PROVINCE OF ALBERTA

Research Council of Alberta *Report No. 34*

University of Alberta, Edmonton, Alberta

GEOLOGY

Part I—General Geology of Alberta

Part II—Rock Salt Deposit at Waterways

Part III—Geology of Alberta Soils

Part IV—Relief Model of Alberta and its Geological Application

Part V—Coal Areas of Alberta

by

JOHN A. ALLAN
Professor of Geology
University of Alberta

EDMONTON
PRINTED BY A. SHNITKA, KING'S PRINTER
1943

PREFACE

Since 1935 there have been no reports published on the geological work carried out by the Research Council of Alberta. Up to and including 1935, annual reports were published on the results of geological survey work carried out each year. Publication of annual reports has been discontinued and results of investigations will be presented as separate reports.

In this publication, Report No. 34, are given some of the results from investigations on a number of geological survey projects undertaken by J. A. Allan between 1936 and 1941 inclusive. The results of many of the smaller investigations undertaken during these years, are not included in Report No. 34, but some of them may be included in later reports.

There are five parts to Report No. 34, prepared by J. A. Allan, which deals with the geology of Alberta. In Part I the general geology of Alberta is discussed briefly and the major geological formations are described. So that this part of the report can be interpreted more fully, the geological map of Alberta on a scale of one inch to 32 miles accompanies the report. Part II contains a discussion of the extensive salt deposit at Waterways in the McMurray district where a salt industry has been developed. In Part III the writer discusses the relation of the geology of soil types in 28,006 square miles in Alberta where detailed soil surveys have been made. In Part IV a large relief map model of Alberta, eight feet by four and one-half feet, made by J. A. Allan, is described and its utility emphasized. Part V deals with the Coal Areas Map of Alberta which accompanies the report. A few notes are given on the coal seams that are known to occur in each area.

The writer extends thanks to all those who have co-operated in various ways in the compilation of Part V. Acknowledgment for this co-operation is given in the text.

In the preparation, proofreading and indexing of this report, valuable assistance was rendered the writer by Mrs. Vera Stover. For helpful discussion in the field and in the laboratory, relative to the soils of Alberta as included in Part III, the writer is grateful to F. A. Wyatt and J. D. Newton, Department of Soils, University of Alberta, and to W. E. Bowser and W. Odynsky, Dominion Department of Agriculture. Plates 20 to 37 included in Part III, with the exception of Plates 25, 28C, 29, 34 and 35A, were loaned by the College of Agriculture, University of Alberta.

MAPS AND ILLUSTRATIONS

PART I.

PART II.

PART III.

CONTENTS

Part IV.—Relief Model of Alberta and its Geological Application

Part V.—Coal Areas of Alberta

Plate. Page

RESEARCH COUNCIL OF ALBERTA

GEOLOGY

REPORT No. 34, PART I—PAGES 11 TO 37

General Geology of Alberta

By J. A. Allan

TABLE OF CONTENTS

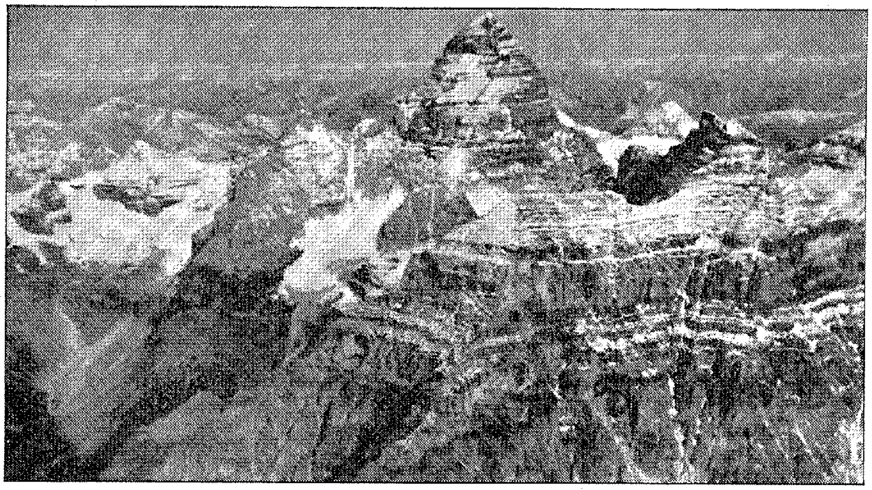
MAP No. 17. GEOLOGICAL MAP OF ALBERTA

PLATES 1 TO 12 INCLUSIVE

Edmonton, Alberta

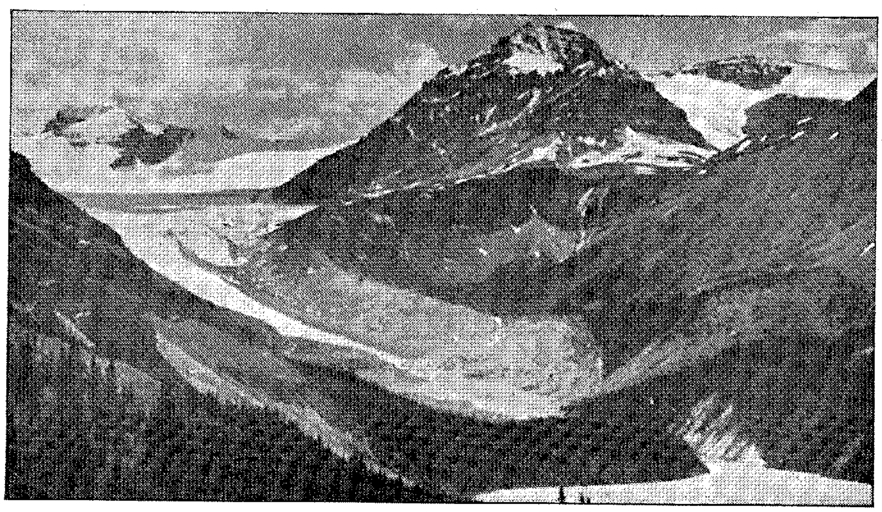
1943

PLATE 1



(Courtesy of Royal Canadian Air Force)

A.—Mountain scenery in aerial view with Mt. Assiniboine in centre.



B.—Mountain scenery near Bow pass. Peyto glacier and lake. The rocks are lower Paleozoic in age.

PART I.

GENERAL GEOLOGY OF ALBERTA

BY J. A. ALLAN

INTRODUCTION

In this report the writer discusses the two latest geological maps of Alberta, and the geological and topographical data shown on these maps. The various geological formations shown on the maps are described in a general way, but no attempt is made to discuss fully the geology of Alberta as it is known to date. Detailed descriptions of the various groups of rock formations and the distribution of each would require a much larger report than can be produced at this time. However, the general descriptions included in this report will enable the reader to obtain an idea of the diversified geology within Alberta, and will indicate that the exposed strata in Alberta include rocks varying widely in age, from the Precambrian to the early Tertiary age. The rock formations in Alberta belong to many geological ages in the whole stratigraphical column, and represent about 65,000 feet of strata or a section approximately 12 miles in thickness.

In an area as large as that represented by Alberta, the thickness of each formation varies widely in different localities, so it is not possible to give an average thickness for any formation throughout the area where it occurs in Alberta. In general, the separate formations thicken from east to west. In no one locality are all the formations represented and in many areas several formations are missing. The absence of a formation may be due to the fact that sediments were not deposited in that area in the geological time represented by a formation, or the absence may be due to the removal by various erosion agents of the strata in a formation before younger sediments were deposited in that area.

This report can be regarded as containing explanatory notes on the information shown on the geological map of Alberta.

GEOLOGICAL MAP OF ALBERTA

In 1925 the Research Council of Alberta published the first geological map of Alberta, which was compiled by the writer from all available geological information published previous to that date. The map is designated as No. 10 in the map serial and is published on a scale of one inch to 25 miles. The map is printed in fourteen colors.

With the development of the petroleum resources in the subsequent ten years many new geological facts had been obtained as a result of field investigations and from the study of drill records obtained from wells being drilled for oil. On this account it was considered advisable to revise the previous edition of the geological map of Alberta.

In 1937 a new geological map was compiled by the writer and published in co-operation with the Alberta Department of Lands and Mines. This map is designated as Serial No. 16 in the publications of the Research Council of Alberta.

The geological map is on the scale of one inch to 16 miles and is printed in sixteen colors. The geography including the outline of lakes, rivers, railways, cities, towns, and also the township and range lines are shown in black. The surveyed base lines and meridian lines are shown as solid black lines. The topography is indicated by contour lines printed in brown and with a contour interval of 400 feet up to an elevation of 5,000 feet above sea level. In the Rocky Mountains there are yet many areas where there have been no topographical surveys made so the contour lines above 5,000 feet in the surveyed areas have been omitted.

Fourteen different tints have been used on the map to show the distribution of the geological formations. A legend at the side of the map indicates the order in which the rock formations occur. The map does not show the distribution of the unconsolidated deposits, which would include the soil types. The geological and topographical information included on the map has been compiled from geological and topographical data available within Alberta, and also from the published records of the Dominion of Canada geological and topographical surveys. An attempt has been made to include the latest data. Almost one-half of Alberta has not yet been surveyed geologically, but the geology along the major drainage courses has been determined. It has been necessary to interpret the rock distribution in the interstream areas from the sections exposed along some of the rivers.

Area

Alberta has an area of approximately 255,285 square miles, and extends from the 49th parallel, which is the International Boundary line, north to latitude 60° north, a distance of 756 miles. The width varies with the latitude. The narrowest part of Alberta is on the south boundary where the width is 182 miles. The widest part is at latitude 53°40′ along a line which passes about 15 miles north of Edmonton. In this position the width is 404 miles. On the north boundary, the width of Alberta is 342 miles.

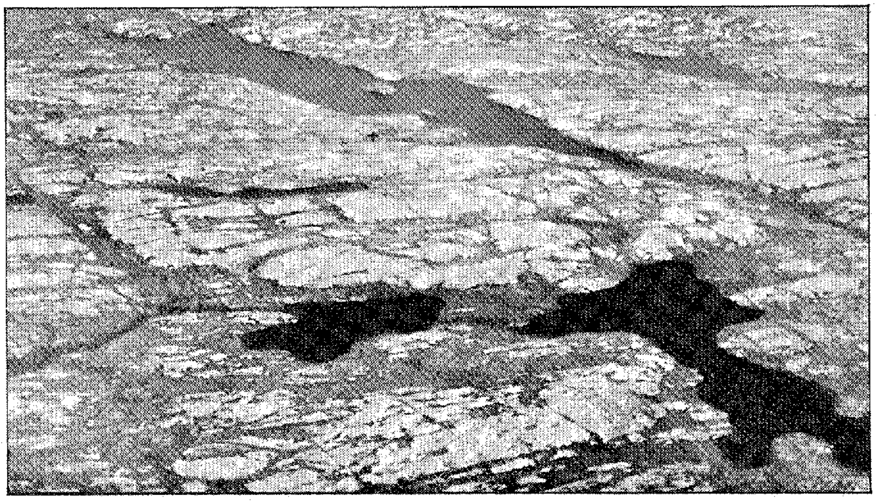
The east boundary of Alberta is longitude 110° and this is also the Fourth meridian. The Fifth meridian is on longitude 114° and passes through Calgary. The Sixth meridian is longitude 118° and passes about three miles east of Jasper. The west boundary of Alberta is the Continental Divide in the Rocky Mountains north to township 55, and it then follows longitude 120° to township 126, which is on the north boundary of Alberta.

Physical Features

In Alberta there are four major physical divisions, namely, mountains, foothills, plains and lastly, the Precambrian area which occurs in the extreme northeast corner of Alberta, and has an area of about 8,000 square miles (Plate 2). The entire Precambrian Shield occupies an area of 2,810,000 square miles of Canada.

Of the total area of Alberta of about 255,285 square miles, the mountain division occupies approximately 15,000 square miles or six per cent of the total area. The foothills represent about 12,000 square miles, or four per cent, and the Precambrian Shield 8,000 square miles or three per cent. The remainder of Alberta, or an area of approximately 220,000 square miles, which is 87 per cent of the total area, is represented by the plains physical division. Alberta is, therefore, largely a "plains" province (Plate 3).

PLATE 2

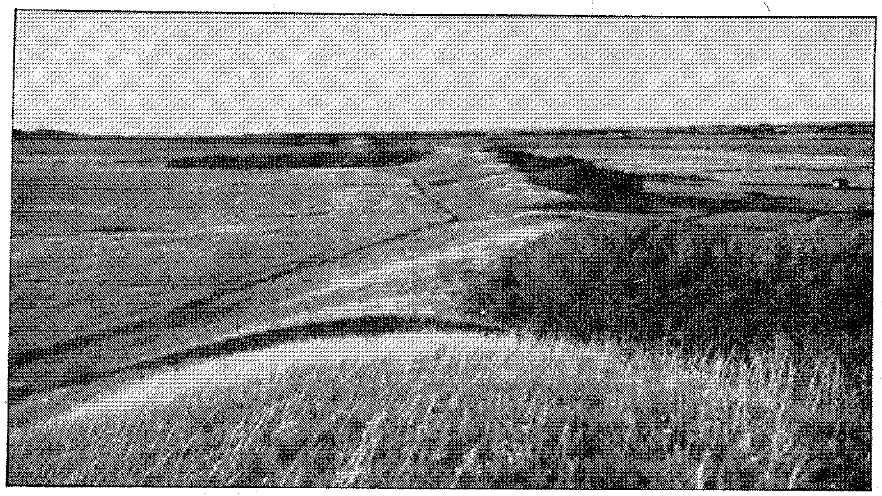


(Courtesy of Royal Canadian Air Force)

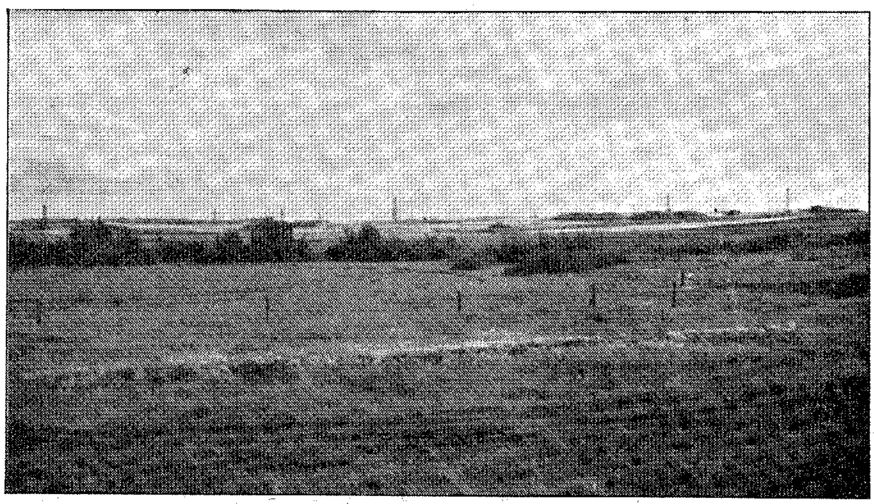
A.—Aerial view east of Fitzgerald, typical of Precambrian Shield.

B.—Aerial view of portion of Charles lake area, north of Lake Athabaska, showing north-south trend of lake basins in Precambrian Shield.

PLATE 3

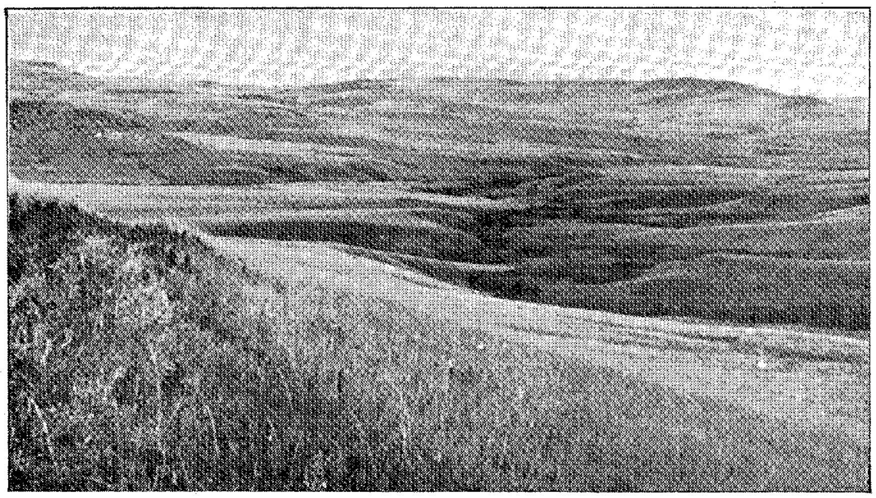


A.—Typical plains scenery in Wainwright sheet, eastern Alberta, showing an esker ridge in section 14, township 47, range 1, west of fourth meridian.

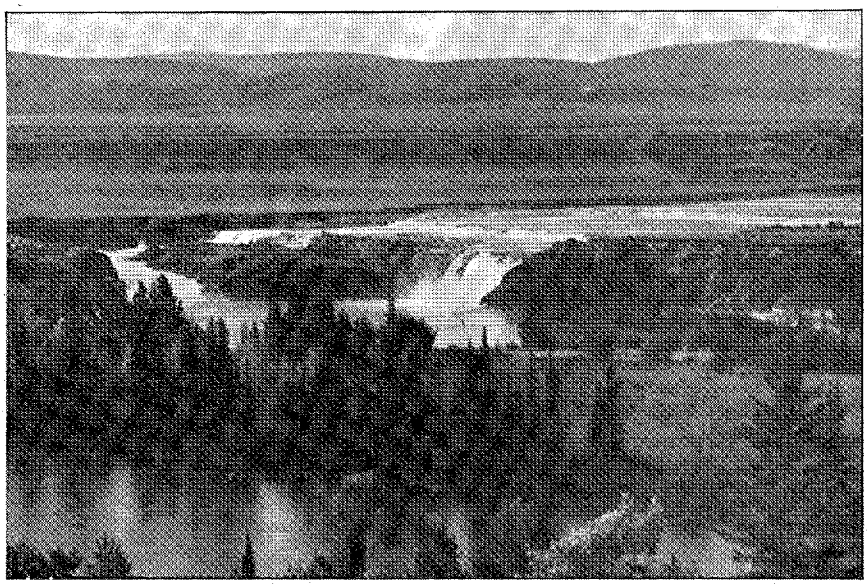


B.—Typical gently rolling plains, Vermilion oil field looking south, chiefly in section 29, township 50, range 5, west of fourth meridian.

PLATE 4



A.—Typical foothills east of Porcupine hills, west of Claresholm in township 12, range 29, west of fourth meridian.



B.—Foothills south of Bow valley. Waterfalls over Benton shale at the junction of the spillway ditch from the Ghost dam and the Bow river.

The lowest part of Alberta above sea level is in the northeast corner between Lake Athabaska (699 feet) and Fitzgerald (665 feet). Fort Smith, close to the north boundary, has an elevation of 565 feet above sea level.

The plains physical division varies in elevation from less than 800 feet above sea level in the lower Peace river district, and about 1,000 feet in the Hay lake district, township 113 in northwestern Alberta, to about 3,500 feet above sea level along the eastern edge of the foothills belt. There are several "hills" or prominences rising several hundreds of feet above the surrounding plains. These are *residual* hills formed by the erosion of the surrounding rocks. The highest of these residual hills include Cypress hills in southeastern Alberta and Swan hills south of Lesser Slave lake, where the elevation on top is close to 4,200 feet above sea level.

There is no sharp line of demarcation between the plains and the foothills belt. The foothills consist of rolling topography with long narrow ridges representing broken and folded strata, and intervening valleys which have been eroded into the softer rocks. The valleys and the ridges, in general, have a trend which corresponds to the direction of the mountains. This is because the rocks under the foothills have been folded by mountain-building forces. Elevations within the foothill belt range generally from 3,000 to 5,000 feet above sea level. There are many ridges which rise locally to higher altitudes than the average elevation of 4,000 feet, particularly north of Bow river (Plate 4).

The mountain division includes the Rocky Mountains in which the elevations range from 3,500 feet along the valleys leading to Crowsnest pass and Yellowhead pass, up to a maximum of 11,870 feet in Mt. Assiniboine, 11,874 feet in Mt. Alberta at the head of Athabaska river, and 12,972 feet above sea level in the Mt. Robson district northwest from Yellowhead pass (Plate 1).

Geology

In mapping a large area such as the whole of Alberta, it is not possible to show the distribution of all geological formations because of the lack of geological information in certain large districts. This is the case in Alberta because only a small part of the Rocky Mountains belt has been surveyed geologically in detail. The same remark applies to the northern third of Alberta, north of township 84 which passes through Peace River town. On account of the fact that a considerable part of Alberta has not yet been surveyed geologically, the various formations which occur within most of the Rocky Mountains belt have been grouped into two divisions, namely, the Precambrian and Early Palaeozoic* for the older formations, and the Palaeozoic and Early Mesozoic for the younger formations. In the Crowsnest district more detailed mapping has been done so that the distribution of several formations has been represented on this map. In the northeastern part of Alberta, from McMurray northwards, it has been possible to show the distribution of the Precambrian, Silurian and Devonian strata and the McMurray formation which contains the bituminous sands, but the major portion of the northern third of Alberta is shown to be underlain by undivided Lower Cretaceous and Lower Upper Cretaceous, each of which may be subdivided at a later date into several formations as shown particularly in the southern half of Alberta.

*The modern spelling "Paleozoic" is used in the text of this report.

GEOLOGICAL MAP No. 17

The demand for an inexpensive geological map for use in the High Schools in Alberta became so apparent, that it was decided to compile a smaller scale map than the colored Map No. 16.

The writer compiled the information and brought the geological data up to date in map form. This map was published in 1939, on a scale of one inch to thirty-two miles. The townships and ranges are not included on this map, but only the parallels of longitude and latitude and the geography including the railways. The map is printed in black and white and fourteen geological formations or groups are shown by different markings. This map has proven to be most serviceable.

On this map and also on the colored geological map, the geology of Alberta is represented by the following divisions:

TABLE OF FORMATIONS ON GEOLOGICAL MAP

TERTIARY	Later Tertiary Early Tertiary—Paskapoo, Willow Creek
UPPER CRETACEOUS	Edmonton—St. Mary River Bearpaw Belly River Lower Upper Cretaceous, chiefly Alberta shale (Benton)
LOWER CRETACEOUS	Blairmore, Kootenay — undivided McMurray (Bituminous Sands)
PALAEOZOIC	chiefly Carboniferous and Devonian
and EARLY MESOZOIC	chiefly Triassic and Jurassic
PALAEOZOIC	Devonian, Silurian — in northeastern Alberta
PRECAMBRIAN	chiefly late Precambrian sedimentary rocks
and EARLY PALAEOZOIC	chiefly Cambrian, Ordovician, Silurian and Devonian
PRECAMBRIAN	undivided in northeastern Alberta

Several formations are grouped together. No attempt is made to show all the geological formations that are known in certain areas. This is not possible on a map of this scale. Because of the lack of geological knowledge in many parts of Alberta it is not yet possible to map the formations separately.

The Precambrian rocks outcropping in the northeastern corner of Alberta are shown separately. This is a part of the Precambrian shield in which many valuable mineral deposits have been opened up by mining outside of the boundaries of Alberta. No mineral deposits have yet been found in the Precambrian area of about 8,000 square miles in Alberta, but this area has not yet been thoroughly prospected. In rocks of similar age outside of Alberta occur the gold deposits at Goldfields, Saskatchewan, at Outpost Island in Great Slave lake, and at Yellowknife in the Northwest Territories. Scheelite, tin, tantalite, beryl and other rare minerals have been found in the Yellowknife district. Farther north occur the radium-bearing pitchblende and silver deposits at Great Bear lake, and the native copper deposits at Coppermine river near Coronation Gulf on the Arctic ocean.

There are Precambrian rocks of sedimentary origin along the western fringe of Alberta close to the Continental Divide, and in

Waterton Park, but these do not contain metallic mineral possibilities. In the Rocky Mountains the old Precambrian and early Paleozoic rocks are mapped together, the latter include strata in the Cambrian, Ordovician, Silurian and Devonian formations.

In the eastern part of the Rocky Mountains the Paleozoic formations and the infolded bands of Triassic and Jurassic rocks of Mesozoic age are mapped where they outcrop. It is in the Silurian strata that the extensive salt deposits occur at Waterways and McMurray, and at Salt Prairie west of Fitzgerald. The gypsum deposits outcropping on Peace river below Vermilion Chutes also occur in Silurian strata.

The Lower Cretaceous formations throughout Alberta are grouped together on this map, except in the McMurray district. The McMurray formation, also known as the bituminous sands, outcrops along the Clearwater and Athabaska rivers below McMurray. The distribution of this formation is shown on this map.

The Upper Cretaceous strata form the surface rocks throughout about one-half of the area of Alberta. These strata are grouped into four formations in some areas. These are, from youngest to oldest, Edmonton, Bearpaw, Belly River and Alberta shale (Benton). The Alberta shale is the lower part of the Upper Cretaceous and is mapped as such in the foothills belt where it has been observed. The same series of rocks is believed to occupy a rectangular area of about 75,000 square miles from the eastern side of Alberta between the North Saskatchewan river and McMurray, diagonally northwestward to the western boundary of Alberta from Peace river to the 50th parallel at the northwest corner of Alberta. There is very little known about the geology of Alberta north of Peace river as it remains unsurveyed geologically, so it is possible that other younger groups of rocks may occur in this large area.

South of the 56th parallel of latitude, the distribution of the Upper Cretaceous strata can be mapped more accurately as shown on the map. There is a belt in the outer foothills northwest from Rocky Mountain House, where the boundary between the Edmonton and the Belly River cannot be drawn from the information available, so this belt is mapped as Upper Cretaceous. The Bearpaw marine shales only occur at the surface down the eastern side of Alberta, south from near the North Saskatchewan river, and do not extend west into the foothills.

The Tertiary rocks cap the Cypress hills, the Hand hills and the Swan hills as islands. The Early Tertiary or Paskapoo strata occur as a narrow belt extending northward from the International Boundary line west of Coutts, through Macleod, Calgary, Red Deer, then trending northwestward to include the Edson district and on to the Little Smoky river.

The table of formations given above indicates the origin of the strata and also the mineral deposits that are known to occur in Alberta in some of these formations. The Edmonton and Belly River formations also contain the fossilized remains of the reptilian animals known as dinosaurs. A large number of dinosaurs have been collected from these strata along the Red Deer river. A few of these have been collected by the University of Alberta and are now in the Department of Geology Museum (Plate 19B), but most of the specimens are in the National Museum, Ottawa, the Royal Ontario Museum in Toronto, and many have been exported to the American Museum of Natural History in New York City.

TABLE OF FORMATIONS

ERA	PERIOD	EPOCH	FORMATION			
CENOZOIC	Quaternary	Recent (gravel, sand, clay, till, dune sand) Pleistocene				
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	Cypress Hills (conglomerate) Paskapoo or Willow Creek			
MESOZOIC	Upper Cretaceous	Montana	Edmonton or St. Mary River Bearpaw (shale) Belly River { Pale beds Belly River { Foremost Belly River { Pakowki (shale) Belly River { Milk River (sandstone)			
				Brazeau Section	**Athabaska Section**	**Peace River Section**
		Colorado	Alberta shale or Benton Crowsnest Volcanics	Wapiabi Bighorn Blackstone	LaBiche (shale) Pelican (sandstone)	Smoky River (shale) Dunvegan (sandstone)
	Lower Cretaceous		Blairmore Kootenay	McLeod	Grand Rapids (sandstone) Clearwater (shale) McMurray (bituminous sand)	St. John (shale) Peace River (sandstone) Loon River (shale)
	Jurassic		Fernie (shale)			
	Triassic	Upper	Schooler Creek			
		Lower	Spray River			

PALEOZOIC	Permian		(not recognized)		
			Rocky Mountain Section	**Slave Lake Section**	**Norman Section**
	Carboniferous	Upper	Rocky Mountain Quartzite		
		Lower	Rundle (limestone) Banff (shale)		
	Devonian	Upper	Exshaw (shale) Minnewanka (limestone) Ghost River (dolomite)	Hay River (limestone) Simpson (shale)	Bosworth (limestone) Fort Creek (shale) Beavertail (limestone)
		Middle		Slave Point (limestone) Presqu'ile (dolomite) Pine Point (limestone)	Ramparts (limestone) Hare Indian River (shale)
		Lower			
	Silurian	Upper	Brisco	Fitzgerald (dolomite)	Bear Mountain (dolomite)
		Middle			
		Lower			
	Ordovician	Upper	Beaverfoot Wonah (quartzite)		
		Lower	Glenogle (shale) Goodsir (shale) (200′)		

	Cambrian	Upper	Goodsir (shale) (5800′) Ottertail (limestone) Chancellor (shale) Sherbrooke (limestone) Paget (limestone) Bosworth (shale)	
		Middle	Eldon (limestone) Stephen (shale) Cathedral (limestone) Ptarmigan (limestone)	
		Lower	Mt. Whyte St. Piran (quartzite) Fort Mountain (sandstone)	
PRECAMBRIAN				**Lake Athabaska Section**
		Late	Hector (shale) Corral Creek (sandstone)	Athabaska Beaverlodge
		Early	*Base not exposed*	Tazin

Approximate thickness of section—64,500 feet.

DESCRIPTIONS OF FORMATIONS

PRECAMBRIAN

Rocks of Precambrian age are exposed in the extreme northeast corner of Alberta, north of Lake Athabaska and east of Slave river. The contact between the Precambrian and rocks of younger Paleozoic age has been traced from the north boundary of Alberta at Fort Smith south to the delta of Athabaska river where it becomes covered with recent river deposits. This boundary continues south of Lake Athabaska and passes out of Alberta north of Clearwater river, about township 96.

These Precambrian rocks form part of the expansive Precambrian Shield which occupies about two and a half million square miles in northern Canada and in which valuable mineral deposits have been developed in Quebec, Ontario, Manitoba, Saskatchewan (at Goldfields), and in the Northwest Territories at Yellowknife and Great Bear Lake. To date no mineral deposits have been found in these rocks in Alberta, but the indications are favorable for the occurrence of metallic minerals in this area. The rocks consist of highly metamorphosed volcanics and sedimentary rocks intruded by granites and other intrusive rocks. The Athabaska series consisting of sandstone, conglomerate, arkose and shale occurs at the top of the Precambrian group of rocks.

Within the Rocky Mountains large areas of Precambrian rocks of sedimentary origin are known to occur at the extreme southwestern corner of Alberta in Waterton Park, also along the Continental Divide in the vicinity of Bow valley from Lake Louise northwestward. Rocks of this age are also recognized in Jasper Park in the vicinity of Yellowhead pass. These old sedimentary rocks within the mountains have not been intruded by igneous rocks and cannot therefore be expected to contain important mineral deposits, although in Jasper Park these rocks contain numerous small veins and veinlets of quartz, some of which might be found to contain gold.

PALEOZOIC

Cambrian

The Cambrian rocks occur within the mountains and contain a very thick series of sedimentary strata consisting of sandstones and conglomerates, shales and limestones. Measured sections in the vicinity of Kicking Horse pass contain at least 18,500 feet or about three and a half miles of sedimentary strata. These rocks extend along the Continental Divide from Kananaskis pass northwest to the Mt. Robson district west of Jasper (Plate 5A).

Ordovician and Silurian

Rocks belonging to these two periods are known to occur within the older part of the Rocky Mountains but their distribution cannot yet be mapped accurately. They have been recognized by the writer towards the headwaters of North Saskatchewan river at Sunset pass in the vicinity of Mt. Coleman and Mt. Wilson (Plate 5B).

Silurian

In northeastern Alberta, upper Silurian rocks have been recognized where the beds outcrop about 80 miles above the mouth of Peace river at Peace Point, and again in the vicinity of Fitzgerald and on Salt river about 20 miles west of Fitzgerald in the Fitzgerald formation.

On Peace river the upper Silurian strata consist largely of gypsum which is exposed on both banks of the river almost continuously for a distance of 16 miles. It is estimated that these outcrops indicate a gypsum deposit containing over 300,000,000 tons. Much of the gypsum is white and some of the beds consist of the white alabaster variety of gypsum.[1]

Gypsum strata in the Fitzgerald formation outcrop in the face of the escarpment on Salt river 25 miles west of Fitzgerald. The Silurian strata also outcrop along the Athabaska river upstream from Caribou island, about eight miles south of Fitzgerald. There are a number of salt springs at the base of the escarpment along Salt river and the brine in some of these is saturated with salt.[2] This indicates that the upper Silurian rocks in this part of Alberta contain rock salt. There are several saline springs along the banks of Athabaska river all the way south to McMurray. At McMurray and Waterways several wells have been drilled for salt. The results show that in this district there are about 200 feet of beds made up largely of anhydrite and gypsum underlain by at least 211 feet of rock salt.[3] This rock salt is now being developed at Waterways by Industrial Minerals Limited. In No. 3 well drilled in 1939, a bed of pure rock salt, 211 feet thick, was encountered between 723 and 734 feet from the surface. It is evident that upper Silurian rocks contain salt and gypsum and that these strata extend all the way from McMurray to the north boundary of Alberta, but the extent has not yet been determined. The presence of salt and gypsum indicates that the climate in these parts in upper Silurian time was mild and possibly arid to cause the precipitation of these minerals on the margin of the sea. The salt deposits are discussed in Part II.

Devonian

Strata of Devonian age outcrop in two regions, namely, in northeastern Alberta and within the Rocky Mountains. Devonian rocks are well exposed in the McMurray district along Clearwater river from the 4th meridian to McMurray, and along Athabaska river north of McMurray. Below Firebag river the Devonian extends from the western edge of the Precambrian westward across Athabaska river to the base of Birch mountains and up the valley of Peace river to a point 2 miles above Vermilion Falls, which are formed in a hard bed of limestone. On the north boundary of Alberta, Devonian strata extend westward on the north side of Caribou mountains to a point not far east of Hay river. The position of this Devonian contact is not known, but the upper beds in the Devonian which occur at Vermilion Falls also form Alexandra Falls on Hay river in the Northwest Territories about halfway between the Alberta boundary and Great Slave lake, and close to the highway now under construction.

