan-Alberta border on the Clearwater River but the eastern limit was not reached. The northern boundary of the McMurray formation is obscured by a cover of glacial drift. From the outcrop information available in the valleys of the Athabasca River, Firebag River, and Reid Creek, and holes drilled by the Shell Oil Company of Canada during the years 1952 to 1954 in the vicinity of McClelland Lake, the approximate position of the boundary has been sketched on map 26. The boundary extends from the northern border of the map in Tp. 103, R. 11 in a southerly direction to the Athabasca River in Tp. 98, R. 10, then in an easterly direction to the south end of McClelland Lake. From its most southerly point in Tp. 97, R. 9 it stretches in a northeasterly direction to the Firebag River in Tp. 98, R. 7 and to Reid Creek in Tp. 100, R. 4. The southern boundary of the McMurray formation has not yet been determined but oil sands were penetrated at a depth of 750 feet in a well drilled near the Pelican Rapids on the Athabasca River (see well log in appendix A).

Lithology. The wide variation in the particle-size composition of the oil sands in the McMurray formation is illustrated in figure 8. The sedimentary deposits between the Clearwater formation and the Devonian limestone formations have been subdivided on lithological evidence into three stratigraphic units.

1. The Lower Member consists of lenticular beds of conglomerate, sand, shale, and silt which occupy the deeper depressions on the pre-Cretaceous erosion surface. The basal strata are residual clays derived from weathering of the Beaverhill Lake limestones. These are overlain by sediment whose general characteristics have been controlled by the topography of the surface on which they were deposited. East of the Athabasca River in the Muskeg River area in Tp. 95, Rs. 9 and 10 the thick deposits of coarse sands found in the Shell Oil Company of Canada Limited wells below an elevation of 750 feet were probably laid down in a valley on the pre-Cretaceous erosion surface. These coarse-grained sands contain large fragments of uncarbonized wood, well-rounded quartz grains, numerous feldspar cleavage fragments, and small amounts of mica. In some test holes this sand is barren and contains only fresh water, in the rest it is impregnated with heavy oil. Interbedded with these sands are grey micaceous siltstones which in many cases have a brown color due to oil staining. At the top of this member in most places is a black or dark-grey carbonaceous shale, which contains wood fragments. The mineralogy of the sand fraction of this shale is very similar to that of the underlying detrital sand beds. Marcasite concretions and marcasite cement are common in this shale.

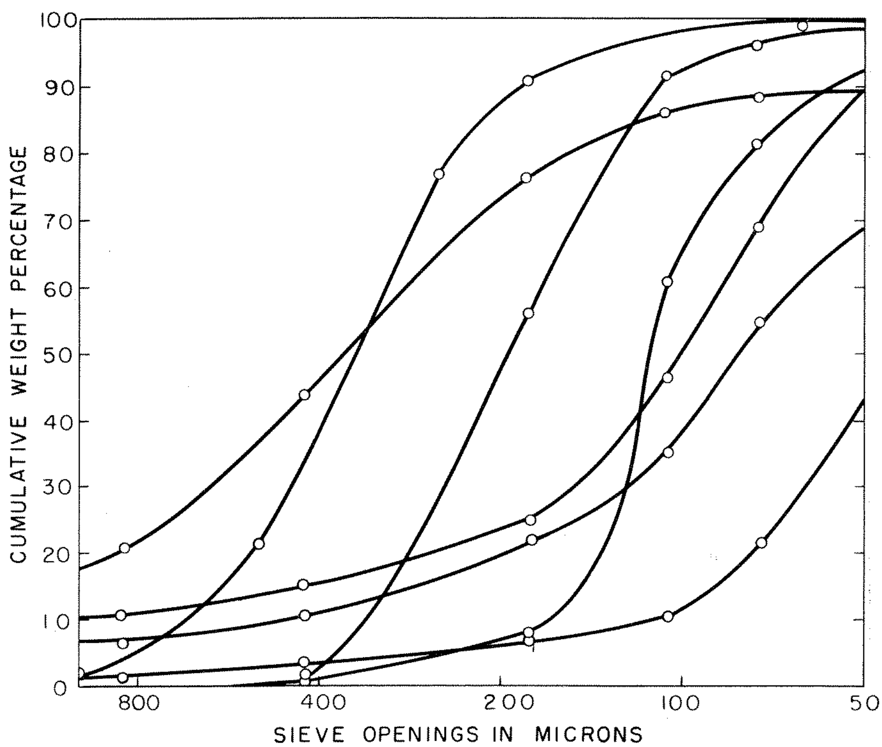


FIGURE 8. Graphs Showing Particle-size Composition of McMurray Formation Sands

Outcrops are present on the Steepbank and MacKay Rivers (plate 5) and on the west bank of the Athabasca River between township 92 and the landing at Fort MacKay. This bed contains boulders of Athabasca sandstone, angular vein-quartz, and some white quartzite grains. The quartz grains vary in shape from angular to rounded, and in thin section individual grains show fractures, crystal intergrowth, a granoblastic texture, and strain extinction when viewed in polarized light. This bed contains many siderite nodules.

2. The Middle Member lies between elevations of 750 or 800 feet and about 940 feet. This is the so-called typical McMurray formation and consists mainly of an oil-cemented quartz sand of very uniform mineralogy, the major accessory mineral being muscovite. Interbedded with these sands are lenticular beds of micaceous silts, shales, and in places clay. Beds of this member are characterized by many primary sedimentary structures, particularly current bedding. They also contain plant remains, worm casts, and oil-impregnated wood and coal.

3. The Upper Member is not everywhere clearly differentiated from the middle member. It has a similar lithology but is mostly horizontally-bedded and is identified by the presence of beds containing a limited brackish-water fauna (Mellon and Wall, 1956).

The approximate elevations of the base of the fossiliferous beds in the upper member are, from south to north: Hangingstone River shell beds (Sec. 9, Tp. 89, R. 9), 930 feet; Socony-Vacuum Hole No. 27 (Tp. 91, R. 10), 945 feet; Dominion Government Mildred Lake Hole B22 (Tp. 92, R. 10), 925 feet; Fort MacKay, Athabasca Oil Sands Project well 77 (Tp. 94, R. 11), 950 feet. The Hangingstone River shell beds have lithological and faunal affinities with the *Metacypris angularis* beds of Badgley (1952) and the *Metacypris persulcata* beds of Loranger (1954b) in central Alberta. Mellon and Wall (1956) postulated, on the basis of microfaunal evidence, that these beds were a transitional sequence of brackish-water sediments related to a transgressing sea. A sharp change in the sedimentary sequence is visible at the contact of these sands with the overlying sands of the lower Clearwater formation where the presence of glauconite pellets indicates marine sediments and a slowing down of the rate of sedimentation. In formations of Cretaceous age higher in the stratigraphic section glauconite is a common accessory mineral.

The contact with the Clearwater formation on the lower Athabasca River is in general at the 1,000 foot contour except in the area of the Bitumount basin where, due to collapse, the contact may be as low as 800 feet (Fig. 7). The upper member as defined here corresponds to the "upper leaner banded beds" of Ells (1926) which generally overlie the richer sands.

Type Sections. No type section for the McMurray formation was designated by McLearn (1917), so a type outcrop section was measured for the McMurray formation so defined. A supplementary subsurface type

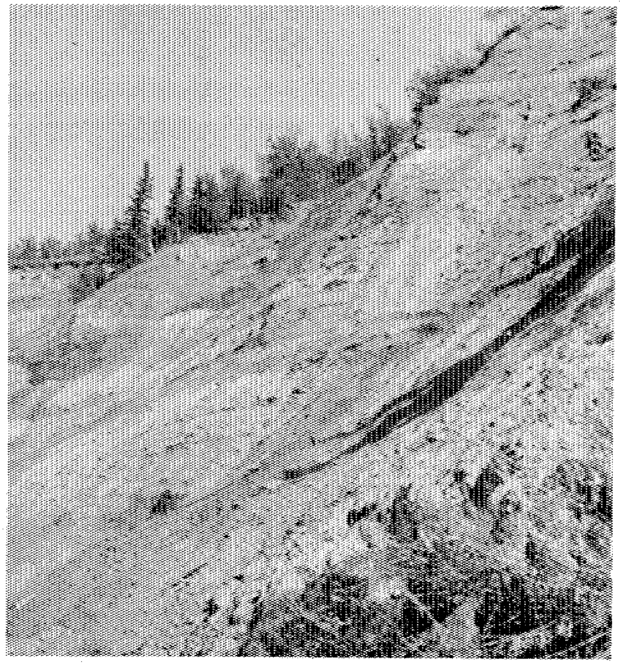


PLATE 4. *Measuring a section on an outcrop of the McMurray formation (Tp. 90, R. 9)*

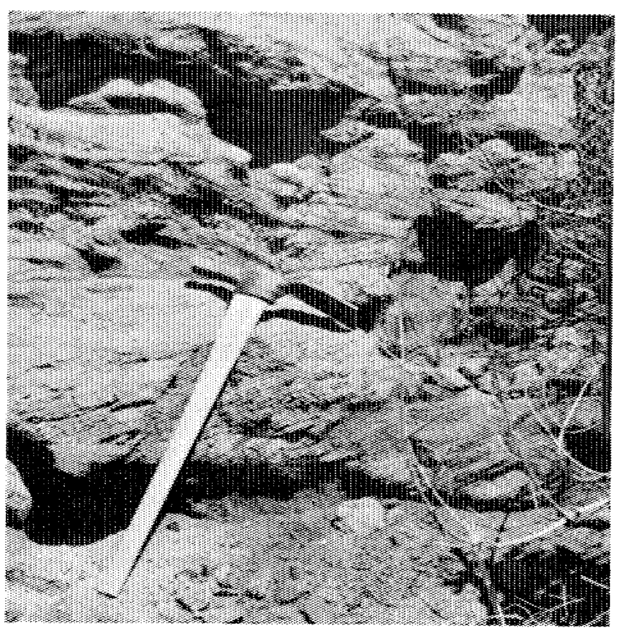


PLATE 5. *Cross-bedding in coarse-grained sand of the McMurray formation (Tp. 94, R. 11)*

section has also been added; this is based on a set of cores presented to the Research Council of Alberta by Mobil Oil of Canada Limited from Socony-Vacuum Exploration Company Hole No. 27, which was drilled in Sec. 27, Tp. 91, R. 10 in 1953.

Descriptions of both sections follow:

Type Section of McMurray Formation Measured on Outcrop on East Side of Athabasca River Three Miles North of McMurray in Sec. 5, Tp. 90, R. 9

Approximate Elevation	Formation	Description of Lithology	Thickness of bed in feet
1063 plus or minus 20 ft.		Grey shale	10
		Ironstone bed	1
		Fine-grained glauconite sandstone, no cement, gypsum crystals on surface	6
		Ironstone bed	1
		Fine-grained glauconite sandstone, no cement, gypsum crystals on surface	7
1037 feet	Clearwater 26 feet	Ironstone bed	1
	Upper McMurray Member 3	Grey shale with salt and crystals of gypsum on surface	12
		Fine-grained horizontally-bedded sandstone, some iron-oxide cement	13
		Ironstone bed	1
		Oil-impregnated and iron-oxide cemented sands, interbedded	6
		Horizontally-bedded oil-cemented sands	9
		Ironstone bed	0.5
		Richly-impregnated oil sand	3
991 feet		Ironstone bed	2
	Middle McMurray Member 2	Rich oil sands, bedding has slight dip	150
799 feet	McMurray 237 feet	Oil sand with small-scale cross bedding, few irregular saline seepages. Lower section obscured by talus	42 plus or minus 5
798 feet		Ironstone conglomerate bed	1
780 feet	Beaverhill Lake	Fossiliferous limestone containing brachiopods and algae	18

ATHABASCA RIVER

Supplementary Type Section (subsurface)
Socony-Vacuum Exploration Company Hole No. 27

Location: 2,785 feet South of north boundary / 2,504 feet West of east boundary } of Sec. 27, Tp. 91, R. 10

Elevation: 1,061 feet **Total Depth:** 296 feet **Cored:** 223 feet **Recovered:** 183 feet

Date Spudded: Sept. 20, 1953 **Completed:** Sept. 24, 1953

Core is available for inspection at the Research Council of Alberta, Edmonton.

Elevation above mean sea level	Formation	Description of Lithology	Depth in feet	Thickness in feet
1061 feet		Glacial clays and sands, few boulders	0- 73	73
		Dark-grey clay, streaks of silt	73- 93	20
		Fine-grained sands with glauconite	93- 98	5
	Clearwater	Sandstone, with siderite cement	98- 99	1
960 feet	(Wabiskaw member) lower 8 feet	Fine-grained, green sandstone, partly cemented, with a few dark-grey clay beds, odor of oil	99-101	2
	Upper McMurray Member 3	Grey clay with streaks of sand and silt	101-108	7
		Low-grade oil sand with interbedded clay	108-117	9
939 feet		Grey clay with few streaks of silty brown oil sand	117-122	5
	Middle McMurray Member 2	Fine-grained, brown, low-grade oil sand	122-132	10
		Low-grade oil sand, with clay streaks up to 2 inches thick	132-152	20
		Hard siderite-cemented sandstone with trace of oil	152-153	1
		Fine-grained silty oil sand with clay interbeds	153-172	19
		Hard siderite-cemented sandstone with oil	172-173	1
775 feet	McMurray, total 185 feet	Clay and silty clay with oil sand beds up to 1 foot thick, and many sandstone seams with siderite cement about 1 inch in thickness	173-286	113
765 feet	Residual clay over Beaverhill Lake formation	White limy clay, part silty	286-296	10

It should be noted that neither type section includes the lower member as defined in this report. Cored sections from wells which penetrate the lower member were not available when this report was prepared.

Fossil Localities

1. Socony-Vacuum Exploration Company Hole No. 27 (Sec. 27, Tp. 91, R. 10) on west side of Athabasca River, microfauna from upper member between elevations of 945 and 960 feet (Mellon and Wall, 1956).

Foraminifera

Ammodiscus sp.
Haplophragmoides cf. *H. sluzari* Mellon and Wall
Haplophragmoides sp.
Miliammina sproulei Nauss var. *gigantea* Mellon and Wall
Trochammina mcmurrayensis Mellon and Wall
Trochammina? sp.
Verneuilinoides? sp.

2. Hangingstone River (Lsd. 12, Sec. 9, Tp. 89, R. 9) macrofauna taken from fossil beds at an elevation of approximately 930 feet (Russell, 1932; McLearn, 1945).

Pelecypoda

"Astarte" natosini McLearn
Unio (Elliptio) biornatus Russell
Murraia naiadiformis Russell

Gastropoda

Viviparus murraiensis Russell
Lioplacodes bituminis Russell
Melania multorbis Russell
Goniobasis? *multicarinata* Russell
Melampus athabascensis Russell

Clearwater Formation (McConnell, 1893a)

Definition. "Clearwater shale" was the name given by McConnell (1893a, p. 30D) to the outcrop eight miles below Grand Rapids on the Athabasca River at Pointe La Biche (Tp. 86, R. 18). He noted that this shale contained lenticular beds of fossiliferous glauconitic sandstone at Burnt Rapids (Tp. 87, R. 16) and published a list of fossils, identified by Whiteaves. He estimated the thickness of the shales to be 275 feet. McLearn (1917) defined the base of the Clearwater formation as the bottom of the well-defined glauconite sand bed underlying the shale and overlying the oil-impregnated sands of the McMurray formation. The age of the formation has been established by paleontological evidence as Lower Cretaceous (Albian) (Whiteaves, 1893; Whiteaves in McConnell, 1893a; McLearn, 1917, 1919, 1932, 1933 and 1945; Wickenden, 1949; Mellon and Wall, 1956; Stelck et al., 1956).

The Wabiskaw member, a glauconite sandstone bed found in Barnsdall West Wabiskaw No. 1 well has been described by Badgley (1952).

Distribution. The Clearwater formation outcrops almost continuously on the Athabasca River from eight miles above Grand Rapids (Tp. 84, R. 17) as far north as the Bitumount basin and probably extends under the higher ground to the northwest at least as far north as township 103. It has been penetrated by wells drilled in the Birch Mountains. In the McMurray area the base of the formation varies in elevation between 1,000 and 1,100 feet and the top lies between 1,250 and 1,300 feet, except in the Bitumount basin (Tp. 96, Rs. 9 and 10), where it has been affected by movement of the Devonian rocks below. The elevation of the base in the Bitumount basin is below 800 feet and the upper contact is not preserved. In the Clearwater River Valley outcrops are rare because of slumping and a thick vegetation cover. One outcrop, however, was found at Whitemud Falls (Tp. 89, R. 1). Other exposures are found in the tributary streams of the Clearwater — Christina River, Cottonwood Creek (Sec. 6, Tp. 89, R. 5) and High Hill River (Tp. 89, R. 3). Microfossils from these locations were identified by J. H. Wall.

Lithology. The lithology of this formation has been described by Badgley (1952). Because exposures showing both upper and lower contacts are not readily found in the McMurray area, descriptions of the lithology in this report are confined to the basal marine sandstone unit and the lower section of the marine shale unit.

A thin bed of glauconitic sandstone, rarely exceeding 20 feet in thickness, has been found at the base of the formation throughout the area, overlying the upper McMurray formation strata. This sand is commonly very dirty and can be described as a shaly or clayey sand. It is composed of a fine-grained well-sorted sand with varying proportions of silt- and clay-size material filling the voids. This bed has so far failed to yield any fossils in this area. Mellon (1956) examined the non-opaque heavy minerals in a single sample taken in Sec. 27, Tp. 91, R. 10 and found the following minerals, in descending order of abundance: garnet (over 50 per cent), tourmaline, apatite, chlorotoid and staurolite, kyanite and zircon.

This lower glauconitic sandstone of the Clearwater formation has been called the Wabiskaw member by the Alberta Oil and Gas Conservation Board (Badgley, 1952). This sand member is found at the base of the Lower Cretaceous sequence to the west and southwest of the McMurray area. It is probably this sand which has been impregnated with heavy oil, and not the McMurray formation, in the Pelican Rapids well drilled by the Geological Survey of Canada (see appendix A for well log). The olive-green color of the basal sandstone bed makes it a useful and reliable guide for mapping.

A grey shale carrying a marine fauna is the characteristic lithology of the Clearwater formation in the McMurray area. Large crystals of gypsum are found on many outcrop faces of this unit. The upper boundary with the Grand Rapids formation is transitional where observed on the Clearwater River near Whitemud Falls.

Fossil Localities

1. Socony-Vacuum Exploration Company Hole No. 27 (Sec. 27, Tp. 91, R. 10) Microfossils from lower Clearwater formation between elevations of 968 and 988 feet (Mellon and Wall, 1956):

Foraminifera

Ammobaculites humei Nauss
Ammodiscus sp.
Bathysiphon sp.
Discorbis norrisi Mellon and Wall
Globulina lacrima Reuss var. *canadensis* Mellon and Wall
Haplophragmoides gigas Cushman var. *minor* Nauss
Haplophragmoides sluzari Mellon and Wall
Lenticulina bayrocki Mellon and Wall
Leptodermella? sp.
Marginulinopsis collinsi Mellon and Wall
Marginulinopsis collinsi Mellon and Wall var.
Miliammina subelliptica Mellon and Wall
Nodosaria aff. *N. proboscidea* Reuss
Pseudonodosaria clearwaterensis Mellon and Wall
Quadrimorphina albertensis Mellon and Wall
Saracenaria trollopei Mellon and Wall
Saracenaria trollopei Mellon and Wall var.
Saracenaria sp.
Tritaxia athabascensis Mellon and Wall
Verneuilinoides? sp.

Ostracoda

Cytheridea (sensu lato) sp.

2. Athabasca River, west side (NE. 1/4, Sec. 30, Tp. 85, R. 17) (Wickenden, 1949). Samples collected by Wickenden contained a number of arenaceous foraminifera including species of:

Haplophragmoides sp.
Ammobaculites sp.
Gaudryina sp.