The Devonian strata at McMurray have been penetrated by the drill when exploring for salt. There are 440 feet of interbedded limestone and shale in No. 1 salt well drilled within the McMurray townsite. This series of beds has been designated the *Waterways* formation and the fossils in these beds have been determined by P. S. Warren to be early upper Devonian in age.[4] This rock formation is underlain by the gypsum-anhydrite-rocksalt-dolomite series of beds which are believed to be of upper Silurian age, although no definite fossil proof of the age of the underlying beds has yet been obtained at McMurray. The Devonian strata in northeastern Alberta may be considerably thicker than it is at McMurray, because the top of this series represents an erosion surface and is overlain by Lower Cretaceous strata which contain bituminous sand. In northern Alberta there are no known occurrences of rocks of Paleozoic age younger than the Devonian.

The Devonian formations have a wide distribution within the Rocky Mountains, particularly in the eastern ranges, such as those east of Jasper along Athabaska valley and southward to the Bow valley, east of Lake Louise (Plate 6A). The Devonian strata in the vicinity of Banff are grouped in the Minnewanka formation capped by a thin series called the *Exshaw shale*. These strata are of upper Devonian age.

Carboniferous

The Carboniferous is divided into Mississippian (lower) and Pennsylvanian (upper). Carboniferous marine strata of both ages are widely distributed along the Rocky Mountains, and overlying the older Devonian strata. The Mississippian is represented by the Banff shale formation overlain by the Rundle limestone which, in turn, is overlain by the Rocky Mountain Quartzite formation of late Pennsylvanian or upper Carboniferous age. The massive limestone beds in the Rundle are common mountain-forming limestones and are capping many of the eastern ranges within the Rocky Mountains.

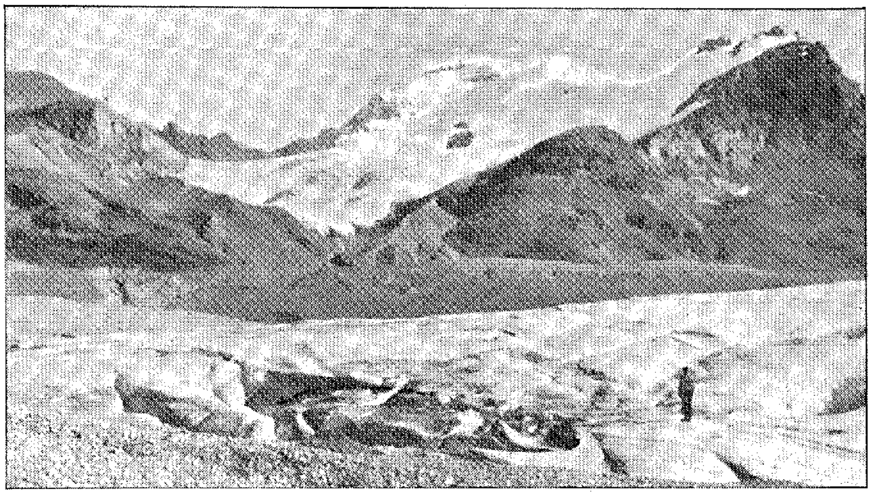
The Carboniferous strata extend east from the front of the Rocky Mountains, under the foothills belt and plains, across the entire width of southern Alberta at least as far north as the latitude of Calgary. This eastward extension under the plains has been determined in wells drilled for petroleum and natural gas. It is not known how far north under the plains in Alberta the Carboniferous strata extend but there are no Carboniferous rocks at McMurray on the Athabaska river or on the lower Peace river.

The principal petroleum and natural gas horizon in Turner Valley oil field and in other districts drilled in the foothills and plains, occurs in porous limestone beds within the upper 400 feet of the Carboniferous strata. The age of this oil horizon has been determined as Mississippian, corresponding to the Rundle formation. Carboniferous rocks outcrop within the foothills as inliers, such as Moose mountain south of Bow river, as the Brazeau and Bighorn ranges on North Saskatchewan river in the vicinity of Nordegg, and as an inlier north of Clearwater river 20 miles southwest from Rocky Mountain House. The Rocky Mountain Quartzite is the uppermost formation in the upper Carboniferous and outcrops only within the Rocky Mountains. The formation consists of light-colored dolomite or calcareous sandstones, quartzitic sandstones and chert beds. The uppermost beds are phosphatic.

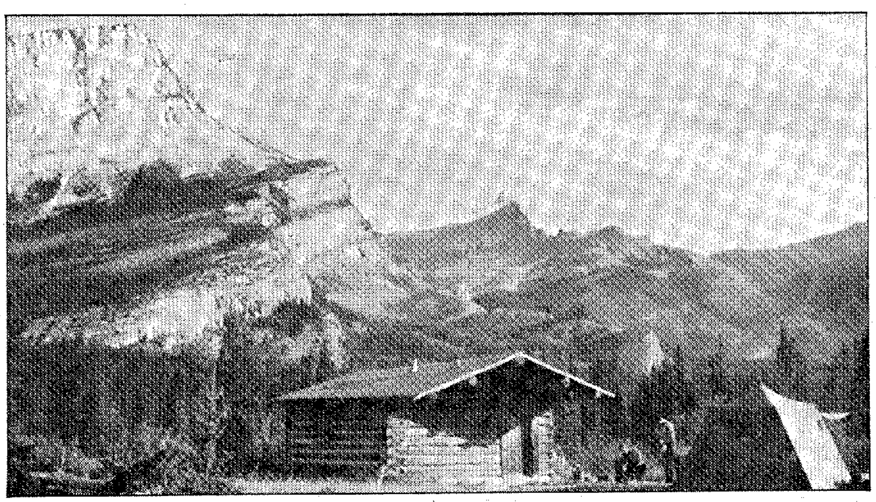
MESOZOIC

The Mesozoic strata are divided into the Triassic, Jurassic and Cretaceous periods. The Triassic and the Jurassic rocks are not mapped separately but are included with the Paleozoic and Early Mesozoic. Many of the known outcrops of these rocks are too small in extent to be shown on the scale of the map.

PLATE 5

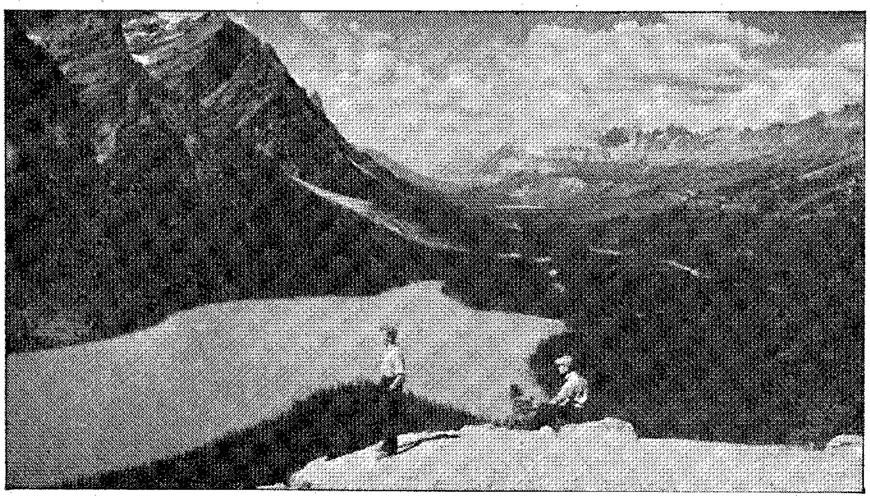


A.—Mt. Athabaska and glacier, showing lateral moraine 72 feet high, bordering Athabaska glacier in foreground. Chiefly Cambrian rocks at left.

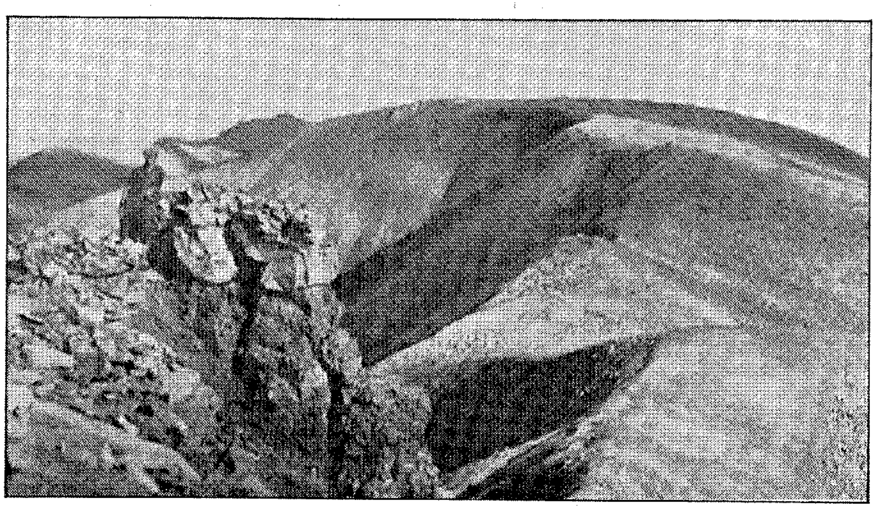


B.—Mountains east of Mt. Wilson from Grizzly cabin on Owen creek at east edge of Jasper Park on North Saskatchewan river. Lower Cambrian in background. Upper Cambrian and Ordovician in foreground on left.

PLATE 6

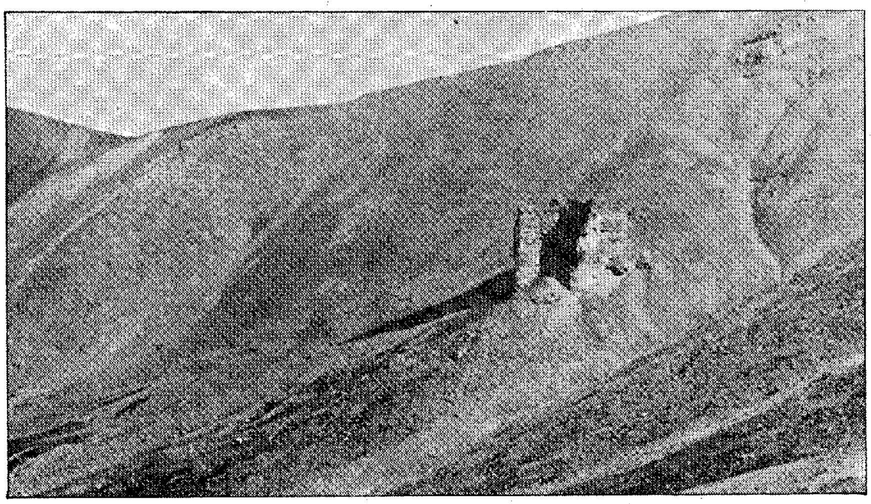


A.—Peyto lake looking north down U-shaped glacial valley of Mistaya river to Waterfowl lake, Mt. Murchison and Mt. Wilson in background. The light line on right is the Jasper-Banff highway. The rocks are chiefly Cambrian, Ordovician and Silurian in foreground, and Devonian and Carboniferous in background.

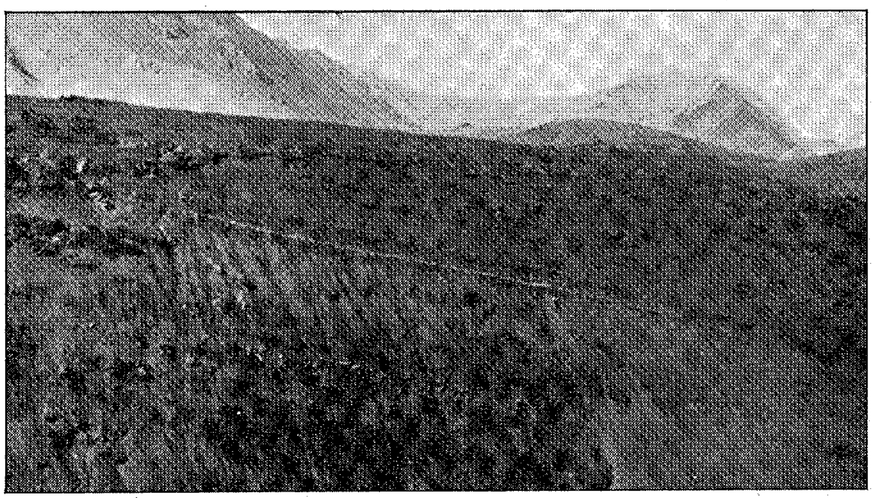


B.—Triassic—typical erosion slopes in gypsum-bearing series on top of Mowitch range at north boundary of Jasper Park, township 51, range 5, west of sixth meridian.

PLATE 7



A.—Knob of hard limestone 38 feet high, called the "Throne," projecting through gentle slopes of gypsum series debris on east side of Mowitch range, north boundary of Jasper Park.



B.—Jurassic—Fernie shales on Mowitch creek, north of Jasper Park.

Triassic

The Triassic strata outcrop in narrow strips within the front ranges of the Rocky Mountains. In the Banff district the Spray River formation has been determined as lower Triassic and consists chiefly of shales, thin-bedded limestones and dolomites with a thickness of about 3,400 feet. Some of the lower beds consist of phosphatic shales. In the Bighorn basin northwest from Nordegg the Triassic is represented chiefly by cream-colored dolomites and shaly limestones. Northwest from Athabaska river on the Snake Indian river and on Mowitch creek at the north boundary of Jasper Park the upper Triassic strata, correlated with the Schooler Creek formation on Peace river, contain thick beds of gypsum of good quality[5] (Plates 6B and 7A).

Jurassic

The Jurassic strata, known as the Fernie formation, consist chiefly of dark to black marine shales. These shales are distributed as narrow bands within the eastern ranges of the Rocky Mountains (Plate 7B). The Jurassic rocks have been encountered in wells drilled in the foothills and plains in southern Alberta. The Jurassic is not known in the Viking-Wainwright district, and does not occur north of McMurray.

Cretaceous

The rocks at the surface over more than three-quarters of the entire area of Alberta are of Cretaceous age. The Lower Cretaceous strata, namely, the Kootenay and Blairmore formations have been mapped as a unit. In the south half of Alberta where the geology has been studied in greater detail, the Upper Cretaceous formations have been mapped separately, as the Lower Upper Cretaceous, and include the Belly River, Bearpaw and Edmonton formations, except in those parts of the foothills where the Upper Cretaceous has not yet been divided into formations.

In northern Alberta the Cretaceous is divided into the Lower Cretaceous and the lower part of the Upper Cretaceous, which includes chiefly the Benton marine shales.

McMurray Formation.

In the McMurray district the basal Lower Cretaceous strata form the McMurray formation which contains the McMurray bituminous sands. This formation has been mapped because its extent has been observed and because of its special economic importance.

The bituminous sands are exposed in the vicinity of McMurray along the sides of Athabaska valley between townships 87 and 99, and along the Clearwater valley from McMurray east to the 4th meridian. This formation consists chiefly of sands varying in texture from very fine to coarse. It is not a sandstone but a loose sand in which the sand grains are held together with bitumen. The texture of the sand varies from about 25 mesh down to finer than 250 mesh. The bitumen content varies in the different beds up to a maximum of about 25 per cent bitumen, but 18 per cent bitumen may be taken as an average sample. The bituminous sands are lying unconformably on the Upper Devonian limestones and are overlain conformably by the Clearwater shales of Lower Cretaceous age. The bituminous sand formation has a maximum thickness of about 200 feet. Full details on the bituminous sands have been given in various reports.[6]

Lower Cretaceous

The Lower Cretaceous in southern Alberta is divided into the Kootenay at the base, consisting chiefly of sandstone with some shale and conglomerate. The Kootenay is overlain by the Blairmore formation consisting of greenish and grey sandstones and shales, and several interbedded thin conglomerates. The Lower Cretaceous strata are believed to extend under the entire plains in southern Alberta and as far as the Devonian outcrops in the north-east corner of the map, about the mouth of Peace river, but the thickness of these strata is known to vary in different parts of Alberta.

There are several narrow bands of Lower Cretaceous rocks folded in with the older rocks within the Rocky Mountains. The Lower Cretaceous is an important coal-bearing series and coal is being mined from this series of beds in the Crowsnest Pass, at Canmore east of Banff, at Nordegg west of Red Deer and at Luscar, Cadomin and Mountain Park on the east side of Jasper Park, west of Edmonton.

The Lower Cretaceous rocks are known to contain important oil and gas sands in Turner Valley, at Wainwright, Vermilion, Lloydminster, and at other points in Alberta.

Upper Cretaceous

There are four major divisions in the Upper Cretaceous in Alberta, namely, Benton, mapped as Lower Upper Cretaceous, Belly River, Bearpaw and Edmonton. In the foothills belt it has not yet been possible to subdivide the Upper Cretaceous into formations so the Upper Cretaceous is mapped as an undivided series. Throughout the plains in Alberta, the four divisions mentioned above have been mapped separately.

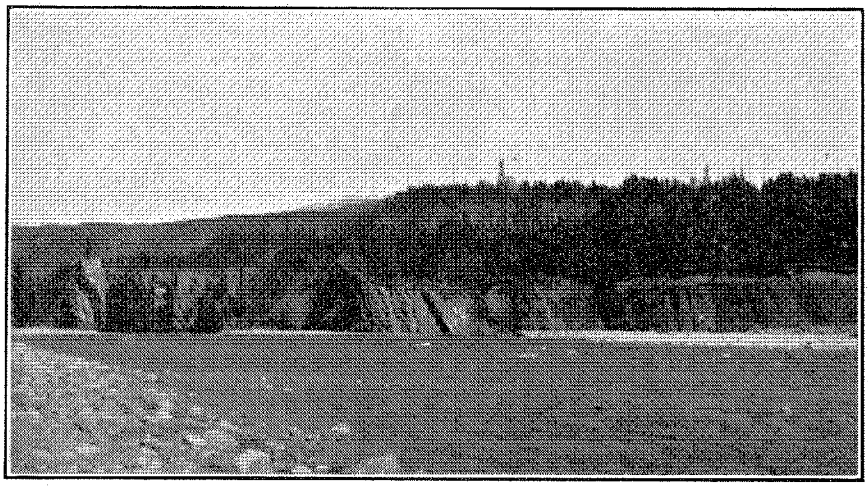
Lower Upper Cretaceous

The lower part of the Upper Cretaceous consists chiefly of marine shales, and in certain parts of the foothills there are sandstone strata within the shale series. Most of these strata belong to the *Colorado group*. In southern Alberta the name *Benton* has been used. The Geological Survey of Canada has proposed the name *Alberta shale* to include the continuous series of marine beds of Colorado age, but which include some beds of shale of Montana age. The Lower Upper Cretaceous as shown on the geological map of Alberta includes the marine shales and the interstratified sandstones. The rocks in this division occur as narrow belts within the inner foothills.

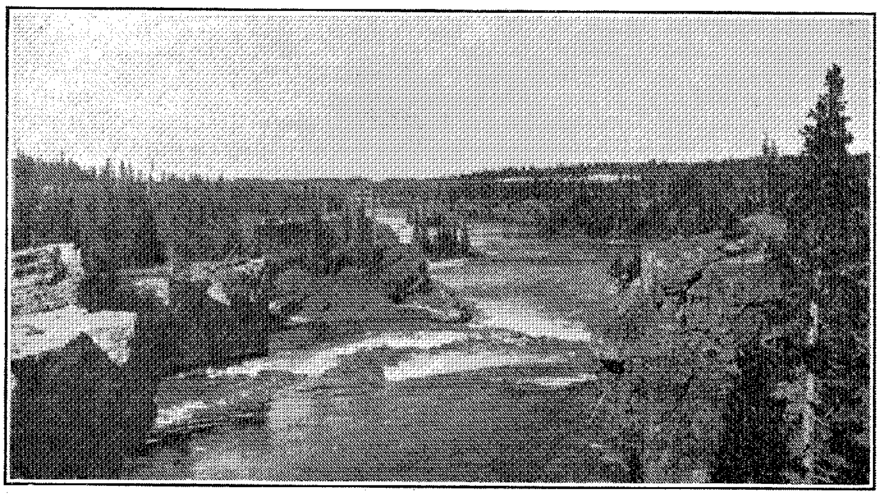
In the Bighorn district, west of Nordegg, there are three formations known as *Blackstone* or lower black fissile shales, 1,200 to 1,700 feet thick, *Bighorn* sandstone, 250 to 350 feet and *Wapiabi* or upper dark-colored shales, 1,500 to 2,000 feet thick, with many bands of ironstone nodules. In the Bow valley district and south to Turner Valley, the Bighorn sandstone or the middle formation, is represented by the Cardium sandstone beds which thin to the south (Plate 8 A and B).

The base of the Colorado or Lower Upper Cretaceous in the Crowsnest district, lies conformably on the Crowsnest volcanics, which in turn rest conformably on the Blairmore non-marine strata. The Crowsnest volcanics consist of well-stratified tuffs and agglomerates with a maximum thickness of about 1,000 feet. These rocks occur in the vicinity of Coleman and Blairmore and are the only igneous rocks known to occur in the Rocky Mountains in Alberta.

PLATE 8

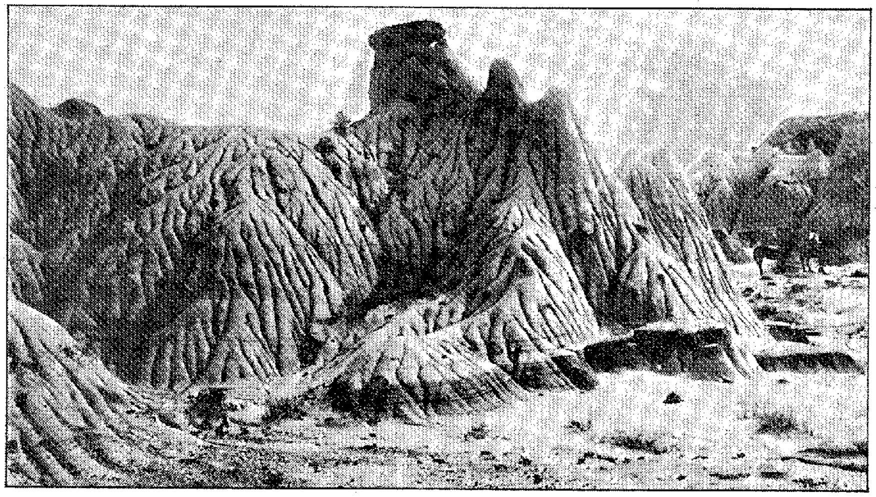


A.—Benton on Blackstone river near mouth of Lookout creek, north of Nordegg. Bighorn formation on the left and Wapiabi on the right.

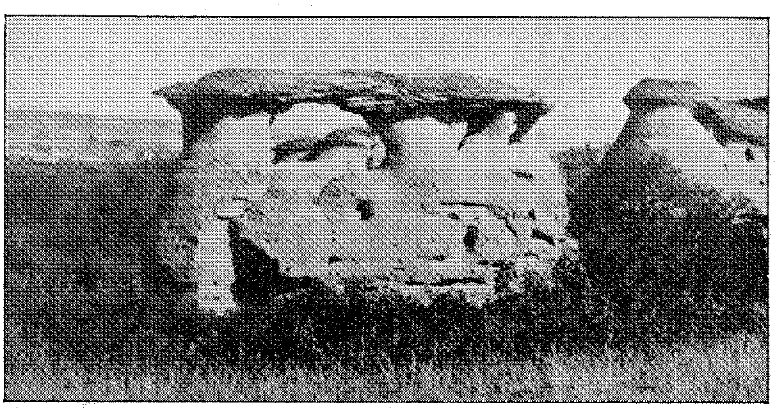


B.—Looking down Bow river from Kananaskis dam, Calgary Power Company, at mouth of Kananaskis river, showing Cardium in foreground and Lower Benton in background.

PLATE 9



A.—Belly River badlands on Red Deer river south of Steveville, containing dinosaur fossils and showing fluted sandstone beds.



B.—Milk River sandstone (Belly River) capped by more resistant shale, forming hoodoos in Milk river valley in township 2, range 13, west of fourth meridian.

On the plains in northern Alberta the Lower Upper Cretaceous extends over 75,000 square miles. In Peace River district the series is represented by the Dunvegan formation consisting of crossbedded sandstones with some interbedded shales, 450 to 550 feet thick, overlain conformably by the Smoky River formation, chiefly shales. This formation is about 925 feet thick.

Gas and some oil horizons have been encountered in the basal beds of the Upper Cretaceous in the Viking, Wainwright, Kinsella, Ribstone, Skiff, Foremost, Bow Island and Medicine Hat fields.

Belly River.

The Belly River strata include several formations that have been differentiated on the plains south from North Saskatchewan river. The beds are of marine, brackish and continental origins. The thickness of the Belly River series varies with the locality. In Lethbridge district the Belly River series is about 1,400 feet thick, but in the foothills belt at Turner Valley, it is about 1,900 feet thick. On North Saskatchewan river east of Edmonton, there are 1,140 feet of strata in this series, but on the same river in the vicinity of Saunders in the foothills belt, the Belly River is over 5,000 feet thick. In the Red Deer valley these strata form "badlands," and include dinosaur fossil beds (Plates 9 and 19B).

The Belly River contains several important coal seams, especially towards the top of the series. Coal is being mined from the Belly River strata in the Lethbridge, Saunders, Coalspur and Prairie Creek coal areas, but coal of this age also occurs in sixteen other coal areas.[7]

Bearpaw.

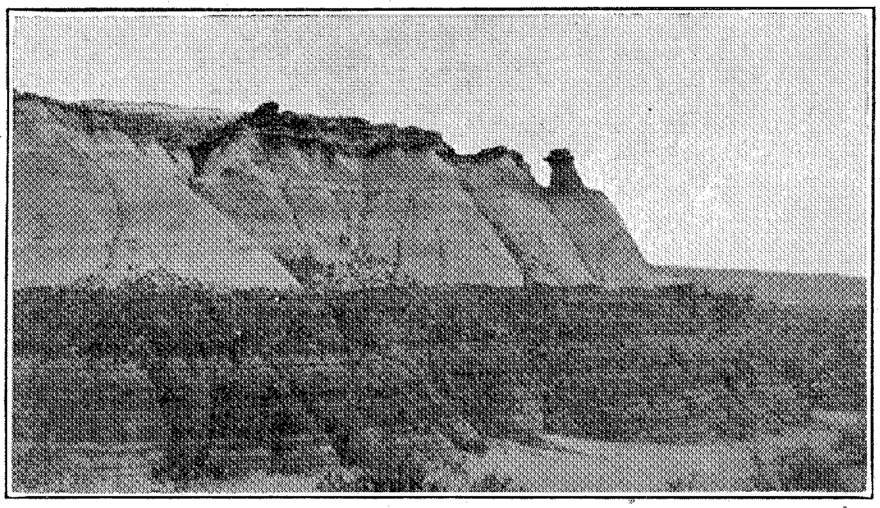
The Bearpaw marine shales are distributed conformably upon the Belly River strata in southern Alberta (Plate 10 A and B). This formation is about 600 feet thick in the Lethbridge district but it thins out towards the foothills and also towards the north in the vicinity of North Saskatchewan river about 20 miles northeast from Edmonton. In southwestern Alberta the Bearpaw is overlain by a relatively thin sandstone which L. S. Russell has called the Blood Reserve sandstone. This member thins northward and is replaced by the Fox Hills sandstone which may be younger than the Blood Reserve member.

Edmonton or St. Mary River.

In southwestern Alberta the Blood Reserve sandstone is overlain by the St. Mary River formation. It consists of non-marine sandstones and shales that are about 3,000 feet thick in the foothills. In southeastern Alberta, particularly in the Cypress Hills area, the Bearpaw shales are overlain by the lower part of the Ravenscrag formation, consisting chiefly of interbedded brown sandstones and dark shales with some thin coal seams. In central Alberta the Bearpaw is overlain by the Edmonton formation, which along the Red Deer river in the Drumheller district is 1,225 feet in thickness. This formation consists of interbedded sandstones, shales and about 14 coal seams.[8] (Plates 11 and 12A.)

The Edmonton formation contains several important coal seams that are mined in Sheerness, Drumheller, Willow Creek, Carbon, Three Hills, Ardley, Edmonton and Pembina coal areas. Coal seams of this age are also known to occur in eight other coal areas in central Alberta. The northern extent of the Edmonton formation is about township 75 which is south of Lesser Slave lake.

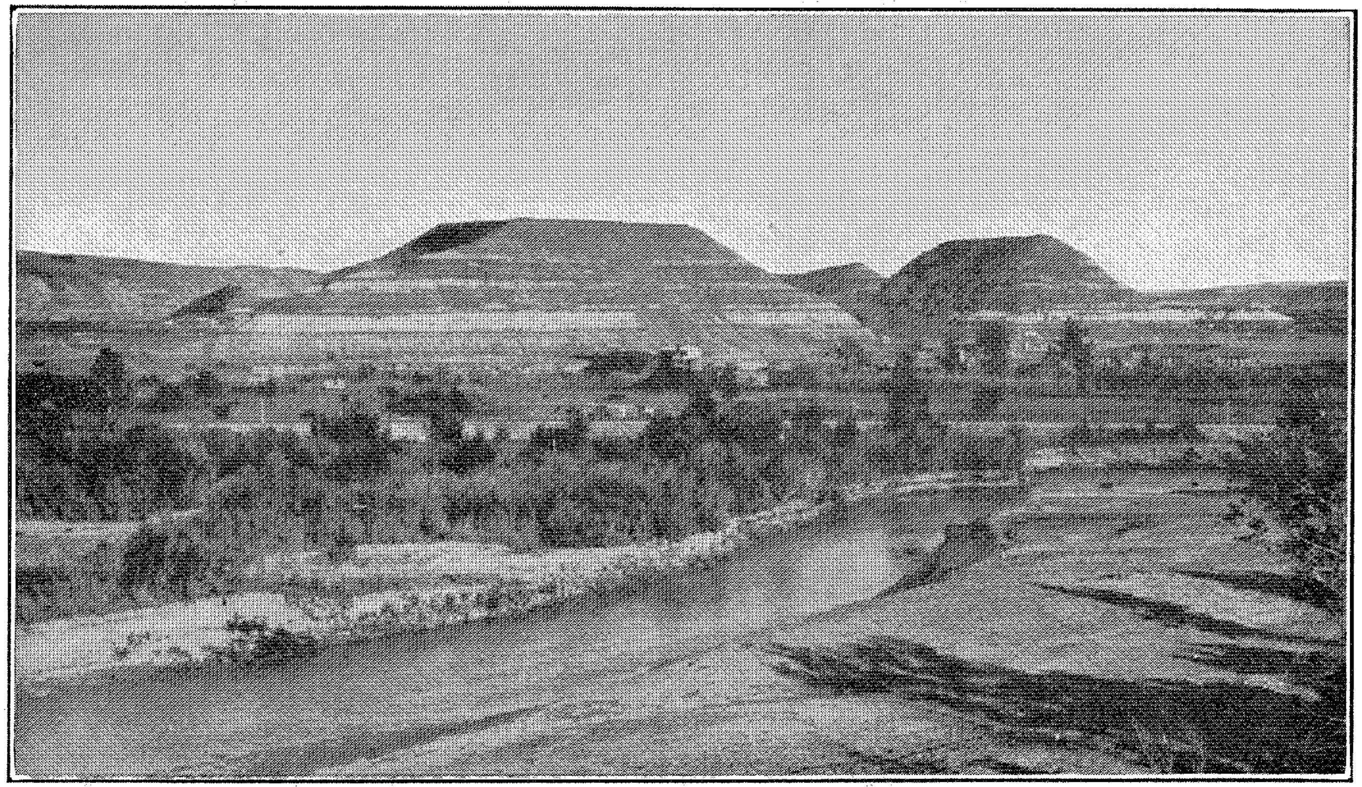
PLATE 10



A.—Sharply defined contact between light-colored basal sandstone in the Edmonton formation and chocolate brown marine shales in the Bearpaw formation on Red Deer river in township 28, near Willow creek.

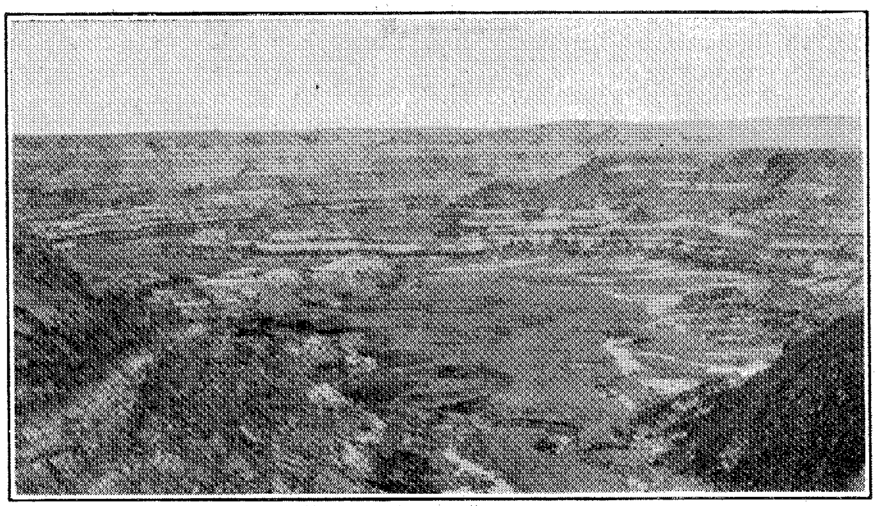
B.—Edmonton-Bearpaw contact between Rosedale and Willow creek on Red Deer river. Shows wind-formed hoodoos in bentonitic sandstones at the base of the Edmonton formation.