3. Athabasca River, Burnt Rapids, greenish glauconite sand lens in the Clearwater shale (McConnell, 1893a, p. 31):

Camptonectes sp.
Modiola sp. allied to *M. tenuisculpta* Whiteaves
Yoldia aff. *Y. evansi* Meek and Hayden
Nucula sp.
Protocardium sp.
Callista tenuis Hall and Meek
Mactra sp.
Cinulia sp.
Desmoceras affine Whiteaves
Hoplites mcconnelli Whiteaves

4. Athabasca River, Drowned Rapids, four miles below Petite Rivière Bouffante, harder arenaceous beds (Bell, 1884):

Fossil wood, apparently coniferous
An ammonitoid like *Olcostephanus* or *Haploceras*; a species with a comparatively simple sutural line
Small gastropod like *Cinulia*
Tellina or *Thracia*
Venus or *Cyprinia*
Protocardium sp.
Nucula sp.
Inoceramus sp.
Pecten sp.

5. Athabasca River, 10 miles below Burnt Rapids, sandstone bed in the Clearwater shale (McConnell, 1893a, p. 32):

Callista tenuis Hall and Meek
Mactra sp.
Yoldia sp.
Nucula sp.
Cinulia sp.

6. Athabasca River, Boiler Rapids, Clearwater shale (McConnell, 1893a, p. 32):

Desmoceras affine Whiteaves
Goniomya sp.
Thracia or *Tellina* sp.

7. Ells River, Clearwater shale (McConnell, 1893a).

Nucula sp.
Yoldia sp.
Camptonectes sp.

8. Pembina (Christina) River, 10 miles above mouth, Clearwater shale (McConnell, 1893a, p. 39):

Cyprina sp.
Nucula sp.
Yoldia cf. *Y. scitula*

9. MacKay River, an outcrop in northeast bank (Sec. 33, Tp. 94, R. 11) yielded the following microfossils which were identified by J. H. Wall:

Ammobaculites humei Nauss
Haplophragmoides gigas Cushman var. *minor* Nauss
Haplophragmoides sluzari Mellon and Wall
Haplophragmoides cf. *H. sluzari* Mellon and Wall
Miliammina subelliptica Mellon and Wall—rare
Proteonina sp.—rare
Tritaxia athabascensis Mellon and Wall
Verneuilinoides? sp. of Mellon and Wall (1956, R.C.A. Rept. 72, Pl. 1, Figs. 13, 14)—rare

10. Athabasca River, an outcrop on east bank, 1 mile south of Bitumount (Sec. 36, Tp. 96, R. 11) yielded the following microfossils which were identified by J. H. Wall:

Ammobaculites humei Nauss
Haplophragmoides gigas Cushman var. *minor* Nauss
Haplophragmoides sluzari Mellon and Wall
Haplophragmoides cf. *H. sluzari* Mellon and Wall
Miliammina cf. *M. subelliptica* Mellon and Wall —one specimen
Tritaxia athabascensis Mellon and Wall
Verneuilinoides? sp. of Mellon and Wall (1956, R.C.A. Rept. 72, Pl. 1, Figs. 13, 14)—one specimen

11. Cottonwood Creek, an outcrop in Sec. 31, Tp. 88, R. 5 yielded the following microfossils which were identified by J. H. Wall:

Ammodiscus sp. of Stelck, Wall et al. (1956, R.C.A. Rept. 75, Pl. 2, Figs. 31, 32)
Haplophragmoides sluzari Mellon and Wall
Haplophragmoides sp.
(all species are rare)

12. Clearwater River, an outcrop in the valley wall north of Whitemud Falls, Sec. 25, Tp. 89, R. 1, sampled by G. A. Collins, 1955, yielded the following microfossils which were identified by J. H. Wall:

Ammobaculites humei Nauss
Ammobaculites tyrrelli Nauss
Haplophragmoides gigas Cushman var. *minor* Nauss—rare
Haplophragmoides sluzari Mellon and Wall
Haplophragmoides cf. *H. sluzari* Mellon and Wall
Miliammina subelliptica Mellon and Wall

Clearwater Shale Faunal List

Cephalopoda

Beudanticeras affine (Whiteaves)
Beudanticeras glabrum (Whiteaves)
Lemuroceras mcconnelli (Whiteaves)
Lemuroceras cf. *L. belli* McLearn
Gastroplites cf. *G. canadensis*? (Whiteaves)

Pelecypoda

Entolium irenense McLearn
Pecten alcesianus McLearn
Camptonectes matonabbei McLearn
Brachidontes athabaskensis McLearn
Nucula athabaskensis McLearn
Inoceramus dowlingi McLearn
Arctica limpidiana McLearn

Thracia kissoumi McLearn
Yoldia kissoumi McLearn
Goniomya matonabbei McLearn
Psilomya elongatissima McLearn
Psilomya peterpondi McLearn
Protocardia alcesiana McLearn
Onestia onestae (McLearn)
Tellina dowlingi McLearn

Gastropoda
Turnus lacombi McLearn

Ostracoda
Cytheridea (sensu lato) sp.

Foraminifera
Ammobaculites humei Nauss
Ammobaculites tyrrelli Nauss
Ammodiscus sp.
Bathysiphon sp.
Discorbis norrisi Mellon and Wall
Gaudryina sp.
Globulina lacrima Reuss var. *canadensis* Mellon and Wall
Haplophragmoides gigas Cushman var. *minor* Nauss
Haplophragmoides sluzari Mellon and Wall
Lenticulina bayrocki Mellon and Wall
Leptodermella? sp.
Marginulinopsis collinsi Mellon and Wall
Marginulinopsis collinsi Mellon and Wall var.
Miliammina subelliptica Mellon and Wall
Nodosaria aff. *N. proboscidea* Reuss
Pseudonodosaria clearwaterensis Mellon and Wall
Quadrimorphina albertensis Mellon and Wall
Saracenaria trollopei Mellon and Wall
Saracenaria trollopei Mellon and Wall var.
Saracenaria sp.
Tritaxia athabascensis Mellon and Wall
Verneuilinoides? sp.

Grand Rapids Formation (McConnell, 1893a)

Definition. The Grand Rapids sandstone was defined by McConnell (1893a) as a formation from its outcrops on the Athabasca River. It is what is commonly called a "pepper and salt" sand and has a heterogeneous mineral composition which includes grains of quartz, feldspar, glauconite, chert, muscovite, and biotite. The greater part of the sand is uncemented, but spherical calcareous nodules up to 10 feet in diameter are present in outcrop sections throughout the McMurray area (plate 6). At the Grand Rapids on the Athabasca River there is a concentration of these large nodular boulders in the river bed. Many outcrops are stained with iron oxide. The sandstone is over 300 feet thick and is overlain by the Pelican shale (McLearn, 1917) or, as it is now known, the Joli Fou formation (Wickenden, 1949).

In the McMurray area, Grand Rapids sandstone outcrops are generally found between the 1,200- and 1,500-foot contours. The bed is porous and permeable and many small springs emerge at its contact with the underlying Clearwater shale. These springs have eroded small blind valleys by cutting away the unconsolidated sand to form vertical cliff faces up to 300 feet high (plate 6). The combined action of many such springs has produced a terrace of varying width at the top of the Clearwater shale which can be easily recognized on vertical aerial photographs. Outcrops have been found in the Athabasca River Valley west of McMurray, on the Clearwater River Valley and in the upper Ells River Valley on the eastern side of Birch Mountain.

Fauna and Fossil localities. Wickenden (1949, p. 29) stated that:

> No diagnostic animal or plant fossils have been reported from the formation, although it is probable that some will be found if detailed studies are made.

He found no sharp change in conditions of sedimentation or environment between strata of the Clearwater and Grand Rapids formations. Recently Stelck et al. (1956) have zoned the Lower Cretaceous sequence on the basis of microfauna. They have noted that the *Haplophragmoides gigas minor* zone of the upper part of the Clearwater extends into the basal portion of a shale unit equivalent to the Grand Rapids formation. Within the Grand Rapids formation equivalent in the Peace River area they have found

PLATE 6. Grand Rapids formation outcrop in Tp. 83, R. 13

two further zones, the lower is the *Haplophragmoides multiplem* zone and the upper the Cadotte microfaunal zone.

Only one fossil locality has been reported on the lower Athabasca River (Wickenden, 1949). It is located near Grand Rapids where the following fossils were collected from a concretion just above the base of the formation. They were identified by McLearn (in Wickenden, 1949):

Pecten (Entolium) irenense McLearn
Pecten n. sp.
Nucula sp.

Joli Fou Formation (Wickenden, 1949)

The name "Joli Fou" was applied by Wickenden (1949) to the dark-grey marine shale formation about 110 feet thick which outcrops near Joli Fou Rapids on the Athabasca River (Tp. 81, R. 17). It was previously known as the Pelican shale (McConnell, 1893a) the contact between the Joli Fou shale and the underlying Grand Rapids sandstone is considered by Badgley (1952) to be useful for stratigraphic correlation and structural interpretation beneath the plains of Alberta. In the McMurray area, outcrops showing this contact are not sufficiently numerous to be of much use for structural interpretation.

McConnell (1893a) found outcrops, a few feet thick, of this formation on the eastern side of the Birch Mountains in the valley of the Ells River. He failed to find any exposures on the north side of the Birch Mountains.

An assemblage of arenaceous foraminifera, sufficient to establish its age as Lower Cretaceous, has been described from this formation by Wickenden (1949). Stelck et al. (1956) have made a more complete study of the foraminifera and have equated them with the *Haplophragmoides gigas* zone of Middle Albian age.

Pelican Formation

This formation is a series of lenses of sands and siltstones of marine origin. It does not outcrop in the McMurray area but is found on the Ells River (Tp. 95, R. 16) (McConnell, 1893a). The thicknesses of the beds have not been determined.

La Biche Formation

Classification of the strata reported as overlying the Pelican formation in the Birch Mountains has not been attempted, but the grey shales, containing limestone concretions, which outcrop two miles below Moose Lake were assigned to this unit by McConnell (1893a).

LITHOLOGY OF THE MESOZOIC ROCKS

In order to explain the origin of the Mesozoic rocks in the McMurray area the various lithofacies within the stratigraphic sequence must be identified. Two sources or provenances are recognized for the sediment

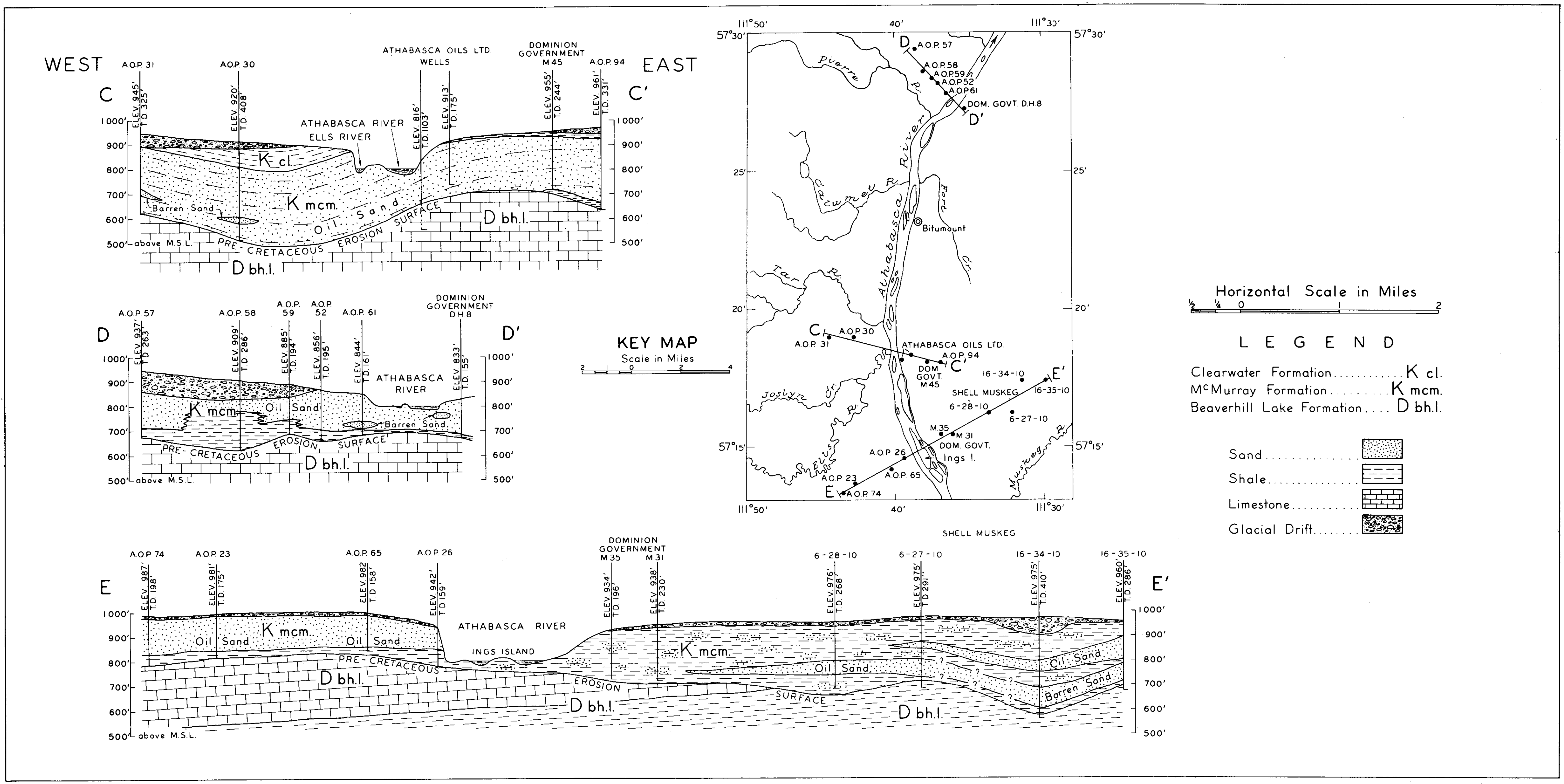


FIGURE 9. Geological Cross Sections of Mesozoic Strata

that has accumulated. One is the adjacent low-lying Precambrian Shield to the east and north, the other is the outwash derived originally from the Cordillera to the west. This section presents a preliminary subdivision and classification of the lithological types of sediment encountered during the field work and in drilling operations in the McMurray area. The nomenclature used is that of Travis (1955).

Sands

(i) *The Coarse Feldspathic Sands.* These consist mostly of coarse-grained worn quartz grains with feldspar cleavage fragments. Grey or smoky quartz grains are numerous and chips of woody material are locally abundant. Clusters of sand grains cemented by marcasite are common.

These sands are present at the base of the McMurray formation. They are barren, oil-stained, or impregnated with heavy black oil.

They are generally overlain by a black-grey carbonaceous shale which carries much marcasite and wood.

(ii) *The Quartz Sands.* Most of the oil sands visible in outcrop can be classified under this heading. The sand is fine- to medium-grained (Fig. 8). It carries quantities of muscovite, and according to Mellon (1956), a small amount of orthoclase and a characteristic suite of heavy minerals which indicate that they were derived from the Precambrian Shield. Interbedded with these sands are thin coal seams, lignite bands, and woody and carbonaceous fragments. The bedding is massive or shows well-developed primary sedimentary structures. These sands are characteristic of the McMurray formation as defined by McLearn (1917).

The heavy mineral assemblages in these sands have been studied by Kupsch (1954) and Mellon (1956). According to Mellon, the McMurray sands contain the following non-opaque heavy minerals in descending order of abundance:

Tourmaline (makes up approximately 50 per cent of total)
Chlorotoid
Zircon, staurolite
Garnet
Kyanite
Apatite, rutile

Kupsch found the following suite of heavy minerals in a series of samples from the outcrops in the Athabasca River Valley in the vicinity of McMurray. Listed in descending order of abundance they are:

Tourmaline (makes up more than 50 per cent of total)
Zircon
Chlorite
Staurolite
Garnet, epidote, zoisite

Rutile
Andalusite, sillimanite
Biotite

Chemical analysis of sand samples combined from six representative outcrops was made by Ells (1926, p. 51) as follows:

SiO_2	95.5
Al_2O_3	2.25
Fe_2O_3	0.35
CaO	0.50
MgO	0.23
Loss on ignition	1.50
Total	100.33

(iii) *Lithic Sands.* These sands are fine-grained, well-sorted, and contain grains of angular quartz, twinned feldspar, chert, muscovite, biotite, and glauconite. They have been described by Badgley (1952) as "salt and pepper" sands, greywacke, and winnowed greywacke. Sands of this type are found in the Clearwater and Grand Rapids formations.

The presence of black angular chert and biotite and the increased abundance of twinned feldspar in these sands indicate that they have a provenance different from that of the quartz sands characteristic of the McMurray formation (Wickenden, 1951). Minor quantities of black chert and twinned feldspar, however, are also found in the upper horizontally-bedded member of the McMurray formation. A slowing down of the rate of sedimentation at the close of McMurray time allowed the formation of glauconite to take place in the transgressing sea of early Clearwater time. There is thus some evidence for postulating a hiatus between McMurray and early Clearwater times. These glauconites have an apparent age of 142 million years (Lipson, 1958), and thus would be Jurassic according to the Holmes' time scale (Umbgrove, 1947). Lipson, however, believes that this age may be somewhat too great.

Sandstones

(i) *Orthoquartzites.* Quartz sands cemented by a siliceous cement were reported from the Muskeg River area by Ells (1932), who believed that they were outcrops of Precambrian quartzite bosses. Subsequent drilling has shown that they overlie the Devonian limestones, and therefore are here included in the McMurray formation. They consist of rounded and angular quartz grains, fractured, and with marked strain extinction; they are poorly cemented by silica and oil, and are porous.

(ii) *Ferruginous Quartz Sandstones.* Quartz sands cemented by siderite or limonite are common in the McMurray formation; coarse-grained sands of this type outcrop at the Fort MacKay landing, other beds have been observed in outcrop and noted in well sections (see type sections) throughout most of the area. They vary in thickness from a few inches to five feet or more. In well sections the cement is generally siderite and the sandstone is grey and hard. In outcrop the same type of bed appears as a limonite- or hematite-cemented sandstone and is brown or red.

Siltstones

Two types of grey siltstones were deposited in the area but in hand specimens they cannot be easily distinguished. One is Pleistocene in age; siltstones of this type outcrop on the Firebag River beneath glacial sands. Similar deposits have been penetrated in wells drilled by the Shell Oil Company of Canada in the vicinity of McClelland Lake. Under oxidizing conditions they weather to a characteristic pink color. The other type is slightly more micaceous and is interbedded with the oil sands of the McMurray formation. The Cretaceous siltstone is prominent in well cores near the Muskeg River. It has been stained brown by oil. In deposits of both ages, scattered larger grains over one milimetre in size have been found. In outcrop, however, boulders, presumably ice-rafted, have been found in the Pleistocene siltstones. X-ray diffraction powder patterns show that quartz is the most abundant mineral in these siltstones and that it is associated with minor amounts of kaolinite, illite, and chlorite.

Shales and Clays

Shale beds in the McMurray formation are lenticular in shape and generally do not have a well-developed parting. The dominant clay minerals present are illite and kaolinite. Small amounts of hydrated calcium sulfate and gypsum were found in the zero to 8-micron size. The Clearwater shale carries a well-developed assemblage of marine faunas but the McMurray shales have so far failed to yield any marine fossils. In the McMurray formation a brackish-water microfauna was found in shales in the upper 50 feet (Hume, 1947; Wickenden, 1951; Mellon and Wall, 1956).

Coal

Thin seams of lignitic coal have been found within the McMurray formation. These beds are not thick enough to be suitable for commercial exploitation (Ells, 1926).