PLATE 11

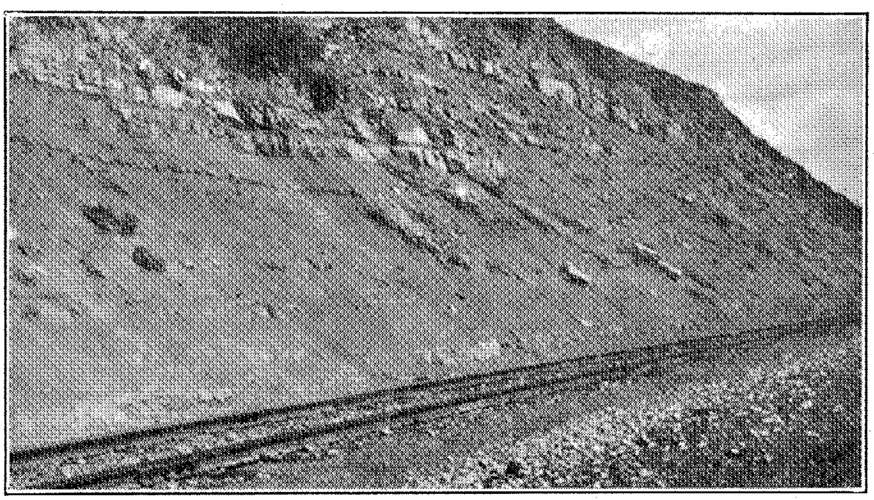


Typical mesa topography along valley of Red Deer river near mouth of Rosebud river, looking east, showing characteristic bed of white bentonitic sandstone and coal seams in Edmonton formation.

PLATE 12



A.—Edmonton formation in Red Deer valley badlands at Drumheller, looking east along former golf course, showing No. 5 coal seam at base of the cliffs and No. 7 coal seam near top in centre background.



B.—Paskapoo soft sandstones and shales in Bow valley east of Cochrane in section 1, township 26, range 4, west of fifth meridian.

CENOZOIC

Tertiary

Paskapoo or Willow Creek.

The youngest strata in Alberta are of Tertiary age and in some places are difficult to distinguish from the older Edmonton formation. The early Tertiary strata in southwestern Alberta are called the Willow Creek formation which consists of soft clayey sondstones, in which there are brilliant colour bands with brick red, orange, buff, maroon and slate blue tints. On Oldman river this formation has a thickness of 1,200 feet. The Willow Creek, which is middle Paleocene in age, is overlain by the Porcupine Hills formation which is Upper Paleocene in age and is about 2,000 feet in thickness.

From the High river area northward through central Alberta to Athabaska river and Swan hills south of Lesser Slave lake, the Early Tertiary is known as the Paskapoo formation. This formation is of freshwater deposition and consists of soft sandstones and sandy clay shales. The Paskapoo lies disconformably on the Edmonton formation along Red Deer river, where several hundred feet of Edmonton beds have been removed by erosion[9] (Plate 12B). The age of the Paskapoo has been determined as Upper Paleocene.[10]

In Cypress hills area the upper part of the Ravenscrag formation is correlated in age with the early Tertiary in central Alberta.

Later Tertiary

The youngest Tertiary formation in Alberta occurs as small areas capping three residual hills. House mountain in the Swan hills, south of Lesser Slave lake, is capped by unconsolidated gravels of preglacial age but younger than the Paskapoo. Similar gravels, that have been consolidated to conglomerate, cap Hand hills east of Drumheller. A third and larger area consisting of conglomerates, marls and sands occurs on top of Cypress hills in southeastern Alberta. These beds have been called the Cypress Hills formation and are determined as of Oligocene age.[11] All three occurrences are believed to be the same age (Plates 28B and 30B).

Quaternary

The younger unconsolidated deposits of Pleistocene and Recent ages have not been mapped. These deposits consist of preglacial gravels[12], glacial till, and boulder clay, alluvial, lacustrine and residual gravels, sands and clays, with local distribution of wind blown deposits. The distribution of these recent deposits are important in the classification of soil types.

Fuller details on the geology of central Alberta have been given in an earlier report of the Research Council of Alberta.[13] This report is accompanied by a geological map that includes that part of Alberta between townships 42 and 84 inclusive. Other reports by the same authors, published by the Research Council of Alberta, deal with the geology in smaller areas within the foothills and plains in Alberta.

TABLE OF FORMATIONS WITH ASSOCIATED IMPORTANT MINERAL DEPOSITS IN ALBERTA

	Formation	Origin	Economic Products
TERTIARY	Later Tertiary (Oligocene)	Continental	Grinding pebbles used in ball mills
	Early Tertiary (Eocene) Paskapoo, Willow Creek	Continental	Building stone
UPPER CRETACEOUS	Edmonton, St. Mary River	Continental	Coal, bentonite, dinosaurs
	Bearpaw (shales)	Marine	
	Belly River Series		
	Pale Beds	Continental	Coal, dinosaurs
	Foremost	Continental	Coal, Gas
	Pakowki (shales)	Marine	
	Milk River	Continental	Artesian water, gas
	Alberta shale	Marine	Gas near base, shale for cement
	Crowsnest Volcanics	Lava flows	
LOWER CRETACEOUS	Blairmore	Continental	Coal, oil, gas
	Kootenay	Continental	Coal, oil, gas
JURASSIC	Fernie (shales)	Marine	Oil at base
TRIASSIC	Schooler Creek	Marine	Gypsum
	Spray River	Marine	Phosphate
PALEOZOIC	Carboniferous Upper	Marine	
	Carboniferous Lower	Marine	Oil, Gas (Turner Valley)
	Devonian	Marine	Some oil
	Silurian	Marine	Salt, gypsum
	Ordovician	Marine	
	Cambrian	Marine	

PRECAMBRIAN (Contains gold and other minerals at Goldfields and Yellowknife).

REFERENCES CITED

1. Research Council of Alberta, Report No. 25, 1930, p. 39.
2. Allan, J. A., Second Annual Report, Mineral Resources of Alberta, 1920, p. 115.
3. Allan, J. A., Trans. C.I.M.M., Vol. 40, 1937, p. 614.
4. Can. Field Naturalist, Vol. 47, No. 8, 1933, p. 148.
5. Allan, J. A., A new deposit of Gypsum in the Rocky Mountains. Trans. C.I.M.M., Vol. 36, 1933, p. 619.
6. Clark, K. A., and Blair, S. M.: The Bituminous Sands of Alberta. Res. Council of Alberta, Rept. No. 18, Pts. I, II and III, 1927-29.
7. Allan, J. A., Res. Council of Alberta, Rept. No. 16, 1925, p. 43.
8. Allan, J. A., Res. Council of Alberta, Rept. 12, 1924, p. 38.
9. Allan, J. A., Res. Council of Alberta, Rept. 12, 1924, p. 39.
10. Russell, L. S., "The Cretaceous-Tertiary Transition of Alberta," Trans. Roy. Soc. Can., Vol. 26, Sec. 4, 1932, p. 121.
11. Williams, M. Y., and Dyer, W. S., Geol. Surv. Can., Mem. 163, 1930, p. 69.
12. Rutherford, R. L., Trans. Roy. Soc. Can., Vol. 31, Sec. 4, 1937, p. 81.
13. Allan, J. A., and Rutherford, R. L., Geology of Central Alberta, Research Council of Alberta, Rept. 30, 1934.

RESEARCH COUNCIL OF ALBERTA

GEOLOGY

REPORT No. 34, PART II—PAGES 40 TO 57

Rock Salt Deposit at Waterways, Alberta

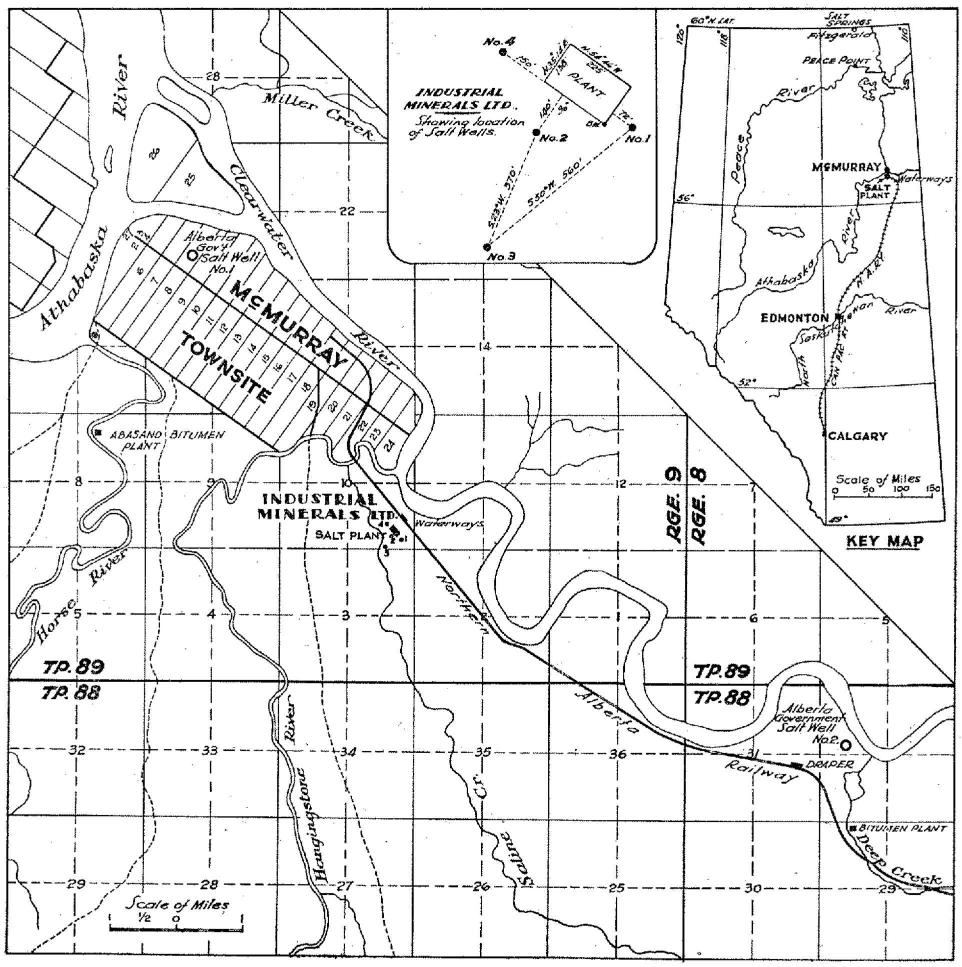
By J. A. Allan

PLATES 13 TO 16 INCLUSIVE

Edmonton, Alberta

1943

PLATE 13



Map of McMurray district, showing positions of salt wells in vicinity of Waterways.

PART II.

ROCK SALT DEPOSIT AT WATERWAYS

BY J. A. ALLAN

INTRODUCTION

In earlier reports of the Research Council of Alberta the writer has discussed the occurrences of salt in various parts of Alberta.[1]

This salt deposit occurs in the vicinity of McMurray at the junction of the Clearwater and Athabaska rivers in latitude 56 degrees, in township 89, range 9, west of the 4th meridian. McMurray is situated about 240 miles northeast from Edmonton. Clearwater river, which rises at Methy portage in Saskatchewan, enters Athabaska river at McMurray. About three miles above the mouth of Clearwater river, the Hangingstone enters from the southwest. Waterways, where the latest salt development has taken place, is situated at the junction of the Hangingstone and the Clearwater, and is at the end of the Northern Alberta Railway, a distance of 304 miles from Edmonton. This railway reaches the bottom of the Clearwater valley at Draper station about 3 miles east of Waterways and near the mouth of Deep creek. The Draper bituminous sand plant, now abandoned, is situated about half a mile east of Draper station. About one mile south of the townsite of McMurray, Horse river enters the Athabaska from the east. The Abasand Company plant for the development of the bituminous sand deposits is situated in the northeast quarter of section 8, about a mile upstream from the mouth of Horse river (Plate 13).

HISTORY OF DEVELOPMENT

Between 1907 and 1912 the Northern Alberta Exploration Company drilled two wells at the mouth of Horse river, to a reported depth of 1,406 and 1,475 feet respectively. Thick beds of rock salt were reported to have been penetrated in these wells, but as the drilling was done with churn drill no salt core was recovered.

It was the enthusiasm and sincere belief in the importance of the mineral resources in Alberta and particularly those in northern Alberta, entertained by the late Senator Jean L. Coté, then member in the cabinet of the Alberta Legislature and formerly Dominion Land Surveyor, that encouraged the Alberta Government, in 1919, to take stock of the mineral possibilities in Alberta. The writer was commissioned to report on the available information relative to the various minerals within Alberta. Particular attention was to be given to the salt resources in northern Alberta and especially in the vicinity of Fort McMurray as it was then known. A compilation of this data was published as the "First Annual Report on the Mineral Resources of Alberta" by the newly formed organization known as the Scientific and Industrial Research Council of Alberta, later known as the Research Council of Alberta, under the chairmanship of the Hon. J. L. Coté.

The presence of brine springs at the northern boundary of Alberta and along the Athabaska valley and the reported discovery of a salt deposit at McMurray were indications of a possible salt industry being established within a province where the entire consumption was imported from points more than fifteen hundred miles distant.

On the recommendation of the writer a well was started in October 1919, by the Alberta Government on Lot 8, McMurray townsite (Plates 13 and 16B). At this time the Alberta and Great Waterways Railway, now known as the Northern Alberta Railway, extended to the edge of the upland near the junction of the Clearwater and Christina valleys, a distance of 26 miles by river from McMurray. The means of transportation between Edmonton and McMurray at this time were far from adequate. Many difficulties and delays were encountered but drilling operations were continued intermittently in salt well No. 1 until the approach of winter in November 1920, when the drilling ceased at a depth of 685½ feet and after approximately 30 feet of salt beds had been penetrated within the lower 60 feet of the strata (Plate 14). Later development indicates that the main salt horizon was not reached in this well.

In 1921 the railway route was changed and the railway was constructed down Deep creek to the floor of the Clearwater valley. In 1922 the end of steel was old Waterways, now Draper station, about six miles east of McMurray. It was decided not to extend the railway to McMurray, but to drill for the salt deposits near the end of the steel. No. 2 salt well was located by the writer between the railway station and the Clearwater river, near the mouth of Deep creek. This well was drilled with the same Davis Calyx drill used in No. 1 well. The well was drilled to a depth of 789 feet and operations ceased after Precambrian granite had been penetrated for five feet. No beds of rock salt were encountered but at various horizons the strata contained cavities and small lenses of salt. Salt water with a measured flow of 24 gallons per minute, was encountered at a depth of 666 feet. This proved that the salt basin does not extend as far east as the mouth of Deep (Sapre) creek.

The importance of a salt industry in Alberta was maintained, and the next step was taken by a private enterprise.

In 1924 the Alberta Salt Company Limited built a grainer plant at the mouth of Horse river to manufacture salt from brine obtained from one of the wells drilled by the Northern Alberta Exploration Company in 1907, about 50 feet from the edge of the Athabaska river. This plant operated intermittently during the years 1925-27 and produced a total of 2,970 tons of salt. Lack of transportation facilities was stated to be the cause of the cessation of operations in this plant. Supplies, equipment and manufactured salt had to be taken from the plant by scow one mile down the Athabaska and then up the Clearwater about 10 miles to the end of the railway.

The continued increase of freight and passenger travel down to the north country and the inconvenience of shipping facilities at the railhead made it necessary, during the year 1928, to extend the railway down the Clearwater valley to the mouth of Hangingstone river, a distance of four and a half miles. A new town of Waterways was built, the old Waterways site was abandoned and the station was renamed Draper. The broad flood plain of boulders and gravel forming the mouth of the Hangingstone prevented the extension of the railway into the townsite of McMurray at this time.*

In October 1928 another attempt was made to develop the salt deposits and a well was drilled by the Alberta Department of Railways close to Waterways station and on the edge of the Clearwater river. A thick bed of salt was reported to have been encountered at 670 feet but no samples of the salt were recovered as the core was dissolved during the drilling. Analyses of the brine from this well are recorded by Cole.[2]

It was not until the spring of 1936 that the latest attempt was made to develop the McMurray salt deposits. Early in the year the Industrial Minerals Limited was organized with F. I. Batcheller as President, and C. H. F. Cottee as Mining Engineer. Through the co-operation of the Hon. C. C. Ross, who was the Minister of Lands and Mines for Alberta, a test well was started in April and was completed in May 1936. The location of the Cottee well, now designated as Industrial Minerals Ltd., No. 1 well, is 589 feet southwest of Waterways station in the southeast quarter of section 10 township 89, range 9, west of the 4th meridian. The well was drilled by O. D. Bush of Edmonton, under the direction of C. H. F. Cottee, Mining Engineer for the company. The results were most gratifying as a continuous bed of rock salt was penetrated for 199 feet between 694 and 893 feet from the surface. The hole was drilled with a diamond drill and a two-inch core was recovered. Much credit is due to the driller, O. D. Bush, as he was also able to recover 67 per cent of the core from the 199-foot bed of rock salt, and much of this salt core is two inches in diameter. This seems to have been a rather remarkable feat for salt recovery as a better record has not been found in literature on rock salt drilling. It is more unusual because the high rock salt core recovery was obtained by drilling with a circulating flow of fresh water. The greatest loss of core occurred in the uppermost 15 feet, while the driller was experimenting as to methods for recovering a maximum core, and at points where the core barrel was emptied. The test well was drilled with a Sullivan (Brave) diamond drill, type N-2″ core barrel, ball-bearing type.

The diamond drill core from this test well was boxed and labelled and when the well was completed at a depth of 898 feet, or five feet below the bottom of the 199-foot bed of rock salt, the boxes were shipped to Edmonton. At the request of the Minister of Lands and Mines, Hon. C. C. Ross, and with the permission of the Industrial Minerals Limited, the writer examined the core samples and compiled a detailed log from the well samples. A detailed geological log showing the succession of the strata is as follows:

INDUSTRIALS MINERALS LIMITED, WELL No. 1 (COTTEE WELL), WATERWAYS, 1936

Surface elevation, 825 feet above sea level.

Depth in feet.	
0-100	Unconsolidated material.
100-101	Limestone, calcareous, grey.
101-105	Limestone, mottled grey to cream (fossils at 103 feet).
105-110	Limestone, light grey with dark bands less than half inch, some shale.
110-118	Limestone, light mottled (fossils).
118-118′2″	Limestone, hard, coarse, with bryozoa, etc., and pyrite.

*In 1942 the railway was extended across Hangingstone river to "The Prairie" on McMurray flats, to accommodate the sudden increased activities in the north related to certain United States Army projects being undertaken.

118-120	Limestone, greenish grey, very compact (almost silt-like).
120-127	Limestone, greenish grey, very compact, with thin shale bands.
127-142	Shale with thin limestone bands interbedded (fossils at 138 feet).
142-147	Shale with thin limestone bands and creamy silty limestone bands of 2″ and 6″.
147-156	Shale, irregular bedded, with lenses of calcareous shale and some limestone.
156-159	Limestone and calcareous shale.
159-165	Shaly limestone and shale interbedded and irregular bedding.
165-171	Shale and limestone interbedded.
171-213	Shale, grey, calcerous.
213-219	Limestone, mottled (fossils).
219-225	Limestone, mottled.
225-231	Limestone (fossils).
231-242	Limestone, fossiliferous, massive.
242-265	Limestone, fossiliferous, some shale.
265-281	Limestone, fossiliferous, massive with ½″ shale at 271′.
281-288	Shale, green with grey limestone.
288-303	Shale, grey and blue, interbedded with limestone.
303-310	Limestone, massive to spotted, irregular shale spots.
310-312	Shale, calcareous, spotted, and limestone.
312-333	Shale, green to blue, calcareous.
333-337	Shale, blue green.
337-338	Limestone, grey (fossils).
338-348	Shale, blue green.
348-349	Limestone (fossils).
349-357	Shale, blue.
357-381	Shale, blue (very soft at 360′) (few fossils).
381-401	Shale, grey, calcareous, with dark shale irregular bands, much pyrite at 397′ and few fossils.
401-416	Shale, grey, calcareous with few thin blue shale bands.
416-423	Shale, blue with shaly limestone (fossils).
423-427	Shale, blue with few large grey fossils.
427-433	Shale bands, blue and grey, calcareous.
433-446	Shale, blue with some grey bands.
446-468	Shale, blue, calcareous with thin bands of shaly limestone.
468-482	Shale, blue, calcareous.
482-490	Limestone, grey, fossiliferous and some pyrite in layers.
490-492	Limestone, grey.
492-493	Shale, grey to black, thin-bedded, calcareous (Poker chips).
493	Gypsum contact.
493-495	Gypsum with band of fibrous gypsum.
495-501	Anhydrite, massive, grey, with gypsum crystals, and a few thin bands fibrous selenite.
501-512	Anhydrite, massive, grey, and veins selenite.
512-513	Dolomite, massive.
513-524	Anhydrite, massive with thin gypsum bands and few thin shale beds.
524-526	Gypsum, dark, interbedded with shale and anhydrite.
526-528	Shale, blue.
528-535	Gypsum, thin-bedded, red and grey with anhydrite and shale.
535-538	Dolomite.
538-544	Shale, dark, interbedded with gypsum.
544-551	Shale, blue, some very thin gypsum layers.
551-556	Anhydrite, massive with gypsum lenses.
556-557	Shale, blue.
557-561	Gypsum, thin-bedded with some shale and anhydrite.
561-571	Anhydrite, mottled, with red streaks and thin bands of gypsum (red mottled anhydrite would polish well).
571-581	Gypsum, thin-bedded, with anhydrite and shale.
581-594	Gypsum, thin to massive.
594-596	Dolomite, grey.
596-604	Gypsum-anhydrite, thin-bedded, and some shale.
604-613	Gypsum-anhydrite, massive.
613-619	Gypsum-anhydrite, thin-bedded.
619-625	Anhydrite-gypsum, massive with some calcareous bands.
625-655	Anhydrite, massive.
655-658	Gypsum, brown, interbedded with anhydrite, salt encrusted.
658-670	Anhydrite, massive (44 inch core).

670-674	Anhydrite and thinly interbedded with gypsum.
674-683	Gypsum, massive, grey, with anhydrite interbedded (679′ salt encrustation).
683-689	Gypsum, brown, with anhydrite interbedded, thin layers.
689-694	Anhydrite, massive, bluish.
694	Top of salt bed.
694-893	Rock salt (core recovered 67%):
	694-711, core recovered 29.4%.
	711-745, " " 77.2%.
	745-785, " " 58.0%.
	785-815, " " 79.4%.
	815-854, " " 60.5%.
	854-883, " " 83.9%.
	883-893, " " 78.3%.
893	Contact of rock salt and gypsum rock.
893-896	Anhydrite, massive, calcareous, with gypsum crystals.
896-898	Gypsum, brown banded, with anhydrite and salt crystals.

Drilling in this test well was discontinued at 898 feet, and there might be other beds of salt below this depth, because the bottom core does not indicate that the base of the salt deposit has been reached.

Fossils collected by the writer from various horizons in the core have been determined by P. S. Warren. The depth from the surface at which the fossils occurred and the name of the fossils are given below.

Depth in feet.	Fossil determination.
113	*Spirifer* cf. *tullia* Hall.
227	*Atrypa reticularis* (Linn.).
273	*Stropheodonta* sp.
	Schizophoria striatula (Schloth.).
277	*Stropheodonta demissa* (Conrad).
337	*Schizophoria striatula* (Schloth.).
	Atrypa reticularis (Linn.).
349	*Schizophoria striatula* (Schloth.).
	Atrypa reticularis (Linn.).
367	*Atrypa reticularis* (Linn.).
422	*Schizophoria striatula* (Schloth.).
	Atrypa reticularis (Linn.).
	Cyrtina billingsi Meek.
423	*Atrypa reticularis* (Linn.).
426	*Atrypa reticularis* (Linn.).
456	*Lingula spatulata* Vanux.

Warren states that "the fauna represented at the different horizons stated above is from the lower part of the Upper Devonian and corresponds to the fauna of the *Waterways* formation at McMurray. It may also be correlated with Upper Devonian lying immediately above the Silurian at Peace Point on Peace river."

The Devonian formation penetrated in this well is exposed along the east side of Athabaska river at McMurray between the mouths of Horse creek and Clearwater river, and also downstream along the Athabaska. This series of strata has been designated the Waterways formation.[3]

ROCK SALT BED

In the Industrial Minerals Ltd., Well No. 1, which is 898 feet deep, only one bed of rock salt occurs. This bed is 199 feet in thickness and is remarkably pure in quality throughout. There are no thin beds of salt associated with the 201 feet of anhydrite and gypsum above the salt in which that portion of the core recovered between 493 and 694 feet represents over 95 per cent of the total section through the anhydrite and gypsum.

The recovery of total salt core is 67 per cent of the 199 feet. This high core recovery of rock salt was obtained by circulating fresh water in the core barrel and by rapid drilling rate. By excluding the uppermost 17 feet between 694 and 711 feet, during experimentation on process for higher recovery, approximately 70 per cent of the total salt core was recovered. Only about 30 per cent of the core was wasted by the fresh water at the points where the core barrel was emptied. This is a creditable drilling feat.

There are no beds of shale or impure sulphates throughout the entire thickness of the salt bed as all sediment from the drilling fluid was collected for observation. Three analyses of the rock salt show that this deposit has a high degree of purity, with 99.57 per cent, 99.45 per cent and 98.27 per cent sodium chloride respectively. In all parts of the bed the rock salt is translucent and in many layers it is transparent. Some layers on the fractured face show the outline of large halite crystals. The powder is paper white in color.

ANALYSES OF CORE SAMPLES FROM INDUSTRIAL MINERALS LTD., SALT WELL No. 1

	1	2	3	4	5	6
Alumina (Al_2O_3)	tr.	0.00	0.00	0.00	....	....
Iron Oxide (Fe_2O_3)	0.01	0.00	0.00	0.00	....	....
Lime (CaO)	0.18	0.20	0.66	28.29	32.40	2.71
Magnesia (MgO)	0.01	tr.	tr.	0.00	0.00	1.57
Sulphates (SO_3)	0.20	0.18	0.83	36.21	46.11	0.14
Chlorine as Salt (NaCl)	99.57	99.45	98.27	35.00	21.05	92.08
Ignition Loss	....	....	....	.40	....	....
	99.97	99.83	99.76	99.50	99.56	96.50

1. Rock salt sample selected by L. H. Cole, analysed by S. R. M. Badger, Division of Chemistry, Mines Branch, Ottawa.
2. Rock salt sample from 855 to 860 feet. Samples 2-8 selected by J. A. Allan.
3. Rock salt sample from 863 feet.
4. Thin hard band, about 2 mm. in rock salt at about 850 feet.
5. Hard band about 1 mm. thick, at 800 feet. This sample contains 78.8 per cent anhydrite and the balance sodium chloride.
6. Encrustation which formed on anhydrite core from depth 679 feet, in damp store room.
7. Sample of core at 666 feet, on analysis showed 97.12 per cent anhydrite.
8. Hard band, 1 mm. thick, separated from core sample at 774 feet by slowly dissolving the rock salt. Contained 99.36 per cent anhydrite.

BANDING IN SALT BED

There is an apparent banding throughout much of the rock salt deposit. An eight-foot core sample of the rock salt between 842 and 850 feet contains 142 distinct beds; some are separated by a thin anhydrite band, or by scattered clusters of anhydrite in subparallel planes. In this portion of the core the salt bands average about 16 mm. in thickness.

This marked regularity in the thickness of the layers of salt seems to suggest an annual banding in the salt deposit. If this is the explanation for the banding in the Waterways salt deposit, the thin beds represent annual rings with an average thickness of 20 millimeters. Furthermore, at irregular intervals, usually ranging from 7 to 11 inches apart, in different parts of the rock salt core, there are broader bands of anhydrite, usually bounded on both sides by rock salt with a slightly darker color. These more distinct bands suggest a cyclic phenomenon, but this is a suggestion difficult to prove.

INITIAL SALT DEVELOPMENT

The Cottee well or Industrials Minerals Ltd. No. 1 well, was a test well in which at least 199 feet of rock salt occurred and the company decided to establish a salt industry. During 1937 a salt evaporation plant, 225 by 133 feet, was erected (Plate 16A). This plant, which was completed in December, consists of three evaporating pans each 110 feet long, 24 feet wide and 18 inches deep, with a daily capacity of 100 tons of salt. This plant contains two 250 h.p. boilers and one 250 h.p. engine. Coal is used as fuel. Other equipment includes one 187 K.V.A. generator, brine pumps, screens, driers and sackers. Filter presses have now been installed.

A production well, 6 inches in diameter was drilled close to the plant and the salt bed was penetrated for a distance of about 170 feet. This is No. 2 production well, and is situated about 140 feet southwest of the plant and at the same level as No. 1 test well. The top of the salt bed was encountered at approximately 694 feet below the surface. A six-inch casing was extended to the bottom of the well and a four-inch pipe was extended into the top of the salt bed. Two water wells were drilled close to the salt well, each to a depth of about 50 feet. The water from these wells was used in the plant. The water is pumped down the salt well to dissolve the salt. The brine is pumped into three settling tanks, and by gravity feed is carried to the evaporating pans.

Salt production began late in December, 1937, and about the middle of January 1938 the first carload of salt was shipped into Edmonton.

It would appear that conditions are quite favorable for the mining of this thick salt bed from a shaft, as the depth to the top of the salt bed is less than 700 feet and the rock conditions are most suitable for shaft sinking, but it has been decided to extract the salt as brine and to produce refined salt by evaporation.

DEVELOPMENT IN 1939

In 1938 Industrial Minerals Limited, was reorganized by the Dominion Tar and Chemical Company, Limited, with Lionel O. P. Walsh as President and Bert Ayres as Manager and Plant Superintendent. As the mining of salt was contemplated, it was decided to drill another test well some distance from the plant.

The writer selected the site for No. 3 test well about 500 feet southwest from the plant and about 370 feet south southwest from No. 2 production well. The elevation of the surface at No. 3 well is 853 feet above sea level, or 28 feet above the lower terrace in Clearwater valley on which the plant is situated.

The drilling of No. 3 well was contracted by O. D. Bush and the driller was R. Scott. A type "N" diamond drill was used. As this was a test well, a 5-inch hole was drilled through the unconsolidated material to 42 feet at the top of the bituminous sand. A 3-inch hole was drilled to 185 feet and the casing was cemented into the limestone. A 2⅞-inch hole was extended to the bottom of the test at 952 feet. The well was spudded in on January 27th, 1939, the top of the salt bed was reached at 723 feet on March 23rd and the well was completed on March 31st at 952 feet. When the top of the salt bed was reached, brine from the plant was used as the drilling fluid to penetrate the salt bed. By using brine an excellent recovery of salt core was obtained. The salt bed in this well is 211 feet thick and the recovery of salt core was 95.3 per cent of the entire salt bed penetrated.

LOG OF INDUSTRIAL MINERALS LIMITED, No. 3 SALT WELL

Depth in feet.	Description.
0- 10	Clay.
10- 23	Gravel and small boulders.
23- 42	Sand.
42- 75	Bituminous sand.
75-151	Shale, soft.
151	Top of limestone.
151-166	Limestone, grey to yellowish.
166-206	Shale, greenish, calcareous, interbedded with thin limestone.
206-247	Shale, greenish, calcareous, with limestone.
247-306	Limestone, light grey to yellowish, mottled.
306-339	Limestone, mottled, shaly, with greenish calcareous shale.
339-345	Limestone, greenish, shaly.
345-370	Shale, greenish, calcareous.
370-372	Limestone, grey, mottled.
372-412	Shale, greenish, calcareous.
412-441	Limestone, light grey, shaly, with shale streaks.
441-449	Limestone, compact, light grey.
449-459	Shale, greenish (fossils).
459-465	Limestone, yellowish grey, with irregular bedding and lenses of greenish shale.
465-477	Shale, soft, greenish, calcareous (will cave easily).
477-480	Limestone, grey mottled, spotted with greenish shale.
480-495	Limestone, greenish, clayey.
495-506	Shale, soft, greenish, fissile (will cave easily).
506-513	Shale, greenish, calcareous (poker chip weathering).
513-525	Limestone, grey, interbedded with dark calcareous shale and yellowish dolomite.
525	Top of gypsum-anhydrite series.
525-538	Gypsum, soft, and some anhydrite bands.
538-555	Anhydrite, massive, hard, bluish, some fibrous gypsum.
555-557	Anhydrite, interbedded with fibrous gypsum.
557-559	Shale, greenish, compact.
559-563	Gypsum, grey, interbedded with greenish shale.
563-567	Gypsum, reddish and grey, interbedded.
567-572	Shale, greenish, compact, calcareous, with gypsum.
572-576	Gypsum, brownish, and waxy shale.
576-584	Shale, dark greenish, with red streaks.
584-586	Gypsum, grey to yellowish, some fibrous gypsum.
586-587	Dolomite, yellowish grey.
587-589	Dolomite and gypsum interbedded.
589-596	Gypsum, spotted reddish, grey and bluish.
596-606	Gypsum, massive, grey with red streaks.
606-609	Gypsum, thin-bedded, reddish and grey.
609-621	Gypsum, greenish to grey.
621-648	Gypsum, grey to white, with some anhydrite.
648-650	Dolomite, buff to yellowish grey, with gypsum.
650-656	Gypsum and anhydrite interbedded.
656-663	Anhydrite, massive, interbedded with gypsum.
663-683	Anhydrite, massive bluish to translucent.
683-686	Gypsum, brown to yellowish grey.
686-699	Gypsum, massive grey.
699-710	Dolomite, yellowish grey, with some gypsum.
710-711	Dolomite band with inclined bedding between gypsum.
711-714	Anhydrite, massive, some layers translucent and interbedded with thin layers of fibrous gypsum.
714-715′3″	Dolomite, brownish, with thin translucent gypsum layers.
715′3″-715′9″	Anhydrite, hard, grey.
715′9″-718	Dolomite, brownish, and gypsum.
718-723	Anhydrite, hard, massive, translucent.