Cementing Agents

The group of sands and sandstones described in the previous section vary in the amount of lithification that has taken place and all stages can be found from loose sands to tightly-cemented sandstones. The cements are varied and no one type of cement is confined to a particular sand. The detrital sands of the lower McMurray member are generally loose but are locally cemented by iron sulfide or heavy black oil. The middle McMurray sands have the greatest variety of cements; at the base silica and iron cements (siderite and hematite) are present, as is heavy oil, but locally the oil may be secondary to both these two previously-mentioned cementing agents. Thin iron oxide-cemented sandstone beds between the oil-cemented beds are common in outcrops throughout the McMurray formation. In the upper McMurray member the cement, where it occurs, is oil or calcite as along the Hangingstone River. Thin veins of calcite were encountered in upper McMurray sands on Cottonwood Creek. In the Grand Rapids formation calcium carbonate-cemented lithic sands form large spherical nodules.

The chemical properties of the heavy black oil cement which has made the McMurray sands famous as a reserve of oil have been described by Krieble and Seyer (1921), Montgomery (1951), Scott et al. (1954), and Hodgson (1954). The physical properties of the oil include a specific gravity varying between 1.002 and 1.027, and a viscosity of 3,000 to 400,000 poise at 60 degrees Fahrenheit (Ward and Clark, 1950). Analyses by Clark (1957a) show that the oil occupies 55 to 89 per cent of the available pore space in the quartz sand, water occupies 1 to 30 per cent, and gas (generally air) the remainder. Most oil sand contains less than 18 per cent by weight of heavy oil.

Hume (1947) reported the existence of beds of free oil, in the McMurray formation, but these are more likely due to separation of oil in the hole during drilling and coring.

Nodules

Siderite nodules are fairly common at the base of the McMurray formation and in places in the coarse-grained sands. Ells (1926, p. 8) has described a concentration of siderite nodules containing 35 per cent iron overlying a bed of clay on the Steepbank River.

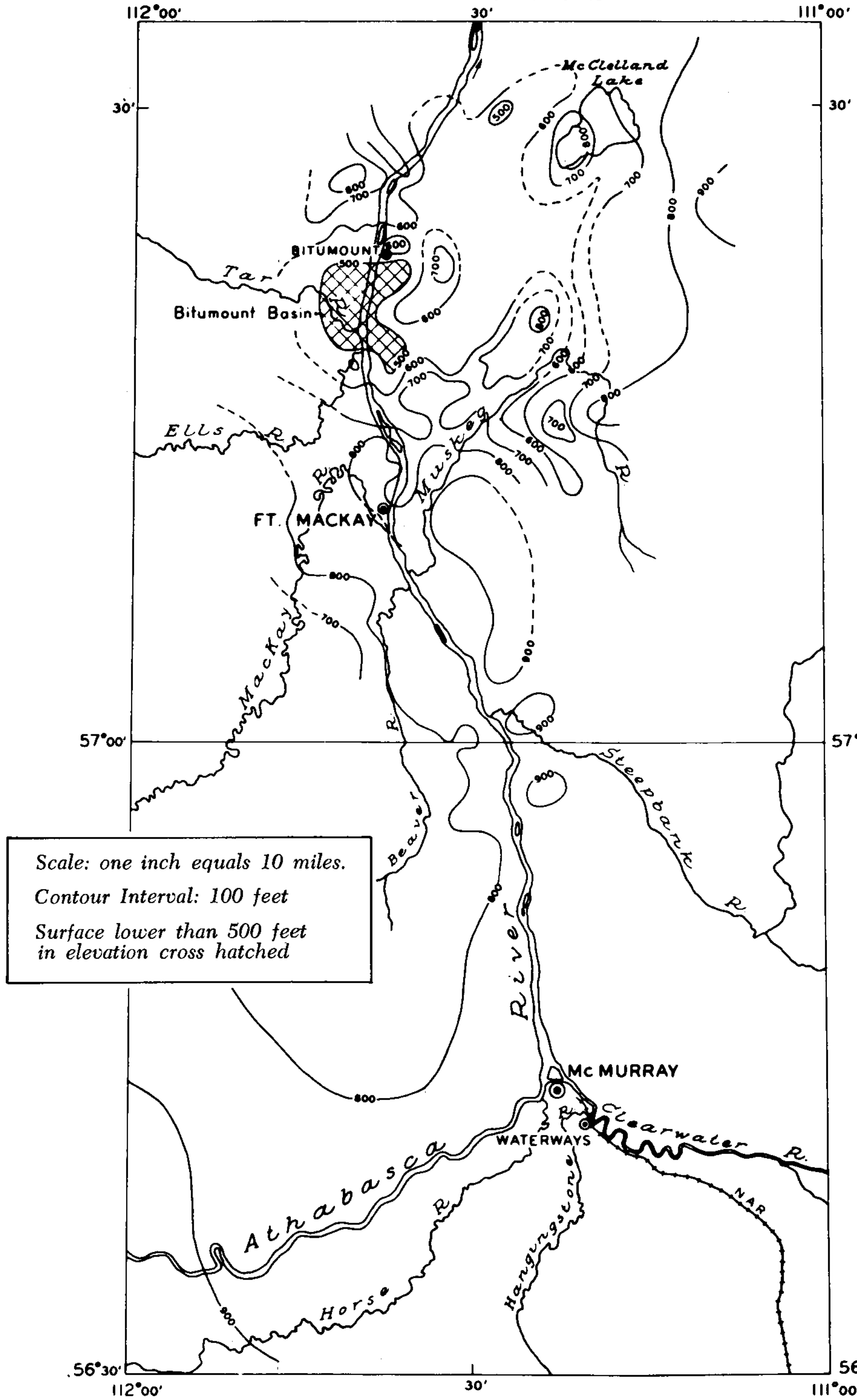
Marcasite nodules are also present; spheres up to six inches in diameter have been found. They are particularly abundant in the old Abasand Quarry in the valley of the Horse River and in the quarry at Bitumount. In both places they are associated with mineable-grade oil sand. Ells reports that many marcasite nodules are associated with siderite nodules and carbonized wood.

STRUCTURE OF THE MESOZOIC STRATA

The Mesozoic formations have a regional slope to the southwest of less than five feet to the mile.

The general picture obtained from a study of the sedimentary facies of the McMurray formation is that these beds were deposited on a pre-Cretaceous erosion surface of low relief. The thickness and lateral extent of the formation is largely controlled by the depths and extent of the depressions on this surface (Fig. 10).

The sediments of the Clearwater formation, however, were deposited on the essentially flat upper surface of the McMurray formation under marine conditions, and their attitudes were not influenced to any great extent by topographic features. The contact between the McMurray and



Sources of information: Canadian Mines Branch Report, Nos. 632 and 826; Alberta Oil and Gas Conservation Board Schedules of Wells, 1949-1957; Drilling and Sampling Records; Athabasca Oil-sands Project, 1952-1954; Shell Oil Company of Canada, 1953-1955; Mobil Oil of Canada, 1953; Sun Oil Company, 1954

FIGURE 10. Contours on the Pre-Cretaceous Erosion Surface of McMurray Area

Clearwater formations is characterized by the appearance of a conspicuous green glauconite sand bed beneath a thick shale sequence, and this has proved to be the best marker bed for structural interpretation in the area mapped. By use of this marker horizon it has been possible to show that the Cretaceous strata have been disturbed near Bitumount (Tps. 96 and 97, Rs. 10 and 11) on the Athabasca River. There the McMurray and Clearwater formations are found in a basin-like structure (Figs. 9 and 10), well below their expected elevations (Kidd, 1951). The reason for this anomaly is believed to be post-Cretaceous subsidence of the Devonian limestone, as mentioned previously. This, however, is not the full explanation. The McMurray formation in this area is largely shaly and clayey in nature, with many thin seams of coal which indicate that the area was a poorly-drained lowland during the deposition of the McMurray sediments. It is possible some of the movement in the overlying beds is due to the compaction that this type of sediment undergoes on burial. McConnell (1893a, p. 38D) stated that the Clearwater shales exposed on the Ells River had an easterly dip.

CHAPTER VI

Cenozoic Deposits

This account of the Cenozoic geology of the McMurray area is based on the examination of detailed topographical maps of 1,260 square miles of the area adjacent to the Athabasca River prepared by Ells (1926) and published on a scale of half a mile to one inch (1:31,680) with a contour interval of 20 feet; a table of elevations (Ells, 1926) and elevations from precise base-line levelling (Montgomery, 1947); vertical aerial photographs in stereoscopic pairs of the entire area and Alberta Government planimetric sheets. Logs of several hundred oil-sand exploratory wells were consulted, but these were of limited use because most of them were drilled through the Pleistocene sediments and only an estimate of the thickness and a very general description of the glacial drift was reported.

A study of the well information, however, and aerial photographs indicates that the preglacial topography was very similar to that of the present. The monadnocks and valleys on the pre-Pleistocene erosion surface are now covered by a relatively thin layer of glacial drift which rarely exceeds 100 feet in thickness.

The regional slope of the land surface is northward and the major valley now occupied by the lower Athabasca and Clearwater Rivers is believed to be glacial in origin (Bell, 1884). The valley walls are straight and parallel, and glacial deposits are found on the valley floor, in the spillway at Mildred Lake, and form some of the rapids in the Clearwater River. Where the valley walls fan out north of the Steepbank River near the Mildred Lake spillway, an escarpment is present (Tps. 92 and 93, R. 10). Mildred Lake can be clearly seen on aerial photographs to be located in an abandoned channel of the Athabasca River.

The direction of glacial advance is indicated by the presence of large granite erratics throughout the area and by the parallel glacial flutings on Birch Mountain at an elevation of 2,500 feet in Tp. 95, R. 17, and Tp. 96, Rs. 14 and 15 (Ells, 1926). These flutings have a trend of north 60 to 70 degrees east. During the retreat of the ice-sheet, drift which gave rise to knob and kettle topography and which obliterated all previous minor drainage channels was deposited. McConnell (1893a) reported that the stratified sands and gravels below and above the "boulder clay" in the lower part of the Athabasca River Valley were evidently lacustrine in origin and were doubtless deposited along the southern margin of the greatly-extended Lake Athabasca of the glacial epoch. He noted that the lower part of the "boulder clay" is reddish and most of the upper part is dark grey.

Ells (1926, p. 17) indicated that the basin of the glacial Lake Athabasca extended south to the northern edge of the Lower Cretaceous rocks and occupied the area north of township 98 between ranges 4 and 10 in the present Athabasca River Valley. The "boulder clays" referred to by Mc-

Connell are grey glacio-lacustrine silts which were deposited in this lake and they were succeeded higher in the section by coarser-grained sands, containing interstratified beds of redeposited oil sand from the McMurray formation (plate 7). The oil in this redeposited oil sand is typically hard and brittle, and thus can be distinguished from the soft and pliable in-situ oil sand of the McMurray formation.

In most places the sands of glacial origin can be recognized by their discontinuous particle size distribution, varying particle shape, heterogeneous mineral composition, and, according to Kupsch (1954), their heavy mineral content. Good exposures of Pleistocene beds are found in the cutbanks of the Firebag, Marguerite and Richardson Rivers. A description of these deposits is given by Ells (1932).

The water level in Lake Athabasca now stands at an elevation of approximately 699 feet and forms the local base-level for erosion. Thus a broad delta is being pushed out into the lake by the Athabasca River. The tributaries of the Athabasca River are post-Pleistocene in age and have been superimposed on the post-glacial surface; the meanders formed on the upland plain are being actively incised down to the contemporary base-level of erosion. For example, the Muskeg River in its upper reaches meanders over the flat swampy surface, but downstream its meanders cut deeply into the surface without corroding laterally.

The glacial outwash sands have been blown into dunes (plate 1) which are now stabilized by vegetation. The intervening depressions are filled with water and form large shallow lakes such as McClelland Lake (Tp. 98, R. 9) and Gregoire Lake (Tp. 96, R. 8) or extensive areas of muskeg.

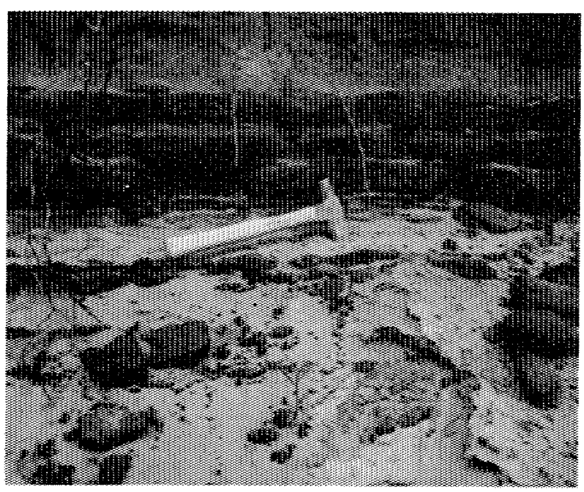


PLATE 7. Oil-impregnated sands overlying glacial sands on the Firebag River (Tp. 98, R. 7)

CHAPTER VII

Economic Geology

In 1958, there were no established industries within the McMurray area, but salt deposits found in the Paleozoic strata beneath Waterways (Allan, 1938, 1943; Crockford, 1949) were formerly exploited commercially and attempts have been made at various times to develop the resources of oil in the McMurray formation. A short historical review of these ventures has been included in this report in order that future development may be viewed in perspective.

SALT

The well logs of the Northern Alberta Exploration Company holes drilled between the years 1907 and 1912 showed that thick beds of salt were probably present beneath the McMurray area. In 1919, the Alberta Government began drilling to confirm these reports and by 1923 two completed wells had shown that a considerable quantity of good-quality sodium chloride was available (Allan, 1924). In 1924 the Alberta Salt Company Limited built a grainer plant at the mouth of the Horse River which used brine obtained from one of the wells drilled by the Northern Alberta Exploration Company. This plant produced a total of 2,970 tons of salt between 1925 and 1927 (Allan, 1943). In 1928 the Alberta and Great Waterways Railroad Company drilled a well which encountered a thick bed of salt at a depth of 670 feet, but it was not until 1936 when Industrial Minerals Limited found a 200-foot bed of salt at a depth of 694 feet that a successful industry was established. An evaporation plant was erected in 1937 and production began in December of that year. Subsequently two further successful wells were drilled by this company. The plant at Waterways produced 228,000 tons of salt before it was closed at the end of 1950, after the more favorably-situated salt plant at Elk Point came into production.

The reserves of salt at McMurray were calculated at 290 million tons by Allan in 1943. Since 1943 drilling has proved the salt beds to be very extensive and the tonnage is therefore much greater than Allan estimated (see appendixes A and B, and Figs. 6 and 7).

GYPSUM

The Middle Devonian strata contain thick beds of anhydrite and gypsum (see appendixes A and B). An impure bed of gypsum eight feet thick was found at a depth of 418 feet in Bear Westmount No. 2 well in Tp. 88, R. 8. The general southwesterly dip of the strata in which it occurs indicates that other deposits may be found closer to the surface east of range 8 in the Clearwater River Valley (Figs. 6 and 7).

OIL SANDS

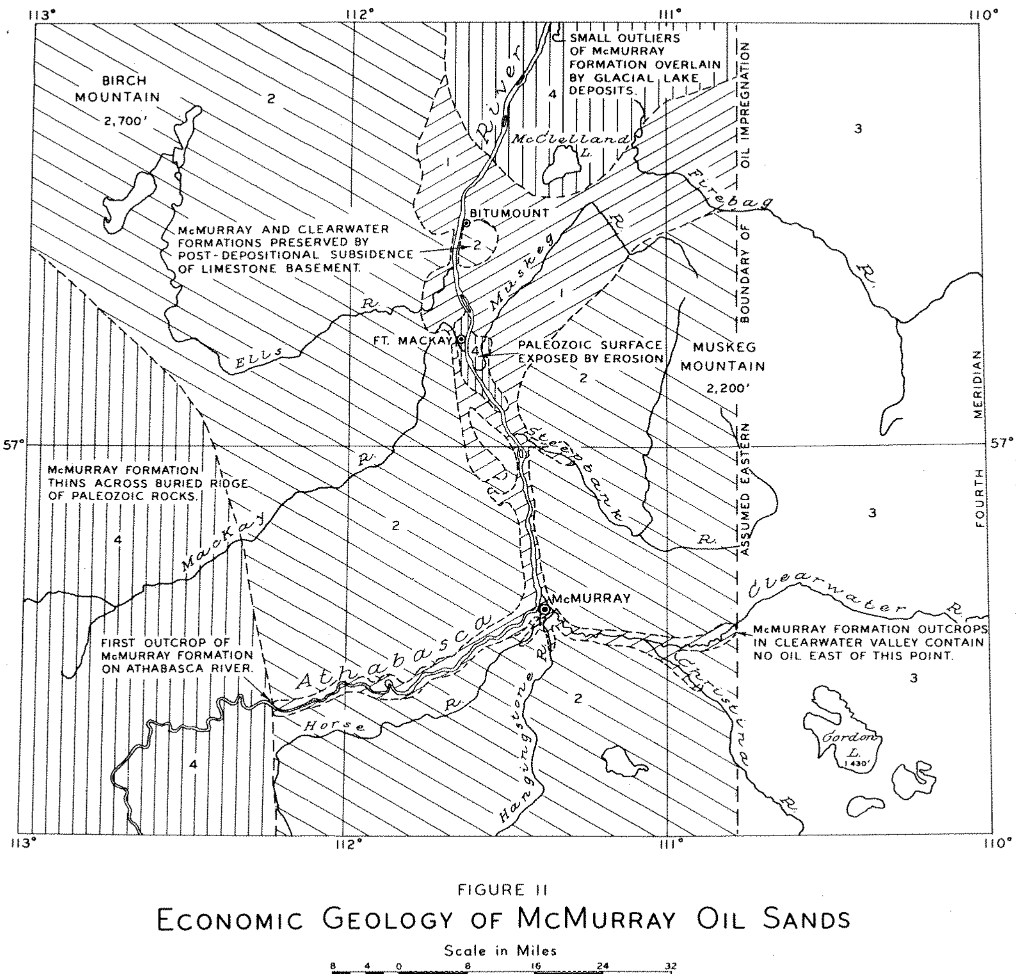
Hopes of exploiting the oil sands have waxed and waned over the years, and the population of McMurray has fluctuated accordingly. A pilot plant to extract oil from the sand was built by the Research Council of Alberta on the Clearwater River in the years 1929 to 1930 (Clark and Pasternack, 1930). The mining for this plant was undertaken by the Federal Department of Mines. A small privately-owned plant was established at Bitumount about 1930 and it operated intermittently until 1944 when the Government of Alberta took a financial interest and later assumed complete control of the project for building a new separation plant on this site. This plant was acquired recently (1954) by the Royalite Oil Company Limited for experimental purposes. Another plant was built by private capital at Abasand in the valley of the Horse River near McMurray. This plant began operating in 1940 and was bought by the Federal Government in 1943 to give its officers experience in plant operation and facilities for full-scale experiments in oil-sand separation. It was destroyed by fire in 1945. During 1959 a pilot plant was erected at Mildred Lake by Canadian Cities Service Petroleum Corporation.

SEARCH FOR OIL

Ever since the oil sands were discovered geologists have hoped that lighter-gravity oil would be found in stratigraphically-equivalent beds down dip from the exposures in the Athabasca River Valley or in the limestone strata directly underlying the oil sands. Bell (1884) favored the latter location and suggested drilling the small structural domes he had observed in the Beaverhill Lake formation on the Athabasca River (plate 2). This suggestion was followed by Von Hammerstein who between 1906 and 1924 drilled eight wells on these structures but failed to find any light oil (Ells, 1926). In 1893 McConnell (1893a, p. 66D) predicted that a well drilled at the mouth of the Pelican River about 80 miles southwest of McMurray would cut the oil sands at a depth of 700 feet and would perhaps produce an oil of lower viscosity. This suggestion was followed by the Geological Survey of Canada and in 1897 oil sands were penetrated at a depth of 750 feet, but the viscosity of the oil was too high for it to flow to the surface (Dawson, 1897 - 1901; Camsell and Malcolm, 1921). Since that time oil companies have drilled many wildcat holes through the oil sands and Paleozoic strata down to the Precambrian basement rocks (table 7) but so far no high A.P.I. gravity oil has been encountered and speculation as to the source of the oil in the McMurray formation continues (Ball, 1935; Sproule, 1938, 1951; Williams, 1949; Hume, 1951b; Link, 1951a, 1951b; Corbett, 1955).