723	Top of Salt Bed.
723-934	Rock Salt.
934	Bottom of Rock Salt.
934-938	Anhydrite, massive, with some gypsum.
938-940	Dolomite, finely interbedded with gypsum and some shale, brown to black with grey patches.
940-942	Dolomite, irregularly bedded, grey, and brown gypsum.
942-943	Dolomite, broad brown and grey bands, and gypsum.
943-951	Gypsum, finely interbedded black and dark brown, with dolomite and shale.
951-952	Anhydrite and dolomite, grey, and thickly bedded black and brown gypsum.
952	Bottom of No. 3 Well, March 31st, 1939.

The log of the strata penetrated in No. 3 well was compiled by the writer from the cores obtained. He supervised the drilling operations at the site when the salt bed was being penetrated. The well is situated on an upper terrace of the Clearwater valley. The upper 23 feet in the well consists of clay, sand and gravel, but no boulders were encountered. There are 19 feet of fine-textured white sand between 23 and 42 feet. A microscopic examination of this sand indicates that the sand is similar to the sand in the bituminous sand, so it is concluded that this white sand has been derived from erosion of the bituminous sand. This sand would form a quicksand if water occurred in the bed, but this sand at the well is free from water.

The top of the bituminous sand was penetrated at 42 feet, but there are only 33 feet of this bituminous sand formation at this location. There was no core obtained of the bituminous sand, but there was no difficulty in drilling through this formation. The water used as drilling fluid agitated the sand and bitumen, which came out of the core barrel as a viscous or semi-fluid mass.

The bituminous sand formation is Lower Cretaceous in age and it is underlain by the Upper Devonian strata consisting of interbedded limestone and shale. These strata are known as the Waterways formation. This formation, encountered at a depth of 151 feet in the well, extends to a depth of 525 feet, and is therefore 374 feet thick.

The contact between the limestone-shale series above and the gypsum-anhydrite series below occurs at 525 feet. Almost all of the strata between 525 feet and 723 feet consist of massive anhydrite, and massive and thinly-bedded gypsum interbedded with anhydrite. No fossils were encountered in this series but it is considered to be Upper Silurian in age.

The top of the salt bed in No. 3 well occurs at a depth of 723 feet. This contact is sharp and the salt bed is immediately overlain by a 5-foot bed of massive, hard, almost translucent anhydrite which forms an excellent roof over the salt.

Character of Salt Bed in No. 3 Well

A continuous bed of clear white rock salt 211 feet thick, was penetrated by the drill between 723 and 934 feet below the surface at the well. Brine from the adjoining salt plant was used as the drilling fluid, in order to recover as much salt core as possible. Much credit is due to the driller, R. Scott, for the care taken in drilling through the salt bed. A most complete salt core was recovered as there were 201 feet of salt core obtained from the salt bed which is 211 feet thick. This represents 95.3 per cent salt recovery. Almost every inch of the salt core is 2 inches in diameter which is the inside diameter of the core barrel used. The core barrel is 10 feet long. One solid salt core 9 feet 10 inches long was recovered and other solid cores were 9 feet 9 inches, 9 feet, several over 5 feet, and many were 5 feet in length (Plate 15).

There are no rock impurities within the entire 211 feet of rock salt. The uppermost 6 feet consist of transparent colourless rock salt, so clear that writing could be read through the salt core. The remainder of the core consists of white to translucent, fine to coarse crystalline rock salt, often with large transparent crystal grains in the mass. Most of the beds are of coarse texture with crystal grains a quarter of an inch up to about one-half inch in diameter.

The only impurities in the entire salt bed consist of very thin bands of bluish grey anhydrite, irregular in extent, and seldom over one millimeter in thickness, except in the lower part of the bed between 903 feet and 923 feet where bands of three to five millimeters occur. In most parts of the bed, the bands are quite uniformly spaced, three to five inches apart, and suggest a seasonal banding. The entire salt core was examined for impurities by placing a strong light behind the core. Some of the bands can only be seen by using a light in this way. By this method the bands in the cores recovered, were counted throughout the salt bed.

The table given below indicates that there are 480 of these thin anhydrite bands in the 201 feet of solid salt core recovered. The combined thickness of these bands, assuming an average thickness of about one millimeter each, represents only about two feet of impurities in the entire salt bed. Representative samples of the salt core tested in the plant laboratory by the writer, contained 0.5 per cent impurities which were anhydrite grains.

The table which follows shows the amount of salt recovered in each run and the number of bands in each part of the salt core.

RECOVERY OF SALT CORE AND NUMBER OF ANHYDRITE BANDS

Depth from Surface in feet	Core recovered from 10-foot core bbl.	Percentage Core Recovery	No. of Anhydrite bands	Remarks
723-733	9′4″	93.3	15	
733-743	9′9″	97.5	12	
743-753	9′4″	93.3	16	
753-763	8′8″	86.6	15	
763-773	9′7″	95.8	21	10′ solid core
773-783	9′8″	96.6	21	
783-793	9′10″	98.3	15	
793-803	9′11″	99.1	19	
803-813	9′10″	98.3	12	
813-822	8′0″	88.8	21	
822-830	7′3″	90.6	20	
830-840	9′11″	99.1	27	
840-850	9′10″	98.3	22	Used single core bbl.
850-860	9′10″	98.3	21	9′ solid core
860-870	9′9″	97.5	12	9′9″ solid core
870-880	10′0″	100.0	28	9′10″ solid core
880-890	7′6″	75.0	12	Stuck in core bbl.
890-900	9′0″	90.0	26	
900-903	3′0″	100.0	24	
903-913	10′0″	100.0	32	Heavy banding at 910′
913-923	10′0″	100.0	55	Heavy bands
923-932	9′0″	100.0	30	Transparent salt
932-934	2′0″	100.0	4	Bottom contact
Total	201′0″	95.3%	480	

The floor of the salt bed is marked by a sharp, smooth, undulating contact at 934 feet below the surface of the well, or at 81 feet below sea level. A solid core sample was obtained which shows the bottom six inches of salt and the upper four inches of floor rock. The strata were drilled for 18 feet below the salt bed. The salt bed is immediately underlain by a massive hard translucent bluish anhydrite bed four feet thick and with only a few salt cavities. The bottom 14 feet of the well is in dark brown to black interbedded gypsum, anhydrite and dolomite. Drilling on this well was stopped at a depth of 952 feet as there was no indication of a deeper salt bed. The occurrence of a deeper bed can only be proven by drilling below the horizon proven in well No. 3.

The character of this salt bed at this locality suggests uniform conditions of deposition and uniform salinity of the sea water for a comparatively long time. If the bands of impurities indicate seasonal conditions, then the time required to deposit the salt in this bed 211 feet thick, would be about 500 years which is only a brief geological time.

It would appear that the top of the salt bed is at approximately the same elevation above sea level in test well No. 1, production well No. 2, test well No. 3 and production well No. 4. There is a thickening of twelve feet in the salt bed between well No. 1 and well No. 3, a distance of 560 feet. This suggests that the deepest part of the salt basin might occur to the southwest of production well No. 2. No. 4 production well is 590 feet north of No. 3 and 260 feet northwest of No. 2 production well.

Correlation in Salt Basin

Exact data have been obtained on the Waterways salt basin in the McMurray district, from the cores of six wells drilled through or into the salt bed. Four of these wells have been drilled by the Industrial Minerals Limited, at Waterways, numbered 1, 2, 3 and 4. Two wells have been drilled by the Alberta Government, namely, No. 1 well on Lot 8 in the McMurray townsite, two and a half miles west of the Waterways wells, and No. 2 well at the junction of Deep creek and the Clearwater river, three and three-quarter miles east of the Waterways wells. The two Alberta Government wells are about six and a quarter miles apart.

Plate 13 shows the geographical position of each of these wells, with a large scale inset of the positions of the four salt wells and the plant of the Industrial Minerals Limited at Waterways. Plate 14 shows the correlation of strata in four salt wells from which quite complete rock cores were obtained. Certain definite horizons can be readily correlated in each of these four wells. The uppermost horizon selected is the top of a massive mottled limestone member which is between 90 and 100 feet thick. The top of this bed rises 96 feet between No. 1 and No. 2 wells, a distance of six and a quarter miles, or an average rise to the east of 15.36 feet to the mile.

The second definite horizon is the top of the anhydrite-gypsum series. This contact is very sharply defined in all four wells. There is a difference of 100 feet in this contact between the two Alberta Government wells, No. 1 and No. 2, or an average rise to the east of 16 feet to the mile.

These two horizons indicate that the shore line at the time of deposition was east of the positions of these three wells or, at least, that the floor of the basin was dipping to the west.

The top of the salt bed is the third horizon which can be used for correlation of strata within the area tested by drilling. The top of the salt is quite sharply marked in the four wells drilled at Waterways by the Industrial Minerals Limited. This salt contact occurs at 131 feet above sea level in the Industrial Minerals Limited, wells Nos. 1, 2 and 4, and at 130 feet in well No. 3. The top of the first salt bed was encountered at 164 feet above sea level in the No. 1 well at McMurray. This indicates a dip to the east between McMurray and Waterways, of 13.2 feet to the mile. No beds of rock salt were penetrated in Alberta Government No. 2 well at the junction of Deep creek and Clearwater river, but the first indications of salt in the form of salt crystals and salt cavities in the dolomite occur in this rock core at a depth of 223 feet above sea level, which is 587 feet below the surface at the well. A strong flow of salt brine occurred at 144 feet above sea level or at 666 feet below the surface. As shown on the correlation chart (Plate 14), this horizon marking the uppermost occurrence of salt, is at 223 feet above sea level in No. 2 well and indicates a rise to the east of Waterways of 24.8 feet to the mile.

The bottom of the salt basin is Precambrian granite at 25 feet above sea level in the most easterly well. The sedimentary rocks have not been drilled through in the other salt wells. At Waterways the bottom of the salt bed occurs at 81 feet below sea level in No. 3 well and at 68 feet below sea level in No. 1. These two wells are about 560 feet apart. It is possible but not probable that there may be some thin beds below the main salt bed in No. 3 well at Waterways which was drilled to a point 99 feet below sea level. The Precambrian granite contact at the mouth of Deep creek occurs 124 feet higher than the bottom of No. 3 well at Waterways, which is three and three-quarter miles to the west. On this account the granite can be expected to occur not far below the bottom of the wells at Waterways.

It is apparent from this correlation chart (Plate 14) that the main salt bed was not reached in the No. 1 well at McMurray. It is also quite probable that if this well had been drilled deeper, a more massive bed of salt would have been penetrated, which would correspond to the thick bed in the Waterways wells. It is unfortunate that a more detailed record had not been kept of the first well drilled in 1907 at the mouth of Horse river, as it now seems probable that the rock salt deposits are also thick at this point.

Extent of Salt Basin

The extent of the salt deposit at Waterways is not yet known but this is not a vital factor in the commercial development of the deposit, because the drilling to date at Waterways has proven that the salt reserves are large. It would appear from the data on hand that the main part of the salt basin occurs at Waterways and possibly extends in a westerly direction towards Athabaska river, a distance of over three miles. The maximum thickness of the salt bed proven to date at Waterways is 211 feet. Assuming that the salt bed has an average thickness of about 200 feet at Waterways and that one ton represents about 14 cubic feet of space, such a deposit would contain about 570,000 tons per acre, or an amount greater than the total annual Canadian production and import of all kinds of salt. It is reasonable to expect such a deposit to extend for a radius of half a mile from the wells at Waterways. Such a deposit would contain over 290,000,000 tons of salt.

Origin of the Salt Deposit

Most salt deposits are formed on the surface of the earth from the evaporation of saline waters along the margins of oceans, or in bays or in closed basins marginal to the sea or in inland lakes of saline water where evaporation exceeds the influx of fresh water. Rock salt or common salt occurs in beds which range in thickness from a minimum up to as much as 3,000 feet in European proven deposits. Thick beds of salt were not deposited in the open sea. Normal sea water contains less than 2 per cent by volume of dissolved sodium chloride, so that a bed of salt 200 feet thick, such as occurs at Waterways, if formed by precipitation over the floor of a basin, would have required 10,000 feet of sea water to have been concentrated to the point where precipitation would occur. Salt is precipitated from brine where the salinity of the solution exceeds 26 per cent. Various theories have been put forward to explain the formation of thick deposits of rock salt, but no one theory may satisfactorily explain a particular deposit.

The Waterways salt deposit was formed in a lagoonal embayment along the eastern margin of a sea, probably during the early Upper Silurian time when a semi-arid climate existed. In this basin, separated by some form of barrier from the open sea that lay to the west of McMurray, evaporation proceeded under desert conditions and quite pure sodium chloride was precipitated. The banded character of the salt bed suggests slight seasonal changes in the concentration of the brines, as many very thin layers of anhydrite occur. There are no shale or carbonate impurities in the rock salt, so there were no sediments washed into the basin from the margin. The eastern edge of this basin is somewhere between Waterways and the position of Alberta Government No. 2 well, three and three-quarter miles to the east, where there are no beds of pure rock salt. To the west, this lagoonal basin, in which rock salt accumulated, extended from Waterways at least as far west as the position of Athabaska river and possibly a considerable distance farther west. The north and south limits of this lagoonal basin remain unknown. A number of saline springs occur along the Athabaska valley below McMurray. The strongest springs observed occur at LaSaline, twenty-seven miles north of McMurray. Strong flows of saline water were encountered in shallow wells drilled for oil along the banks of the Athabaska river, downstream from McMurray. A well was drilled in 1911 by the Athabaska Oils, Ltd., on the east bank of the Athabaska river, about 20 miles below Fort McKay, and 56 miles north of McMurray. Precambrian granite was encountered at 1,105 feet below the surface. No beds of pure rock salt were encountered but strata bearing salt water are recorded.[4] These saline springs and the presence of strata containing salt water suggest that the margin of Waterways lagoonal basin extended in this direction.

Potassium salts sometimes occur interbedded with rock salt which is sodium chloride. The salt cores from the wells at Waterways and McMurray were closely examined by the writer. There are no beds of potassium salts in any of these cores from the rock

LATE 14

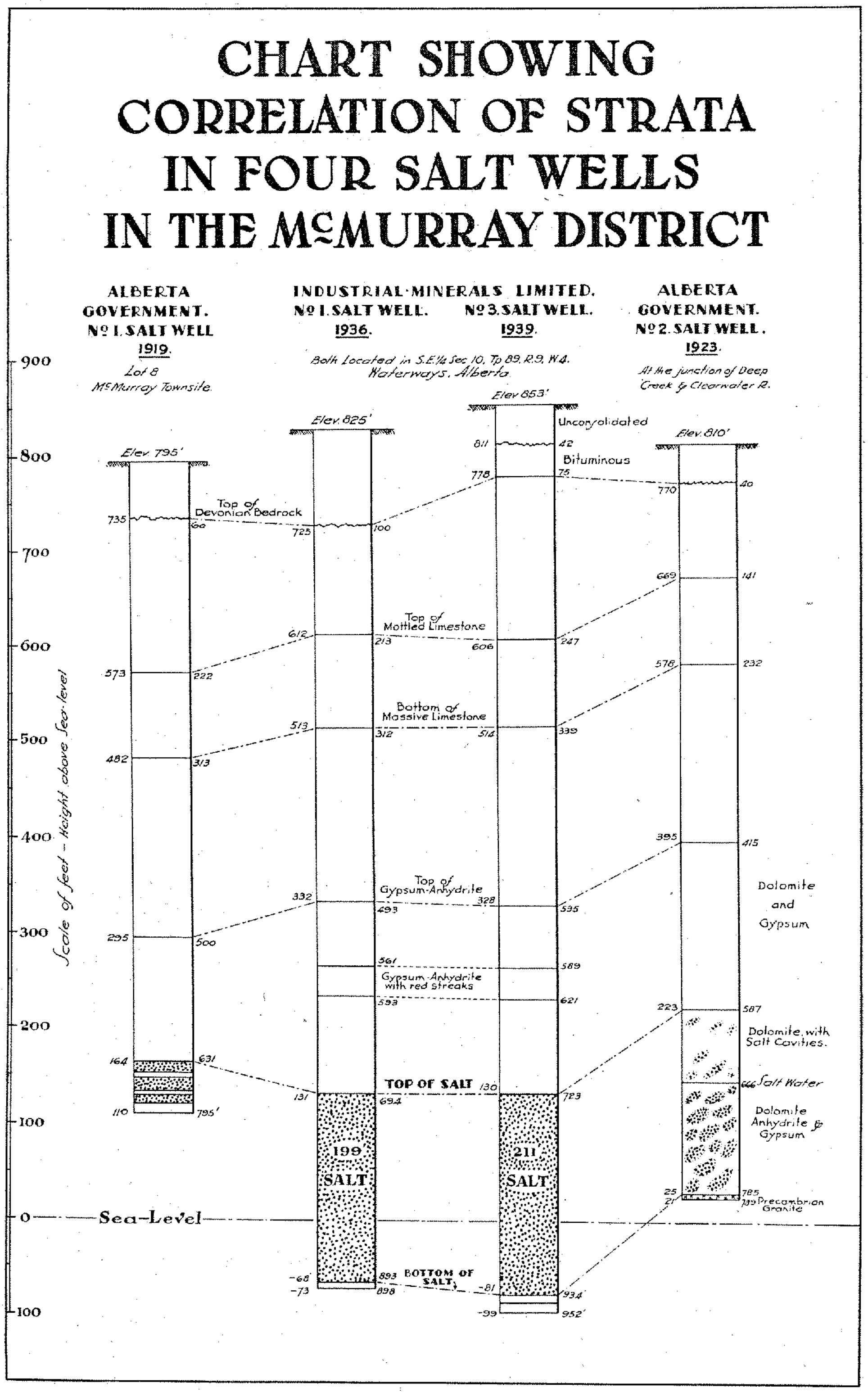
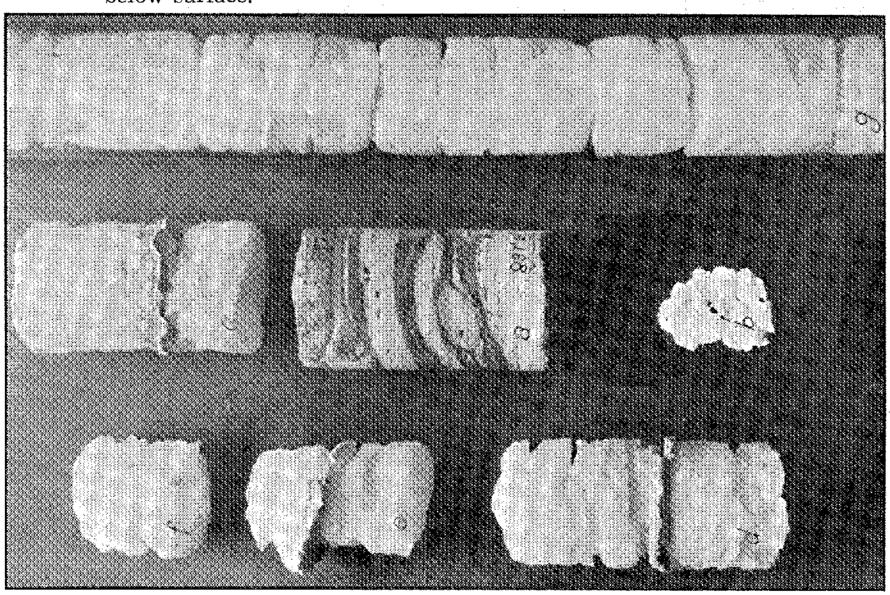


CHART SHOWING
CORRELATION OF STRATA
IN FOUR SALT WELLS
IN THE McMURRAY DISTRICT
ALBERTA GOVERNMENT. No 1. SALT WELL 1919.
Lot 8 McMurray Townsite.
INDUSTRIAL MINERALS LIMITED.
No 1. SALT WELL. 1936.
No 3. SALT WELL. 1939.
Both Located in S.E.¼ Sec 10, Tp 89, R.9, W.4. Waterways, Alberta.
ALBERTA GOVERNMENT. No 2. SALT WELL. 1923.
At the junction of Deep Creek & Clearwater R.
Elev. 795'
Elev. 825'
Elev. 853'
Elev. 810'
Unconsolidated
Bituminous
Top of Devonian Bedrock
Top of Mottled Limestone
Bottom of Massive Limestone
Top of Gypsum-Anhydrite
Gypsum-Anhydrite with red streaks
TOP OF SALT
199 SALT
211 SALT
BOTTOM OF SALT
Dolomite and Gypsum
Dolomite with Salt Cavities.
Salt Water
Dolomite Anhydrite & Gypsum
Precambrian Granite
Sea-Level
Scale of feet - Height above Sea-level
900
800
700
600
500
400
300
200
100
0
100

PLATE 15

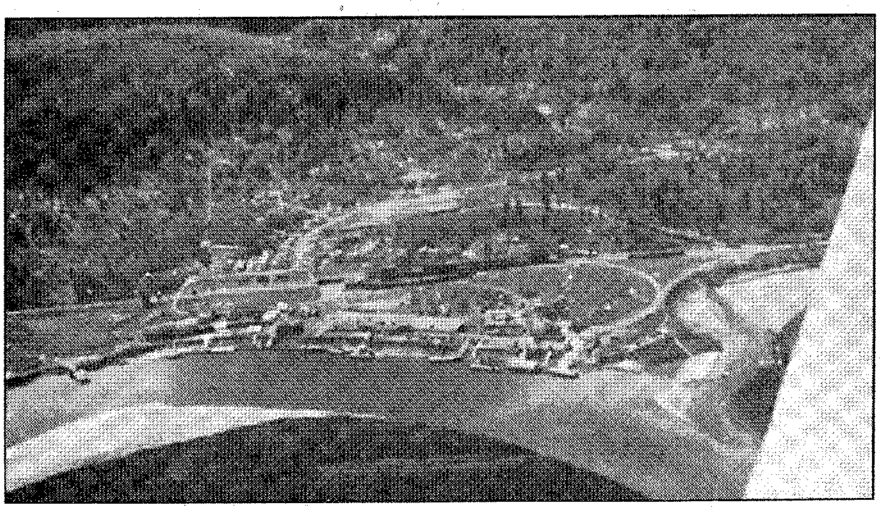
A.—Salt core from Industrial Minerals Ltd., Well No. 3, Waterways. Nine feet nine inches of salt core in one piece from depth of 137 feet below surface.



B.—Seven core-sample fragments from Salt Well No. 1, Industrial Minerals Ltd., Waterways.

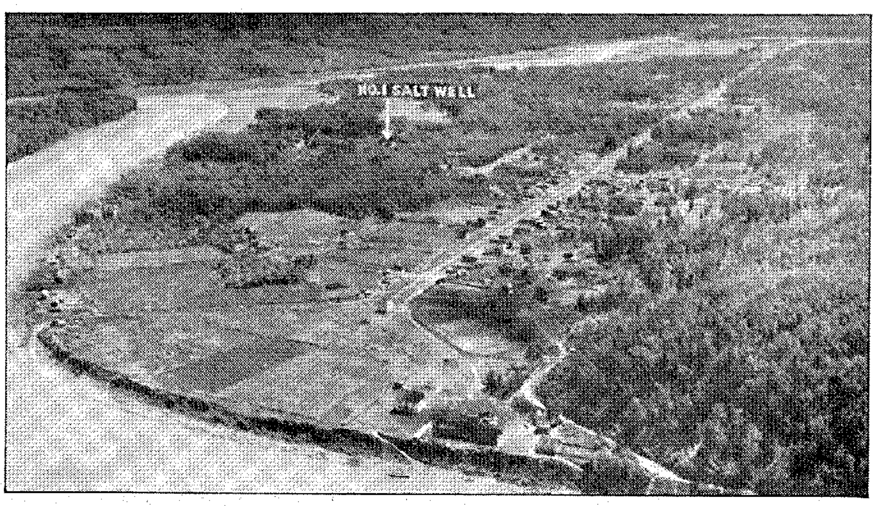
(a) Banded gypsum at 897 ft. 6 in.; (b) hard band of anhydrite separated from salt core; (c) (d) (e) rock salt with hard bands of anhydrite; (f) transparent salt; (g) 12 inches of rock salt core.

PLATE 16



(Photo by J. A. Allan)

A.—Aerial view of Waterways, showing salt plant of Industrial Minerals Limited, in centre background.



(Courtesy of Royal Canadian Air Force)

B.—Aerial view of McMurray settlement about 1935, looking east from Athabaska river, showing the position of No. 1 salt well drilled by Alberta Government, and the hydroplane landing field on Clearwater river.

salt beds or from the gypsum, anhydrite or dolomite strata associated with the rock salt. It would seem unlikely that potash-rich beds occur in this salt basin in the McMurray district.

REFERENCES CITED

[1]Allan, J. A., First Annual Report, Mineral Resources of Alberta, 1919, p. 87.
Second Annual Report, Mineral Resources of Alberta, 1920, p. 102.
Annual Report, Res. Council of Alberta, No. 3, 1920, p. 33.
Annual Report, Res. Council of Alberta, No. 10, 1923, p. 48.
Salt and Gypsum in Alberta, Trans. Can. Inst. Min. & Metallurgy, Vol. 32, 1929, p. 232.
Salt Deposits at McMurray, Trans. Can. Inst. Min. & Metallurgy, Vol. 40, 1937, p. 614.

[2]Cole, L. H., Mines Branch Report, No. 716, 1930, p. 69.

[3]Warren, P. S., Canadian Field Naturalist, Vol. 47, No. 8, 1933, p. 148.

[4]Allan, J. A., First Ann. Rept., Mineral Resources of Alberta, 1919, p. 97.

RESEARCH COUNCIL OF ALBERTA

GEOLOGY

REPORT NO. 34, PART III—PAGES 60 TO 146

Geology of Alberta Soils

By J. A. Allan

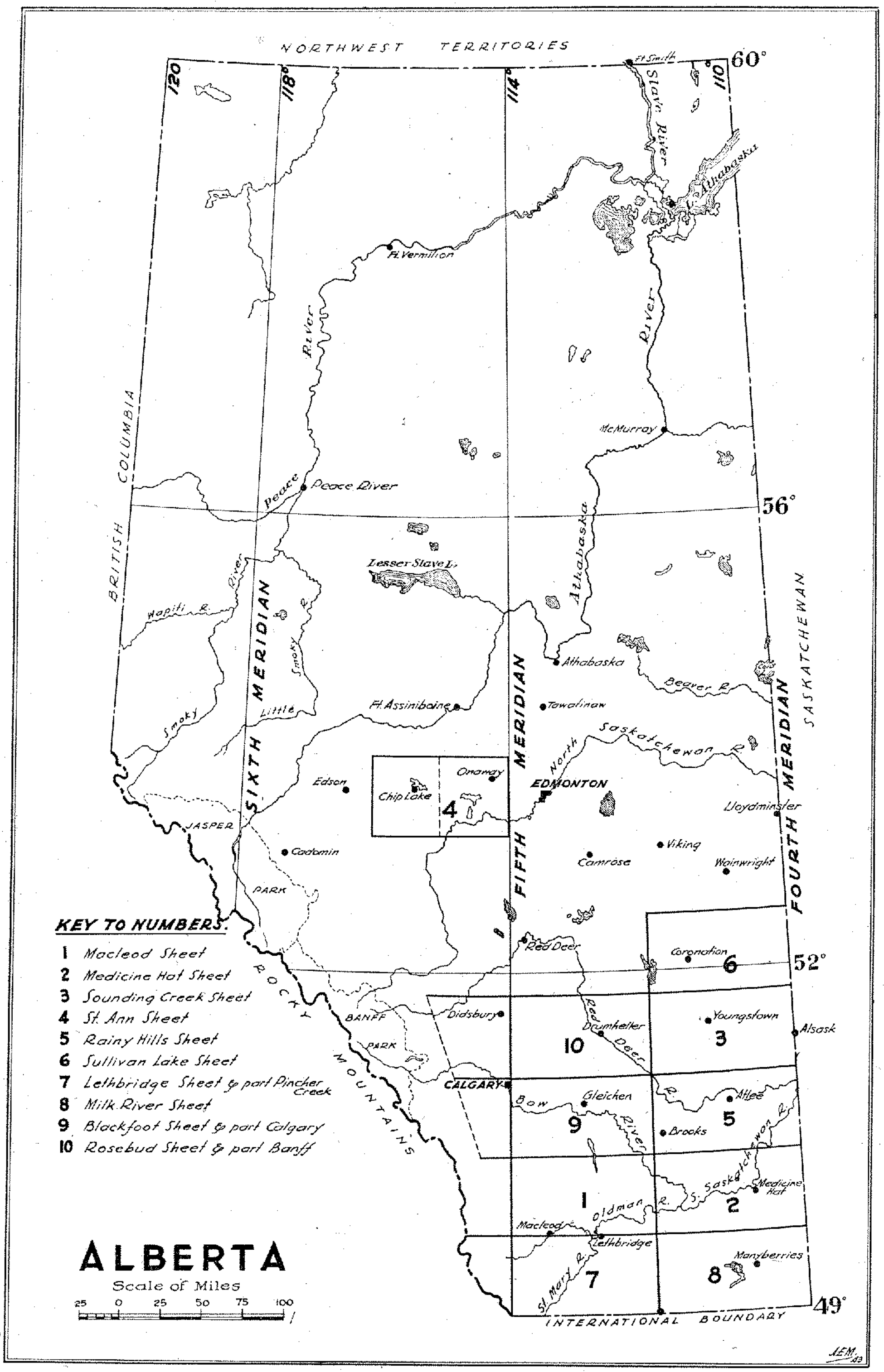
TABLE OF CONTENTS

PLATES 17 TO 44 INCLUSIVE

Edmonton, Alberta

1943

PLATE 17



Sketch map of Alberta showing locations of map areas for which soil survey reports have been published and in which the geology of the soils has been discussed.

PART III.

GEOLOGY OF ALBERTA SOILS

BY J. A. ALLAN

INTRODUCTION

During the past eighteen years a soils survey has been carried out by the Soils Department at the University of Alberta under the direction of F. A. Wyatt. The classification of soils is directly related to the geology of a district and the writer as geologist in the Research Council of Alberta, has co-operated to the fullest extent in this soil survey by examining and investigating the relation of the surface soils to the underlying geological formations. In this work the writer has endeavored to interpret the origin of the soils in each of the map-areas being studied by the Soils Department in co-operation with the Dominion Department of Agriculture and the Prairie Farm Rehabilitation program.

To date geological co-operation has been given in the soil survey reports on the following areas which are designated by the names of the sectional sheets according to the classification by the Topographical Survey of Canada:

(1) Macleod sheet; (2) Medicine Hat sheet; (3) Sounding Creek sheet; (4) St. Ann sheet; (5) Rainy Hills sheet; (6) Sullivan Lake sheet; (7) Lethbridge and part of Pincher Creek sheets; (8) Milk River sheet; (9) Blackfoot and part of Calgary sheets; (10) Rosebud and part of Banff sheets. (Plate 17.)

These map-areas are numbered in the order in which the surveys were made. Only a limited time each field season, has been spent on the geological investigations in each of these areas, and no attempt has been made to work out in detail the geological structure or the surficial deposits in any of these areas. Such a detailed geological investigation would require much more time than has been available in the past for this co-operative work.

In this report a few geological observations particularly related to the soils are recorded on each map-area, Rainy Hills (1936), Sullivan Lake (1937), Lethbridge and Pincher Creek (1938), Milk River (1939), Blackfoot and eastern part of Calgary (1940) and Rosebud and eastern part of Banff (1941). The geological investigations consisted in observing the surface deposits and in correlating these unconsolidated surficial deposits with the various soil types as mapped by the soil survey party. Reports of soil surveys of each of these map-areas have been published by the College of Agriculture, University of Alberta, as Bulletins 28, 31, 32, 36, 39 and 40 respectively.

GEOLOGY OF SOILS

The geology of the soils in Alberta is quite important to the industrial development and in some districts even more important than the bedrock geology. From the geological point of view soils may be regarded as young deposits of Pleistocene or Recent ages and are unconsolidated rock. Natural soil consists of a complex mixture of mineral and rock fragments, very fine rock flour, decayed or partly decayed plant fragments and other remains of various classes belonging to the animal kingdom. Some soils are made up almost entirely of rock particles, but other soils, like peat, are made up largely of decayed plant material. Most soils in which plants are grown are made up chiefly of a mixture of small rock fragments and varying amounts of decayed plant material.

The inorganic part of soil consists of mineral and rock particles which vary in size and shape, but these particles have been derived at some time and in some way from solid rock formations. This unconsolidated mantle of weathered rock material when acted upon by organic agencies and mixed with organic matter, may contain the required conditions to support vegetable growth. When rocks are exposed at the surface, various chemical and mechanical agents of erosion act upon the rock surfaces and slowly transform the solid rock into soil. The more soluble constituents in the rock are first affected and the structure of the rock is weakened. The less soluble portions of the rock remain to form the regolith or unconsolidated mantle which may be further broken up by mechanical agents of erosion to produce gravel, sand, clay or silt. If the rock debris produced by weathering is not removed by other agents then the product is residual soil, that is, soil which has been formed *in situ* from the underlying rock. Soils formed in this way will have some of the physical and mineral characteristics of the underlying rock.

All soils are formed from the decomposition and disintegration of rocks, but all soils are not formed from the rock immediately underlying the soil. There are four major processes in the development of soil, namely, decomposition, distintegration, transportation and deposition.

Most soils have been transported from their original source and have become mixed during the process of transportation. The three principal transporting agents are wind, running water and ice in the form of glaciers. However, transported material must eventually come to rest and here the fourth process in the development of soil, namely deposition, results. The material transported by wind or by glaciers may be deposited on a land surface. Such deposits transported by wind are known as dune, eolian, or some loess deposits. Moraines are deposits left from the melting of glaciers. Water transported material is usually deposited in bodies of water, such as lakes, giving rise to lacustrine deposits, swamps as palustrine deposits, and along the margin of river courses as alluvial soils. In water transported deposits there is greater sorting action and the finer particles will be carried farther than the coarser particles. Such deposits might vary from the finest clays and silts, and even colloidal particles, up to the coarsest of gravel. This fact often explains why the texture of a soil may change materially even within the same section of land. During the process of transportation, the debris from many kinds of rocks become mixed and the soils produced from these transported deposits may be heterogeneous mixtures and of complex mineral composition as, for example, a soil produced from weathering of an interbedded sandstone-shale formation will be different from a soil derived from a shale formation, or from shale and granite rock debris, and so on.

There is still another kind of unconsolidated material influenced by water transportation. Rain falling upon any kind of surface deposit such as glacial moraines, residual soils or wind deposits may wash out the finer rock particles and deposit them further down the hillside or on the flats at the bottom of the slopes. These are known as alluvial fans or outwash plains. The character of the soil in these outwash areas might be quite different physically and even chemically from the soil on which the outwash has become deposited.

These introductory notes on the origin of soils are given to make it clear that there is frequently an obvious and close relationship between the kind of soil and even the depth of soil in an area and the geology of the district. There is obviously no sharp line of demarcation in surficial unconsolidated deposits between what may be called soil and what may be called gravel, sand, till, or boulder clay. In some parts of Alberta, particularly in the mountains, or in the Precambrian rock area in northeastern Alberta, certain types of vegetation grow on gravel deposits and even in fractures on rock surfaces void of soil. In the latter case the plants derive their food from decomposed products of minerals in the solid rock. If the rock contains potash-bearing minerals, the rock decay will produce potassium carbonate which is favorable to plant growth. Other rocks with a phosphate content will support a luxuriant plant growth even though the soil is scarce.

ORIGIN OF ALBERTA SOILS

The rocks in Alberta range over a wide age from the oldest, Precambrian, to quite young Tertiary strata, and all are capped by an unconsolidated mantle of clay, sand and gravel which constitute the soils. The age range between the oldest and the youngest rocks in Alberta is, according to geophysicists, about 1,600 to 2,000 million years. Some of the rock formations were formed from sediments deposited in seas, or in lakes, some marine, some freshwater, or in rivers or broad flats, or in sand dunes formed from wind action. Alberta is underlain by rocks with a wide range in chemical composition and in kind, and these rocks produce an equally wide range in soil types.

In Alberta there are three major physical divisions—mountains, foothills and plains. In the mountains, the oldest rocks are exposed, made up chiefly of limestones, sandstones, quartzites, shales and in some places the shales have been changed to slates. The soils within the mountains have been formed locally from these rocks. In the foothills, the rocks are folded and broken and are largely younger than those within the mountains, but older than those under much of the plains area. These rocks consist chiefly of sandstones, shales, carbonaceous shales and coal seams. Most of the soils in the valleys and lowlands between the foothill ridges, have been derived from the decayed rock on the ridges, or partly from outwash from the mountain ranges. There cannot be a very wide range in the composition of the soils throughout the foothills because all these soils have been formed from similar rocks. The foothill soils between Cochrane and Cardston, that is, south of the Bow valley, will be quite similar in mineral composition to those soils in the foothills between the Bow river and the Athabaska river, except locally where the factors contributing to the formation of the soil may be quite different within small areas.

The outwash from the rock debris within the mountains and within the foothills has been carried eastward principally by the rivers and has become mixed with other unconsolidated material of local or of glacial origin on the plains. The soils on the plains will be more varied, depending upon the source of the rock material making up the soil. The plains are underlain, in large part, by rock formations chiefly younger and softer than those in the foothills belt.

The younger rock formations under the plains consist chiefly of soft sandstones and shales, including sandy shales and clayey sandstone, and all are easily disintegrated to form soil. Some of the sand is of such a texture that it is moved about easily by wind. There are no limestone formations near the surface under the plains to influence the soils. If the soils in any area on the plains contain much limestone, then that limestone material must have been transported by ice or by rivers from the mountains, where the only limestones in Alberta come to the surface.

CHARACTER OF UNCONSOLIDATED MATERIAL

There are three sources from which unconsolidated materials are derived and therefore there are three different origins of soils in Alberta:

1. Residual soils,
2. Transported soils,
3. Resorted or mixed soils.

Residual soils are formed from the weathering and decay of the underlying rocks. If the underlying rocks from which the residual soils have been formed, contain alkalies, or salt or alum or other soluble minerals, then these mineral impurities will show up in the residual soils unless the soluble minerals have been subsequently removed by leaching. On the other hand if alkalies are not abundant in the rock, these impurities will not be abundant in the residual soils formed from such rocks. Residual soils are common in Alberta and frequently they are formed from softer shale formations, often of marine origin containing soluble mineral impurities like alkalies or alum.

Transported soils consist of rock debris transported great distances by ice, water or wind and the composition of this type of soil differs from the underlying bedrock. Ice has been the most widespread transporting agent in Alberta. There were two sources of the ice sheets which for a time extended over a large part of the plains and foothills of Alberta. The Keewatin ice sheet extended from the northwest side of Hudson Bay, across the Precambrian Shield and reached Alberta from the northeast. The material left by this glacier consists chiefly of debris from Precambrian rocks, many of them high in potash, magnesia and alumina.

The other ice sheet was from the northern Cordillera. Glaciers flowed through the valleys within the Rocky Mountains and spilled out eastward through the transverse valleys of the Peace, Athabaska, Saskatchewan and Bow, into the foothills of Alberta, to form a piedmont glacier which advanced eastward from the front of the mountains. The debris left by this ice sheet consists largely of rock from the mountains where limestones and dolomites predominate. On this account the glacial debris in Alberta differs according to the source of the debris. For the same reason the soils later developed on the rock debris brought by the glaciers from the northeast differ from those formed from the mountain rock debris. Rivers also moved about the finer material down the surface slopes chiefly from west to east. Water transported soils are also widespread and wind carried deposits are of more local distribution.

Resorted or mixed soils are widely distributed. It is almost impossible to recognize the boundaries between the resorted deposits and the older glacial or alluvial deposits. The reworking of the unconsolidated deposits by rain, running water or wind has produced mixed soils. Outwash from eastern moraines may be mixed with residual deposits or with alluvial debris brought from the west or from moraines derived from the mountain glaciers. Mixed soil types can only be defined after detailed field soil surveys have been made. A knowledge of the kind of soil in any part of Alberta is necessary for the intelligent development of the area. The soils in some areas are suitable for one kind of agriculture but not for another.

RELATION OF THE GEOLOGY TO THE SOILS IN THE RAINY HILLS SHEET

Surface Features

The area embraced by the Rainy Hills sheet is part of the Alberta plains. The surface of this plain is gently rolling except adjacent to the main drainage courses where the surface becomes more irregular.

The Red Deer river extends with a meandering course across the northern half of the sheet. The postglacial valley is deeply incised into the plain, and varies in depth from one hundred to 350 feet below the general plain level. The valley is over one mile wide in most places. The widest part of the valley is from the vicinity of Steveville south through ranges 12 and 11, where it varies from 3 to 4 miles in width. The course of this river across this sheet is about 145 miles long. The elevation of the river where it enters the sheet north of Hutton in township 24, range 15, is 2,134 feet above sea level, and at Empress at the east side of the map-area the low water elevation is 1,911 feet. The difference in elevation between these two points is 223 feet which represents a stream gradient of about one and one-half feet to the mile. The Red Deer valley between ranges 15 and 8 or possibly further east is postglacial in origin.

The South Saskatchewan river cuts across the southeast corner of Rainy Hills sheet. The river enters the sheet in range 5 where the stream elevation is 2,021 feet above sea level and passes out of the sheet in township 22, range 1. The elevation at the fourth meridian is 1,902 feet. The river on the Rainy Hills sheet is 75 miles long and the average stream gradient is 1.57 feet to the mile. The valley of the South Saskatchewan is also deeply incised into the plain, one hundred to four hundred and fifty feet deep and approximately one mile wide. It is a youthful valley and is also of postglacial origin.

These two valleys give extensive exposures of the rock formations. There are almost continuous rock exposures along both sides of the South Saskatchewan river within the sheet. Along the Red Deer valley the rock exposures extend all the way from the northwest corner of the map in range 16 downstream to the west side of range 10 near Parvella. There are also continuous rock exposures in range 4 from the vicinity of Alkali creek to the west side of range 3.

There are a number of small valleys tributary to both sides of the Red Deer and cutting back into the uplands, but these do not contain running water except for a short time in wet seasons.

On the upland there are four prominent hills. The Middle Sand hills are on the west side of South Saskatchewan river in townships 18, 19 and 20 and consist chiefly of dune sand. The Outer Rainy hill rises about one hundred feet above the plain at the south boundary of the sheet, chiefly in township 17, range 10. The Inner Rainy hill is a pronounced physical feature in range 10, extending from the north half of township 19, northwards beyond Iddlesleigh into township 21. The top of this hill is about 2,600 feet above sea level. The fourth group of hills on the sheet occurs in township 20, range 6, south of Majestic. The top of this group has an elevation about 2,675 feet above sea level. This is the highest point recorded within the Rainy Hills sheet. These last mentioned three groups of hills are *residual hills,* that is, they are remnants of erosion as the surrounding plains have been worn down by erosion agents. All three hills are capped by the Bearpaw shale formation which has not been removed by erosion from the underlying Belly River beds.

Sub-surface Geology

The geological formations which occur at the surface or immediately below the unconsolidated deposits in the entire area of the Rainy Hills sheet belong to the Upper Cretaceous (Plate 18). There are three formation represented by the rocks under this map-area, which in order of age, from the youngest formation to the oldest, are as follows:

Bearpaw—mainly marine shales.
Belly River series:
- Pale beds (Oldman)—non-marine sandstone and shale.
- Foremost—non-marine, brackish water, sandstone and shale.

The Belly River rocks consist of two formations, the Foremost below and the Pale beds above. These two formations are somewhat alike and in places are difficult to distinguish from one another. The main difference is one of colour. The Pale beds are lighter in colour than the Foremost which are sombre and brownish.

In the Rainy Hills sheet the Foremost member of the Belly River series is exposed only along the South Saskatchewan river, from the south boundary of the sheet, downstream through townships 17, 18 and south half of 19, chiefly in the narrow gorge formed by the river where only about 90 feet of the upper part of this formation are exposed. There are several coal seams in the Foremost, but none were observed in the map-area. The total thickness of the Foremost in the vicinity of Medicine Hat is about 350 feet. The strata in the Foremost consist chiefly of brownish and yellowish sandstones and shales interbedded.

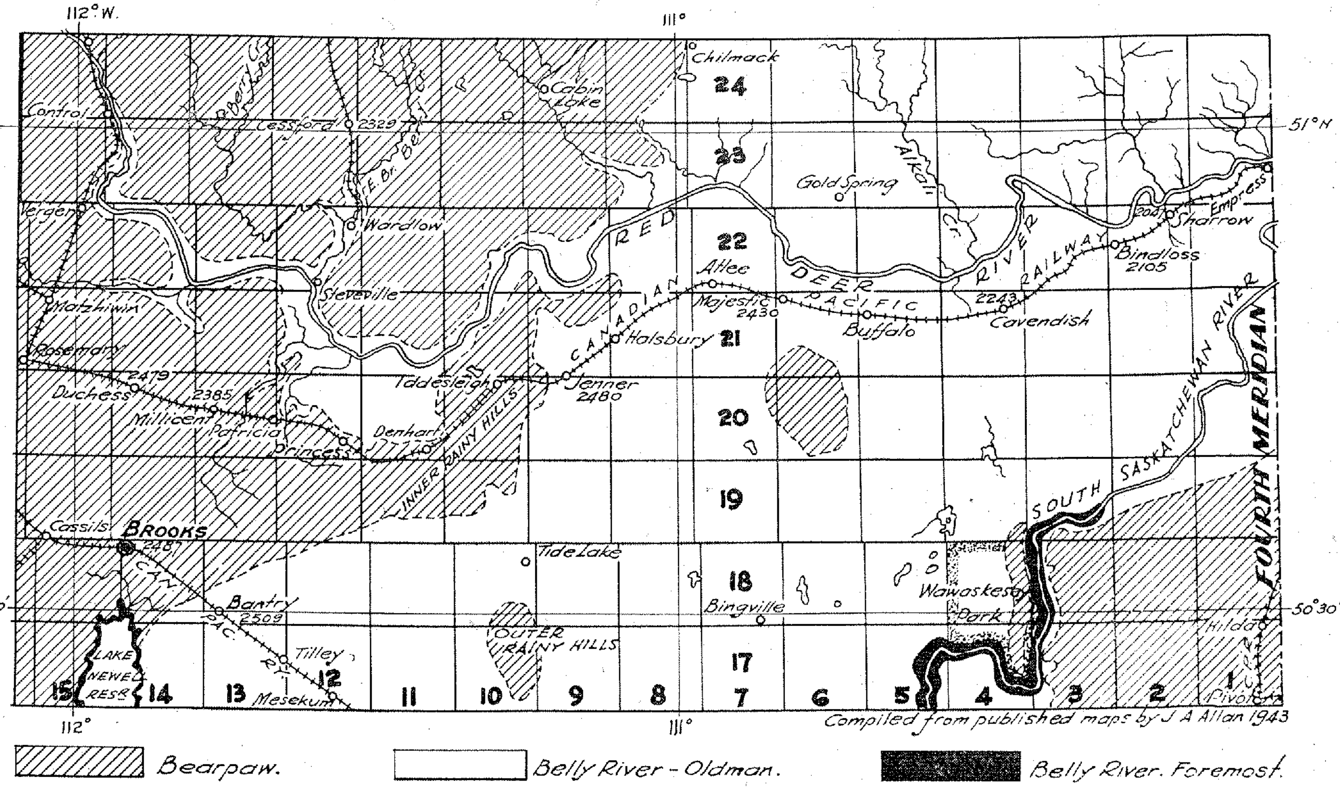
The Pale beds have a wide distribution in the Rainy Hills sheet. On the south boundary of the map-area the Pale beds extend from The Rapid Narrows on the South Saskatchewan river in range 3, west to Lake Newell in range 14. On the Red Deer the Pale beds extend from Empress, upstream almost completely across the map into the centre of township 24 in the vicinity of Hutton. There is a continuous exposure along the sides of the Red Deer valley west of range 8 and including the famous badlands in the Steveville district from which scores of more or less complete dinosaur skeletons have been collected (Plate 19A). Specimens from these fossil beds are on display in the museum in the Department of Geology at the University of Alberta (Plate 19B). Large exhibits have been prepared in the National Museum, Ottawa, the Royal Ontario Museum, Toronto, and the American Museum of Natural History, New York. The Pale beds are also exposed along an old river course which occurs along the south border of township 17, range 8, and which is shown distinctly on the accompanying map. Along this old channel the Pale beds are overlain by Bearpaw shales, but the area was so small that they are not shown on the geological map (Plate 18). A complete section of the Pale beds, 350 feet thick, is exposed in the deep gorge on the South Saskatchewan river in the vicinity of The Rapid Narrows in townships 17 and 18. There is a continuous exposure of the Pale beds throughout the whole extent of the South Saskatchewan river on this map-area. On the north boundary of the Rainy Hills sheet the Pale beds form the surface member west to about range 7.

The Pale beds are of freshwater deposition and consist of "pale" yellowish sandstones and shales often lenticular in form. Cross-bedding is common in the sandstone. Frequently there is bentonite in the strata, which when wet forms a very slippery surface. Concretions of hard sandstone and often clay ironstone are common in this formation. In the badlands erosion has developed fantastic mesas and pinnacles, producing a beautiful scenery of a very high order. This scenery attracts many visitors and is worthy of wider publicity to interest the tourist. Coal seams occur chiefly near the top of the formation and are exposed in ranges 14 and 15. Coal from these seams has been mined in the vicinity of Hutton in township 23, range 14.

At the close of Belly River time the land surface was submerged and the sea covered this part of Alberta. In this area were deposited marine muds which have been consolidated into shales. These shale strata form the Bearpaw formation which is of marine origin. The Bearpaw consists mainly of shales varying in color with grey, brown and green predominating. There are occasional beds of sandy shale and a few bands of ironstone nodules. There are several bentonitic beds in this formation. One of the chief characteristics of bentonite is that it absorbs water rapidly up to seven times its own volume and forms a very soap-like clay. Small quantities of bentonite mixed with clay is commonly known as "gumbo". Where these bentonitic shales occur at the surface gumbo clays are produced which are very slippery when wet. The characteristic is readily recognized when driving along the roads after a rain storm, particularly in the northwest corner of the Rainy Hills sheet, such as in the vicinity of Bullpound, Berry and Blood Indian creeks.

The Bearpaw shales are almost entirely free from lime so that any soils formed from these rocks will not contain any appreciable amount of lime unless it has been washed in from the glacial till.

Calcium sulphate in the form of gypsum crystals occurs rather abundantly in this formation. Sodium and magnesium sulphates have been observed by the writer in areas where the Bearpaw is the surface formation. These sulphates are at least in part responsible for the alkali content of the soils and particularly the alkali flats in the northwest part of the Rainy Hills sheet as shown on the map. The alkali flats south of Brutus along the old river channel at the south end of township 17, range 8, have been formed from the Bearpaw strata which occur over the Belly River on the south side of this old valley.

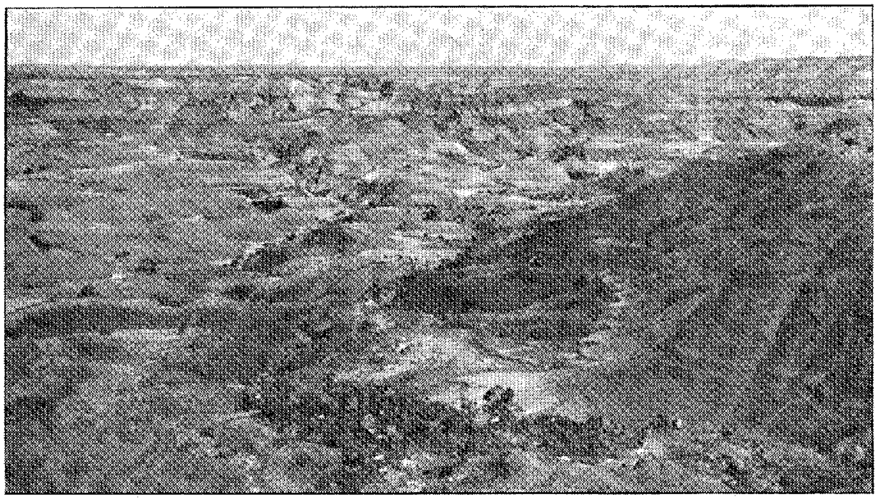


GEOLOGY OF THE RAINY HILLS SHEET

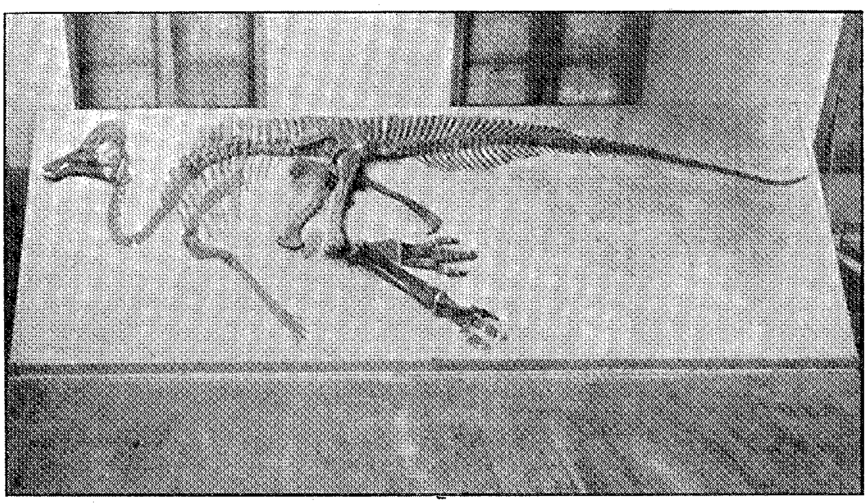
Scale of Miles: 6 0 6 12 18

A.M. 1943

PLATE 19



A.—Badlands in Belly River formation in valley of Red Deer river south of Steveville.



B.—*Corythosaurus* sp., a fossil dinosaur collected by G. F. Sternberg in Belly River (Oldman) beds from Red Deer river badlands, 90 feet below prairie level, in township 20, range 12, west of fourth meridian. This fine specimen is exhibited in an oblique mount in the Geology Museum, University of Alberta.

The Bearpaw shales form the surface member in the extreme southeast corner of the Rainy Hills sheet on the east side of the South Saskatchewan river in townships 17, 18 and 19. It also caps the Belly River on the west of the river gorge in range 4. The largest area of Bearpaw is in the northwest part of the map-area. The contact between the Bearpaw and Belly River is not exposed, but it occurs approximately along a line from Lake Newell in a northeasterly direction, passing east of Inner Rainy hill, and Iddesleigh, and northwards to some point near the east side of township 24, range 8. Along the valley of Red Deer river west of range 8, the Bearpaw overlies the Belly River.

At one time the Bearpaw extended across the whole of the area included in the Rainy Hills sheet, but erosion has removed these shales from the central part where the Belly River now forms the surface member. There are two small islands of Bearpaw, as shown in Plate 18. These are represented by Outer Rainy hill in township 17, range 10 and the hilly area in township 20, range 6 south from Majestic and Buffalo on the Canadian Pacific Railway. It is believed that the Bearpaw shales have been to a large extent responsible for the formation of the "blow-out series" of soil types which are shown on the accompanying map to be widely distributed west of range 8 in the Rainy Hills sheet.

Origin of Surficial Deposits

It is not always possible to determine the origin of the surface deposits in certain areas, because frequently the unconsolidated material is of mixed origin. This is particularly true in the case of reworked deposits such as outwash plains, alluvial and marginal deposits.

The soil differs from underlying deposits upon which it is developed in that weathering agents have changed its original texture, color and composition. In some soils the accumulation of organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. In most cases surface leaching has deprived the soils of certain original minerals, and often the mineral content of the subsoils has been changed. In many of the soils in the Rainy Hills sheet the calcareous content has been reduced by process of weathering and an increase of the lime content occurs in the subsoil. In general it is a fact that the surface unconsolidated deposits in the Rainy Hills sheet are lower in calcium carbonate than are the deposits to the west and southwest of the map-area. This is due to the fact that the older rocks underlying much of the Rainy Hills sheet are lower in calcium content than are the younger rock formations closer to the foothills. On the other hand, if the unconsolidated deposits contain certain soluble minerals these are brought to the surface in the ground waters, and in such cases the soils will be richer in those minerals than the subsoils. All these conditions have to be considered in explaining the origin of the soil types that occur in the map-area.

The unconsolidated deposits in the Rainy Hills sheet can be classified into four major types:

1. Glacial moraine, unsorted.
2. Resorted glacial deposits.
3. Transported deposits of alluvial, lacustrine and dune or eolian origin.
4. Residual deposits.

Most of the surficial deposits in this area are of glacial and postglacial ages. The preglacial topography has not yet been determined in detail. It is known however that there was a preglacial drainage in a few places. It has been mentioned that much of the present courses of the South Saskatchewan and Red Deer rivers is of a youthful character and has been formed in postglacial time. The preglacial topography has to a large extent been obliterated by the glaciers which covered much of the Rainy Hills sheet.

It is believed that the Red Deer enters a preglacial valley about range 8 and continues in this old valley much of the way to the confluence with South Saskatchewan river about 5 miles east of Empress. This accounts for the lack of rock exposures along this part of the present valley. There was also a preglacial valley extending westward from The Rapid Narrows in township 17, range 3. There might have been several tributary valleys to the west, but at least one of these old valleys is seen in township 17, range 8, south of Brutus.

The glacial deposits consist of till or boulder clay in the form of moraines which have been left by the ice sheet. These deposits are unstratified and consist of an unsorted mixture of boulders, gravel, sand and clay.

Morainal deposits are distributed widely in the Rainy Hills sheet, particularly in ranges 1 to 5 on the east side, and in ranges 13 to 15 on the west side of the map-area. The thickest moraine occurred along the eastern side of the sheet. Boulders are common from the Hilda district to Empress. The Middle Sand hills, between the South Saskatchewan and the Red Deer are very sandy and in part were formed as sand plains marginally to the last retreat of the continental glacier. These deposits have been resorted. The wind has developed dunes which are migrating in an easterly direction. To the west reworked glacial deposits extend west for several miles. There are also outwash deposits from the glacial moraine extending to the centre of the sheet. In many areas boulders are common, and in places a stony surface has been developed from the ground moraine by the removal of the finer materials in the moraine. Occasional boulders are found over much of the sheet, but many of these have been transported from the main morainal belts. Boulders are very common along the west side of the Middle Sand hills belt.

A thick morainal covering is also quite evident in the western side of the sheet in ranges 13, 14 and 15. Here again there has been much resorting of the material. There is considerable eolian material principally wind-blown sand in the northwest corner of the Rainy Hills sheet. In these areas there are no boulders visible, while in other areas the boulder content increases until in some spots the surface is high in coarse gravel from which the finer material has been blown or washed.

It is not possible with the data available to differentiate the morainal and resorted morainal areas on this sheet. In some cases outwash plains have been formed from deposits carried out by streams coming from the margin of the ice sheet. One such plain occurs at the northeast corner of the map-area. This is the south continuation of the Acadia valley plain and it has been, at least in part, built up from the finer material washed out of the glacial moraine which occurs both to the east in range 1 and to the west in ranges 3 and 4.

The third type of surface material includes the transported deposits. The transporting agents are wind and running water, either in streams or as run-off. The former gives rise to dunes or eolian plains, the latter to alluvial, flood plain and lacustrine deposits. Transported soils are bedded in character due to the sorting action of the transporting agents. The sand and clay may occur in separate layers, forming a sandy soil or a clay soil. These deposits may also be a mixture of sand and clay with varying proportions of each, giving rise to a sandy clay, a clay loam or a sandy loam soil. The dune areas in the southeast part of Rainy Hills sheet and in the northwest corner of the sheet have been described in dealing with glacial deposits because much of the eolian sand has been derived from glacial or glacio-lacustrine deposits. There are also eolian deposits associated with the "blow-out" areas shown on the accompanying map, throughout the western half of the sheet.

The alluvial deposits are distributed along the present drainage channels as flood plains and flats and terraces and along the old preglacial channels such as those described above. These alluvial plains are usually irregular in extent and limited by the shape of the valley. There are prominent alluvial plains in the vicinity of Parvella, north of Atlee, at Steveville and north of Hutton.

Due to the pronounced slopes of the sides of the Red Deer and other smaller valleys, the finer materials from the drift on top or from the rocks exposed in the sides of the valley have been removed by the "run-off' and washed down and spread out over the floor of the valleys. This characteristic is marked in the "badland" area, such as those in ranges 11 and 12 on the Red Deer. Differential erosion by water and wind has produced fantastic forms of buttes, mesas and pinnacles. This grotesque landscape is known as "badlands". Where badlands are formed throughout the sheet the covering of glacial material is usually thin.

There are many dry valleys which indicate earlier drainage and the floors of these usually contain water-sorted soils. No attempt will be made to mention many of them, but this type occurs east of Bingville, north of Middle Sand hills in range 4, tributary to Alkali creek, and in the northwest corner in townships 23 and 24, range 15, as well as many other points.

The lacustrine deposits consist chiefly of clays and fine sand deposited on lake basins, sometimes large but usually small in area. There may be a small lake remaining or there may not be any surface evidence of such a lake at the present time except a broad plain surface. In this type of deposit the character and composition of the soil are usually quite uniform. Lake Newell is the only large lake at the present time on the Rainy Hills sheet and is now used as an artificial reservoir for irrigation purposes. This lake basin is of glacial origin as it occurs in the moraine. This lake at one stage was much larger than it is today as there are lake deposits marginal to the present lake. Berry lake is reported to contain water in wet seasons but this lake basin is much larger than is indicated on the map. Many of the small lakes on this map-area are intermittent, as some of them contain water after a period of rainfall.

The fourth type of soil includes the residual deposits formed by erosion processes from the underlying rock formation. Soils formed in this way will have a composition somewhat similar to the composition of the underlying rock from which the soil has been formed. Frequently the residual soils have been reworked and in such cases the composition is not similar to that of the underlying strata. The principal residual soil areas observed are distributed mainly down the central part of the map-area in ranges 10, 11 and 12 where the glacial drift is absent or extremely thin. North of Red Deer river and both east and west of the east branch of Berry creek there is a large area where much of the soil has been formed *in situ* from the Bearpaw shales. These Bearpaw residual soils usually contain a higher alkali content than most of the other types. The extent of all the residual soils has not been determined.

Water Supply

There is a lack of accurate information on the possible water supply or on the possible water-bearing horizons in the Rainy Hills sheet. There is a scarcity of good water on the surface and in shallow wells in much of this map-area, particularly in the central part of the sheet. There are possibly some areas where this does not apply. The presence of irrigation ditches in the western part of the map-area suggests that there is a deficiency of surface water. This deficiency of water may be due to lack of precipitation, to rapid run-off, to the porous surface soils or to sulphate or alkali impurities in the surface soil which make the water unfit for domestic use. It is a fact that water collecting on the Bearpaw shales or obtained from the shales is usually unfit for domestic use due to dissolved salts. There are many stream courses in this map-area but most of these have dry channels throughout most of the year and some are always dry. Experience in central Alberta has shown that the glacial deposits usually contain good water if the deposit is thick enough to collect a water supply. There are water seepages along some of the coulees in the morainal deposits at the western side of the sheet and good water has been obtained in some shallow wells in the sand deposits.

One is not advised to dig or drill a well into the Bearpaw shale. The writer has not come across any good water in wells drilled into the Bearpaw formation in either the Rainy Hills or the Sounding Creek sheets. As it has been stated previously this formation consists chiefly of shales of marine deposition in which the alkali content is high. Good water cannot be expected to be encountered in this formation. In the Bearpaw shale area good water is scarce unless it can be obtained from the overlying glacial deposits, or by drilling through the Bearpaw into the underlying Belly River strata. The depth that would have to be drilled to reach the Belly River would vary with the location as the Bearpaw has a maximum thickness of over 500 feet west of the map-area and thins out to the east to the place where the Belly River reaches the surface.

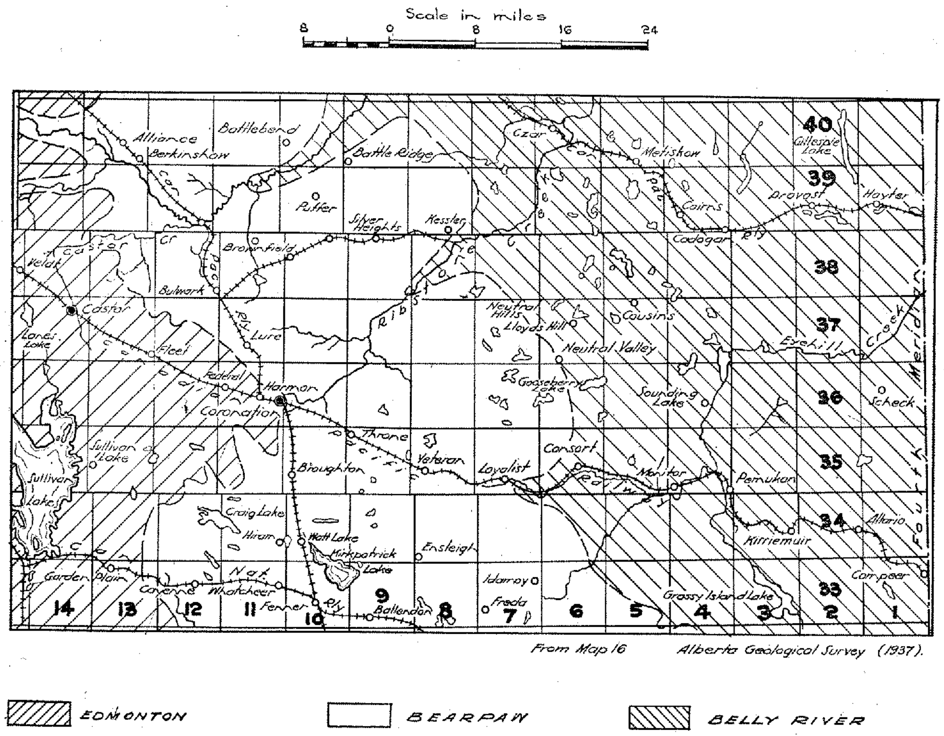
The Belly River strata contain much sandstone suitable as a container of water and are of continental or freshwater origin. It should be possible to obtain good water by drilling into the Pale beds member of the Belly River. North of this map-area and three miles east of Alsask the writer observed a series of strong flowing springs of excellent water coming from the sandstone near the top of the Pale beds. This suggests that water might be expected to occur in some of the uppermost sandstone beds in the Belly River within the Rainy Hills sheet.

In 1936 the Water Development Committee, Dominion Department of Agriculture, drilled No. 1 well north of Atlee on the north side of the Red Deer river in legal subdivision 10, section 10, township 23, range 7, west of 4th meridian. This well was abandoned in 1937 at a depth of 640 feet. The drift is 85 feet thick. Some water was encountered at 25, 99, 270 and 370 feet. No. 2 well drilled in 1938 in legal subdivision 15 of section 10, to a depth of 1305 feet, is a small gas well. The main water horizons were encountered at 315 feet and at 400 feet. The drift is 80 feet thick in this well.[1]

There were no artesian wells found and there are very few running springs. Many of the sloughs in the map-area are at present dry and stock-water supply is a serious problem in some of the districts that are farthest removed from the rivers, thus the water conservation program of the P.F.R.A. will result in benefits throughout the Rainy Hills sheet.