PETROLEUM RESOURCES

A summary of the estimates of the petroleum resources of the oil sands is given in table 10. In 1958, 1.67 billion barrels had been proved by intensive drilling and a further 200 billion barrels is a conservative estimate



LEGEND

GEOLOGY		ECONOMIC PROSPECT
1. McMurray formation; oil-impregnated outcrops overlain by glacial drift	1	Development by surface mining methods.
2. McMurray formation; oil-impregnated, and overlain by Cretaceous strata, and glacial drift	2	Possibly suitable for development by in situ recovery methods.
3. McMurray formation; believed to be without oil, and overlain by Cretaceous strata and glacial drift	3	Further exploration by drilling required.
4. McMurray formation; believed to be thin or absent. Oil-impregnated sands found in overlying Cretaceous strata	4	Further exploration by drilling required.

FIGURE 11. Economic Geology of McMurray Oil Sands

of the quantity of oil underlying the official Bituminous Sands Area proclaimed by the Government of Alberta. Oil sands are known to be present outside of this area.

The official Bituminous Sands* Area comprises 315 townships with an area of 11,340 square miles. By mid-1958, some 830 holes had been drilled in 61 townships to determine the extent of oil-impregnation of the McMurray formation. The average number of drill holes over the 2,196 square miles involved was thus 0.4 per square mile. This is one-tenth of the number required for accurate estimates of the quantity of oil present in this area (Hume, 1947). However, the drill holes are distributed in such a manner as to justify the belief that oil will be found in the basal Cretaceous sand formations over most of the area west of range 5 where favorable geological conditions exist. From a knowledge of the geology and topography it is possible to outline on a map (Fig. 11) the economic potential of various parts of the oil-sands area. Oil-impregnated beds have not been observed east of range 6 between townships 89 and 99, and outcrops of the McMurray formation in the valley of the Clearwater River east of range 6 show no signs of having been impregnated with oil at any time. The most easterly outcrop of oil sands found was at Cottonwood Creek where the oil sands overlie clean white barren sands (plate 8).

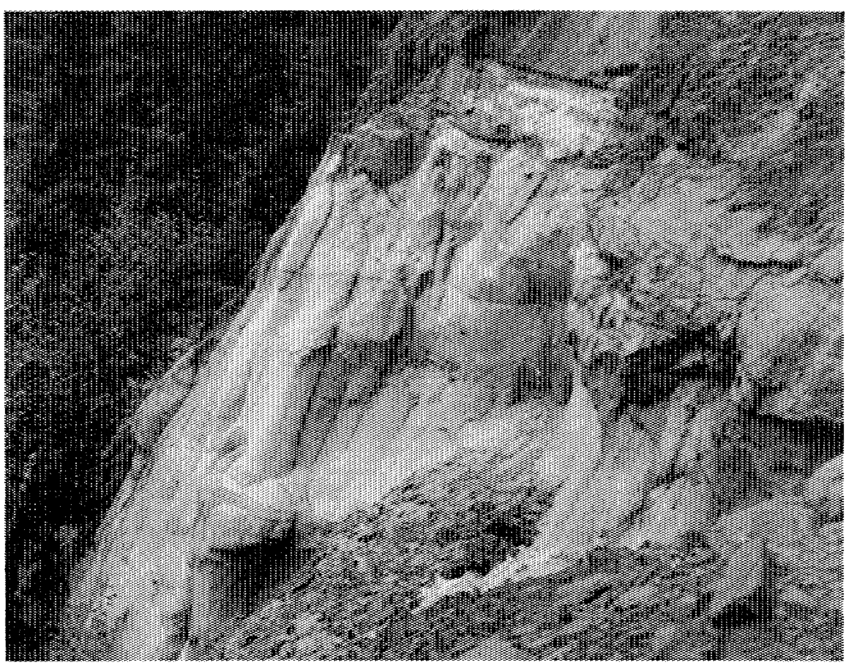


PLATE 8. Clean white sands overlain by oil-impregnated sands on Cottonwood Creek, (Tp. 89, R. 5)

* The term "Oil Sands" is preferred to "Bituminous Sands" and has been used throughout this report. The term "Tar Sands" is no longer used by geologists when referring to the petroleum-impregnated beds of the McMurray formation.

The problems of coring to obtain samples for analysis have been adequately discussed by Hall (1951). A rapid method for estimating the oil content of core samples was outlined by Dyck (1944).

Regulations regarding the oil-sand development are administered by the Alberta Oil and Gas Conservation Board in Calgary.

Table 10: Petroleum Resources of the McMurray Oil Sands

Nature of Resource	Estimated Quantity of Oil Present
A. Proven by closely-spaced drilling and sampling — Mildred-Ruth Lakes area; Ref.: Canada Bureau of Mines Report 826, Vols. I, II and III; Royalite Oil Company Limited, submission to the Borden Royal Commission on the Energy Resources of Canada (1958).	1.67 billion barrels (recoverable by surface-mining methods).
B. Outlined by drilling and sampling by private oil companies.	2 billion barrels (probably suitable for surface mining).
C. Amount of oil present in beds of the McMurray formation under an area of 2,500 square miles where it has been proved to exist by widely-spaced exploratory drilling and sampling.	At least 100 billion barrels (exploitation depends on advances in technology to create favorable economic circumstances).
D. Amount of oil estimated to be present in the McMurray formation where, from geological extrapolation supported by some drilling and sampling, it is believed to be present with similar thickness and oil-saturation as in the Athabasca River Valley.	200 billion barrels (exploitation depends on advances in technology to create favorable economic circumstances).

NATURAL GAS

Small gas "blows" have been encountered during the drilling of the oil sands. No attempt has yet been made to evaluate the significance of these occurrences.

UNDERGROUND WATER

Little information is available on water-table levels in the McMurray area, but the lake and river levels suggest that it does not lie at any great depth below the surface of the upland plain.

Chemical analyses of some groundwater samples are given in table 11.

Table 11: Chemical Analyses of Groundwater from McMurray Area

Samples collected by Clark and Blair (1925) and analyzed by Provincial Analyst, Alberta (parts per million)

	1	2	3	4
	Seepage hole on Athabasca River 2 miles north of Fort MacKay	Seepage hole on Athabasca River opposite mouth of Tar River	Top of hill at location of sample 2; surface seepage water	Sample of water in shaft on Horse River taken some months after completion of shaft
Total Solids	270	340	350	2,270
Alkalinity*	90	272	290	1,300
Sulfates (SO_3)	34	nil	nil	21.3
Sulfuretted hydrogen	nil	0.25	0.25	36.0

Saline Springs

Many saline springs have been found in the valleys throughout the area mapped. The best known of these springs is found at La Saline (Tp. 93, R. 10) where a cone of calcareous tufa about 15 feet high and 200 feet in diameter has been built up by the mineralized waters from the spring. The top of the cone is about 820 feet above sea level. Other saline springs are found in the Clearwater River Valley at Whitemud Falls (Tp. 89, R. 1) and four miles below Cascade Rapids (Tp. 89, R. 3). The odor of hydrogen sulfide in this vicinity is most noticeable. McConnell (1893a) reported saline springs in the Christina River Valley 12 miles upstream from its confluence with the Clearwater River. Analyses of waters flowing from borehole casing in some abandoned wells which penetrate the Devonian rocks were reported by Ells (1926) and the results have been compared with analyses made on the natural spring at La Saline (table 12). The similarity in chemical composition is close enough to indicate that the water flowing from these springs originates in the Paleozoic rocks. The Methy formation dolomites yielded an artesian flow of slightly saline water during the drilling of Bear Rodeo No. 2 well, Alberta Government Salt Well No. 2, and Athabasca Oils Limited No. 1 well. A second water-bearing stratum was encountered in the sand beds overlying the Precambrian basement in the Athabasca Oils Limited No. 1 well.

* The alkalinity in No. 4 is due to carbonates of sodium, calcium, and magnesium; and in Nos. 1, 2, and 3 to carbonates of calcium and magnesium.

Table 12: Comparative Water Analyses of Samples from a Saline Spring and Overflow Water from Deep Wells

(after Ells, 1926, p. 9)
(parts per million)

	1	2	3
	La Saline Spring (Sec. 15, Tp. 93, R. 10)	Overflow from casing head of "Salt of the Earth" well (Lot 12, Tp. 95, R. 11, total depth 615 feet)	Overflow from casing head of Athabasca Oils Ltd. No. 1 well (Tp. 96, R. 11, total depth 1,130 feet)
Calcium (Ca)	1,821	1,347	1,638
Magnesium (Mg)	571	585	385
Potassium (K)	496	336	296
Sodium (Na)	21,184	76,268	22,988
Bicarbonic acid (HCO_3)	530	372	469
Carbonic acid (CO_3)	nil	nil	nil
Chlorine (Cl)	39,792	118,636	36,188
Sulfuric acid (SO_4)	4,688	4,920	4,144
Specific gravity at 15.5°C.	1,052	1,133	1,047

SILICA SAND

Tailings from the oil extraction plant at Bitumount were studied by Lilge (1945) to evaluate their possibilities in glass manufacture. He concluded that with some beneficiation the sand could be used. The chief impurities encountered were muscovite and titanium-bearing minerals.

LIMESTONE

Extensive outcrops of a pure limestone (95 per cent $CaCO_3$) are present in the area (see table 8) but no attempt has been made to exploit them.

CLAY

The clay deposits were sampled by Ells (1915b, 1926) and Hume (1924). None of the deposits in the area has been developed in any way.

GOLD

A wildcat well drilled by Athabasca Oils Limited in Tp. 96, R. 11 is reported to have encountered gold in the Precambrian rocks between depths of 1,105 and 1,130 feet (Allan, 1920). During 1958 some claims were staked in the vicinity of this well.

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Wildcat Well Logs

Name: Bear Westmount No. 1, drilled in 1949 by the Bear Oil Company Limited

Location: Lsd. 14, Sec. 9, Tp. 86, R. 7, W. 4th Meridian

Elevation of Surface: 1622 feet **Total Depth:** 1793 feet

Depth in feet	Thickness in feet	Description*
0— 80		Pleistocene and Recent
	80	Glacial drift
		Unconformity
80— 375		Grand Rapids formation
	295	SANDSTONE with thin beds of grey shale
375— 750		Clearwater and upper McMurray formations
	375	SHALE, dark-grey marine, with several thin beds of sandstone
750— 865		McMurray formation
	115	Lithology not described
		Unconformity
		Beaverhill Lake formation
865— 980		Christina member
	115	SHALE, calcareous, fossiliferous; *Atrypa*, crinoid stems, worm burrows
980—1078		Calumet member
	98	LIMESTONE, grey, dense, fossiliferous with brachiopods: *Atrypa reticularis* (Linnaeus)
1078—1264		Firebag member
	25	SHALE, calcareous
	15	LIMESTONE
	30	SHALE, calcareous
	20	LIMESTONE
	30	SHALE, calcareous
	10	LIMESTONE, fossiliferous; *Lingula* sp.
	56	SHALE, calcareous
1264—1416		Dawson Bay formation equivalent and Prairie Evaporite formation, undifferentiated
	26	ANHYDRITE
	22	SILTSTONE
	104	ANHYDRITE, grey, massive, with thin bands of gypsum and siltstone

* Lithology from Bear Oil Company report, fossil identifications after Greiner (1956).

Depth in feet	Thickness in feet	Description
1416—1648		Methy formation (Greiner, 1956); lower 106 feet is the Elm Point formation equivalent (Van Hees, 1956)
	126	DOLOMITE, brown, porous, mottled, dense
	106	LIMESTONE, dolomitic to argillaceous, abundantly fossiliferous at 1542 feet and below; *Atrypa* cf. *A. arctica* Warren, *Atrypa reticularis* (Linnaeus) *Synatophyllum* sp. *Actinostroma* sp. *Favosites* cf. *F. cervicornis* De Blainville *Gypidula* cf. *G. comis* Owen *Martiniopsis* cf. *M. sublineata* Meek Gastropod
1648—1772		Ashern formation and Meadow Lake formation equivalents, undifferentiated
	42	SHALE, green, silty with white acicular gypsum and buff bands of chert throughout
	82	SANDSTONE, red, iron-stained
		SHALE, red, silty, chert and quartz
		Unconformity
1772—1793		Precambrian basement
	21	GRANITE, red hornblende

Name: Bear Vampire No. 1, drilled in 1949 by the Bear Oil Company
Location: Lsd. 7, Sec. 28, Tp. 87, R. 12, W. 4th Meridian
Elevation of Surface: 1540 feet **Total Depth:** 2304 feet

Depth in feet	Thickness in feet	Description*
0—640		Lower Cretaceous
		Undifferentiated sediment
		Unconformity
		Beaverhill Lake formation
640—910		Moberly and Christina members
	70	LIMESTONE
	20	SHALE, calcareous
	20	LIMESTONE, dolomitic? fossiliferous
	160	LIMESTONE and LIMESTONE, calcareous, SHALE, grey, dense, fossiliferous
910—980		Calumet member
	70	LIMESTONE, fossiliferous; *Atrypa* sp.
980—1190		Firebag member
	190	SHALE, calcareous
	10	SILTSTONE, *Tentaculites* sp.
	10	LIMESTONE, fossiliferous
1190—1270		Dawson Bay formation equivalent
	30	ANHYDRITE
	50	SILTSTONE
1270—1915		Prairie Evaporite formation
	35	ANHYDRITE
	415	ROCK SALT
	195	ANHYDRITE and GYPSUM
1915—2130		Methy formation
	215	DOLOMITE containing corals and brachiopods, vuggy and mottled
2130—2215		Ashern formation equivalent?
	85	SHALE, green, chert in bands, and containing pelecypods
2215—2300		Meadow Lake formation equivalent?
	85	SHALES, siltstones, red sandstones, red quartz and chert in calcareous groundmass, brecciated sandstone at base
		Unconformity
2300—2304		Precambrian basement
	4	GRANITE, red hornblende

*Lithology from Bear Oil Company report. Electric log available.

Name: Bear Biltmore No. 1, drilled in 1949 by the Bear Oil Company Limited

Location: Lsd. 7, Sec. 11, Tp. 87, R. 17, W. 4th Meridian

Elevation of Surface: 1440 feet **Total Depth:** 2865 feet

Depth in feet	Thickness in feet	Description*
0— 460		Cretaceous
	460	Undifferentiated sediment
		Unconformity
460— 505		Grosmont reef (Belyea, 1952)
	45	LIMESTONE, dolomitic, excellent tarry staining; scattered fossil fragments
505— 850		Ireton formation (Belyea, 1952)
	150	LIMESTONE, argillaceous, pelletoid with fossil fragments: Ostracodes
		Abursus beaumontensus Loranger
		Abursus biltmorensus Loranger
		Bairdia biltmorensa Loranger
		Kloedenia kinsella Loranger
		Bythocypris biltmorensis Loranger
		Macronotella biltmorensa Loranger
		Halliella bellipuncta (Van Pelt)
	50	LIMESTONE, medium-to coarse-grained, fossiliferous;
		Plagionephrodes biltmorensus Loranger
	71	SHALE, calcareous
	10	LIMESTONE, dense, shaly
	43	LIMESTONE, containing spores
	9	SHALE, calcareous, greenish-grey, finely silty, fairly fissile; few thin layers of dense dark-grey, argillaceous limestone; lower 1.5 feet thinly laminated
	12	LIMESTONE, brown, dense, medium-grained, nodular; dark- and light-brown, finely laminated, shaly limestone; abundant pyrite
850— 987		Cooking Lake formation (Belyea, 1952)
	9	LIMESTONE, light-brown and buff, cryptocrystalline, in part pelletoid, medium-grained, in part fossiliferous — fragmental, abundant small spores; scattered fine, dark lamination

*The original lithological descriptions of the strata in this well were made by geologists of the Bear Oil Company. Subsequently the cores have been examined by H. R. Belyea, C. H. Crickmay, D. M. Loranger, and H. R. Greiner and much detailed information has been added. The information published by all these geologists has been included in the description presented here.

Depth in feet	Thickness in feet	Description*
	26	LIMESTONE, as above with scattered small vugs, *Thamnopora*-type corals, pelecypods
	10	LIMESTONE, as above with abundant stromatoporoids, medium to coarsely pelletoid; scattered small brachiopods, flowage (?) structure
	10	LIMESTONE, as above with brown carbonaceous specks and fine calcite veins, fossiliferous; brachiopods, ostracodes, stromatoporoids or corals, irregular brown shaly partings
	17	LIMESTONE, as above, with rare scattered crinoids, some shale
	5	LIMESTONE, grey-buff, dense, slightly dolomitic in 2-inch bands; interbedded with dark-brown-grey shaly limestone in 0.25 to 0.5 inch beds; few stylolites
	6	LIMESTONE, buff, ooliths 0.25 to 0.5 millimetres diameter
	2	LIMESTONE, grey-buff, dense, with thin brownish shaly streaks
	46	LIMESTONE, buff, cryptocrystalline, dolomitic and fossiliferous, pelletoid in parts
	6	LIMESTONE, buff-grey, slightly argillaceous with dark-grey streaks and pyrite specks; upper one foot fossiliferous
		Beaverhill Lake formation
980—1120		Mildred member* (Crickmay, 1957)
	14	LIMESTONE, grey, argillaceous, with *Leiorhynchus* sp., *Eleutherokomma killeri* Crickmay
	19	SHALE, green-grey
	10	LIMESTONE, green-grey, argillaceous; *Leiorhynchus* sp., *Eleutherokomma killeri* Crickmay, *Productella* sp., *Balantoides biltmorensus* Loranger
	9	LIMESTONE, buff, fine to dense
	12	LIMESTONE, green-grey, argillaceous; *Productella* sp.
	19	SHALE, green-grey
	3	LIMESTONE, green-grey, argillaceous
	18	LIMESTONE, buff, fine to clastic
	3	SHALE, green

*This member includes the basal 7 feet of the Cooking Lake formation of Belyea (1952).