PLATE 20

GEOLOGY OF SULLIVAN LAKE SHEET



SOIL GEOLOGY IN SULLIVAN LAKE SHEET

Physical Features

The Sullivan Lake sheet is in the eastern part of the central plains of Alberta, extending eastward from Sullivan Lake in range 14 to the fourth meridian, which is the eastern boundary of Alberta, and from township 33 to township 40, inclusive, embracing an area of approximately 4,100 square miles.

This geological investigation was carried out in co-operation with the Soils Department at the University of Alberta. More details on the geology in relation to the soils in this area have been included in the report entitled, "Soil Survey of Sullivan Lake Sheet."[2] Only major geological points will be mentioned here.

A correct interpretation of the soil occurrences requires a knowledge of the sub-surface geology, the structure of the rocks underlying an area, and especially the source of the transported soils, and also the sorting and mixing processes which have occurred since the transported material has been deposited by these agents. This detailed geological information is not available in some parts of the Sullivan Lake sheet. Rock exposures are confined largely to the valley slopes along Battle river, Sounding creek, and a number of smaller tributaries where erosion has exposed the bedrock.

The surface relief in the Sullivan Lake sheet ranges from a minimum of 2,000 feet on Battle river at the north margin of the sheet in range 9, to a maximum of 2,955 feet above sea level in Nose hill, 11 miles north of Veteran, and to 2,900 feet in the southwest corner of the sheet in township 33, range 14, west of the fourth meridian. Over 90 per cent of this map-area lies between 2,200 feet and 2,700 feet above sea level.

The greater part of the map-area consists of rolling topography with the exception of a lowland plain extending from Coronation in a southeasterly direction to Kirkpatrick lake and the south boundary of the sheet (Plate 21A). There are two prominent uplands in the Sullivan Lake sheet known as Neutral Hills and Mud Buttes. The Neutral Hills (Plate 21B) have a trend of N.65°W. west of Sounding creek. These hills terminate in the northwest corner of township 37, range 7. Nose hill was formerly part of Neutral Hills but has been disconnected by erosion.

Sub-surface Geology

The areal geology of the Sullivan Lake sheet is shown on Plate 20. This information is taken from the geological map of Alberta (Research Council Map No. 16), prepared by the writer in 1937.

The geological formations which occur at the surface or below the unconsolidated deposits in the entire area of the Sullivan Lake sheet belong to the Upper Cretaceous, with the older rock occurring at the east side of the area. These rocks occur on the east side of the Alberta syncline. There is a gentle dip of the strata to the west and southwest towards the syncline so that the youngest rocks are exposed on the west side of the Sullivan Lake sheet. There are three Upper Cretaceous formations under this area. In order of age from the youngest to the oldest, the formations are:

Edmonton—Non-marine or continental in origin, consisting of soft sandstone and dark shale with some thin coal seams.

Bearpaw—Mainly marine sandstone and shale.

Belly River series—Pale beds formation, consisting of sandstone and shale of non-marine or freshwater deposition.

The distribution of these formations is shown on the accompanying map (Plate 20). In 50 out of 114 townships in this area the Belly River series forms the surface rocks. The contact between the Belly River and Bearpaw may be represented by a line drawn from the centre of the south boundary of township 33, range 4, in a northwest direction to the north boundary of the sheet in township 40, range 10. These strata consist of "pale" yellowish to grey sandstone, clayey sandstone, sandy shale, with lenses and thin seams of coal of a domestic rank. There is considerable bentonite in some of the strata, which when wet forms a very slippery or gumbo surface. The best exposures are in Mud Buttes south of Monitor, along Monitor and Loyalist creeks southwest of Monitor, along Ribstone creek and especially along Battle river in township 39 and 40.

At the close of the Belly River time the land surface was submerged by a sea in this part of Alberta. In this sea were deposited marine muds which have been consolidated to form the Bearpaw shale formation. This marine formation consists chiefly of grey, brown and green shales, sandy shales with ironstone nodules and several interbedded layers of bentonite that produces a gumbo soil. The Bearpaw shale formation underlies 45 out of 112 townships in the Sullivan Lake sheet. Where these shales occur close to the surface, broad flats of heavy soil occur, such as the flat that extends from Coronation southeast to Fitzgerald lake in township 33, ranges 7, 8, 9 and 10. There is a close relationship between the occurrence of the Bearpaw formation where it comes near to the surface, and the "blow-out" areas in the loam and silt loam types of soil.

North of Coronation there is a sandstone member in the Bearpaw formation known as the Bulwark sandstone. This sandstone member is water-bearing and is therefore important as a source of well water. As the strata dip to the west, the depth to this water-bearing sandstone increases towards the west. The depth that would have to be drilled to encounter this water-bearing sandstone would depend upon the location. The entire Bearpaw formation is about 400 feet thick in the Sullivan Lake sheet.

The Edmonton formation is of continental, or freshwater deposition, overlying the Bearpaw and represents the uppermost Cretaceous strata in Alberta. The strata consist of rather soft crossbedded sandstones, light and dark colored sandy shales, bentonitic clays and sandstones and several thin coal beds. This formation forms the surface rock in 17 townships out of 112 townships, and occurs along the west side of Sullivan Lake sheet, chiefly in ranges 13 and 14, with an eastward projection as far as Coronation in township 36.

Origin of Surficial Deposits

It is not always possible to determine the origin of the surface deposits in certain areas because frequently the unconsolidated material is of mixed origin. This is particularly true in the case of reworked deposits such as outwash plains, alluvial and marginal deposits.

The soil differs from underlying deposits upon which it is developed in that weathering agents have changed its original texture, color and composition. In some soils the accumulation of organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. In most cases surface leaching has deprived the soils of certain original minerals, and often the mineral content of the subsoils has been changed.

The surface unconsolidated deposits in the Sullivan Lake sheet are higher in calcium carbonate on the west side of the map-area than in the centre and eastern part of the sheet. This may be explained by the fact that the Edmonton formation which occurs in the western part of the map-area is higher in lime, than the Bearpaw or Belly River strata which underlie the eastern three-quarters of the Sullivan Lake sheet. On the other hand, if the unconsolidated deposits contain certain soluble minerals, these are brought to the surface in the ground waters and in such cases the soils will be richer in those minerals than the subsoils. All these conditions have to be considered in explaining the origin of the soil types that occur in the map-area.

The unconsolidated deposits in the Sullivan Lake sheet can be classified under four major types:

(1) Residual,
(2) Glacial moraine, unsorted,
(3) Resorted glacial deposits,
(4) Transported deposits of alluvial, lacustrine and dune or eolian origin.

The first type includes the residual soils formed by erosion processes from the underlying rock formation. Soil formed in this way will have a composition somewhat similar to the composition of the underlying rock from which the soil has been formed. More frequently the residual soils have been resorted or affected in some way by various transporting agents or erosion and in such cases the composition of the soil is not similar to that of the underlying strata. There are very few areas on the Sullivan Lake sheet where residual soils occur which have not been partly sorted by later erosion. Between Castor and Sullivan lake are patches of residual soil and also at points through the lowlands underlain by the Bearpaw shales and where there has been little if any ground moraine. It is, however, apparent that much of the soil in the "blow-out" areas in the western half of the sheet is in part of residual origin, in places mixed by the different transporting agents.

The second major type includes those deposits of glacial origin which occur in the form of terminal moraine, often quite thick, or as ground moraine, usually thin or represented by scattered glacial boulders and pebbles (Plate 22A).

The glacial deposits in this part of Alberta have been transported by Keewatin glacial ice during the Ice Age from the northeast. Some of the boulders and pebbles have been carried from the Precambrian areas in the vicinity of Hudson Bay. When the ice melted the gravel, sand and clay were left over the surface. If the ice front remained in one position for a longer time, a terminal moraine was formed consisting of an unsorted "dump" of till or boulder clay. If the ice front retreated steadily, a ground moraine was left over the surface. During the thousands of years that have elapsed since the glaciers melted in this part of Alberta, erosion agents in various forms, such as running water or wind, have resorted or washed over the slopes on the moraines and removed the finer materials to lower levels. Glacial deposits which have not been affected by water or wind, can be recognized by the presence of unstratified boulder clay or till without many pebbles and boulders. When stratification or evidence of sorting occurs in the surficial deposit, the material would be classed in the third or fourth type.

The Sullivan Lake sheet contains a portion of one of the morainal belts in Alberta. It has been called the Viking moraine by Dr. P. S.

Warren.[3] This Viking moraine marks the limit of advance of a great ice sheet from the northeast. Warren states that the westerly side of this moraine extends from the west end of Cypress hills northwards to Medicine Hat, then continues in a north northwesterly direction passing east of Steveville, Youngstown, Coronation, Viking, Vegreville and Athabaska. In the Sullivan Lake sheet this moraine forms the Neutral Hills.

It is not possible with the data available, to differentiate the unsorted morainal deposits from the third type, which includes the resorted deposits chiefly of glacial origin. From the Viking moraine, surface waters have removed the finer material and washed gravel, sand, clay and silt down the slopes to the southwest and also to the northeast. Outwash plains have been developed marginal to the thick moraine, and the finer material has been carried further and deposited in numerous local basins.

The fourth type of surface material includes the transported deposits. The transporting agents are wind and running water, either along stream courses or as run-off. The former gives rise to dunes or eolian plains, the latter to alluvial, flood plain and lacustrine deposits. Transported soils are bedded in character, due to the sorting action of the transporting agents. The sand and clay may occur in separate layers or lenses, forming a sandy soil or a clay soil. These deposits may be a mixture of sand and clay with varying proportions of each, giving rise to a sandy clay or a clay loam or a sandy loam soil (Plate 22B). There are 80,000 acres of sand in Sullivan Lake sheet.

It is not always possible to distinguish the fourth type, that is, the transported deposits of recent origin, from the resorted or transported glacial deposits. There are dune deposits formed by wind in the Viking morainal area, chiefly in the eastern end of Neutral Hills to the northeast, and also in the vicinity of Kirkpatrick lake. Alluvial deposits are distributed along the present drainage channels such as Sounding, Eyehill and Ribstone creeks, Battle river and some of its tributaries, and also along old drainage courses that were more active after the ice sheet had melted (Plate 22C).

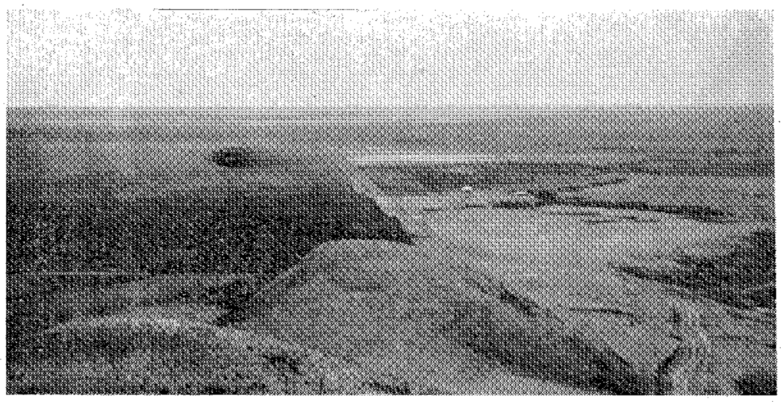
The lacustrine deposits consist chiefly of clays and fine sand and silt deposited in lake basins sometimes large as in the former extension of Sullivan lake, Grassy lake and Sounding lake, but usually small in extent. There is a large lacustrine basin extending from Provost to the north boundary of the map-area.

Water Supply

There is a lack of accurate information on the possible water supply or on possible water-bearing horizons in the Sullivan Lake sheet. The Geological Survey of Canada obtained considerable information on water wells throughout part of this map-area in 1936, but the results have not yet been published and are not available.

The domestic water supply problem is not considered acute except locally. There is usually water associated with the sand area and especially on and along the slopes of Neutral Hills. Springs were observed in section 2, township 34, range 1, about 2 miles from Compeer, and in section 21, township 34, range 3, west of Kerriemuir. The water at Castor comes from beds close to the coal seams and is distinctly coloured by the organic matter, but the quality is reported satisfactory. There is a scarcity of good water reported

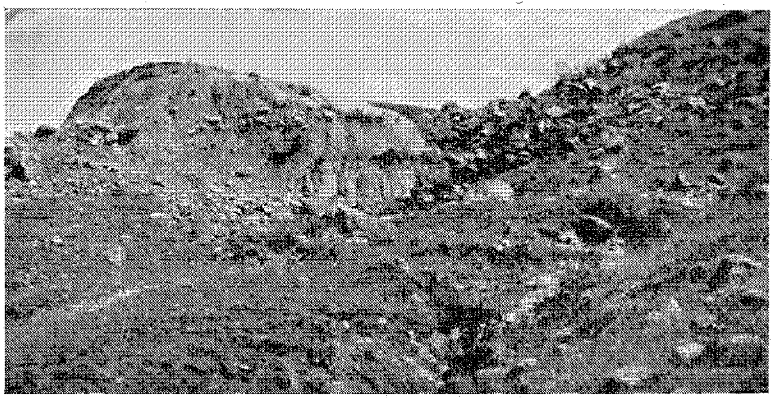
PLATE 21



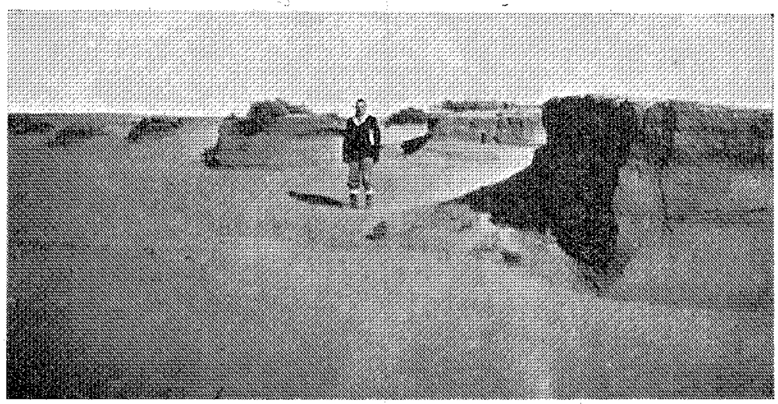
A.—Looking south over an undulating plain to Veteran from the top of Nose hill in township 37, range 9.

B.—Neutral Hills from the south, capped by thick moraine, in township 37, range 7, west of fourth meridian.

PLATE 22



A.—Erosion on Bulwark sandstone in Bearpaw formation in valley of Battle river, southeast of Alliance. The small boulders have accumulated from the weathered glacial till.



B.—Wind erosion on sandy land once cultivated, about 6 miles southeast of Monitor.

C.—Flood plain on Ribstone creek near Airways in secton 36, township 38, range 8.

from the lowlands underlain by the Bearpaw marine shales, due no doubt to the soluble salts associated with these shales.

The Bulwark sandstone which is a marine sandstone member in the Bearpaw shales, is regarded as a good water-bearing sandstone. A good supply of water has been obtained in several wells drilled into this horizon. There should be no great difficulty getting good water in sandstone beds both in the Belly River series and in the Edmonton formation. Fuller details on the water supply cannot be supplied at the present time.

RELATION OF THE GEOLOGY TO THE SOILS IN THE LETHBRIDGE SHEET

Introduction

Co-operating with the Soils Department of the University of Alberta and the Prairie Farm Rehabilitation Program survey the writer investigated the relation of the surface geology to the distribution of soil types as determined by the Soil Survey party.

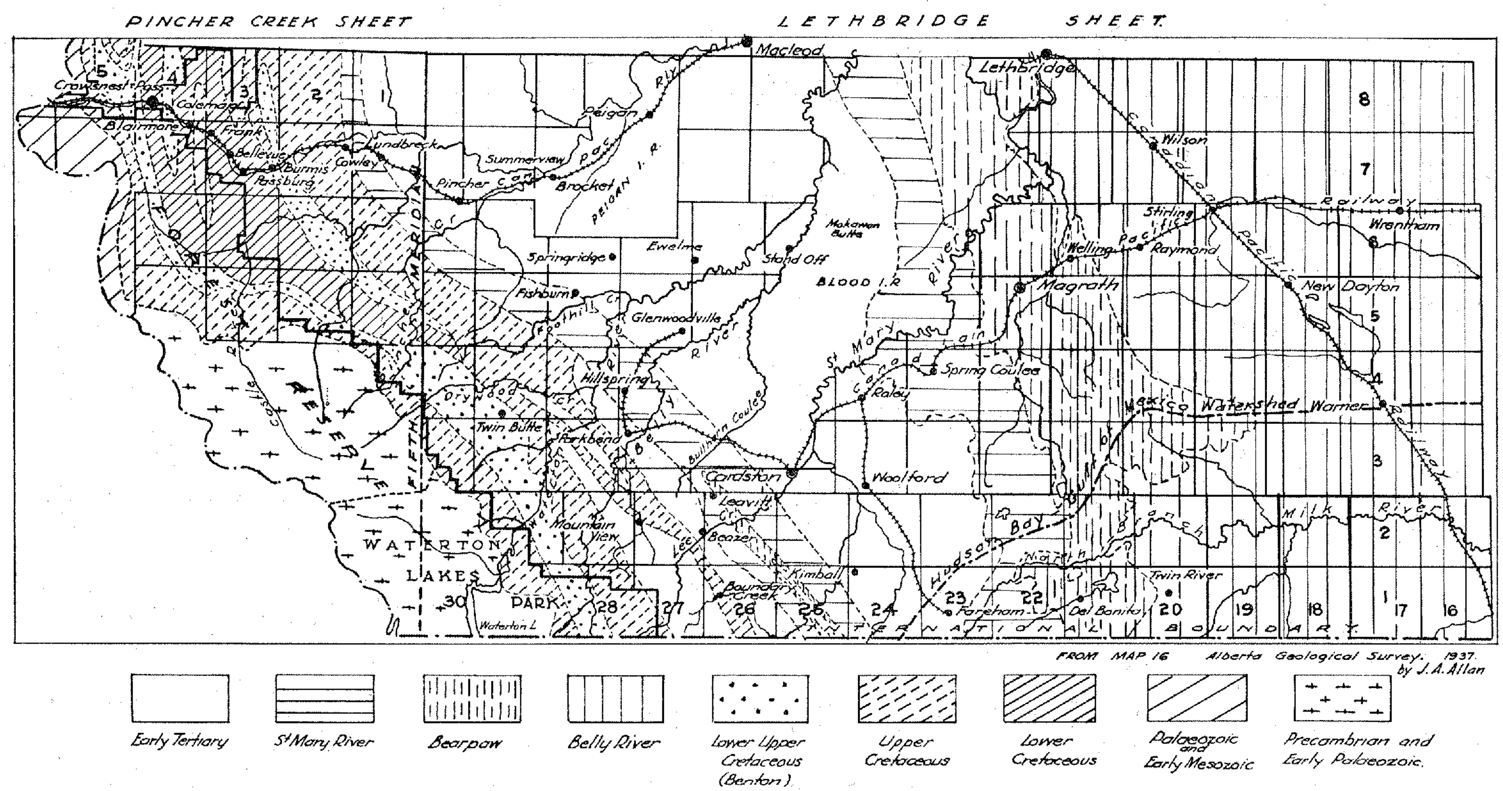
The Lethbridge sheet includes townships 1 to 8 inclusive, and ranges 16 to 30 inclusive, west of the fourth meridian. The western boundary of this map-area is the fifth meridian. The soil survey was extended west to include that part of the foothills belt in townships 5 to 11 and ranges 1 and 2 west of the fifth meridian in the northeast corner of the Pincher Creek sheet, and the southeast corner of the Porcupine Hills sheet. Geological observations were also made in this area. The map-area being considered is shown in Plate 23 and includes that part of southern Alberta from Coutts west to the eastern edge of Waterton Park along the International Boundary line. The northern edge of this map-area includes from the vicinity of Chin coulee west to the front of the Livingstone range in the Rocky Mountains.

Surface Features

The surface of this map-area is represented by the southwestern plains of Alberta and the narrow foothills belt which borders the east side of the Rocky Mountains from Waterton lakes to Crowsnest pass and the Livingstone range. The foothills belt in this area has an average width of 10 to 15 miles, which in most places terminates abruptly on the west in the older rocks of the mountains, but merges gradually into the plains on the east. Elevations in the foothills belt range from 4,200 to about 5,000 feet above sea level. The surface of the plains varies from low relief or broad gentle easterly slopes in the eastern part of the area, to gently or more abruptly rolling character on the west (Plate 24).

Practically the whole of the Lethbridge sheet is classed as plains topography with the exception of the narrow fringe of foothills in the southwest corner, east of Waterton park. The altitude varies from a minimum elevation of 2,800 feet above sea level on Chin coulee, to a maximum of about 5,200 feet in Porcupine hills. The plain-like surface of the Lethbridge map-area is broken by the Milk River ridge in the southeast quarter of the sheet, and the Porcupine hills in the northwest corner of the map-area. The altitudes in the Milk River ridge range from about 4,250 feet at the east end of townships 3 and 4, ranges 18 to 21, to about 4,500 feet south of Spring coulee and about 4,600 feet in the vicinity of Fareham in range 23 at the west end of the ridge. The slopes on the

PLATE 23

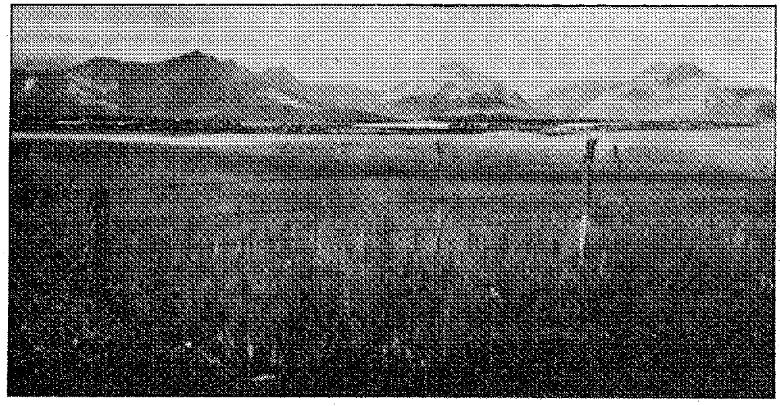


GEOLOGY OF THE LETHBRIDGE-PINCHER CREEK SHEETS

10 5 0 10 20 30

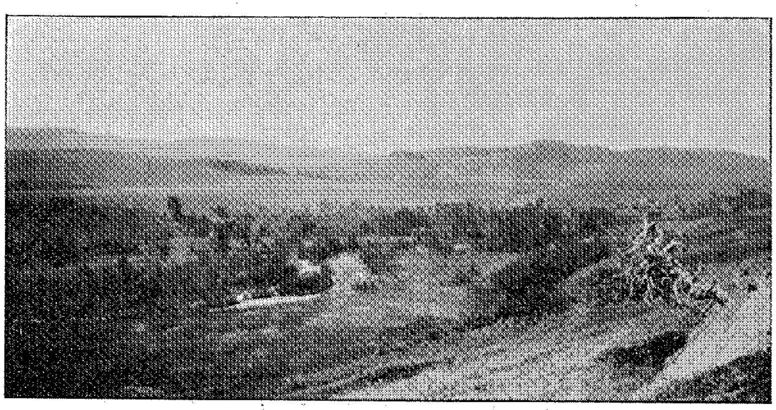
Scale of miles

PLATE 24



A.—Looking west to the Rocky Mountains from section 24, township 4, range 29, west of the fourth meridian, east of Twin Butte.

B.—Parallel rock outcrops in foothills one and one-half miles west of Lundbreck in township 7, range 2, west of fifth meridian.



C.—Pincher creek valley in the foothills near the mountains, in section 11, township 6, range 1.

north face of Milk River ridge are much more abrupt than those in the south. The highest altitude in the Porcupine hills in the Lethbridge sheet is about 5,200 feet but a higher upland occurs north of this area, with an altitude of approximately 5,600 feet above sea level. The south slope to Oldman river is much more abrupt than to the west where there is a series of ridges becoming lower to the west.

Drainage.—The southeast corner of the Lethbridge sheet, south of Milk River ridge, is drained by Milk river which is part of the Mississippi drainage system. Verdigris, Etzikom and Chin coulees are sub-parallel old glacial drainage courses, sloping to the southeast and trending in a northwesterly direction.

North of the height of land which is the top of Milk River ridge the drainage is part of the Hudson Bay system. Milk river enters Alberta from Montana in range 25, thirteen miles south of Cardston and six miles southwest of Kimball. It is joined by Waterton river, the outlet of Waterton lakes, in township 7, five miles north of Stand Off at the base of Mokowan butte. The Oldman river rises in the Rocky Mountains behind the Livingstone range and it is joined by Racehorse creek at the Gap through the range. The Oldman is joined by Crowsnest river, which rises at Crowsnest pass in township 7, four miles east of Lundbreck and two miles north of Cowley, and by Castle river two miles farther east. The Oldman is joined by the Belly river ten miles northwest of Lethbridge and by the St. Mary river six miles south of this city. The St. Mary and the Belly rivers define the east and west boundaries of the Blood Indian Reserve.

There are no large lakes on the plains and foothills but many small ones especially in the foothills, in the western margin of the plains and on Milk River ridge where occur Shanks, Reservoir, Reed, Ross and Woolford lakes. Stirling lake, Tyrrell lake, Chin coulee and other smaller basins are used as irrigation reservoirs.

Within the Lethbridge sheet there are several irrigation districts where operations have been carried out. These include parts of the Lethbridge Northern and A. R. & I. districts in the vicinity of the city of Lethbridge, Raymond, Magrath, Mountain View and United irrigation districts. Other areas being considered for irrigation include the Leavitt, Beaver Creek, South Macleod, New Dayton, Watner and Milk River irrigation projects.

Origin of Surficial Deposits

The geology of the Lethbridge map-area and the foothills belt west of Pincher Creek consists of the unconsolidated surface deposits and the older underlying rock formations (Plate 23). Each of these will be mentioned briefly. More attention was given to the superficial deposits because in the field investigation special consideration was given to the relation between the various kinds of surface deposits and the various types of soils as mapped.

Much of the area in the Lethbridge and Pincher Creek sheets is veneered with glacial deposits left when the ice sheets melted. Glaciation was general over most of the area and the rock debris carried in and on the glaciers was strewn about as deposits of irregular thickness after the ice sheets had retreated from the area. There is also a widespread distribution of reworked glacial deposits, as well as alluvial and lacustrine deposits transported by rivers and numerous small drainage systems. It has not been possible to classify as to origin all types of surface deposits, in the time available for this investigation. There are also smaller areas of residual soils which have been developed by the erosion of the underlying rock formations. In the formation of these residual deposits, transporting agents have not been active, so that the soils formed from the underlying rock will have a similar composition to the parent rock, except in cases where solutions have removed a part of the more soluble constituents. The various types of surface deposits are classified as follows:

(1) Glacial deposits—moraines, tills, boulder clay.
(2) Reworked glacial deposits—outwash plains, etc.
(3) Alluvial and lacustrine and eolian deposits—along river courses, in river terraces, alluvial plains, mud flats and lake basins. These also include wind-sorted and dune deposits.
(4) Residual soils—weathered and disintegrated underlying rock.

The glacial deposits occur as terminal moraines, often quite thick, or as ground moraines, usually thin or represented by scattered glacial boulders and pebbles. The glacial deposits have been derived from one of two sources. The mountain or alpine glaciers originated within the Rocky Mountains and proceeded eastward over the foothills and plains, carrying rock debris from the rock formations within or possibly west of the front ranges of the Rocky Mountains; and the Keewatin or Continental glaciers that originated in the vicinity of Hudson Bay, bringing with them a very different kind of rock debris derived from the Precambrian rocks in the Canadian Shield and also the rock material from the plains over which the glaciers passed. No attempt will be made to discuss in detail the glacial history or the deposits of glacial origin which were left in this part of Alberta.

The morainal material transported from the mountains consists largely of limestone, shale, slate and quartzitic sandstone, or volcanic rock such as that derived from the Crowsnest volcanics in the vicinity of Coleman.

The detrital material transported from the northeast by the Keewatin glaciers consists largely of igneous rocks such as granite, gabbro, gneiss, greenstone, etc., and locally of harder sandstone from the younger rock formations under the plains over which the ice moved.

The mountain glaciers extended down the valleys and spread out over the intervening ridges. The ice was deflected southwards by the Porcupine hills, but spread eastward south of Oldman river. The most easterly extension of these glaciers is not yet known but large boulders of quartzitic sandstone from the mountains were observed at an elevation of about 3,500 feet above sea level, between the Belly and Waterton rivers, four miles northeast of Glenwoodville in the southwest corner of section 29, township 5, range 26, west of the fourth meridian (Plate 25A). This boulder is 25 feet high, 50 feet long and about 35 feet wide above the surface. Other smaller boulders of similar quarzitic sandstone were observed about 12 miles north of Cardston in the Blood Indian Reserve. There is a conglomerate boulder, possibly from the Blairmore formation, about seven feet in diameter, on a hill about four miles east and one mile south of Brocket in the Peigan Indian Reserve. Small boulders and pebbles occur in glacial till from the mountains as far east as Del Bonita in range 21, and north to the top of Milk River ridge in townships 2, 3 and 4. There are mountain boulders in the vicinity of Spring coulee. At the crossing of Milk river, in the northeast corner of section 11, township 1, range 23, west of the fourth meridian, there is a section of two boulder tills separated by about one foot of coarse boulders and gravel. On this exposure the lower dark-colored till is 15 feet thick and contains mountain boulders, but the upper till is yellowish and silty with many small Keewatin pebbles indicating an eastern origin (Plate 25B). This exposure indicates that there is an overlapping of the Keewatin boulder clays and the corresponding material from the mountain glaciers. It would appear that the mountain glaciers extended at least as far east as range 21 and that later the Keewatin glaciers extended considerably farther west and overrode the older mountain boulder clay and moraines. No evidence of glacial boulders was observed on top of Porcupine hills in townships 11 and 12, but boulders are reported as occurring farther north.

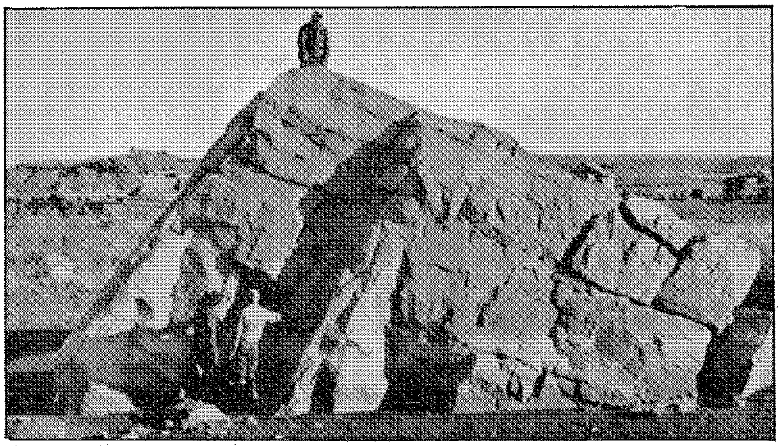
Keewatin pebbles were found by the writer as far west as section 30, township 7, range 30, west of the fourth meridian on the south end of Porcupine hills, and north of Pincher station at an elevation of about 4,225 feet above sea level. Two small Keewatin boulders were found by the writer on the top of a ridge at an elevation of approximately 4,900 feet above sea level, near the west side of section 13, township 3, range 30, between Dungarvan creek and the south fork of Yarrow creek, 20 miles south of Pincher Creek. This is the highest point at which the writer has found Keewatin drift in southwestern Alberta. The high altitude of Keewatin glacial boulders and drift in southwestern Alberta, carried by glaciers from the Hudson Bay district, has been explained by Rutherford as due to uplift during or following glaciation.[4]

The Keewatin drift occurs on the south slope of the Porcupine hills, but the boulder clay of mountain origin is exposed in the bank of the Oldman river, at the north end of the traffic bridge in the southwest quarter of section 17, township 7, range 29, west of the fourth meridian, about one mile northwest of Brocket station. At this point there is a section of 80 feet of till overlain by 6 feet of alluvial gravels.

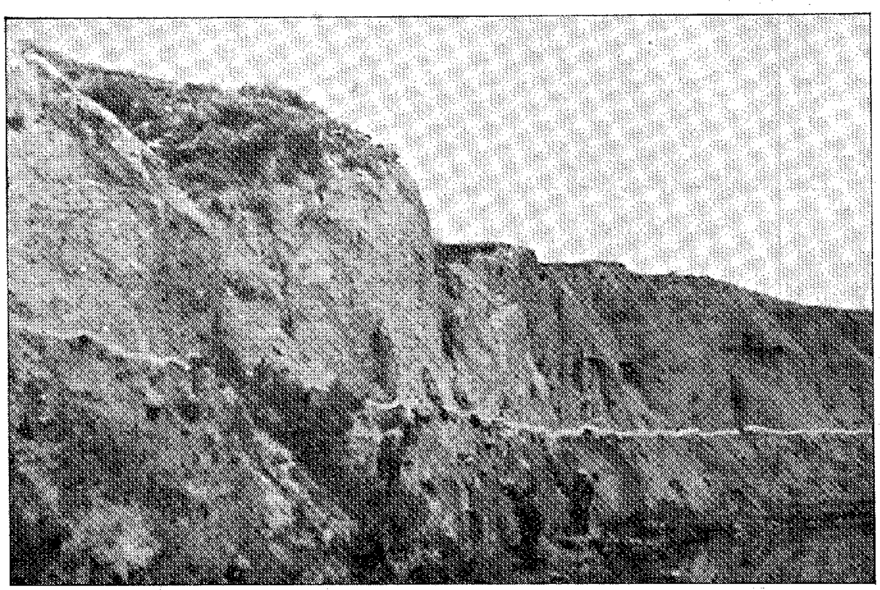
There is a prominent morainal belt from the valley of Pincher creek in township 5, extending in a southeasterly direction across Drywood and Yarrow creeks to Twin Butte. A cluster of lakes on the west tide of the Belly river west of Caldwell and Mountain View are formed in the moraine. Many excellent examples of kettle holes were observed. This morainal belt forms the irregular topography southwest and south of Cardston, and also at Kimball and eastward to Fareham. The irregular upland south of Milk River and west of Coutts is capped with morainal deposits. There are two pronounced narrow ridges of moraine in the northeast corner of the map-area, one parallels the strike of Etzikom coulee on the north side and extends to the junction of the Oldman and St. Mary rivers. The other glacial ridge is about 3 miles north and extends from Wrentham to Lethbridge.