Depth in feet	Thickness in feet	Description
	7	LIMESTONE, grey to brown, argillaceous, clastic; *Atrypa* cf. *A. randalia* Stainbrook
	2	SHALE, green
	8	LIMESTONE, green-grey, argillaceous; *Eleutherokomma killeri* Crickmay
	10	No record
	6	SHALE, green-grey
1120—1320		Moberly member (Crickmay, 1957)
	9	LIMESTONE, grey, argillaceous; *Eleutherokomma hamiltoni* Crickmay
	18	LIMESTONE, buff, fine
	4	LIMESTONE, argillaceous, dark
	13	SHALE, green-grey
	17	LIMESTONE, brown, fragmental
	20	SHALE, green-grey; *Eleutherokomma hamiltoni* Crickmay
	63	LIMESTONE, grey to brown, fragmental to fine; *Atrypa clarkei* Warren
	8	SHALE, green-grey
	12	LIMESTONE, grey to brown, fragmental to fine; *Atrypa clarkei* Warren
	21	LIMESTONE, as above; *Atrypa clarkei* Warren *Allanaria allani* (Warren)
	2	SHALE, green-grey
	13	LIMESTONE, grey, fragmental; *Atrypa clarkei* Warren, *Eleutherokomma* sp.
1320—1410		Christina member (Crickmay, 1957)
	7	SHALE, green-grey; *Hypothyridina* n. sp., *Allanaria* aff. *A. minutilla* Crickmay
	4	LIMESTONE, buff, fine; *Eleutherokomma* sp.
	23	LIMESTONE, grey, argillaceous, and shale; *Atrypa* cf. *A. bentonensis* Stainbrook
	3	SHALE, green-grey; *Hypothyridina* n. sp. A., *Eleutherokomma* sp.
	3	LIMESTONE, green-grey, argillaceous; *Cyrtina* sp.
	4	LIMESTONE, fragmental and fine, buff; *Atrypa* cf. *A. tenuicosta*
	10	LIMESTONE, grey, argillaceous; *Eleutherokomma* cf. *E. jasperensis* (Warren)
	36	SHALE, green-grey; *Schizophoria* cf. *S. lata* Stainbrook
1410—1512		Calumet member (Crickmay, 1957)
	54	LIMESTONE, grey to buff, fine; *Atrypa* cf. *A. trowbridgei* Fenton and Fenton, *Stropheodonta costata,* Owen

Depth in feet	Thickness in feet	Description
	14	LIMESTONE, green-grey, argillaceous; *Eleutherokomma* n. sp.
	4	SHALE, green-grey; *Schizophoria* cf. *S. athabaskensis* Warren
	12	LIMESTONE, grey, and shale; *Eleutherokomma* n. sp.
	18	LIMESTONE, grey, fine; *Stropheodonta* cf. *S. costata* Owen
1512—1683.5		Firebag member (Crickmay, 1957)
	52	SHALE, green-grey; *Atrypa* cf. *A. independensis* Webster, *Atrypa* cf. *A. littletonensis* Stainbrook
	27	LIMESTONE, grey, argillaceous; *Atrypa* cf. *A. independensis* Webster, *Eleutherokomma impennis* Crickmay
	7	SHALE, green-grey; *Leiorhynchus* sp.
	36	LIMESTONE, grey, argillaceous; *Atrypa* cf. *A. independensis* Webster, *Eleutherokomma impennis* Crickmay
	42	SHALE, green-grey; *Lingula spatulata* Vanuxem, *Atrypa* cf. *A. independensis* Webster, *Cyrtina billingsi* Meek
	3	LIMESTONE, grey, fine
	1.5	SHALE, well-bedded, hard, dark
	2	LIMESTONE, grey, fragmental, rubbly at base; *Atrypa independensis* Webster
1683.5—1688		Slave Point formation equivalent (Crickmay, 1957)
	4.5	LIMESTONE and DOLOMITE, buff-brown, thin-bedded; *Atrypa* aff. *A. independensis* Webster, *Ambothyris* sp.
1688—1770		Dawson Bay formation equivalent
	13	DOLOMITE and ANHYDRITE, buff to light-brown, dense, with dark mottling and laminae; scattered anhydrite crystals; thin gypsum laminae; lenses of brown anhydrite
	5	LIMESTONE, buff, and light brown; grains round to angular, medium- to coarse-grained, with calcite matrix; finely laminated with dark brown shale; streaks and specks of anhydrite.
	2	DOLOMITE, cream-buff, fine-grained, finely porous (?)
	10	ANHYDRITE, brown and brown-grey, dolomitic, and fine-grained anhydritic dolomite

Depth in feet	Thickness in feet	Description
	9	DOLOMITE, grey to light-brown, very fine-grained; in part with fine, dark-brown laminae
	1	SILTSTONE, grey in part with a greenish tinge, inter-laminated with dolomite, argillaceous
	1	DOLOMITE, buff-grey, fine-grained
	20	SHALE, grey to greenish-grey, finely silty, dolomitic; in part silty dolomite; scattered *Charophyta*
	10	SHALE and DOLOMITE, intermixed, mostly greenish-grey to greenish-buff
	11	ANHYDRITE, silty and dolomitic; siltstone; anhydritic dolomite, greenish-grey, in part with red mottling
1770—2467		Prairie Evaporite formation
	36	ANHYDRITE, red
	636	ROCK SALT, brown, translucent, massive; grey shale, anhydrite, and dolomite beds up to 3 feet in thickness
	25	ANHYDRITE, dolomitic at base
2467—2660		Methy formation (Greiner, 1956); includes 71 feet of Elm Point formation equivalents of Belyea (1952)
	3	DOLOMITE, brown, microgranular, finely layered, some dark-brown shaly partings; finely vuggy in layers; vertical anhydrite-filled cracks
	1	ANHYDRITE, grey, finely crystalline, pure
	4	DOLOMITE, as above; but some granular patches
	5	ANHYDRITE, massive as above, locally dolomitic
	11	DOLOMITE, as above; with anhydrite layers up to one foot thick, thin shale partings; one foot of breccia at the base
	10	DOLOMITE, brown, microgranular, flow-type layering at top, mostly dense; irregular structures (due to stromatoporoids or corals?) start at 2496 feet, possibly part of reef
	20	DOLOMITE, brown, microgranular as above, rather dense, irregular structures, with occasional coarser vugs filled with anhydrite or salt; shaly partings; some breccia in lower parts; brachiopod at 2511 feet; possibly reef
	9	DOLOMITE, dark-brown, microgranular, locally argillaceous, irregular structures with some coarse vugs filled with anhydrite, mostly dense; probably reef

Depth in feet	Thickness in feet	Description
	59	DOLOMITE, brown, granular, locally crystalline, irregular structures, rather dense to finely vuggy, some coarse anhydrite-filled vugs, some dark shaly films; corals, probably reefal
	10	DOLOMITE, brown, with chert interbands irregularly layered, salt-filled vugs to two inches; chert is often sugary, porous to finely vuggy, probably represents coralline or other growth; dolomite is generally crystalline, locally vuggy; somewhat brecciated below; crinoidal
	22	DOLOMITE, brown, with white chert interbands, porous and sugary; dolomite is dense and irregularly layered with shaly films; brachiopods present
	39	DOLOMITE, dark brown, massive, granular, small irregular structures probably due to re-solution or dolomitization; mostly dense, finely vuggy locally, some anhydrite infillings, fragmental and argillaceous at base
2660—2856		Ashern formation and Meadow Lake formation equivalents?
	20	DOLOMITE, shaly, and anhydrite
	30	DOLOMITE, silty, and anhydrite
	90	CLAYSTONE, red and green, increasingly silty towards base, locally arenaceous, broken by occasional layers of anhydrite
	10	ANHYDRITE
	12	DOLOMITE and claystone
	34	SANDSTONE, red, rounded grains, becoming arkosic pebblestone at base
		Unconformity
2856—2865		Precambrian basement
	9	GARNET SYENITE GNEISS

Name: Bear Westmount No. 2, drilled in 1949 by the Bear Oil Company Limited

Location: Lsd. 9, Sec. 36, Tp. 88, R. 8, W. 4th Meridian

Elevation: K. B. 837 feet **Total Depth:** 936 feet

Depth in feet	Thickness in feet	Description*
		Beaverhill Lake formation
5— 46		Moberly member
	38	LIMESTONE, light-grey to light-buff, cryptocrystalline, argillaceous, massive, occasionally rubbly; cut by numerous dark-grey shaly and silty bands, fairly regular; crinoid stems, a few brachiopods
	1	LIMESTONE, dark-grey, argillaceous, interbanded with buff, granular limestone and dark-grey calcareous shale
	1	SHALE, greenish-grey, calcareous
	1	LIMESTONE, dark-grey, highly fossiliferous, granular breaks
46— 123		Christina member
	16	SHALE, greenish-grey, calcareous, with a few limy bands
	6	Core lost
	3	SHALE, as above
	4	LIMESTONE, mainly grey, argillaceous, mottled in black, highly fossiliferous at top, rubbly in places, due to numerous shaly bands; pyrite
	3	LIMESTONE, argillaceous, locally grading to shale, many shaly bands; 0.2 feet coquinoid (brachiopods) at 77 feet
	45	SHALE, greenish-grey, calcareous, locally almost an argillaceous limestone, fair parting, some pyrite
123— 217		Calumet member
	15	LIMESTONE, cryptocrystalline to crystalline, irregular texture due to fossil parts, tight, some granular concentrations locally, pyrite, silty, some brachiopods
	8	SHALE, green, limy silty, almost a silty limestone some brachiopods
	45	LIMESTONE, buff, looks fragmental at top, generally with irregular thin argillaceous breaks, cryptocrystalline, occasionally interbedded with limy shale bands to 2 feet thick,

*Lithology after Greiner (1956).

Depth in feet	Thickness in feet	Description
		some crinoid stems and brachiopods, slightly silty, tight
	26	LIMESTONE, greenish-grey, argillaceous, almost a shale, silty, locally grading to shale, many brachiopods, massive, tight
217— 407		Firebag member
	66	SHALE, mostly green, calcareous, with some limy concentrations and silt; some brachiopods at top and in thin coquinoid limestone beds below; some pyrite; increasingly interbedded with limestone below
	35	LIMESTONE, grey with green argillaceous bands, argillaceous and limy shale, a few brachiopods, microgranular
	24	SHALE, green, calcareous, some brachiopods
	5	LIMESTONE, rubbly, argillaceous, with shale bands
	32	SHALE, grey to greenish-grey, locally fissile, some limy concentrations; *Lingula* sp. present
	4	SILTSTONE, green-grey, calcareous, interbanded with shale
	24	SHALE and LIMESTONE, closely interbanded in one- to two-foot layers; shale as above; limestone, grey cryptocrystalline to microgranular, possibly silty
407— 562		Dawson Bay formation equivalents and Prairie Evaporite formation, undifferentiated.
	1	CLAYSTONE, grey, silty, calcareous to dolomitic
	4	LIMESTONE, buff to light-brown, silty, massive, some breccia
	3	CLAYSTONE, SILTSTONE and DOLOMITE, interbanded; claystone is grey, silty, and dolomitic; dolomite is buff
	3	CLAYSTONE, mainly grey, silty, dolomitic, with gypsum bands
	8	GYPSUM, with many bands of silty claystone
	3	DOLOMITE, buff, matt to microgranular, finely layered, cut by numerous gypsum bands
	12	SILTSTONE and SILTY CLAYSTONE, interbanded with shale and some limestone, greenish-grey, dolomitic, with some gypsum

Depth in feet	Thickness in feet	Description
	8	CLAYSTONE, grey to buff, dolomitic, silty, with numerous thin layers of dolomitic silt, and gypsum bands and stringers
	13	GYPSUM, some green shale at top, numerous dolomite stringers
	6	DOLOMITE, buff, bedded, argillaceous, with some gypsum concentrations
	9	GYPSUM, grey, mottled in black with many shale bands
	17	GYPSUM and ANHYDRITE, anhydrite is highly brecciated and partly altered to gypsum; shaly
	33	ANHYDRITE, brecciated in part and altered to gypsum containing shaly impurities; also contains some dolomitic bands
	1	DOLOMITE, light-buff, microgranular
	34	ANHYDRITE, with numerous dolomite stringers, brecciated locally
562— 768		Methy formation (Greiner, 1956)
	2	DOLOMITE, buff, cryptocrystalline to microcrystalline, layered, anhydritic, silty, anhydrite filling vertical fractures
	5	ANHYDRITE, grey, crystalline, massive
	1	GYPSUM, grey, with much dolomite at top
	11	DOLOMITE, light-grey to buff, microgranular, in part recrystallized, mostly dense at top, excellent fine vugginess lower down, probably due to stromatoporoids, indistinct evidence of coral; irregular shaly layering locally; vertical anhydrite stringers at top
	4	DOLOMITE, greenish-grey, irregular fine vugginess (due to stromatoporoids?), microgranular, slightly argillaceous
	10	DOLOMITE, light-grey, microcrystalline, massive, generally tight, some evidence of corals, indistinct layering locally
	10	DOLOMITE, buff, grey to greenish-grey, microcrystalline, very finely vuggy throughout, vugs locally up to 0.25 inches, layered throughout, locally shaly, vugs lined with calcite crystals
	12	DOLOMITE, buff to greenish-grey, as above, some breccia, a few irregular structures, locally shaly, probably reef
	13	DOLOMITE, as above, definite irregular structures, definite coral, probably reef, vugginess

Depth in feet	Thickness in feet	Description
		generally poor; brecciated near bottom; also some limy phases, with stylolites
	10	DOLOMITE and DOLOMITIC LIMESTONE as above, irregular structures, corals (some only partly dolomitized) and coral sand; calcite-filled vugs up to 0.75 inches
	13	DOLOMITE, as above, crystalline, stromatoporoids, corals and crinoid stems; locally fragmental; fair to good vugginess, with vugs to 1 inch in diameter
	17	DOLOMITE, brownish-grey, layered at approximately 25° to horizontal (flow-type layering), contains some corals, many paper-thin brownish-black bituminous shale layers, some limy films and anhydrite blebs; dolomite has sugary texture, fair to good microporosity, possibly a few corals and brachiopods
	1	DOLOMITE, breccia, buff matrix and brown coarse fragments, somewhat layered, small local vugs; coquinoid, with corals, stromatoporoids, brachiopods and crinoid (?) fragments
	3	DOLOMITE, dirty-brown, sugary texture, finely layered, possibly fragmental; vugs up to 1.5 inches in diameter
	4	DOLOMITE, brown, limy dolomite near the base, brecciated, some coralline material, stramatoporoids, crinoid stems, and brachiopods; considerable amounts of finely-broken fossil material
	16	DOLOMITE, dirty-brown, becoming greenish-grey, microcrystalline, locally shaly, vugs up to 1 inch, some breccia, corals and byozoans (*Fenestella*?); shaly partings; possibly reefal
	10	DOLOMITE, greenish-grey, becoming mottled with buff, some breccia, vugs, crinoid stems
	26	DOLOMITE, dark-grey becoming mottled and compact at base, limy, microcrystalline, vugs, irregular layering at high angle; crinoid stems, stromatoporoids, bryozoans, and brachiopods; brecciated in lower part
	2	DOLOMITE, grey, irregularly layered and argillaceous, vugs; larger vugs filled with gypsum
	5	DOLOMITE, dark-grey, argillaceous, finely bedded, slightly silty, dense, many crinoid stems

Depth in feet	Thickness in feet	Description
	20	DOLOMITE, dark-brown to dark-grey, very argillaceous, finely bedded, a few brachiopods, many crinoid stems, scattered coarse gypsum-filled vugs, becoming massive and tight below and indefintely layered; some bryozoans (*Fenestella*?)
	11	DOLOMITE, green at top, becoming dark-brown, buff at base, slightly layered at top, microcrystalline, massive, many small anhydrite inclusions, a few crinoid stems; bottom six inches shows no structures; shale, greenish-grey, dolomitic, with fair to good parting, and fractures filled with dolomite at base
768— 908		Ashern formation and Meadow Lake formation equivalents, undifferentiated
	7	SHALE, ANHYDRITE and DOLOMITE, interbanded, with many gypsum stringers
	12	DOLOMITIC CLAYSTONE, olive-green, locally interbanded with dolomite or anhydrite, occasionally brecciated, some gypsum
	18	CLAYSTONE and DOLOMITIC CLAYSTONE, greenish-grey, buff, green, some argillaceous dolomite and gypsum, slightly silty
	2	CLAYSTONE, as above, but mottled in red
	41	DOLOMITIC CLAYSTONE, red, becoming increasingly arenaceous and silty below; local gypsum concentrations
	10	SANDSTONE, red, with rounded quartz grains, some arenaceous claystone; gypsum concentrations throughout
	26	CLAYSTONE, arenaceous, rusty red and green, silty, with gypsum concentrations
	24	BRECCIA, rusty red, argillaceous, dolomitic, fragments up to one inch, some siltstone, sandstone, and gypsum
		Unconformity
908— 936		Precambrian basement
	28	FELDSPAR HORNBLENDE GNEISS, highly weathered at top, gypsiferous

Name: Bear Rodeo No. 1 drilled in 1948 by the Bear Oil Company Limited

Location: River Lot 5, McMurray, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: 817 feet **Total Depth:** 1142 feet

Depth in feet	Thickness in feet	Description*
0— 30		Pleistocene and Recent
	30	RIVER GRAVELS and SANDS
		Unconformity
		Beaverhill Lake formation
30— 126		Moberly member
	96	LIMESTONE, buff to greenish-grey, microgranular and locally fragmental at top becoming argillaceous and shaly at base
126— 205		Christina member
	79	SHALE, greenish-grey, calcareous, fair cleavage, locally flaky, limestone marker beds at top
205— 296		Calumet member
	91	LIMESTONE, buff to khaki, grey, microgranular, in part recrystallized, silty and argillaceous; *Tentaculites*?, Ostracodes
296— 470		Firebag member
	80	SHALE, olive-grey, calcareous, only fair parting a few fossiliferous lime bands, locally a claystone; silty at top
	35	LIMESTONE, greenish-grey, argillaceous, mottled, silty with shale bands at base
	35	LIMESTONE and shale, interbedded
	24	SHALE, green, calcareous; excellent parting with small limestone concretions at base; fossiliferous; *Lingula* and *Tentaculites*
470— 573		Slave Point formation equivalent (upper 5 feet), and Dawson Bay formation equivalent
	15	LIMESTONE and silty claystone with carbonaceous fragments, brown
	35	ANHYDRITE and silty limestone
	30	SILTSTONE, CLAYSTONE, SILTY SHALE, DOLOMITE, interbedded
	15	ANHYDRITE
	8	SILTSTONE

*Lithology from Bear Oil Company report.

Depth in feet	Thickness in feet	Description
573— 842		Prairie Evaporite formation
	49	ANHYDRITE
	4	ROCK SALT
	5	ANHYDRITE
	12	ROCK SALT
	30	ANHYDRITE
	2	ROCK SALT
	20	ANHYDRITE
	5	DOLOMITE
	12	ANHYDRITE
	30	DOLOMITE, buff, microgranular, in part recrystallized, bedded
	100	ROCK SALT, white to aquamarine, translucent
842— 954		Methy formation (Greiner, 1956)
	43	DOLOMITE, buff to brown, microgranular, recrystallized, fragmental
	34	LIMESTONE, locally dolomitized, brecciated
	35	LIMESTONE, coarse fragmental, interbedded with a brownish-black dolomitic shale, local beds of chert containing *Atrypa arctica* Warren (Elm Point formation equivalents)
954—1125		Ashern formation and Meadow Lake formation equivalents, undifferentiated
	10	ANHYDRITE
	24	CLAYSTONE, green, dolomitic, silty, some anhydrite
	137	CLAYSTONE, grading to siltstone and sandstone, all green at top, mottled in rusty red; some gypsum and anhydrite throughout
		Unconformity
1125—1142		Precambrian basement
	17	FELDSPAR PORPHYRY

Name: Northern Alberta Exploration Company* No. 2, drilled between the years 1907 and 1912

Location: Sec. 16, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: about 817 feet **Total Depth:** 1405 feet

Depth in feet	Thickness in feet	Description**
0— 17	17	Pleistocene and Recent
		SOIL
		Unconformity
		Devonian
17— 77	60	LIMESTONE
77— 92	15	SHALE
92— 152	60	LIMESTONE
152— 192	40	SHALE
192— 197	5	SHALE, soft
197— 237	40	LIMESTONE
237— 242	5	SHALE
242— 362	120	LIMESTONE
362— 382	20	SHALE
382— 462	80	LIMESTONE
462— 502	40	SHALE
502— 562	60	LIMESTONE
562— 592	30	SHALE
592— 604	12	LIMESTONE
604— 704	100	SALT (salt water), probably gypsum
704— 779	75	LIMESTONE
779— 869	90	SALT (salt water), probably gypsum
869— 999	130	LIMESTONE
999—1059	60	SHALE
1059—1139	80	SANDSTONE, brown
1139—1405	266	ROCK, red, hard, streaked

*Also known as the Great Northern Exploration Company. Well No. 1 was drilled 155 feet west of Well No. 2 and reached a depth of 1475 feet, but the log is less satisfactory (Allan, 1920, p. 97).