There is a wide distribution of the second type, namely, sorted and reworked glacial deposits. These are common soil types along the eastern, northern and western margins of Milk River ridge. The upland in the Blood Indian Reserve consists largely of these sorted glacial deposits. Where the surface slopes are pronounced, there appears to have been a greater sorting effect in the original moraine. There is very little wind sorting of the silts and finer textured soils except in quite small areas such as those southwest of Cardston, and also west and southwest of Lundbreck.

PLATE 25

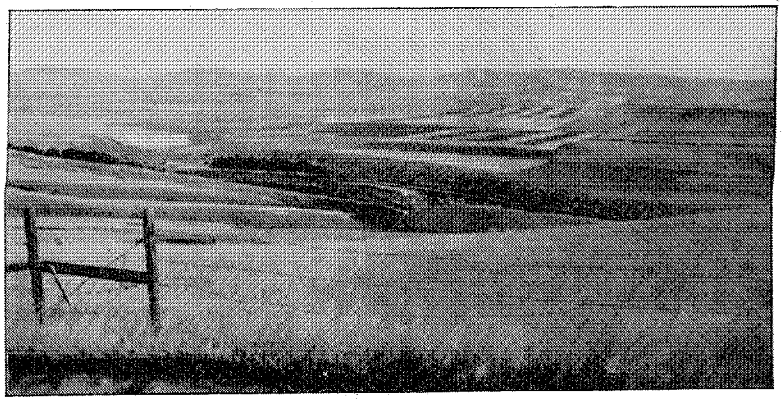


A.—A glacial erratic of quartzitic sandstone of Rocky Mountain origin, 50 feet long, about 35 feet wide and 25 feet high above the surface, northeast of Glenwoodville in section 29, township 5, range 26, west of fourth meridian. Similar erratics occur southwest of Macleod and south of Stand Off.

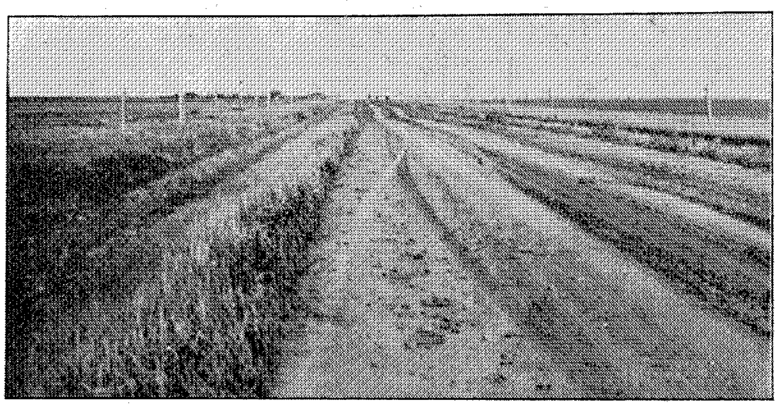


B.—Two boulder tills separated by about one foot of coarse boulders and gravel on Milk river in section 11, township 1, range 23. The till above the white line is of Keewatin origin and the lower till consists of mountain debris.

PLATE 26



A.—Terraces along Oldman river, three miles north of Pincher and on south slope of Porcupine hills.



B.—Del Bonita plateau in section 10, township 1, range 21, west of fourth meridian, underlain by a considerable depth of Saskatchewan gravels.

C.—Mokowan butte, northeast of Stand Off in Blood Indian Reserve, formed by the erosion of the colorful Willow Creek bedrock. Much of the west central portion of the area is underlain by this formation. Belly river flat is seen in the backgrund.

Along the courses of the larger valleys there are several well defined flat-topped terraces, covered with well or poorly sorted gravel, sands and clays. This physical feature is conspicuous along such valleys as the Oldman, Crowsnest, Pincher and parts of the valleys of the Waterton, Belly and St. Mary rivers. Two terraces at different levels are quite common and on the Oldman north of Pincher there are five distinct terraces (Plate 26A). On some of these terraces, there is a thin layer of till or gravel. The highest terrace observed on the Crowsnest river and on the Oldman opposite the mouth of Castle river, is about 200 to 225 feet above the river level.

There is a conspicuous bed of well washed gravel interbedded with the glacial till. This bed was named the "Saskatchewan gravels" by G. M. Dawson in 1896. This bed is interglacial in age, that is, the gravels were deposited between two advances of the glaciers, so are both underlain and overlain by glacial till. The Saskatchewan gravels are exposed along the highway from Lethbridge to the crossing of Oldman river where they are about 15 feet thick and are overlain by till. On the north branch of Milk river, three miles north of Del Bonita post office in section 5, township 2, range 21, west of the fourth meridian, the Saskatchewan gravels are 18 feet thick and consist of smooth, or well rounded boulders and pebbles of quartzites, quartzitic sandstone, metargillite and other siliceous rocks such as occur in Precambrian formations in the Crowsnest and Waterton areas in the Rocky Mountains. In other places these gravels are only about one or two feet in thickness, so the thickness varies considerably. The extent is not yet known, but they are believed to extend into the foothills. This bed of gravel makes a good marker in working out the glacial deposits.

The history of the movements of the glaciers is not yet clearly understood. The glacial deposits in Alberta are now being studied and when the investigation is more complete, it may be necessary to make some changes in the sequence noted below. The glacial debris has been classified by Stewart into seven stages from the oldest to the youngest as follows:[5]

(1) Glacial drift from Rocky Mountains.
(2) Interglacial gravels.
(3) Boulder clay from Keewatin glaciers.
(4) Interglacial beds of gravel, sand and clay.
(5) Drift from the mountain glaciers.
(6) Keewatin boulder clay and till, and partly stratified debris.
(7) Recent fluvial deposits, along river courses.

The third type of surface material includes the transported deposits. The transporting agents are wind and running water, either along stream courses or as run-off. The former gives rise to dunes or eolian plains, the latter to alluvial flood plain and lacustrine deposits. Transported soils are bedded in character due to the sorting action of the transporting agents. The sand and clay may occur in separate layers or lenses, forming a sandy soil or a clay soil. These deposits may be a mixture of sand and clay with varying proportions of each, giving rise to a sandy clay or a clay loam or a sandy loam soil.

It is not always possible to distinguish the third type, that is, the transported deposits of recent origin, from resorted or transported glacial deposits.

There are true alluvial and lacustrine deposits in addition to the glacio-fluviatile and glacio-lacustrine deposits in this area. The alluvial beds are confined chiefly to the drainage courses of postglacial formation.

There are several broad flats in this map-area that appear to be of lacustrine origin. These old lake basins represent areas where the earlier drainage was dammed, lakes were formed and later the basins were filled in with silts, clays and sands.

The *Lundbreck flat* extends along the Oldman, north of township 7, range 1, west of the fifth meridian where it is joined by the Crowsnest and Castle rivers. The *Halifax flat* extends from the town of Pincher Creek southeast to Waterton river in township 5. The *Hillspring flat* lies between the Waterton and Belly rivers, mainly in township 4. The *Glenwoodville flat* is narrow and marginal to the Belly river and may be the eastern end of the Halifax flat, but it is at a lower elevation. There is a small lacustrine basin nine miles south of Magrath at the McIntyre ranch. The *Stirling flat* is probably the largest of the lacustrine basins and includes Stirling lake which is now used as a storage reservoir. There has been considerable laking along the drainage southeast from New Dayton, occupied by Suds, Tyrrell, Weston and Verdigris lakes that are now scarcely more than alkali flats. There is distinct evidence of laking along Milk river in ranges 17, 18 and 19, west of the fourth meridian, at an elevation of 3,850 feet above sea level, but this may have been of glacio-lacustrine origin. This type of lake, formed at the front of a glacier, is a proglacial lake. This bench is associated with laking in Milk river valley and is different from the upland plain north of Del Bonita which is part of a preglacial surface known as *Flaxville plain* that is more pronounced in Montana (Plate 26B).

There are many old drainage courses in the Lethbridge and Pincher Creek sheets that are not occupied by flowing streams today. Some of these channels are of preglacial age. Mention will be made of a few of the more obvious ones. One of the oldest buried channels in the map-area occurs under the city of Lethbridge at a depth of approximately 300 feet below the surface. This old channel, determined by drilling, extends from Oldman river eastward towards Chin coulee. One of the largest preglacial valleys extended from the Lundbreck flat, southeast under the Halifax flat toward Ewelme and Stand Off about the junction of the Waterton and Belly rivers. Glacial or postglacial laking has alluviated this depression and formed the various flats.

Another pronounced drainage extended from the north branch of Milk river in township 2, range 20, in a northwesterly direction through Lonely valley and the southeast fork of Pothole creek to township 4, range 22, and joined with St. Mary river about three miles north of Spring Coulee, or possibly extended northward through the clay flats about a mile west of Magrath. In much of this course the depression is floored with clay, clay loam and silty clay loam. Both Middle coulee and Kipp coulee were old drainage channels, possibly most active drainage ways during the retreating stages of glaciers. Both of these channelways extend from the vicinity of Welling in an easterly direction to Verdigris coulee, the former by way of McNab station and the latter by way of New Dayton, Suds lake and Tyrrell lake. The depression between New Dayton and McNab is of postglacial origin.

Alluviation has reduced the size of most of the present lakes in the map-area. Verdigris, Weston and Suds lakes in Verdigris coulee are temporary lakes or playa lakes. In almost every case old lake basins can be recognized by the flatness of the surface, and by the fineness and uniformity of the clay or silt unless the fine soil has been piled up by wind action.

There are very few small areas of residual soil in this map-area, but there are some sorted residual soils bordering the south end of Porcupine hills north of Pincher Creek and Brocket, and also in Blood Indian Reserve marginal to Mokowan butte which are underlain by flat-laying Willow Creek and St. Mary River starta.

Sub-surface Geology

The geological formations which occur at the surface or immediately below the unconsolidated deposits in the plains and foothills belt in the map-area are Cretaceous and Tertiary in age. The rocks within the Rocky Mountains and exposed in the transverse valley across the mountain ranges from Burmis to Crowsnest pass which is included in the soils map-area, range in age from Precambrian up to Cretaceous.

It is not necessary to discuss each of these units in detail but mention will be made of some of the characteristics of each group. The succession of the rock formations from the youngest to the oldest, is as follows:

Period	Formation	Thickness	Character of Rock
Quaternary	Unconsolidated deposits	0-200′+	Glacial gravels, boulder clays, alluvial and lacustrine deposits.
Tertiary	Porcupine Hills	2,000′±	Soft shaly sandstones and clays.
	Willow Creek	500′±	Soft sandstones, shales and clays. Commonly red, mauve and grey.
Upper Cretaceous	St. Mary River	1,600′±	Sandstones, irregular bedded and cross-bedded, shales and some coal near base. Mainly continental.
	Bearpaw	500′±	Dark grey clay-shale with limestone concretions. Marine.
	Belly River Series		
	Pale Beds	480′±	Light grey, greenish grey, buff sandstone and shale with carbonaceous layers. Continental.
	Foremost	270′±	Shale and coal in upper 50′ underlain by shale, sandstone and ironstone bands. Oyster beds. Brackish water.
	Pakowki	0-250′	Grey brown shale, some sandstone near top. Black chert pebble bed at base. Marine.
	Milk River	325′±	Massive sandstone and sandy shale. Freshwater origin.
	Alberta Shale (chiefly Benton)	1500-1700′	Dark grey shale with bentonite bands; interbedded sandstone in lower 60′. Marine.

Lower Cretaceous	Crowsnest Volcanics	0-1000′	Volcanic tuffs and breccias.
	Blairmore-Kootenay	400-1500′	Green, grey and reddish shale with grey sandstone beds in lower part. Non-marine.
Jurassic	Fernie	40-225′	Dark grey to black shales. Marine.
Triassic	(not yet recognized)		
	Erosion Unconformity		
Paleozoic			Mainly marine limestones, dark calcareous shales and some quartzitic sandstones and conglomerates.
Precambrian			Marine slate, quartzitic sandstones varied in color.

The large area in the central part of the map is underlain by the youngest formations of Tertiary age. These strata occupy the southern part of what is known as the Alberta syncline. The older rocks come to the surface on the east and on the west of this trough. The Porcupine hills are capped by the Porcupine Hills formation. Around the south end of Porcupine hills and extending south to Cardston and down to the International Boundary, the soft sandy shales and sands have influenced the soils where they occur near the present surface. These beds are low in line. The most continuous section of these beds is in Mokowan butte east of Stand Off, shown in Plate 26C.

East of the Tertiary basin and occupying the eastern half of the Lethbridge sheet, Upper Cretaceous rocks occur and are divided into the St. Mary River, Bearpaw and Belly River groups from west to east. On the west side of the Tertiary basin, the strata are less regular in extent because in the foothills the structure is more folded and broken than in the plains.

The St. Mary River non-marine strata underlie the Willow Creek formation of Early Tertiary age and represent the uppermost Cretaceous strata in Alberta. This formation consists mainly of highly calcareous light grey sandstones and sandy shales (Plate 27A). Irregular bedding and crossbedding are common. Soils which have been influenced by these beds have a pronounced lime content. Freshwater oyster shells are common in this formation. There is one bed near the base of the formation consisting almost entirely of the shells of oysters. These shells have been ground to make chicken feed in the vicinity of Cardston. This shell bed occurs in a number of localities near the base of the St. Mary River formation and is usually underlain by a coal seam.

The marine Bearpaw formation consists mainly of dark grey clay shales and sandy shales. In some places there are numerous limestone concretions in the lower part of the formation. Quite commonly the concretions and some of the shale beds contain fossils such as *Baculites* and *Placenticeras*. These are often coated with an iridescent layer of lime carbonate known as "mother-of-pearl".

The largest area of Bearpaw extends from township 1, range 21 at the south margin of the map, northwards to include the Magrath plain and the plain west of Lethbridge in township 8, ranges 22 and 23. The clay loam and silt loam in the vicinity of Magrath and north to Lethbridge have been influenced in a large way by these marine shales. A narrow band of Bearpaw shales extends from Cardston, southeast beyond Kimball and includes in part, the clay loam and silt loam areas in the vicinity of Kimball.

The Belly River series forms the surface rocks in forty-two townships in the east side of the Lethbridge sheet. The contact between the Belly River and Bearpaw occurs at the west side of range 20 on the International Boundary, swings round the east end of Milk River ridge in townships 3 and 4, passes midway between Raymond and Magrath, and extends north to Lethbridge where it occurs in the bottom of the valley and below the Bearpaw. The Belly River also occurs in narrow bands on the west side of the Tertiary basin throughout the foothills belt and within the mountains between Coleman and Crowsnest pass.

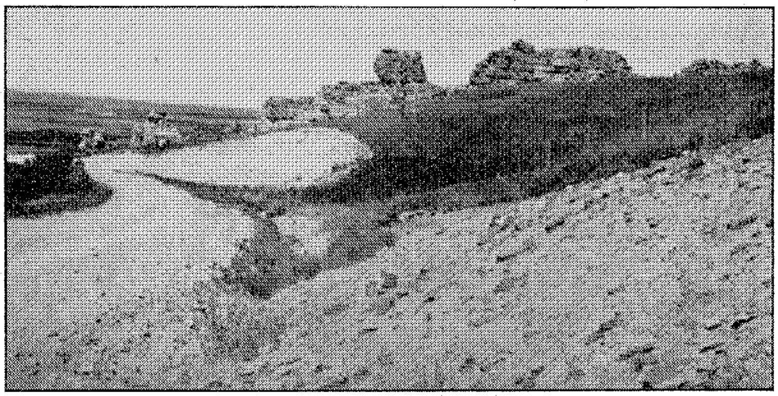
The Belly River strata are of freshwater deposition and consist chiefly of grey, greenish and buff sandstones interstratified with grey, greenish and carbonaceous shales.

Crossbedding caused by deposition in shallow water is common in the sandstone. There are lenses of conglomerate but these are not extensive. There are several coal beds in the Belly River. Coal from the Belly River starta is mined at Lethbridge. A number of small coal mines have been worked in the Pincher Creek, Lundbreck and Magrath districts.

The strata in the lower part of the Upper Cretaceous is represented by the Alberta Shale formation which includes what was formerly known as the Benton shale. This formation consists chiefly of dark grey shale of marine deposition. The shale is interbedded with thin beds of sandstone and several thin beds of bentonite. These strata occur as two narrow bands in the inner foothills. One of these bands extends in a southeasterly trend from Burmis but this formation has not influenced the soil types to any marked degree.

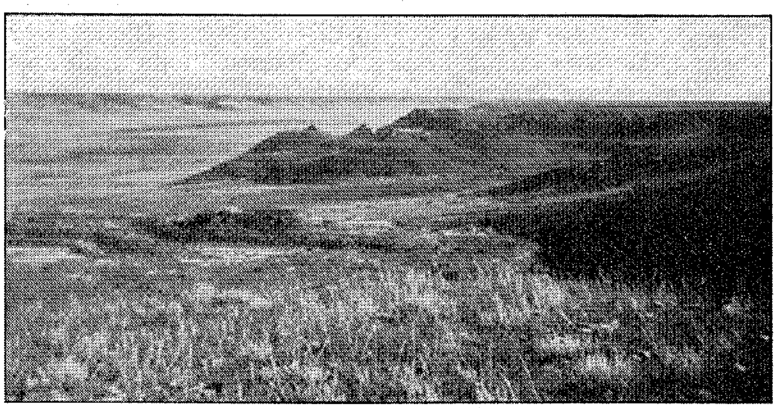
The Lower Cretaceous and older formations occur at the surface at the western edge of the map-area and within the Rocky Mountains. Many kinds of rock occur in these formations. Between the Alberta Shale and the Blairmore (Upper Cretaceous) there are the Crowsnest volcanics which consist of volcanic tuffs and breccias. These rocks occur in the vicinity of Blairmore and Coleman. Boulders and pebbles are common in the soils in the foothills belt. This is the only igneous rock within the southern part of the Rocky Mountains in Canada. The Lower Cretaceous (Blairmore-Kootenay) are composed essentially of sandstones and shales and several coal seams that are mined at Bellevue, Hillcrest, Blairmore and Coleman. The Jurassic and Triassic rocks are mainly shales and thin sandstones. The Paleozoic strata are mainly limestones, calcareous shales with some quartzitic sandstone. The Precambrian strata are slates, quartzites, argillites, conglomerates and metamorphosed limestones. The color of these rocks is varied with red, green, grey and white predominating. The Precambrian and Paleozoic rocks have been extensively eroded and the rock debris has been carried by glaciers and by running water eastward from the mountains and deposited throughout the western side of this map-area.

PLATE 27



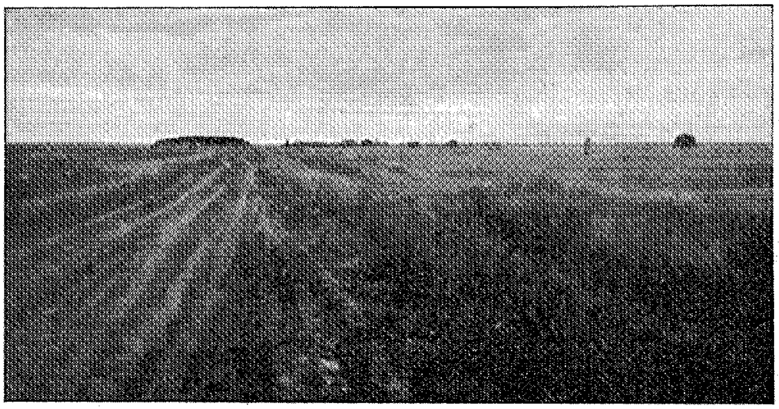
A.—St. Mary sandstone on the escarpment of Milk River ridge, south of Magrath in section 19, township 3, range 21, west of fourth meridian. The Magrath plain that stretches to the north is on a much lower elevation. Considerable material must have been eroded off this plain.

B.—Typical of Milk river valley from range 8 to range 13. The alluvial fans shown in this picture are in range 10.



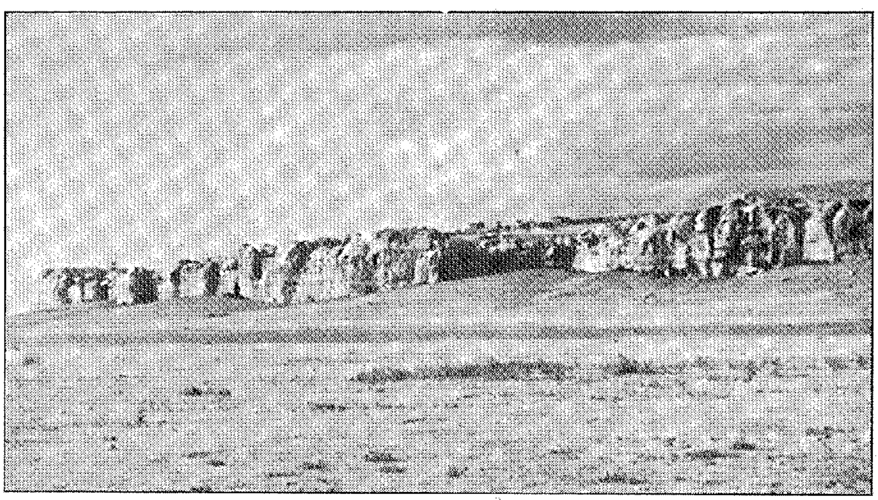
C.—Belly River sandstones on Chin coulee, northeast of Foremost. A shallow mantle of glacial till covers most of the Belly Rver formation. This coulee is one of several old drainage ways in the Milk River sheet.

PLATE 28



A.—The level bed of old Lake Pakowki about section 8, township 5, range 7, west of fourth meridian.

B.—Level unglaciated top of Cypress hills about section 8, township 8, range 2, west of fourth meridian. The underlying conglomerate shown in Plate 30B is from 2 to 4 feet below the surface.



C.—Writing-on-Stone cliffs of Milk River sandstone along Milk river, south of Masinasin.

RELATION OF THE GEOLOGY TO THE SOILS IN THE MILK RIVER SHEET

Introduction

The Milk River sheet includes southeastern Alberta, from the International Boundary north for eight townships, and from the Alberta-Saskatchewan boundary, west for 15 ranges to Coutts. The area is approximately 4,500 square miles of which about 1,000 square miles are drained by Milk river into the Gulf of Mexico. The Cypress hills occupy the northeastern corner of the sheet where there are about 1,000 square miles of rough topography. This sheet includes the Skiff area where there are oil and gas possibilities; the Foremost natural gas field; the Coutts-Red Coulee potential oil area; promising structures for oil and gas south of Milk river; and a well defined artesian-water area.

Surface Features

The Milk River sheet lies entirely within the plains area with an average elevation of 2,800 to 3,000 feet above sea level. This plain is interrupted only by two prominent uplands, Cypress hills in the northeast corner of the map-area arising to 4,800 feet above sea level, and the northern slope of Sweet Grass hills of northern Montana with a maximum elevation of about 4,200 feet above sea level in range 12 on the International Boundary.

The drainage in the Milk River sheet is both preglacial and postglacial. Milk river is the major active drainage today, but the size of this valley indicates that it was a more active river at one time. East of the town of Milk River in range 16, the river meanders through silts until it reaches the bedrock of the upper part of the Milk River formation at the western edge of range 15. East of this point the valley narrows and the river follows a box canyon with craggy sandstone walls over 50 feet high, especially east of section 2, township 2, range 15, where the river has cut into the harder sandstones in the lower part of the Milk River formation (Plate 27B). Verdigris coulee enters Milk river valley in range 14 as a hanging valley about 45 feet higher than the river level. The valley of Verdigris, extending northwest to New Dayton, is considerably wider than that of Milk river. This coulee represents a drainage course formed along the front of the retreating ice sheet. Other large coulees, as Etzikom, Chin, Fortymile and Sevenpersons, have been formed in a similar way along the front of the ice sheet at successive stages in the ice retreat (Plate 27C). Several narrow and in places canyon-like valleys enter Milk river from the south on the slopes of Sweet Grass hills. The valleys of each of these tributaries are deeply eroded into the solid rock, which forms castellated crags and badland profiles. Deadhorse coulee represents an abandoned river channel and is peculiar in that it opens at both ends into Milk river. On the north side of Milk river the most prominent drainage is Pendant d'Oreille coulee which extends from the river valley in range 8 to Pakowki lake. The south end of this coulee is at least 10 feet higher than the river level and the north end at Pakowki lake is 36 feet lower than Milk river. This indicates that the preglacial valley of Milk river was filled up with glacial deposits and the south end of the coulee was filled in, also the present stream of Milk river was cut in these higher level gravels. East of Pendant d'Oreille coulee, the valley of Milk river is canyon-like about one mile wide and 350 to 450 feet deep as far as range 5 where it crosses the International Boundary into Montana. The sides of this portion of the valley are deeply eroded as is shown on the soil map. There is no doubt that this canyon portion of Milk river valley was cut by a much larger and more active river than the present one. The numerous other abandoned drainage channels on the Milk River sheet all suggest an earlier drainage of large volumes of water, although today the amount of surface water is very small.

Pakowki lake now has inland drainage, but formerly received the drainage from Etzikom coulee, which is an old glacial drainage course. It is possible that Pakowki lake was originally formed when the drainage channels from the lake to Milk river became filled in with rock debris from the melting ice sheet (Plate 28A).

In the north part of the Milk River sheet the drainage pattern influenced by the melting ice sheet is seen in Chin, Fortymile and Sevenpersons coulees which drained into the South Saskatchewan river south of Medicine Hat. The size and regular outline of the various coulees suggest that much water drained from this area since glacial time.

Sub-surface Geology

The areal geology of the Milk river sheet is shown on the small scale map (Plate 31) accompanying this report. The geological information shown on this map is compiled from the geological map of Alberta prepared by the writer in 1937, and from maps published by the Geological Survey of Canada in 1940 and compiled by L. S. Russell and R. W. Landes.[6]

The geological formations which occur at the surface or immediately below the unconsolidated deposits in the Milk River sheet are all Upper Cretaceous in age, except on top of the Cypress hills in the northeast corner of the map-area where the strata are of Tertiary age (Plate 28B).

On the geological map (Plate 31), nine different geological formations are shown. It is not necessary to discuss in detail each of these units, but mention will be made of some of the chief lithological characteristics of each formation. The exposures of these various rocks are limited in area on the Milk River sheet, and are confined largely to the eroded areas along drainage courses. In other areas on this sheet the information on the rock formations has been obtained only from well records. The rock formations in this map-area, in order of age from the youngest to the oldest, are as follows:

Period	Formation	Character of Rock
Tertiary	Cypress Hills	Conglomerate, non-marine, light-coloured quartzite boulders held together loosely with finer gravel and sand. Thickness 25 feet in range 3, thickens to east.
	Ravenscrag	Sandstone, massive, crossbedded, buff in colour, freshwater origin and about 560 feet thick.
Upper Cretaceous	Whitemud	Clays, 30 feet dark clay overlain by about 17 feet whitish, kaolinized clay in Eagle butte and west end Cypress hills.
	Eastend (Edmonton)	Sandstone, shale and coal, 440 feet thick in Eagle butte.

Bearpaw	Shale, dark-coloured with sandy beds, some bentonite, marine. Thickness 830 feet in Eagle butte and 630 feet near Manyberries.
Pale Beds (Oldman)	Sandstone and shale, coal seams in uppermost part. Some massive crossbedded buff sandstone. Freshwater deposition. Thickness 480 feet at Eagle butte.
Foremost	Shales, and sandstone with numerous coal seams in upper part. Dark shale and silt with thin coaly beds in lower part. Brackish-water deposition. On Milk river 270 feet thick but thins to east.
Pakowki	Shales, dark, some sandy beds, marine. Black chert pebble bed at base.
Upper Milk River	Sandstone, argillaceous, sandy shale, lenticular sandstone, streaks of lignite and ironstone. Freshwater deposition and about 130 feet in thickness.
Lower Milk River	Sandstone, massive, light-coloured, about 100 feet thick, underlain by about 50 feet shaly sandstone and sandy shale. Freshwater deposition.
Alberta	Shale, dark marine with ironstone concretions.

The oldest formation, the Alberta shale, is only exposed at one point in the Milk River sheet, at the International Boundary on Deer creek in the southeast corner of section 5, township 1, range 12.

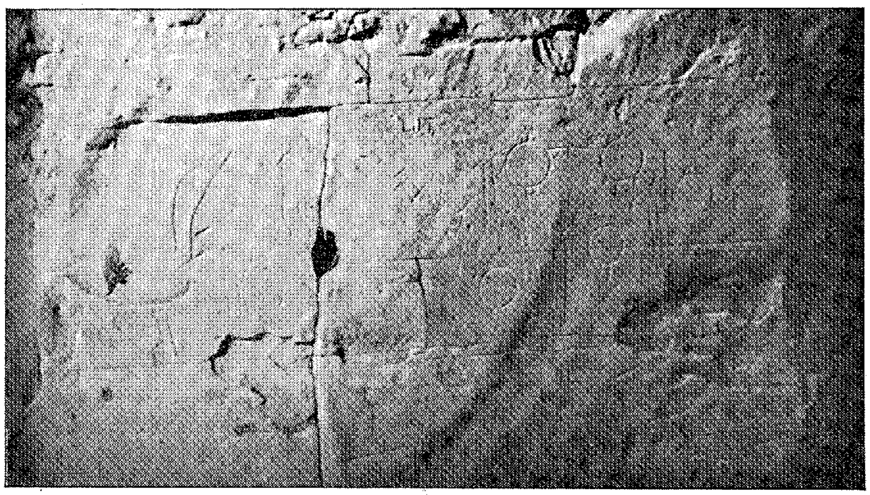
The Milk River formation is exposed only in the southwestern corner of the map-area along the Milk river valley in townships 1 and 2, ranges 11 to 15. This formation is divided into two parts which can be readily distinguished in the field. The lower part of the formation consists of harder beds of sandstone and commonly forms castellated cliffs, pinnacles and bizarre outlines on erosion along the sides of the valleys particularly along the Milk river and the mouth of Police creek.

The Writing-on-Stone cliffs south of Masinasin in section 35, township 1, range 13, are in the lower part of the formation. Figures and various characters have been carved in the massive sandstones (Plate 29A). This area where the "writing" occurs is worthy of being made a park reserve. Unfortunately, vandals have disfigured some of these ancient Indian inscriptions. Nodules of pyrite through the sandstone are readily weathered out, leaving grotesque pits and holes in the face of the cliff which extends for about a mile along the valley (Plate 29B). Many extraordinary castellated forms of particular scenic beauty occur in section 31, township 1, range 12 (Plate 9B).

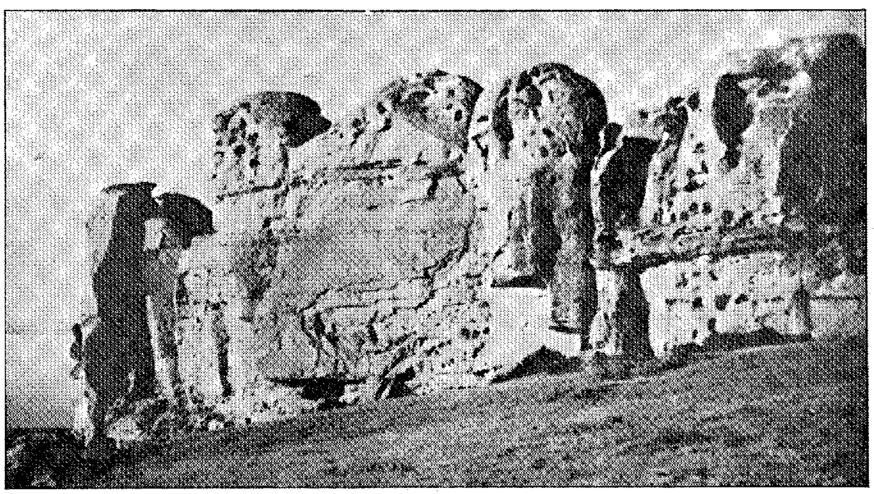
The lower part of this formation disappears at the river level in the northeast corner of section 33, township 1, range 12. In the artesian basin, mapped by D. B. Dowling in 1917,[7] west of Pakowki lake and south of Chin coulee, water is obtained from sandstones in the lower part of the Milk River formation.