**Dowling et al (1919).

Name: Bear Rodeo No. 2, drilled in 1949 by the Bear Oil Company Limited

Location: Lsd. 5, Sec. 17, Tp. 91, R. 9, W. of 4th Meridian

Elevation of Surface: 804 feet **Total Depth:** 1064 feet

Depth in feet	Thickness in feet	Description*
		Beaverhill Lake formation
0— 97		Moberly member
	30	LIMESTONE, dense, fossiliferous
	15	SHALE, greenish, calcareous
	52	LIMESTONE, buff, rubbly, fossiliferous, argillaceous with some shale bands
97— 185		Christina member
	44	LIMESTONE and shale interbedded
	44	SHALE, thin-bedded, calcareous
185— 280		Calumet member
	35	LIMESTONE, buff, fosiliferous, massive, argillaceous
	60	SHALE and limestone
280— 458		Firebag member
	80	LIMESTONE and SHALE layers
	30	LIMESTONE, grey, dense, argillaceous
	68	SHALE and limestone, interbedded
458— 467		Slave Point formation equivalent
	9	LIMESTONE
467— 730		Dawson Bay formation equivalent and Prairie Evaporite formation, undifferentiated
	53	SILT and argillaceous dolomite with anhydrite beds at base
	145	ANHYDRITE and gypsum
	25	DOLOMITE and anhydrite
	40	ANHYDRITE
730— 877		Methy formation
	147	DOLOMITE, brown, granular, good porosity; *Atrypa arctica* at 807 feet (Greiner, 1956); lower 70 feet may be Elm Point formation equivalent
877—1063		Ashern formation and Meadow Lake formation equivalents?
	113	CLAYSTONE and ANHYDRITE, green to red, locally arenaceous, with a few gypsum beds

*Lithology from Bear Oil Company report.

Depth in feet	Thickness in feet	Description
	73	SANDSTONE, red, argillaceous, grain size decreasing towards base, underlain by quartzose bed with calcareous cement
		Unconformity
1063—1064		Precambrian basement
	1	FELDSPAR PORPHYRY
Driller's Note:		An artesian flow of brackish water was encountered 54 feet below the top of the dolomite; there was a continuous flow of slightly saline water (with an odor of H_2S) from 635 feet to end of hole

Name: Bear Vampire No. 2, drilled in 1949 by the Bear Oil Company Limited

Location: Lsd. 4, Sec. 32, Tp. 93, R. 10, W. 4th Meridian

Elevation of Surface: 793 feet **Total Depth:** 883 feet

Depth in feet	Thickness in feet	Description*
0— 11		Pleistocene and Recent
	11	SURFACE DEPOSITS
		Beaverhill Lake formation
11— 58		Moberly member
	47	LIMESTONE, buff, granular, silty, locally argillaceous
58— 141		Christina member
	83	SHALE, olive-grey, calcareous, with occasional light-grey calcareous bands; fair to good parting
141— 234		Calumet member
	93	LIMESTONE, buff to grey, fossiliferous
234— 425		Firebag member
	86	SHALE, calcareous, silty
	40	LIMESTONE, grey-green, argillaceous, coarse fracturing
	65	SHALE, calcareous, *Lingula* sp. 360 to 400 feet
425— 445		Slave Point formation equivalent?
	20	LIMESTONE, brown
445— 604		Dawson Bay and Prairie Evaporite formations, undifferentiated
	65	DOLOMITE and CLAYSTONE, argillaceous, coarse dolomite breccia in shale matrix
	94	ANHYDRITE, with some gypsum
604— 808		Methy formation
	166	DOLOMITE, buff, massive, fossiliferous
	38	DOLOMITE, dark-brown, argillaceous, finely crystalline, crinoid stems, brachiopods and sponge spicules
808— 875		Ashern formation and Meadow Lake formation equivalents?
	51	ANHYDRITE, underlain by interbedded dolomitic claystone and silty argillaceous dolomite
	16	CLAYSTONE, green mottled in red, grading at base into granite wash
		Unconformity
875— 883		Precambrian basement
	8	GRANITE, red, hornblende

*Lithology from Bear Oil Company report.

Name: Athabasca Oils Limited No. 1, drilled between the years 1911 and 1912

Location: Lsd. 8, Sec. 2, Tp. 96, R. 11, W. 4th Meridian

Elevation of Surface: 816 feet **Total Depth:** 1130 feet

Depth in feet	Thickness in feet	Description*
0— 13		Pleistocene and Recent
	13	SURFACE DEPOSITS
		Unconformity
13— 155		McMurray formation
	65	SAND, bituminous
	20	SHALE
	57	SAND, bituminous
		Unconformity
155— 590		Beaverhill Lake formation
	175	SHALE
	65	LIMESTONE
	20	SHALE
	175	LIMESTONE
590— 720		Dawson Bay and Prairie Evaporite formation equivalents undifferentiated
	130	GYPSUM
720— 912		Methy formation
		LIMESTONE (containing a salt water stratum)
975—1105		Ashern and Meadow Lake formation equivalents
	63	RED ROCK
	130	SAND, reddish, hard, flinty (second salt water stratum)
		Unconformity
1105—1130		Precambrian basement
	25	GRANITE, reddish (containing gold)

*Lithological description after Allan (1920)

Name: Pelican Rapids, drilled in the years 1897 - 1899 by the Geological Survey of Canada at mouth of Pelican River

Location: About Sec. 6, Tp. 79, R. 17, W. 4th Meridian

Elevation of Surface: not given **Total Depth:** 837 feet

Depth in feet	Thickness in feet	Description*
0— 86		Pleistocene and Recent
	86	SAND and gravel
		Unconformity
86— 185		Joli Fou formation**
	15	SHALE, dark-bluish, very soft
	4	SANDSTONE, soft
	80	SHALE, dark-bluish, very soft, slightly saline water at 185 feet
185— 465		Grand Rapids sandstones**
	40	SHALE, reddish-brown, rather hard
	9	SANDSTONE, water at 225 feet
	11	SANDSTONE and brown shale
	8	SHALE, grey, hard; water and gas at 253 feet
	27	SHALE, light-greenish-grey
	10	SHALE, greenish-grey, soft, cement-like
	18	SHALE, brown, with strata of grey shale
	2	SHALE, brown
	1	SANDSTONE, hard, gas and water
	17	SHALE, brown, and sandstone in alternate strata
	12	SANDSTONE
	13	SHALE, brown
	12	SAND ROCK, hard, with layers of softer rock; struck maltha and gas at 355 feet
	45	SANDSTONE, rather hard
	17	SHALE, brown
	23	SHALE, brown, hard
	15	SANDSTONE, more gas and water
465— 750		Clearwater shales**
	61	SHALE, grey
	6	IRONSTONE
	21	SHALE, grey
	3	SANDSTONE
	2	IRONSTONE, very hard
	5	SANDSTONE, very hard
	10	SHALE, brown

*After Dowling et al. (1919).
**Dawson, Geol. Surv. Can., Summ. Repts. 1897, 1898.

Depth in feet	Thickness in feet	Description
	17	SHALE, grey, streaks of sandstone
	30	SHALE, grey, brown shale and sandstone in alternating strata; the cuttings show traces of maltha
	5	SHALE, grey, strong flow of gas at 625 feet; considerable maltha coming away with the water
	18	SANDSTONE, very hard
	5	SHALE, grey, soft
	4	SANDSTONE, hard
	13	SHALE, grey, soft, sandy
	10	IRONSTONE
	9	SHALE, grey, soft
	1	SANDSTONE, hard
	18	SHALE, dark-grey, soft
	10	SANDSTONE, hard
	5	SHALE, grey, soft, sandy
	5	SANDSTONE, hard
	10	SANDSTONE
	10	SHALE, grey, soft
	7	SHALE, grey, soft, with streaks of soft sandstone; strong flow of gas at 750 feet; a heavy oil mixed all through the sandstone and shale
750— 837		Oil sands*
	31	SHALE, dark-grey, soft, and soft sandstone, heavy oil throughout; at 773 feet a heavier flow of gas
	19	SHALE, grey, soft, and soft SANDSTONE interbedded; increased quantities of heavy petroleum; gas increasing in volume
	20	Same as foregoing; at 820 feet, a tremendous flow of gas of which the roar could be heard for 3 miles or more
	10	SANDSTONE, soft; hard streak, and light flow of gas at 830 feet
	6	SANDSTONE, soft
	1	IRON PYRITES NODULES, embedded in cement-like sandstone; very strong flow of gas

*Dawson, Geol. Surv. Can., Summ. Repts. 1897, 1898.

Salt Well Logs

Name: Alberta Government Salt Well No. 1, drilled in 1920 by the Government of Alberta

Location: Lot 8, McMurray townsite, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: 795 feet **Total Depth:** 685 feet

Depth in feet	Thickness in feet	Description*
0— 95		Pleistocene and Recent
	13	LOOSE DIRT
	3	QUICKSAND
	26	ALLUVIAL MUD, blue
	13	SAND, white, silica
	5	SAND and BOULDERS
	18	LIMESTONE, argillaceous fragments
	17	SAND and BOULDERS
		Unconformity
		Beaverhill Lake formation
95— 144		Moberly member
	1	LIMESTONE, lithographic, colorless calcite replacements, and shell replacements, marcasite veining
96	—	LIMESTONE, grey, band two inches thick, soft, irregularly compacted, fossiliferous, crinoid stems *Atrypa devoniana* Webster *Allanaria allani* (Warren)
	9	LIMESTONE, buff-brown, with thin interbands of brown-grey argillaceous limestone, fossiliferous; brown limestone contains colorless crystalline calcite replacements
	5	LIMESTONE, brownish-grey, argillaceous, irregularly compacted
	10	LIMESTONE, grey-brown, massive, colorless, crystalline, calcite veining and replacements
	13	LIMESTONE, mottled with buff-brown and argillaceous brown-grey limestone, calcite replacements in buff-brown, disseminated marcasite in argillaceous limestone, stylolitic, fossiliferous
131	—	*Allanaria allani* (Warren), crinoid stems
	2	LIMESTONE, grey-brown, argillaceous, irregularly compacted

*Lithology and faunal list after Allan (1921) and MacDonald (1947).

Depth in feet	Thickness in feet	Description
	4	LIMESTONE, buff-brown, mottled, calcite veins and replacements, stylolitic argillaceous grey-brown limestone
	5	LIMESTONE, buff-brown, and brown-grey argillaceous limestone interbands, fossiliferous
144— 223		Christina member
	11	LIMESTONE, grey-brown, argillaceous, massive
	6	SHALE, green-grey, calcareous, fragmental
160	—	LIMESTONE, eight inches thick, mottled with colorless calcite and shell fragments cemented in green-grey calcareous shale *Allanaria allani* (Warren) *Atrypa reticularis* (Linnaeus) Crinoid stems
	3	LIMESTONE, argillaceous, and fragmental calcareous shale interbands, disseminated marcasite
	59	SHALE, green-grey, calcareous, fragmental, fossiliferous horizons and marcasite bands
170	—	*Allanaria allani* (Warren) Trochiliscids; marcasite
223— 315		Calumet member
	7	LIMESTONE, grey-buff, calcite veins and colorless crystalline replacements, fossiliferous; *Atrypa devoniana* Webster *Atrypa albertensis* Warren *Schizophoria* cf. *S. iowensis* Hall *Stropheodonta* sp.
	9	LIMESTONE, buff-grey, argillaceous, irregularly compacted, fosiliferous; *Atrypa devoniana* Webster *Cyrtina billingsi* Meek *Stropheodonta inequiradiata* Hall *Spirorbis omphaloides* Goldfuss Crinoid stems
	1	LIMESTONE, colorless to buff and grey, mottled, stylolitic, crystalline calcite replacements and veinlets, fossiliferous; crinoid stems
	1	SHALE, green-grey, calcareous, fragmental, fossiliferous; crinoid stems
	19	LIMESTONE, buff and grey, mottled, colorless crystalline replacements in the buff limestone, stylolitic grey calcareous shale, fossiliferous;
241— 243	—	*Atrypa devoniana* Webster *Schizophoria* cf. *S. iowensis* Hall

Depth in feet	Thickness in feet	Description
250	—	*Stropheodonta demissa* (Conrad)
257	—	*Stropheodonta demissa* (Conrad)
	10	LIMESTONE, buff, massive, fossiliferous;
264	—	*Stropheodonta demissa* (Conrad)
270	—	Pelecypod—*Leda*?
	22	LIMESTONE, buff-grey, argillaceous, dispersed twinned marcasite aggregates, fossiliferous;
276	—	*Crania famelica* Hall and Whitfield *Schizophoria* cf. *S. iowensis* Hall *Stropheodonta demissa* (Conrad) Crinoid stems, fish plates
285	—	*Lingula* cf. *L. ligea* Hall *Schizophoria* cf. *S. iowensis* Hall (*Schizophoria* partially replaced by marcasite) Crinoid stems
	4	SHALE, green - grey, calcareous, fragmental, fossiliferous; *Productella* sp. Trochiliscids Crinoid stems
	19	LIMESTONE, buff-grey, argillaceous, some calcite veining, fossiliferous
301	—	*Schizophoria* cf. *S. iowensis* Hall
307	—	Trochiliscids *Atrypa devoniana* Webster *Schizophoria* cf. *S. iowensis* Hall Crinoid stems
312— 315	—	*Stropheodonta demissa* (Conrad) *Atrypa devoniana* Webster Crinoid stems
315— 497		Firebag member
	71	SHALE, green - grey, calcareous, fragmental, scattered plant remains replaced by marcasite;
328	—	*Allanaria allani* (Warren) *Atrypa devoniana* Webster Disseminated marcasite
340	—	*Spirobis omphaloides* Goldfuss *Atrypa devoniana* Webster *Rhombopora* sp. Crinoid stems
354	—	*Atrypa devoniana* Webster Crinoid stems
364	—	*Atrypa devoniana* Webster

Depth in feet	Thickness in feet	Description
	16	LIMESTONE, grey - brown, argillaceous, calcite veining and replacements, marcasite replacements
391	—	*Atrypa devoniana* Webster
400	—	*Atrypa devoniana* Webster
	4	SHALE, green-grey, calcareous, fragmental
	6	LIMESTONE, grey-brown, argillaceous, massive
	7	SHALE, green-grey, calcareous, some bands more calcareous
	9	LIMESTONE, brown-grey, argillaceous, some shaly bands, marcasitic
	7	SHALE, green - grey, calcareous, fragmental, fossiliferous; *Atrypa devoniana* Webster *Lingula* cf. *L. ligea* Hall *Allanaria allani* (Warren)
	7	LIMESTONE, grey-brown and green-grey, mottled, calcite crystalline replacements, stylolites, fossiliferous; *Schizophoria* cf. *S. iowensis* Hall *Atrypa* sp. straight-beaked var. Pelecypod
	13	SHALE, green-grey, calcareous, fragmental, fossiliferous; *Lingula* cf. *L. ligea* Hall
450— 455	—	*Tentaculites mackenziensis* Kindle Fish jaw
	2	LIMESTONE, brown-grey, argillaceous, stylolitic, calcite and marcasite replacements
	23	SHALE, green-grey, calcareous, fragmental, fossiliferous; *Leptodesma* sp. *Atrypa albertensis* Warren *Atrypa devoniana* Webster *Lingula* cf. *L. ligea* Hall Fish plates
478— 480	—	*Tentaculites mackenziensis* Kindle
	5	SHALE, calcareous and argillaceous, limestone interbands *Lingula* cf. *L. ligea* Hall *Tentaculites mackenziensis* Kindle
	5	SHALE, green-grey, calcareous, fragmental, fossiliferous; *Lingula* cf. *L. ligea* Hall

Depth in feet	Thickness in feet	Description
	7	LIMESTONE, grey-buff, massive, black, speckled with conodonts, some crystalline limestone, also some marcasite and fossils *Atrypa* sp. *Atrypa albertensis* Warren *Atrypa devoniana* Webster Conodonts Nautiloids, *Orthoceras*-type *Paracyclas* cf. *P. elliptica* Hall
497— 502		Slave Point formation equivalent
	3	LIMESTONE, buff-brown and creamy, platy, fractured, calcite veined
500	—	LIMESTONE, creamy, band, one inch thick
	2	LIMESTONE, buff, dolomitic, finely bedded, fractured, dark-brown, platy bituminous bands
502— 685		Dawson Bay and Prairie Evaporite formations, undifferentiated
502	—	GYPSUM, powdery white and grey-brown; one-inch band, somewhat fibrous but irregularly arranged; dolomite and partially replaced anhydrite present
	1	LIMESTONE, buff, dolomitic, finely bedded and platy, satin spar bands; grades to buff dolomite with anhydrite veins, and anhydrite vugs which show the process of gypsum replacement
503	—	GYPSUM, one-inch band, white and grey-brown, powdery appearing but fibrous and irregularly arranged, some dolomite
	2	GYPSUM, brown, crystalline and buff dolomite interbands
	5	DOLOMITE, buff, fine-grained, banded with rock gypsum and some anhydrite showing replacement by gypsum
	4	ANHYDRITE, buff to brown-grey, dolomitic, crystalline, some gypsum bands
	2	LIMESTONE, grey-buff, massive, some anhydrite and gypsum present
	8	ANHYDRITE, buff-grey, dolomitic, and crystalline, some greyer fine-grained salty bands, interbanded with satin spar
524	—	DOLOMITE, two-inch band, green-grey, very salty, some anhydrite

Depth in feet	Thickness in feet	Description
	7	ANHYDRITE, crystalline, mottled, dolomitic and salty
	3	DOLOMITE, buff, very fine-grained with white or colorless gypsum veins and bands; some gypsum present in the dolomite
	3	ANHYDRITE, colorless, coarsely crystalline with dolomite, mottling
	2	DOLOMITE, grey, salty, banded with satin spar
	1	DOLOMITE, GYPSUM and ANHYDRITE, mottled, salty
	11	DOLOMITE, green-grey, very fine-grained, some gypsum and salt
	14	DOLOMITE, brown-grey, with some green-grey salty bands, some gypsum and also satin spar bands
	5	DOLOMITE, buff-brown, fine-grained, with colorless crystalline, dolomite replacements
	1	DOLOMITE, dark-brown, very fine-grained, some gypsum and anhydrite
	4	ANHYDRITE, colorless, crystalline, massive, a very small amount of dolomite
	3	ANHYDRITE, colorless, crystalline, with thin bands of maroon and green-grey, salty dolomite
	1	ANHYDRITE, DOLOMITE, green-grey, some gypsum and salt, very fine-grained
	4	ANHYDRITE, colorless, crystalline, cemented in brown dolomite, banding evident
	2	ANHYDRITE, colorless, crystalline, embedded in maroon and green-grey, dolomite
	1	ANHYDRITE, colorless, crystalline, some dolomite
	4	DOLOMITE, green-grey, fine-grained, some anhydrite
	35	ANHYDRITE, mottled and streaked with buff to fine-grained green-grey dolomite, satin spar veins and interbands in the salty dolomite
	1	DOLOMITE, buff, fine-grained with anhydrite replacements
	1	No core, saline washings
	3	ANHYDRITE, brown, dolomitic, finely crystalline
	5	ANHYDRITE, buff, porous, fine-grained granular salt
	1	DOLOMITE, buff, fine-grained, grading to grey-brown anhydrite
	5	No core, saline washings
	4	ANHYDRITE, SALT, DOLOMITE mixture

Depth in feet	Thickness in feet	Description
	2	ANHYDRITE, buff, dolomitic, crystalline, mottled
	1	DOLOMITE, green-grey, fine-grained, some anhydrite, salty
	14	ROCK SALT, colorless, crystalline, transparent, some inclusions or air spaces, contacts irregular
	1	ANHYDRITE, mottled with buff dolomite, banded with grey dolomite and salt
	3	DOLOMITE, green-grey to buff, satin spar and anhydrite interbands
	1	ANHYDRITE, mottled with brown dolomite
	8	SALT, ANHYDRITE, and DOLOMITE mottled and interbanded, some iron oxide-stained anhydrite; most of the salt has been dissolved
	5	ANHYDRITE, brown, dolomitic, fine, grading to mottled blue-grey and brown
	1	ANHYDRITE, dolomitic, with irregular rock salt bands
	4	ANHYDRITE, mottled blue to brownish, dolomitic, finely crystalline
	—	Bottom of well

Name: Alberta Government Salt Well No. 2, drilled in 1923 by the Government of Alberta

Location: Sec. 32, Tp. 88, R. 8, W. 4th Meridian

Elevation of Surface: 810 feet **Total Depth:** 789 feet

Depth in feet	Thickness in feet	Description*
0— 40		Pleistocene and Recent
	40	Unconsolidated sand and gravel
		Unconformity
		Beaverhill Lake formation
40.0— 59.4		Moberly member
	3.2	LIMESTONE, grey, massive
	4.2	LIMESTONE, shaly
	10	SHALE, dark-grey
	2	LIMESTONE, massive
59.4— 141.2		Christina member
	23.7	SHALE, calcareous, and thin limestone, interbedded
	3.2	LIMESTONE, shaly
	10.3	SHALE, calcareous, interbedded hard layers
	44.6	SHALE, massive, calcareous
141.2— 232.0		Calumet member
	10	LIMESTONE, grey, massive, mottled, fossiliferous
	60	LIMESTONE, shaly
	1.2	LIMESTONE, shaly
	19.6	LIMESTONE, grey, massive, fossiliferous
232.0— 415		Firebag member
	8.9	SHALE, calcareous
	14.8	SHALE, and limestone, interbedded
	1.4	LIMESTONE, hard, fissile, mottled
	7.0	SHALE, bluish, soft, calcareous
	1.6	LIMESTONE, grey, fossiliferous
	4.4	SHALE, fissile
	1.8	LIMESTONE, fossiliferous
	7.2	SHALE, bluish, soft
	9.5	SHALE, grey, calcareous, fossiliferous
	37.3	LIMESTONE, grey, massive, fossiliferous
	3.7	SHALE, bluish-grey, calcareous
	2.5	LIMESTONE, mottled, fossiliferous
	36.2	SHALE, bluish, and limestone, grey, interbedded, fossiliferous
	2	LIMESTONE, grey, mottled
	3.3	SHALE, bluish-grey, soft

*Lithological description after Allan (1924).

Depth in feet	Thickness in feet	Description
	1.8	LIMESTONE, argillaceous
	25.6	SHALE, calcareous, with pyrite
	3	LIMESTONE, fossiliferous
	6	SHALE, hard, fossiliferous
	5	LIMESTONE, grey, massive, fossiliferous
415— 587		Dawson Bay formation equivalent and Prairie Evaporite formation, undifferentiated
	33	ANHYDRITE, with thin bands of gypsum and shale
	2	SHALE, massive
	2	GYPSUM, and anhydrite, pink, thin-bedded
	1	DOLOMITE, pinkish, banded
	13	SHALE, with gypsum veins and anhydrite
	6	ANHYDRITE, grey, massive
	2	DOLOMITE, chocolate-colored, with gypsum
	15	ANHYDRITE with pink bands of gypsum
	91	GYPSUM, mottled, folded, with salt cavities and anhydrite
	7	ANHYDRITE, bluish, hard, with gypsum veins
587— 766.8		Methy formation
	14.8	DOLOMITE, chocolate, banded with gypsum
	27.5	DOLOMITE, brownish, massive
	22	DOLOMITE, massive, with irregular veins of selenite, salt pits
	15.5	DOLOMITE, yellowish, with salt and selenite crystals (salt water flow was 24 gallons per minute)
	48	DOLOMITE, brownish, with gypsum lenses and salt crystals
	8	DOLOMITE, yellowish, with pronounced dip
	7	ANHYDRITE, salt and gypsum lenses
	4	DOLOMITE, dark-grey and massive
	8	DOLOMITE, yellowish, brittle, with some gypsum
	19	ANHYDRITE, and gypsum
	6	DOLOMITE, massive, with selenite lenses
766.8— 785		Ashern formation equivalent
	13.2	GYPSUM, white, fibrous, thin-bedded, with anhydrite and shale
	2	GYPSUM, with many angular grains of quartz
	3	QUARTZ, angular grains, with gypsum matrix
		Unconformity
785— 789		Precambrian basement
	4	GRANITE, grey, coarse-grained

Name: Alberta and Great Waterways Railroad Company well, drilled in 1928

Location: SE. 1/4, Sec. 10, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: 800 feet approximately **Total Depth:** 976 feet

Depth in feet	Thickness in feet	Description*
0— 116	116	SAND and gravel
116— 127	11	BOULDERS, sand and gravel
127— 131	4	LIME ROCK, into fine gravel
131— 151	20	Bedrock
151— 274	123	LIMESTONE
274— 313	39	SHALE
313— 335	22	LIMESTONE, mottled; shale and shale lime rock
335— 490	155	SHALE and limestone, streaked with shale
490— 530	40	LIMESTONE, brown and grey rock streaked with crystal shale
530— 560	30	LIMESTONE, brown and grey, brown and white rock, pitted limestones with streaks of clay
560— 595	35	LIMESTONE and SHALE
595— 629	34	LIMESTONE with brown streak and limestone
629— 670	41	LIMESTONE, salt indications at 643 feet
670— 883	213	SALT (cannot recover—presumed to be salt by drillers)
883— 893	10	ROCK
893— 923	30	LIMESTONE
923— 932	9	GYPSUM
932— 948	16	LIMESTONE and SHALE
948— 953	5	GYPSUM
953— 958	5	SALT and GYPSUM
958— 962	4	SALT
962— 976	14	GYPSUM

*Cole (1930).

Name: Industrial Minerals Limited Salt Well No. 1, drilled in 1936

Location: SE. 1/4, Sec. 10, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: 825 feet **Total Depth:** 898 feet

Depth in feet	Thickness in feet	Description*
0— 100		Pleistocene and Recent
	100	Unconsolidated material
		Beaverhill Lake formation
100— 118		Moberly member
	1	LIMESTONE, brownish-grey, argillaceous
	4	LIMESTONE, buff and grey, mottled, marcasitic, stylolitic, fossiliferous; *Allanaria allani* (Warren) Crinoid stems
	5	LIMESTONE, argillaceous, narrow bands of grey-buff, and buff-grey
	8	LIMESTONE, buff and grey-brown, mottled, stylolitic, marcasitic, and fossiliferous; *Athyris* sp. *Allanaria allani* (Warren) *Atrypa devoniana* Webster
118— 213		Christina member
	7	LIMESTONE, grey-buff, argillaceous, with green-grey calcareous shale, some calcite replacements in the limestone
	5	SHALE, green-grey, calcareous, fragmental
	10	LIMESTONE, brown-grey, argillaceous, and calcareous shale, green-grey, interbedded, some calcite veining
131	—	Coral, *Pachypora* type
	17	LIMESTONE, buff-grey, argillaceous, and calcareous shale, green-grey, fragmental, interbedded
	3	LIMESTONE, brown, crystalline and argillaceous limestone, brown-grey, fossiliferous; *Atrypa devoniana* Webster Conodonts Crinoid stems
	10	LIMESTONE, brownish green-grey, argillaceous, and calcareous shale, green-grey interbands
	43	SHALE, calcareous, green-grey, fragmental, marcasitic

*Lithology and faunal descriptions after Allan (1943) and MacDonald (1947).

Depth in feet	Thickness in feet	Description
213— 310		Calumet member
	36	LIMESTONE, grey-brown and grey, mottled, stylolitic, marcasitic, and fossiliferous;
213— 229	—	*Atrypa devoniana* Webster *Atrypa albertensis* Warren *Cyrtina billingsi* Meek *Schizophoria* cf. *S. iowensis* Hall *Stropheodonta* sp. *Bryozoa* Crinoid stems
237	—	*Atrypa albertensis* Warren *Atrypa devoniana* Webster *Productella* sp. *Stropheodonta demissa* (Conrad) Crinoid stems
	28	LIMESTONE, grey-brown, argillaceous, marcasitic, fossiliferous;
249— 254	—	*Atrypa devoniana* Webster *Stropheodonta demissa* (Conrad) *Stropheonella* sp. Crinoid stems
265	—	*Atrypa devoniana* Webster *Chonetes* sp. *Productella* sp. *Stropheodonta demissa* (Conrad) Crinoid stems
271— 277	—	*Atrypa devoniana* Webster *Pugnax pugnus* (Martin) *Schizophoria* cf. *S. iowensis* Hall *Schizophoria striatula* (Schlotheim) *Stropheodonta demissa* (Conrad) *Stropheonella* sp. Pelecypod
	8	SHALE, green-grey, calcareous, fossiliferous; *Atrypa devoniana* Webster *Lingula* cf. *L. ligea* Hall *Schizophoria* cf. *S. iowensis* Hall *Stropheodonta demissa* (Conrad) Crinoid stems
	9	LIMESTONE, grey-brown, argillaceous, and calcareous shale interbeds, marcasitic, fossiliferous; *Lingula* cf. *L. ligea* Hall *Schizophoria* cf. *S. iowensis* Hall
	10	LIMESTONE, colorless, mottled, crystalline, and brown, argillaceous, fossiliferous;

Depth in feet	Thickness in feet	Description
294— 300	—	*Atrypa devoniana* Webster
		Cyrtina billingsi Meek
		Schizophoria cf. *S. iowensis* Hall
		Allanaria allani (Warren)
		Stropheodonta demissa (Conrad)
		Stropheonella sp.
		Trochiliscids
		Crinoid stems
	2	SHALE, green-grey, calcareous, fragmental
	4	LIMESTONE, mottled, grey-brown and grey, fossiliferous;
		Atrypa devoniana Webster
		Stropheonella sp.
310— 490		Firebag member
	71	SHALE, green-grey, calcareous, marcasitic bands, fossiliferous;
310— 314	—	*Atrypa devoniana* Webster
		Stropheodonta sp.
322	—	*Atrypa devoniana* Webster
		Allanaria allani (Warren)
		Crinoid stems
325	—	Algae
331	—	*Atrypa devoniana* Webster
		Crinoid stems
		Fish plates
338	—	*Atrypa reticularis* (Linnaeus)
		Atrypa devoniana Webster
		Cyrtina billingsi Meek
		Styliolina fissurella Hall
		Schizophoria striatula (Schlotheim)
		Crinoid stems
345— 351	—	*Atrypa reticularis* (Linnaeus)
		Atrypa devoniana Webster
		Cyrtina billingsi Meek
		Allanaria allani (Warren)
		Schizophoria striatula (Schlotheim)
354	—	*Atrypa devoniana* Webster
368	—	*Atrypa reticularis* (Linnaeus)
		Atrypa devoniana Webster
		Allanaria allani (Warren)
		Cyrtina billingsi Meek
		Leptodesma?
		Fish plates
		Crinoid stems
		Marcasitic replacement of these fossils

Depth in feet	Thickness in feet	Description
378	—	*Atrypa devoniana* Webster *Lingula* cf. *L. ligea* Hall *Orbiculoidea* sp.
	35	LIMESTONE, grey-brown, argillaceous, with thin interbeds of calcareous green-grey shale, fossils scarce
	2	SHALE, green-grey, calcareous, marcasitic, and fossiliferous; *Cyrtina billingsi* Meek *Leptodesma* sp. Crinoid stems
	1	LIMESTONE, grey-brown, argillaceous, marcasitic
	9	SHALE, green-grey, calcareous, marcasitic, and very fossiliferous; *Atrypa devoniana* Webster *Atrypa reticularis* (Linnaeus) *Atrypa*, straight beaked var. *Crania famelica* Hall and Whitfield *Schizophoria striatula* (Schlotheim) *Cyrtina billingsi* Meek *Spirifer delthyris* *Lingula* cf. *L. ligea* Hall *Leptodesma* sp. *Modiomorpha*?
	4	LIMESTONE, brownish green-grey argillaceous, and fossiliferous, calcareous shale interbeds *Lingula* cf. *L. ligea* Hall *Leptodesma* sp.
	13	SHALE, green-grey, calcareous, fragmental, fossiliferous; *Lingula* cf. *L. ligea* Hall *Atrypa devoniana* Webster *Cyrtina billingsi* Meek *Leptodesma* sp.
	2	LIMESTONE, brown to green-grey, mottled, stylolitic, with marcasite disseminated along the faces
	37	SHALE, green-grey, calcareous, fragmental, fossiliferous; *Atrypa devoniana* Webster *Lingula* cf. *L. ligea* Hall *Leptodesma* sp.
452	—	LIMESTONE nodules, irregular, elongated, flattened, no internal structure, some grains of marcasite

Depth in feet	Thickness in feet	Description
456	—	*Lingula spatulata* Vanuxem
460	—	LIMESTONE nodules, circular, discoidal *Tentaculites mackenziensis* Kindle is abundant on the nodule coating
460— 478	—	*Tentaculites mackenziensis* Kindle *Lingula* cf. *L. ligea* Hall *Leptodesma* sp. Fish plates
	1	SHALE, greenish-brown, calcareous, platy, ripple-marked, limestone nodules, fossiliferous; *Lingula* cf. *L. ligea* Hall
	2	LIMESTONE, buff-brown, black speckled with conodonts, marcasite replacements
	3	LIMESTONE, buff-grey, marcasite replacements, fossiliferous; Nautiloids Gastropods
490— 493.5		Slave Point formation equivalent
	2	LIMESTONE, dark-brown, dolomitic, platy, bituminous stained
	1.5	LIMESTONE, creamy to buff, deep-brown crystalline gypsum replacements in the buff limestone
493.5— 898		Dawson Bay formation equivalent and Prairie Evaporite formations, undifferentiated
	3.5	GYPSUM, dark-brown, crystalline, some dolomite and anhydrite
	9	ANHYDRITE, with deep-brown crystalline gypsum replacements, anhydrite grades to buff dolomitic anhydrite
	1	LIMESTONE, buff-brown, with 0.5 inch band of satin spar and grey dolomitic salty anhydrite
	4	ANHYDRITE, colorless, crystalline, mottled with buff dolomite and grey salty dolomite
	2	ANHYDRITE and dolomite interbeds, some satin spar veining and banding in the grey salty dolomite
	5	DOLOMITE, dark grey-brown, salty, with both anhydrite and satin spar veining
	5	ANHYDRITE, colorless, crystalline, mottled with buff-brown dolomite
	28	DOLOMITE, green-grey, salty, some anhydrite lenses or globules, some satin spar interbands

Depth in feet	Thickness in feet	Description
	4	ANHYDRITE, grey-brown, dolomitic, salty, grading to buff
	5	DOLOMITE, dark-brown, salty, satin spar veining, pink and colorless anhydrite inclusions
	11	ANHYDRITE, green-grey, dolomitic
	4	LIMESTONE, reddish-brown, dolomitic, grading to dolomite, salty, green-grey, mottled reddish-brown
	45	ANHYDRITE, colorless, mottled with dolomite, grey and salty, some satin spar veining and interbanding
	2	LIMESTONE, buff, dolomitic
	2	ANHYDRITE, buff, dolomitic, crystalline
	2	DOLOMITE, dark-grey, salty, with some anhydrite
	14	ANHYDRITE, buff to bluish-grey, finely crystalline, dolomitic
	17	ANHYDRITE, mottled blue-grey and buff, dolomitic
	3	DOLOMITE, buff, vugs of colorless, crystalline anhydrite, interbedded with finely crystalline dolomitic anhydrite
	10	ANHYDRITE, mottled grey and brown, dolomitic, finely crystalline anhydrite
	10	DOLOMITE, buff, salty, satin spar veins and interbands, some anhydrite
	4	ANHYDRITE, buff, dolomitic, crystalline
	2	DOLOMITE, buff, salty, finely bedded, some anhydrite
	1	ANHYDRITE, mottled with buff dolomite, crystalline
	3	DOLOMITE, buff, finely bedded satin spar veins and interbands, some anhydrite and salt
	4	ANHYDRITE, dolomitic, finely crystalline, mottled with buff dolomite
694— 893	199	ROCK SALT, colorless, transparent
	4	ANHYDRITE, colorless, crystalline, mottled with buff dolomite
	1	LIMESTONE, buff, porous, thin bedded, with satin spar veins and interbands

Name: Industrial Minerals Limited Salt Well No. 2, drilled in 1937

Location: SE. 1/4, Sec. 10, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: Approx. 820 feet **Total Depth:** 875 feet

Depth in feet	Thickness in feet	Description*
0— 50	50	SAND and gravel
50— 62	12	SAND, water-bearing
62— 100	38	SAND
100— 108	8	CLAY, blue
108— 131	23	LIMESTONE
131— 150	19	SHALE
150— 176	26	SHALE, with streaks of limestone
176— 220	44	SHALE
220— 228	8	No record
228— 420	192	LIMESTONE and shale
420— 480	60	SHALE
480— 696	216	LIMESTONE
696— 875	179	SALT

*O.D. Bush, Driller, from files of Research Council of Alberta, Edmonton.

Name: Industrial Minerals Limited Salt Well No. 3, drilled in 1939

Location: SE. 1/4, Sec. 10, Tp. 89, R. 9, W. 4th Meridian

Elevation of Surface: 853 feet **Total Depth:** 952 feet

Depth in feet	Thickness in feet	Description*
0— 42		Pleistocene and Recent
	10	CLAY
	13	GRAVEL and small boulders
	19	SAND
42— 151		McMurray formation
	33	SAND, bituminous
	76	SHALE, soft
		Unconformity
		Beaverhill Lake formation
151— 166		Moberly member
	15	LIMESTONE, grey to yellowish
166— 247		Christina member
	40	LIMESTONE and green shale, interbedded
	41	LIMESTONE and shale, greenish, calcareous
247— 339		Calumet member
	59	LIMESTONE, light-grey to yellowish, mottled, fossiliferous;
		Atrypa devoniana Webster
		Stropheodonta navalis Swallow
		Stropheodonta callowayensis Swallow
		Fish plates
		Crinoid stems
	33	LIMESTONE, greenish, mottled, shaly and shale, calcareous
		Atrypa devoniana Webster
		Stropheodonta sp.
339— 513		Firebag member
	6	LIMESTONE, greenish, shaly
		Trochiliscids
		Crinoid stems
	25	SHALE, greenish, calcareous
	2	LIMESTONE, grey, mottled
		Atrypa devoniana Webster
	40	SHALE, greenish, calcareous
		Atrypa devoniana Webster
		Spirorbis omphaloides Goldfuss
		Leptodesma sp.

*Lithological description after Allan (1943) and MacDonald (1947).

Depth in feet	Thickness in feet	Description
	37	LIMESTONE, light-grey, shaly with shale streaks
	10	SHALE, greenish
		Atrypa devoniana Webster
		Cyrtina billingsi Meek
	6	LIMESTONE, yellowish-grey; shale, greenish in irregular bedding and lenses
		Cyrtina billingsi Meek
		Atrypa devoniana Webster
	12	SHALE, greenish, soft, calcareous (will cave easily)
		Camerophoria cf. *C. gregeri* (Branson)
		Lingula cf. *L. ligea* Hall
		Leptodesma sp.
	3	LIMESTONE, grey, mottled and spotted with greenish shale
		Atrypa albertensis Warren
		Athyris sp.
		Modiomorpha sp.
	15	LIMESTONE, greenish, clayey
		Lingula cf. *L. ligea* Hall
		Tentaculites mackenziensis Kindle
	11	SHALE, greenish, soft, fissile (caves easily)
		Tentaculites mackenziensis Kindle
	7	SHALE, greenish, calcareous (poker-chip weathering)
		Atrypa albertensis Warren
		Nautiloids
		Leptodesma sp.
		Tentaculites mackenziensis Kindle
513— 938		Slave Point formation equivalent? (upper 7 feet), Dawson Bay formation equivalent, and Prairie Evaporite formation, undifferentiated
	12	LIMESTONE, interbedded grey shale, dark, calcareous; yellowish dolomite
	13	GYPSUM, soft, and some anhydrite bands
	19	ANHYDRITE, bluish, hard, massive
	2	SHALE, greenish, compact
	8	GYPSUM, grey, with green shale interbedded
	5	SHALE, greenish, compact, and calcareous, with gypsum
	4	GYPSUM, brownish; shale, waxy
	8	SHALE, dark-greenish and red streaks
	2	GYPSUM, grey to yellowish, some fibrous gypsum

Depth in feet	Thickness in feet	Description
	3	DOLOMITE, yellowish-grey, interbedded with gypsum
	59	GYPSUM, spotted reddish, grey, and bluish, massive, grey with red streaks
	2	DOLOMITE, buff to yellowish-grey, with gypsum
	6	GYPSUM, and anhydrite interbedded
	27	ANHYDRITE, massive, gypsum interbedded in upper 7 feet, lower 20 feet massive, bluish to translucent
	16	GYPSUM, brown to yellowish grey, massive
	11	DOLOMITE, yellowish-grey, with some gypsum (saline to taste)
	1	DOLOMITE
	3	ANHYDRITE, massive, some layers translucent and interbedded with thin layers of fibrous gypsum
	1.3	DOLOMITE, brownish with thin translucent gypsum layers
	0.5	ANHYDRITE, grey, hard
	2.2	DOLOMITE, brownish, and gypsum
	5	ANHYDRITE, hard, massive, translucent
	211	ROCK SALT
	4	ANHYDRITE, massive, and some gypsum
938— 952		Methy formation
	2	DOLOMITE, finely interbedded with gypsum and some shale, brown to black with grey patches Gastropods Ostracodes
	2	DOLOMITE, broad brown and grey bands with gypsum Brachiopod—cf. *Rhynchotrema capax* Gastropod—*Hormotoma gracilis* Hall? Ostracodes—*Aparchites whiteavesi* Jones?
	9	GYPSUM, black and dark-brown, dolomite and shale, finely interbedded
	1	DOLOMITE, grey, anhydrite and thickly bedded gypsum *Tentaculites* sp.

APPENDIX C. Stratigraphic Distribution of the Devonian Faunas

Stratigraphic units / Faunal list	Slave Point formation	Beaverhill Lake Formation					Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
		Firebag member	Calumet member	Christina member	Moberly member	Mildred member						
Actinostroma sp.												10
Stromatopora sp.					16*					10, 15	10, 15	10, 15
Cyathophyllum athabascense Whiteaves							5					
Cylindrophyllum sp.								16				
Cysteophyllum sp.							3					
Pachyphyllum sp.			18									
Pachypora sp.					9							
Spirorbis omphaloides Goldfuss		9			6		5					
Conodonts					9							
Ascodictyon stellatum Nicholson							5					
Hederella canadensis Nicholson							5					
Rhombopora sp.		9										
Bryozoa			9		6							
Allanaria allani (Warren)		9	9		9, 16						10, 15	
Allanaria minutilla Crickmay												15
Allanaria aff. *A. minutilla* Crickmay				16								
Allanaria sp.					16							

*Numbers refer to reference list on page 124.

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Ambothyris cf. *A. halli* (Branson)												10
Ambothyris sp.	16											
Athyris occidentalis (Whiteaves)					16		5, 7					
Athyris parvula (Whiteaves)							5					
Athyris vittata var. *brandonensis* Stainbrook												10, 15
Athyris vittata var. *randalia* Stainbrook											10, 15	
Athyris sp.		9					4					
Atrypa cf. *A. bentonensis* Stainbrook				16								
Atrypa cf. *A. brandonensis* Stainbrook								16				
Atrypa bremerensis Stainbrook												10
Atrypa cf. *A. bremerensis* Stainbrook												15
Atrypa clarkei Warren					16						10, 15	
Atrypa clarkei Warren var.												10, 15
Atrypa devoniana Webster		9	9	9								
Atrypa cf. *A. gigantea* Webster					15						15	
Atrypa independensis Webster		16					13			3, 10, 13	10	
Atrypa cf. *A. independensis* Webster		16								15	15	
Atrypa aff. *A. independensis* Webster	16											
Atrypa cf. *A. littletonensis* Stainbrook		16	16									
Atrypa cf. *A. owenensis* Webster												
Atrypa cf. *A. randalia* Stainbrook						17					10, 15	

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Atrypa reticularis (Linnaeus)		6, 8	6, 8	6	6, 9		2, 3, 4, 7					
Atrypa reticularis var. *aspera* Schlotheim							5					
Atrypa scutiformis Stainbrook												10, 15
Atrypa spinosa Hall			6	6	6		7					
Atrypa cf. *A. tenuicosta*				16								
Atrypa cf. *A. trowbridgei* Fenton and Fenton			16									
Atrypa sp.					16	13	13			13		
Camerophoria gregeri (Branson)							13					
Camerophoria sp.					16							
Chonetes logani var. *aurora* Hall							5					
Chonetes sp.			9				7					
Cranaena sp.											10	15
Crania (Petrocrania) famelica (Hall and Whitfield)		9										
Crania hamiltoniae Hall							5					
Cyrtina billingsi Meek		8, 9, 16	9				3, 5, 7, 13			13	10, 15	
Cyrtina hamiltonensis Hall							5, 7					
Cyrtina triquetra Hall												10
Cyrtina sp.		6	6, 16	6	6						10, 15	
Cyrtospirifer sp.												15

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Calumet member	Christina member	Moberly member	Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Devonoproductus sp.			16									
Eatonia sp.		6										
Eleutherokomma beardi Crickmay						11						
Eleutherokomma hamiltoni Crickmay					11, 16	11						10, 15
Eleutherokomma impennis Crickmay		11, 16										
Eleutherokomma jasperensis (Warren)			11									
Eleutherokomma cf. *E. jasperensis* (Warren)				16								
Eleutherokomma killeri Crickmay						11, 16	17					
Eleutherokomma leducensis Crickmay					11	11	15					
Eleutherokomma cf. *E. leducensis* Crickmay								16				
Eleutherokomma sp.			16		16	13					10, 15	10
Eosyringothyris thomasi Stainbrook							13					
Gruenewaldtia gregeri (Rowley)							7					15
Gruenewaldtia cf. *G. gregeri* (Rowley)		9										
Hypothyridina cf. *H. cameroni* Warren					16							
Hypothyridina sp.				16								
Leiorhynchus sp.		9	9									
Lingula cf. *L. ligea* Hall		6, 8,										
Lingula spatulata Vanuxem		16										
Lingula cf. *L. spatulata* Vanuxem		16								10, 15		

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Martinia richardsoni (Whiteaves)							5					
Maclarenella maculosa Stehli					14, 16							
Nudirostra athabascensis (Kindle)						13	15					
Nudirostra sp.		16				16						
Orbiculoidea sp.		9										
Productella cf. *P. belanskii* Stainbrook											10, 15	
Productella callawayensis Swallow							7					
Productella hallana Walcott							7					
Productella sp.			9		6							10, 15
Productus dissimilis Hall							3, 5					
Productus subaculeatus Murchison							2					
Protoleptostrophia sp.			16									
Pugnax pugnus Martin			9				5, 7					
Pugnax sp.											10, 15	
Pugnoides kakwaensis McLaren							13, 17			13		
Reticularia sp.		6										
Rhynchonella sp.							2					
Schizophoria allani Warren											10, 15	
Schizophoria athabascensis Warren											10, 15	
Schizophoria cf. *S. athabascensis* Warren			16									
Schizophoria cf. *S. iowensis* Hall			9				3					
Schizophoria lata Stainbrook											10, 15	
Schizophoria cf. *S. lata* Stainbrook				16								

APPENDIX C

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Schizophoria cf. *S. resupinata* (Martin)							1, 2					
Schizophoria striatula (Schlotheim)		6, 8	6, 8	6	6		4, 5, 7					
Schizophoria sp.							13			10, 13, 15	10	
Spinatrypa albertensis (Warren)		9	9		16		17				10, 15	
Spinatrypa albertensis (Warren) var.											10	
Spinocyrtia capax Hall			16									
Spinocyrtia euruteines (Owen)							13					
Spinocyrtia sp.		6	6	6	6						15	
Spirifer delthyris		9										
Spirifer inutilis Hall							5					
Spirifer subattenuata Hall							5					
Spirifer tullia Hall var.							5, 7					
Spirifer cf. *S. tullia* Hall					8							
Spirifer cf. *S. ziczac* Hall							4					
Spirifer sp.							1					
Strophalosia productoides Murchison							4, 5					
Stropheodonta cf. *S. callawayensis* Swallow			9									
Stropheodonta costata Owen			16									
Stropheodonta cf. *S. costata* Owen			16									
Stropheodonta demissa (Conrad)		9	6, 8, 9				3, 5, 7					
Stropheodonta dorsata Stainbrook												10
Stropheodonta cf. *S. dorsata* Stainbrook												15

Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Stropheodonta halli Cleland												10, 15
Stropheodonta inequiradiata Hall							7					
Stropheodonta inflexa Swallow							7					
Stropheodonta iowensis Owen												10, 15
Stropheodonta cf. *S. navalis* Swallow			9									
Stropheodonta perplana (Conrad)							7					
Stropheodonta plicata Hall												10, 15
Stropheodonta subdemissa Hall							7				10, 15	
Stropheodonta cf. *S. subdemissa* Hall			16									
Stropheodonta umbonata Stainbrook												10
Stropheodonta cf. *S. umbonata* Stainbrook												15
Stropheodonta sp.			8, 9, 16				13					
Stropheonella sp.			9									
Actinopteria boydii Conrad							5					
Aviculopecten cf. *A. flabellum* (Conrad)							7					
Aviculopecten sp.		6					3					
Leda (?) sp.			9									
Leptodesma demus Hall							5					
Leptodesma jason Hall							5					
Leptodesma sp.		6, 9	9		6		4					10, 15
Megambona sp.												10, 15
Modiomorpha sp.		9					7					

APPENDIX C

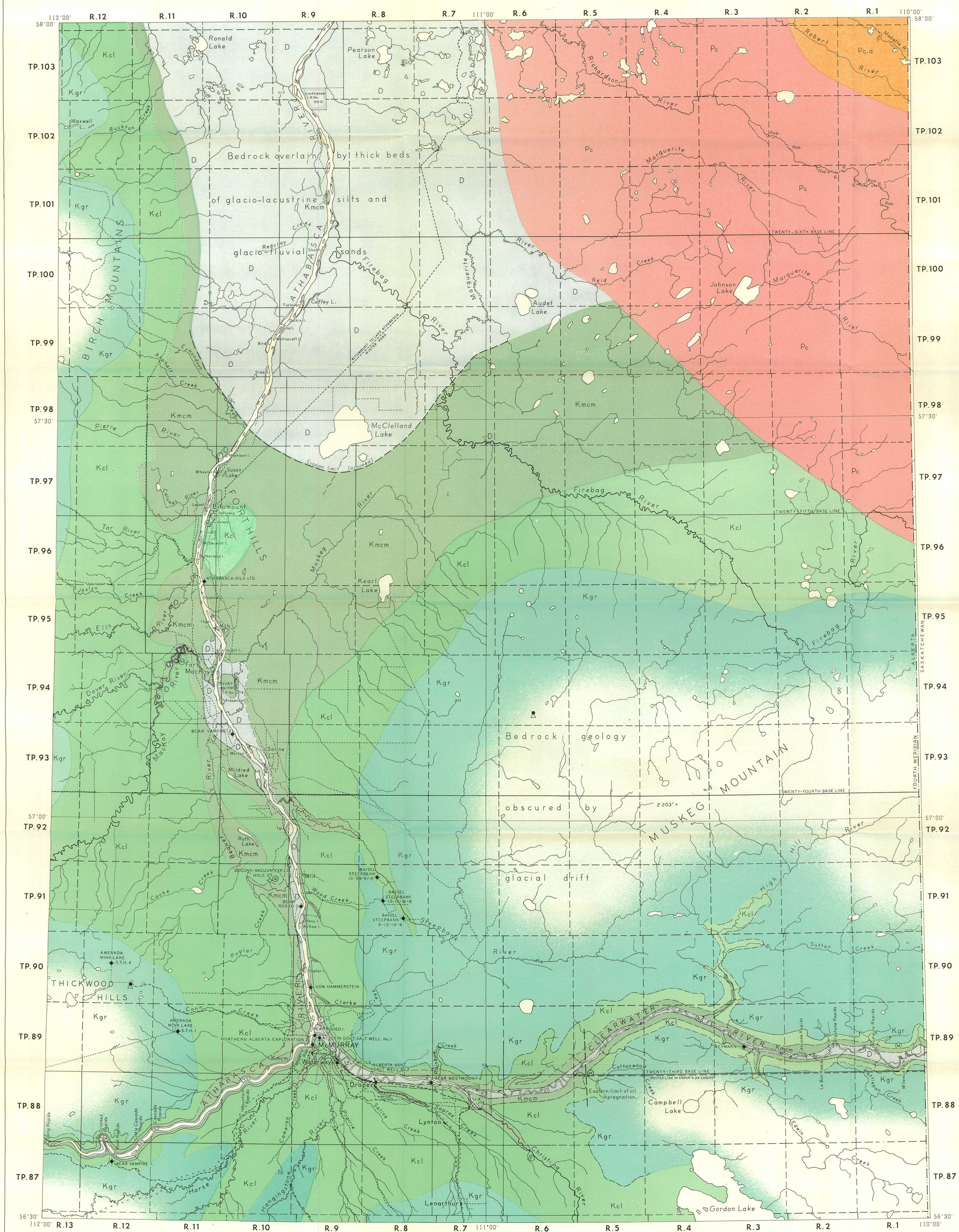
Faunal list / Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Calumet member	Christina member	Moberly member	Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Palaeoneilo sp.							4					
Paracyclas elliptica Hall							4, 7					
Paracyclas sp.		9	6	6								10
Posidonomya sp.							2					
Ptychopteria aequivalvis Whiteaves							5					
Bucania sp.							4					
Buchiola retrostriata Von Buch							7					
Euomphalus sp.			6									
Pleurotomaria sp.							2, 3, 4					
Conularia salinensis Whiteaves							5					
Styliolina fissurella Hall		9										
Tentaculites mackenziensis Kindle		9										
Tentaculites cf. *T. mackenziensis* Kindle							7					
Tentaculites sp.										10, 15		
Gomphoceras sp.											15	
Gomphoceras?							4	19				
Nautiloids		9			19		19					
Abursus beaumontensus Loranger									12			
Abursus biltmorensus Loranger									12			

Faunal list \ Stratigraphic units	Slave Point formation	Beaverhill Lake Formation: Firebag member	Beaverhill Lake Formation: Calumet member	Beaverhill Lake Formation: Christina member	Beaverhill Lake Formation: Moberly member	Beaverhill Lake Formation: Mildred member	Beaverhill Lake formation	Cooking Lake formation	Ireton formation	*Lingula spatulata* zone	*Allanaria allani* zone	*Eleutherokomma hamiltoni* zone
Aparchites mitis Jones							5					
Bairdia biltmorensa Loranger									12			
Balantoides biltmorensus Loranger						12						
Balantoides sp.			19									
Bythocypris biltmorensis Loranger									12			
Cooperatia biltmorensa (Loranger)									12			
Halliella bellipuncta (Van Pelt)									12			
Kloedenia kinsella Loranger									12			
Macronotella biltmorensa Loranger									12			
Plagionephrodes biltmorensus Loranger									12			
Plagionephrodes sp.		19	19									
Ostracoda		19	19	19	19							
Charophyta		19	19		19							10
Trochiliscids			9		9							

References Used in Compilation of Stratigraphic Table

1. Franklin (1828)
2. Richardson (1851; repeated in Isbister, 1855)
3. Meek (1868)
4. Bell (1884)
5. Whiteaves (1891; repeated in McConnell, 1893a)
6. Allan (1921)
7. Warren (1933)
8. Allan (1943)
9. MacDonald (1947; 1955)
10. Warren and Stelck (1950)
11. Crickmay (1950; 1953)
12. Loranger (1954a)
13. McLaren (1954)
14. Stehli (1955)
15. Warren and Stelck (1956)
16. Crickmay (1957)
17. Taylor (1957)
18. Belyea and McLaren (1957)
19. This report

RESEARCH COUNCIL OF ALBERTA
GEOLOGICAL DIVISION



MAP 26
GEOLOGY OF
McMURRAY AREA, ALBERTA

WEST OF FOURTH MERIDIAN

Scale 1 inch to 4 miles

5 0 5 10

LEGEND

MESOZOIC
CRETACEOUS
LOWER CRETACEOUS

Kgr — *GRAND RAPIDS FORMATION : white to yellow fine-grained lithic sand and sandstone.*

Kcl — *CLEARWATER FORMATION : grey-black marine shale, grey and green glauconitic sandstone.*

Kmcm — *McMURRAY FORMATION : shale, siltstone, fine to coarse-grained quartz sand, in part oil-saturated.*

PALEOZOIC
DEVONIAN

D — *BEAVERHILL LAKE and METHY FORMATIONS : calcareous shale, limestone and dolomite.*

PRECAMBRIAN

Pc.a — *ATHABASCA FORMATION : orthoquartzite.*

Pc — *UNDIVIDED : basement complex, mainly granite gneiss and schist.*

Geological boundary (defined)
Geological boundary (approximate)
Geological boundary (assumed)
Locality (macrofossils)
Locality (microfossils)
Saltwell
Oil-sand test hole
Wildcat well

Geology by M. A. Carrigy, 1957, 1958 and G. A. Collins, 1953, 1954, 1955.

Winter and summer road (condition unknown)
Railway
Railway (abandoned)
Telephone or telegraph line
Forestry lookout tower
Interprovincial boundary
Township boundary (surveyed)
Township boundary (unsurveyed)
Indian reserve boundary
Boat landing
Stream (permanent, intermittent)
Rapids — Rapids
Waterfall
Height in feet above mean sea-level — 2203'

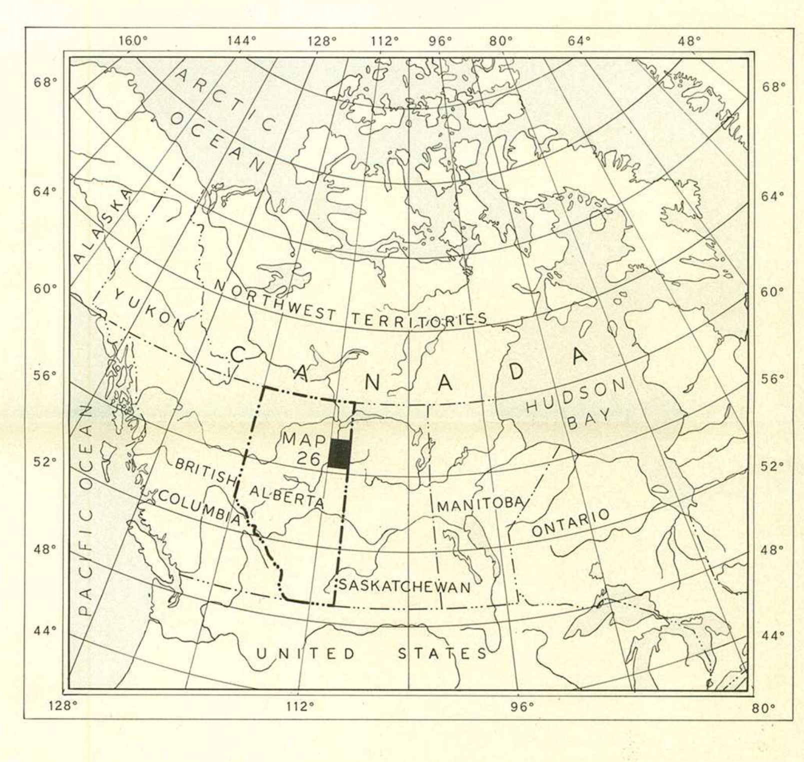
Magnetic declination over the area was 25°00' E. to 27°00' E. in 1954. The declination of the compass needle is decreasing 6' annually.

Boundaries of Athabasca formation after Blake. D. A. W., (1956), Geological Survey of Canada, Paper 55-33.

Base map compiled from planimetric sheets 74 D/NW, NE, and 74 E/SE, SW, NW, NE, published by Government of Alberta, Department of Lands and Forests; Scale One Inch to Two Miles, (1952).

Road information supplied by Government of Alberta, Department of Highways, Shell Oil Company of Canada Ltd., and Bailey Selburn Oil and Gas Ltd., (1958).

INDEX MAP



Map to Accompany Memoir 1

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