The dark coloured Pakowki marine shales occur at the surface, marginal to the underlying formation, along the north side of Milk river valley from Verdigris coulee east to Pendant d'Oreille coulee in range 11. This shale formation has not had much direct influence on the soil types, except possibly in local areas such as the fine sandy loam in township 2, range 11, and the clay along Pendant

PLATE 29

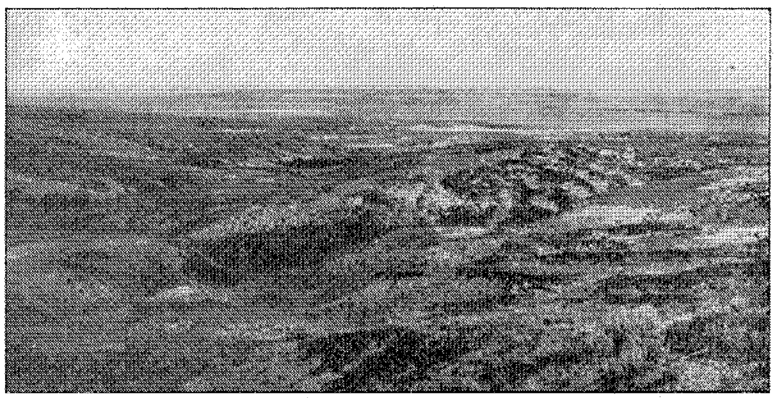


A.—Carvings on Writing-on-Stone cliffs south of Masinasin in section 35, township 1, range 13, west of fourth meridian, opposite the mouth of Police creek.

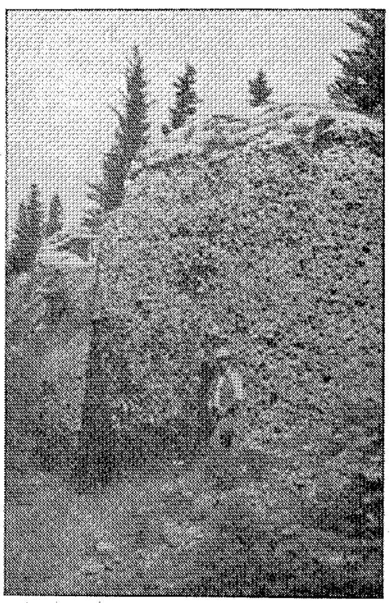


B.—Writing-on-Stone castellated cliffs, pitted by wind erosion, where the carvings shown in Plate 29A occur in the lower part of the Milk River formation.

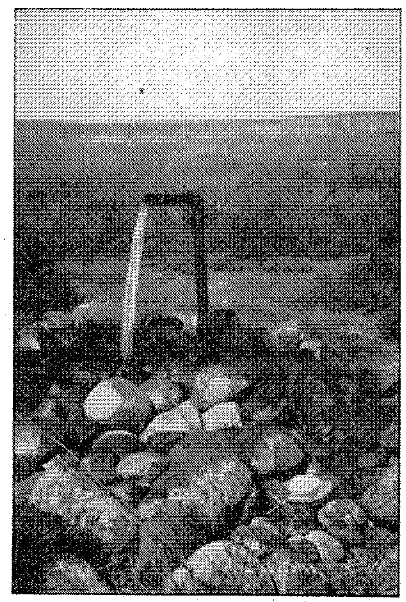
PLATE 30



A.—Exposed Bearpaw shale southeast of Manyberries in section 20, township 4, range 4, west of fourth meridian. The surface mantle in much of the east portion of the Milk River sheet is formed on the Bearpaw.



B.—Cypress conglomerate of Tertiary age which is a cemented gravel 50 feet thick, underlies the Cypress hill plateau shown in Plate 28B.



C.—Artesian well in Nemiscam park in township 7, range 9, west of fourth meridian. The water is derived from the lower part of the Milk River formation.

d'Oreille coulee in range 8. The shale debris has been intermixed with the glacial till. In general the soils in the west half of the map-area have been developed in sorted and unsorted glacial till.

The non-marine Foremost formation consisting of soft sandstones and shales underlies about two-thirds of the Milk River sheet west of range 7 and north of township 2, also in township 1, ranges 9 and 10. In all about 50 townships are underlain by this formation, beneath the unconsolidated mantle of glacial till. The debris from these rocks is reddish to yellowish in colour. There are numerous coal seams in this formation and many beds of brackish-water molluscs. This is an important coal-bearing formation. In this map-area small quantities of coal have been mined by open pits on Fortymile coulee in sections 1 and 12, township 8, range 11, at several places on Sevenpersons and Chin coulees, near Comrey and at other points. The coal is lignite in rank. It is quite possible that much of the heavy loam, the silt loam and clay loam in the western half of this map-area has been influenced by this formation which has been worked over by the ice sheet.

The term Oldman formation has been proposed by L. S. Russell to replace the term Pale Beds which is the highest member of the Belly River group. This formation outcrops in the map-area usually as extensive badlands along both sides of the valley of Milk river from range 7 eastward and especially along Lost creek from the International Boundary northwest to the escarpment north of Comrey. Numerous patches of badlands occur on Sage creek and Cripple creek. The upper beds in the formation occur around Manyberries and to the northwest where in outcrops west of Bullshead butte in section 11, township 8, range 7. This formation also occurs between Fortymile and Sevenpersons coulees in townships 7 and 8. The strata in this formation consist chiefly of soft light coloured shales and sandstones, but clays or clayey shales predominate. The coarser sandstones are commonly crossbedded, indicating shallow water deposition. Near the top of the formation there are thin coal seams and coaly shales. The soft character of the shales and sandstones in both the Oldman and Foremost formations have influenced to a marked degree the types of soils in this area. These strata have been easily disintegrated by the advancing ice sheets, and weathered by the water from the melting ice. These two formations have a combined thickness of about 750 feet in this map-area. The upper part of the Oldman has been called the Lethbridge coal member. It contains thin coal seams and some thin bentonite beds. Some coal has been removed by open pit in sections 2 and 15, township 5, range 5, but there is no coal mining in these thin seams in this map-area.

The Bearpaw formation consists almost entirely of dark shales of marine deposition. This formation occurs under the unconsolidated mantle as a belt from the east side of Milk River sheet, which is the Alberta-Saskatchewan boundary in townships 3, 4, 5 and 6, extending in a northwesterly trend to township 8, ranges 4, 5 and 6, bordering the Cypress hills on the south and west (Plate 30A). There are numerous outcrops of these shales as badlands east of Manyberries on the headwaters of Manyberries and Sage creeks and also northeast of Bullshead butte. There are many thin beds of bentonite interstratified with the shales. This bentonite makes the clays derived from this formation heavy. This formation has influenced the distribution of the clay loams along the eastern side of the map-area in townships 4, 5 and 6, ranges 1 and 2. A large exposure of these shales was examined on Willow creek 4 miles south of Thelma postoffice in section 23, township 6, range 3. On this exposure the dark coloured shales are traversed by a number of steep-dipping "sandstone dikes", less than one foot in width and pinching out downwards. These "dikes" consist of sand grains held together by gypsum. They have been formed by downward moving solutions from the Eastend (Edmonton) sandy beds.

The term Eastend formation was proposed by L. S. Russell for the beds above the Bearpaw and below the Whitemud formation. The Eastend is correlated with the Edmonton formation to the north and the St. Mary River formation to the west. In this map-area this formation is well exposed on the creek south of Thelma at the southwest end of Cypress hills in township 7, range 3. Another section was examined in the southeast quarter of section 7, township 8, range 3, north of the road at the extreme west end of Cypress hills where the formation is about 325 feet thick, consisting of soft crossbedded sandstone overlain by about 100 feet of soft shale that breaks down readily, thin massive sandstone with shales and a thick coal seam which is mined at Elkwater lake on the north side of the hills and at Thelma on the south slope. This formation occurs as a narrow band around the top of Cypress hills which is capped by Tertiary strata. The Eastend (Edmonton) also occurs as an island west of Lodge creek and forming Eagle Butte hills. This formation which occurs on the steep upper slopes of Cypress hills has influenced the soil types immediately lower on the slopes, as sorted residual or sorted by glacial action. Cypress hills is an erosional residual, and erosion has been largely by ice.

The Whitemud formation has not been shown on the geological map (Plate 31) because the areas where it occurs are small. The formation is only about 50 feet thick but it contains a very prominent bed of whitish clay that makes a good geological marker and which contains a one-foot bed of highly refractory clay. There is a hard light coloured stratum near the top, about 6 inches thick, which is believed to be of volcanic origin. This thin series outcrops near the top of the escarpment on the west end of Cypress hills, both to the east and west of Fly lake, and as four small islands fringing Tertiary beds on the top of Eagle Butte hills.

The Tertiary strata cap the Cypress hills and underlie about 150 sections in townships 7 and 8, ranges 1, 2 and 3. The underlying Ravenscrag formation about 560 feet thick, consists chiefly of massive crossbedded sandstone forming the prominent escarpment round the west end of Cypress hills. West of Lodge creek there are four small outliers on the hills about Eagle butte. The sands from this formation are distributed through the soil types farther down the slopes of Cypress hills.

The Cypress Hills formation overlies the Ravenscrag and caps the entire surface of Cypress hills. In section 10, township 8, range 3, at the west end of Cypress hills, this formation consists of about 35 feet of conglomerate made up of light coloured quartzite boulders held together by sand, clay and some fine gravel. One hard bed forms a vertical escarpment at the edge of the plateau (Plate 30B). The soil on the top of Cypress hills is residual and there is no glacial debris on this flat surface. Gravel and boulders from this formation are scattered down the flanks of Cypress hills especially on the south side where there are gravels and stones in the soil types. The age of this formation is considered to be early Oligocene and it is the youngest formation recognized in Alberta. The conglomerates on the top of Handhills east of Drumheller, and those on top of Swan hills south of Lesser Slave lake are considered to be of the same age.

Two miles north and one mile east of Manyberries in the southwest quarter of section 5, township 6, range 3, the writer observed two small outcrops of a soft clayey crossbedded sandstone on the side of Manyberries creek. This rock possibly represents an interglacial deposit, but L. S. Russell has suggested, on lack of other evidence, that it is possibly of Pliocene origin.[8] If this is the case, then it would be the youngest rock formation in Alberta.

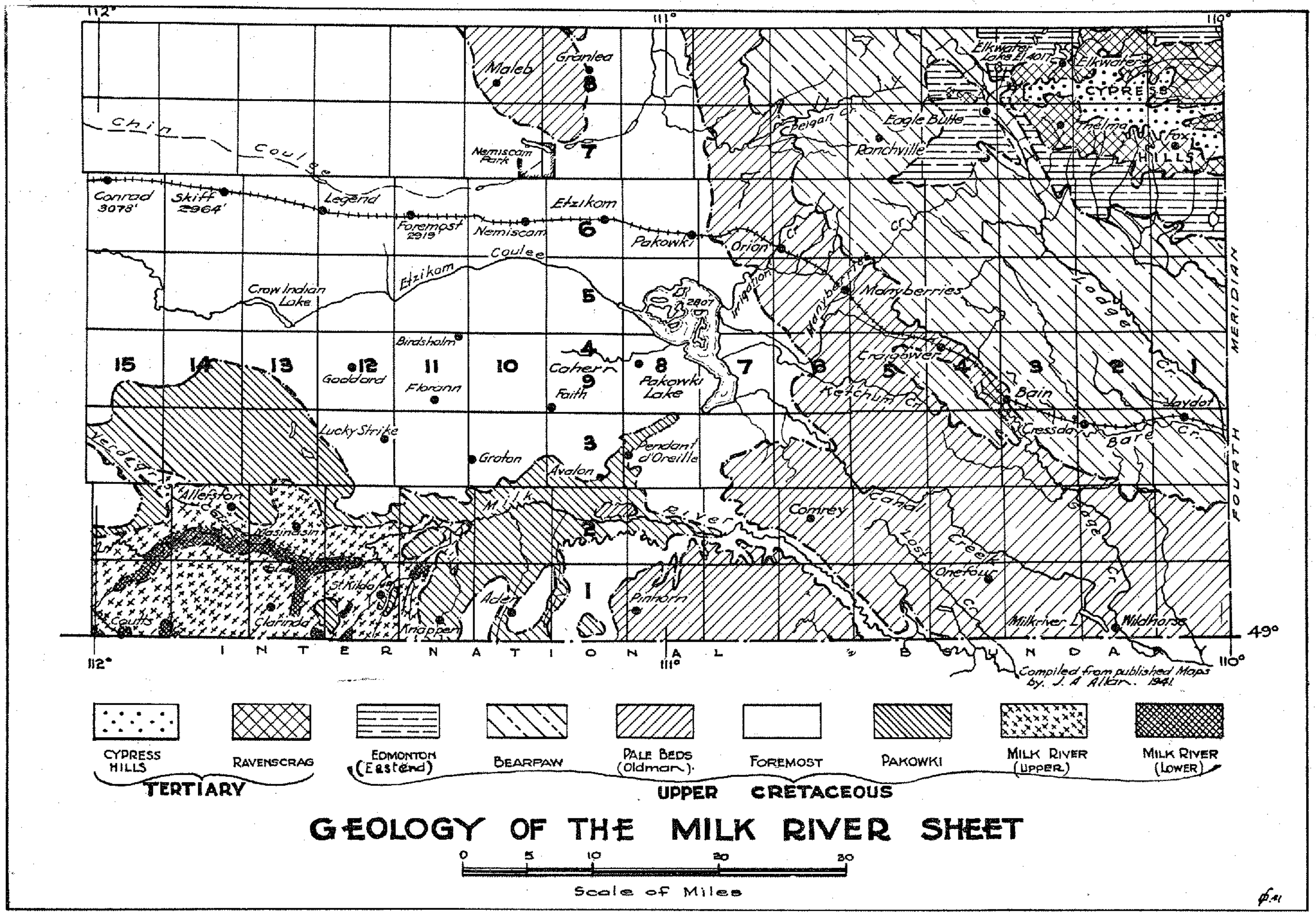
Origin of Surficial Deposits

It is not always possible to determine the origin of the surface deposits in certain areas, because frequently the unconsolidated material is of mixed origin. This is particularly true in the case of reworked deposits such as outwash plains, alluvial and marginal deposits.

The soil differs from underlying deposits upon which it is developed in that weathering agents have changed its original texture, color and composition. In some soils the accumulation of organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. In most cases the surface leaching has deprived the soils of certain original minerals, and often the mineral content of the subsoils has been changed.

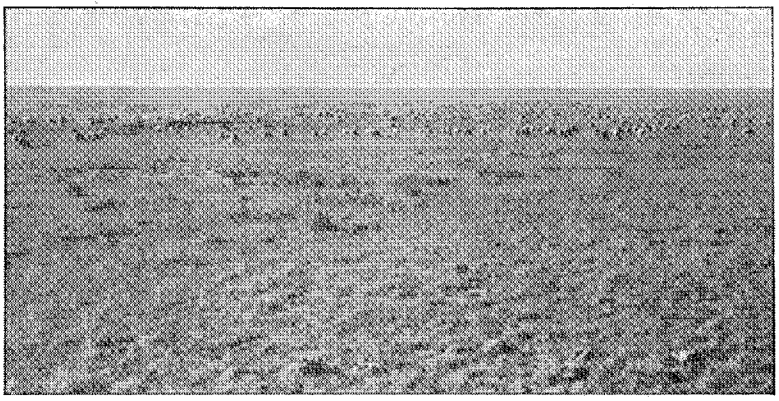
The general character of the surface of the Milk River sheet indicates to some degree the character and distribution of the unconsolidated deposits. Approximately 11 per cent of the Milk River sheet is represented by eroded areas and much of this area is on bedrock exposure. Over two-thirds of the map-area has a level to gently rolling surface in which the unconsolidated deposits consist largely of alluvial, residual or well sorted glacial moraine. The hilly areas represent only 7 per cent and these include Cypress hills in the northeast corner of the map and that portion of Alberta chiefly in township 1, south of Milk river on the slopes of Sweet Grass hills in northern Montana. The definitely rolling areas that represent the deeper morainal ridges, occupy 12.1 per cent of the map-area. The lack of surface moisture in the southeastern part of Alberta is shown by 1.4 per cent of lakes and marshes. On the other hand, the geological history and the number of large well defined coulees and abandoned channels indicate a drainage pattern adapted to transport large volumes of surface water in comparatively recent geological time.

With the exception of Pakowki lake basin there are no large postglacial, interglacial or preglacial lake basins in evidence in the Milk River sheet. There is a wide distribution of alluvial soils, residual soils and ground moraines that have been more or less extensively reworked in some places by the action of running water. In general the soils south of a line from Cypress hills, Manyberries and Pakowki to the International Boundary, and a strip to the west along both sides of Milk river are mapped as residual, sorted residual and glacial residual. This soil has been influenced by the parent rock which is usually close to the surface. It has not been possible to classify as to origin all

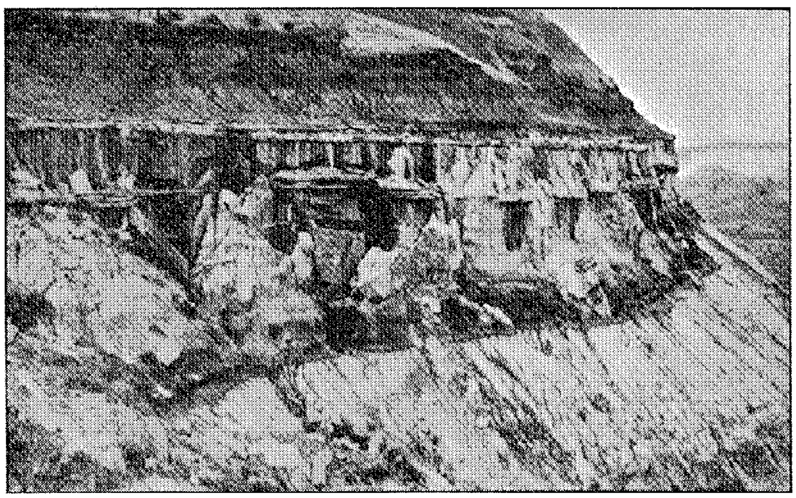


GEOLOGY OF THE MILK RIVER SHEET

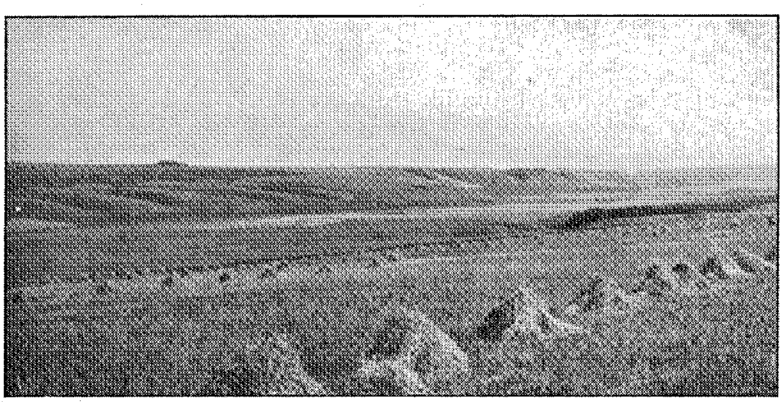
PLATE 32



A.—Alluvial plain southeast of Manyberries, in township 3, range 2, west of fourth meridian.



B.—Flat-lying Edmonton formation consisting of interbedded sandstone and shale in township 20, range 19, west of fourth meridian, on east side of Jumping Buffalo hill, southwest of Bassano.



C.—Old drainage way in Cameron coulee through rolling topography, section 1, township 20, range 1, west of fifth meridian, looking south to Tongue creek on west side of Sitook-Spagkway.

types of surface deposits in the time available in the field for this investigation.

The unconsolidated surface deposits in the Milk River sheet can be classified under four major types:

(1) Residual.
(2) Glacial moraine, unsorted.
(3) Resorted glacial deposits.
(4) Transported deposits of alluvial, lacustrine and dune or eolian origin.

The first type includes the residual soils formed by erosion processes from the underlying rock formation. Soil formed in this way will have a composition somewhat similar to the composition of the underlying rock from which the soil has been formed. More frequently the residual soils have been resorted or affected in some way by various transporting agents of erosion and in such cases the composition of the soil is not similar to that of the underlying strata.

In Milk River sheet the areas of residual soil that have not been partly sorted by later erosion, are irregularly distributed along the north side and west end of Cypress hills and southwest to Manyberries creek, and also along the International Boundary in township 1, ranges 4, 5 and 6. In this same part of the map-area there is a wide distribution of residual soils that form a large part of the glacial till and ground moraine. There are also irregular areas of sorted residual soils, some sorted by moving water, extending along the south border of the map-area, on both sides of Milk river valley and in townships 1 and 2 from Sage creek in range 2 west to range 13 in the vicinity of Masinasin and north into township 3. Some of these soils have in places been moved along the old drainage channels. Some of the changes that may be recognized in the composition of these soils, are due to the different kind of Upper Cretaceous strata from which the residual soil has been derived.

The second major type includes those deposits of glacial origin which occur in the form of ridges of terminal or ground moraine, usually thin or represented by scattered glacial boulders and pebbles. The glacial deposits may consist of till which is glacial debris without boulders. In morainal ridges there may be much coarse material.

The glacial deposits in this part of Alberta have been transported by Keewatin glaciers during the Ice Age from the northeast during the Wisconsin stage. Some of the boulders and pebbles have been carried from the Precambrian areas in the vicinity of Hudson Bay. When the ice melted, the gravel, sand and clay deposits were left over the surface. If the ice front remained in one position for a longer time, a terminal moraine was formed consisting of an unsorted "dump" of till or boulder clay. If the ice front retreated steadily, a ground moraine was left over the surface. During the thousands of years that have elapsed since the glaciers melted in this part of Alberta, erosion agents in various forms, such as running water, or wind, have resorted or washed over the slopes of the moraines and removed the finer materials to lower levels. Glacial deposits which have not been affected by water or wind, can be recognized by the presence of unstratified boulder clay or till without many pebbles and boulders. When stratification or evidence of sorting occurs in the glacial deposit, the material would be classed in the third type, namely, resorted glacial deposits.

It has already been pointed out that the rocks underlying the Milk River sheet are mainly relatively soft sandstones, shales and coal seams of Upper Cretaceous age, all of which are easily eroded by the movement of glaciers. A large amount of glacial debris in this map-area has been derived from these Upper Cretaceous strata. There may be glacial erratics and smaller boulders and gravel from distant points, but most of the glacial deposits in this southeastern part of Alberta have been derived from the underlying or subjacent formations over which the ice has passed in the close proximity of the deposit. In the Milk River sheet much of the glacial materials has not been transported more than a few miles from the parent rock.

There is a wide distribution of glacial deposits in this map-area and it is not always possible to distinguish the glacial from the residual material. There are several low morainal ridges subparallel to many of the coulees that represent drainage courses formed at different stages along the front of the retreating ice sheet. One of these morainal ridges extends along the north side of Etzikom coulee. Other similar ridges occur east of Lucky Strike and west of Pendant d'Oreille coulee. Morainal ridges and heavy ground moraine form the surface material south of Etzikom coulee over most of the area from Pakowki lake and Pendant d'Oreille coulee in range 8 to the west boundary of Milk River sheet in range 15, and within townships 1 to 5 inclusive, with the exception of the slopes along Milk river and its small tributaries. Much of the surface east of Pakowki lake and in townships 2 to 5, between the drainage courses, contains irregular areas of moraine and glacial deposits mixed with residual soils. Ridges of moraine mixed with residual soil are widespread between Lodge creek and Sage creek in townships 2, 3 and 4, ranges 1, 2 and 3. Thick morainal deposits are not common. The thickest till deposits observed are along Peigan creek in township 7, ranges 7 and 8, where the till ranges from 30 to 50 feet in thickness. Glacial erratics that have been transported long distances are rare. The writer observed a few boulders of Presqu'ile dolomite east of the Lucky Strike plain in section 33, township 3, range 11. These Middle Devonian boulders have been transported by ice from the vicinity of Great Slave lake about 850 miles north of their present position.

There are several small areas of the third type, namely resorted glacial deposits, shown on the Milk River sheet. Well sorted and varved clays, indicating seasonal deposition, were observed at a number of places. In a railway cut close to Manyberries station, the till is exposed to depth of 18 feet, and the upper part is distinctly varved.

The fourth type of surface material includes the transported deposits. The transporting agents are wind and running water, either along stream courses or as run-off. The former gives rise to dunes or eolian plains, the latter to alluvial, flood plain and lacustrine deposits. Transported soils are bedded in character due to the sorting action of the transporting agents. The sand and clay may occur in separate layers or lenses, forming a sandy soil or a clay soil. These deposits may be a mixture of sand and clay with varying proportions of each, giving rise to a sandy clay or a clay loam or a sandy loam soil. It is not always possible to distinguish the fourth type, that is, the transported deposits of recent origin, from the resorted or transported glacial deposits.

The true alluvial deposits consist of well sorted clay, silt, sand and gravel that have been transported and deposited in running water. The most recent alluvial deposits occur as terraces along the sides of drainage channels, or in some places in the upland plains where sediments were deposited before the present drainage pattern was developed. In the Milk River sheet fluviatile deposits are mapped along the floors of the valleys such as Milk river, Verdigris, Etzikom, Chin, Fortymile, Sevenpersons, Medicine Lodge coulees, Coal, Canal, Lodge and other creeks. Older alluvial terraces occur marginal to Milk river. Alluvial plains occur west of Sevenpersons coulee, near Crow Indian lake (Kings' lake), and at several other places close to some of the coulees (Plate 32A).

The true lacustrine deposits are represented in this map-area, but with the exception of Pakowki lake basin, all the others are small. Pakowki lake was formerly considerably larger than it is today. The lacustrine beds extend south along Pendant d'Oreille coulee to Milk river, southeast up Canal and Ketchum creeks, north through the centre of range 7, by Fourways to Peigan creek.

There is a prominent lake basin with a north-south trend, one to two miles wide and eleven miles long, situated within heavy moraine. This basin which might have been another arm of Pakowki lake, extends north along the boundary between ranges 7 and 8, from section 35, township 6, range 8, two and one-half miles north of Pakowki station, across Peigan creek to the centre of township 8, where the lake basin turns sharply to the west and enters Sevenpersons coulee in sections 28, township 8, range 8. There is a smaller lake basin at the southeast corner of the map north of Wildhorse, mostly within township 1, range 2. This basin is an extension of the present Milk River lake. The lacustrine deposits in this basin were derived chiefly from the underlying Oldman (Pale Beds) formation.

Eolian deposits may be found on any kind of fine textured soils. There are many small dune areas in the Milk River sheet. One of the most prominent dune areas occurs around the north and east sides of Pakowki lake in township 5, range 7, and east side of range 8. This dune sand has been derived mainly from the underlying sandstones in the Foremost formation.

The "blowout" areas do not seem to be directly related to the parent rock. There is one "blowout" over the Bearpaw shales in township 8 at the east side of range 7, and six miles west there is another "blowout" in the fine lacustrine clays.

Artesian Water

An artesian water basin was discovered in 1915 by D. B. Dowling of the Geological Survey of Canada. This artesian basin lies between Milk river and the South Saskatchewan river, and from the vicinity of Pakowki lake in range 6 west to the vicinity of Skiff and Taber. In general the northwest part of the Milk River sheet lies within the basin. In 1916 the Federal Government drilled three wells to test the geological conclusions with reference to artesian water. The results were satisfactory. One well produced 4,000 gallons a day, a second produced 11,000 gallons and a third produced 30,000 gallons per day. Today there are approximately 100 artesian wells within this basin. A table is given below showing the location of each well and the depth to the water-bearing sandstone within the Milk River sheet.

In this artesian basin the strata rise in three directions, to the Cypress hills on the east, to the Sweet Grass hills on the south and to the Milk river ridge on the west.

It is the sandstones in the lower part of the Milk River formation in which the artesian water is found. The water enters a permeable sandstone where it is cut by the Milk river, especially between Milk River station and Deadhorse coulee, chiefly in ranges 12 to 15. This sandstone is overlain by an impervious shale which prevents the water from seeping to the surface. The water moves down through this porous sandstone to the northeast. The water continues down the bed of sandstone until it reaches the natural gas in the same stratum, and until the pressure exerted by the gas will prevent the water from travelling further to the north. The water in the aquifer, that is, the water-bearing sandstone, is under pressure depending upon the height of the source of supply which is the Milk river where the lower part of the Milk River formation comes to the surface (Plate 30C). If a well is drilled into the water-bearing sandstone the water will rise to this source level. If the surface level at the well is lower than the source of supply, then water will flow from the well and will be an artesian well.

The depth to the water-bearing sandstone in this map-area, as shown in the last column of the accompanying table, varies with the location, from 490 feet to 895 feet.

In many of the artesian wells and water wells a quantity of gas came out with the water. In some cases both gas and water are utilized from the one well. The water contains some soluble salts, sodium chloride and sodium carbonate. The soluble salts content which is not large, appears to increase slightly to the north. The water is quite soft and the slight taste is not detrimental for domestic or stock usage. When used for irrigation there is a danger of an accumulation of carbonate of soda in the soil.

Beyond the limits of the artesian basin, water can usually be obtained by pumping from sandstone beds, or in some parts from gravels and sands of glacial or alluvial origin.

ARTESIAN WELLS IN LOWER PART OF MILK RIVER FORMATION

Listed in Geol. Surv. Can., Summ. Rept., Part B, 1922

Section		Township	Range	Elevation feet	Depth to sands feet
SW ¼	7	4	6	2,853	637
NW ¼	9	3	7	2,891	654
NE ¼	32	4	7	2,811	616 (1)
	35	4	7	2,836	640
	36	4	7	2,846	694
E ½	11	5	7	2,830	717
	2	5	7	2,836	665
	19-30	4	8	2,919	620
NW ¼	30	8	8	2,711	740
NW ¼	21	4	9	2,998	680
	14	6	9	2,893	718
NE ¼	19	7	9	2,803	714
W ½	20	7	9	2,803	736
SW ¼	31	5	10	2,859	532
	16	6	10	2,900	762
NE ¼	7	7	10	2,833	677
SW ¼	15	7	10	2,843	665
S ½	25	7	10	2,813	714
	26	7	10	2,858	712
S ½	28	7	10	2,813	685
W ½	32	7	10	2,823	650
	5	8	10	2,823	700
S ½	6	8	10	2,833	684

Section		Township	Range	Elevation feet	Depth to sands feet
W ½	6	8	10	2,833	707
NW ¼	7	8	10	2,806	726
N ½	20	8	10	2,811	780
E ½	29	8	10	2,796	765
	24	2	11	2,903	167
	28	3	11	3,167	510 (2)
SW ¼	8	4	11	3,159	508 (2)
	1	6	11	3,004	....
SW ¼	4	6	11	2,967	708
NW ¼	9	6	11	2,940	690
SW ¼	13	6	11	2,997 (3)	....
	16	6	11	2,922	650
NW ¼	33	6	11	2,853	625
SW ¼	2	7	11	2,853	650
NW ¼	2	7	11	2,843	640
SW ¼	4	7	11	2,833	....
SW ¼	14	7	11	2,800	646
S ½	15	7	11	2,800	646
SE ¼	18	7	11	2,816	....
SE ¼	20	7	11	2,776	650
N ½	20	7	11	2,731	....
	21	7	11	2,776	640
SW ¼	24	7	11	2,803	625
E ½	2	8	11	2,775	....
NE ¼	7	8	11	2,730	600
NW ¼	9	8	11	2,740	630
W ½	15	8	11	2,760	650
LSD 4	23	8	11	2,621	490
	30	8	11	2,714	637
	33	8	11	2,705	665
	36	6	12	2,656	....
NE ¼	3	8	12	2,770	640
N ½	10	8	12	2,753	620
NE ¼	20	8	12	2,743	650
NE ¼	33	8	12	2,703	640
	30	5	13	3,035	630 (4)
	1	7	13	2,660	350
	8	7	13	....	....
NW ¼	15	7	13	2,906	680
	4	8	13	2,831	650
	10	8	13	2,800	655
	11-12	8	13	2,781	630
	15	8	13	2,771	640
	22	8	13	2,751	602
SE ¼	30	8	13	2,791	652
SE ¼	31	8	13	2,765	642
SE ¼	33	8	13	2,720	630
	34	5	14	3,027	610
	26	6	14	2,957	683
SW ¼	24	8	14	2,841	735
	21	7	15	2,713	503
	36	8	15	2,833	895 (5)

NOTE:

(1) With gas.
(2) Water does not reach surface.
(3) Water pumped from 2,982 feet.
(4) Water rises to 72 feet from surface.
(5) Chiefly gas.

SOIL GEOLOGY IN BLACKFOOT AND CALGARY SHEETS

Introduction

The distinction between rock and soil is a physical one. No sharp line of demarcation can be drawn between materials that are classed as rock and materials that are classed as soil.

The map-area discussed in this report includes the whole of the Blackfoot sheet and that part of the Calgary sheet east of the Rocky Mountains Forest Reserve boundary, principally within ranges 1 to 4 west of the fifth meridian, and townships 17 to 24 inclusive. In addition, it includes range 5, north of Elbow river in townships 23 and 24.

The geological map (Plate 33) shows the distribution of the geological formations within the Blackfoot sheet, and within the eastern six ranges in the Calgary sheet which includes parts of Moose mountain and the Highwood range within the inner foothills belt and eastern side of the Rocky Mountains.

The surface of the Blackfoot sheet lies entirely within the plains area with elevations ranging from about 2,400 feet above sea level at the east side of the Blackfoot sheet, to above 3,650 feet at the west boundary of this sheet along the fifth meridian. There are two higher points in the Blackfoot sheet, these are Buffalo hill (3,860 feet) in the southeast of section 17, township 19, range 23; West Arrowwood hills (3,760 feet) in the southeast section of 20, township 19, range 24; and Sitook-Spagkway (3,860 feet) in sections 4 and 5, township 20, range 29, west of the fourth meridian.

The surface of that portion of the Calgary sheet included in this map-area consists of the western edge of the plains area and the eastern part of the foothills belt. No sharp line separates the plains from the foothills, but the western edge of the plains is approximately along a line drawn from the junction of Pekisko creek and Highwood river, northwest through Black Diamond east of Turner Valley, along Calling valley to Priddis, and to the vicinity of Jumpingpound postoffice about the centre of range 4, in township 24. The lowest elevation along the east side of the Calgary sheet is about 3,400 feet above sea level, except in the Bow valley where the elevation is 3,300 feet on the fifth meridian. In the foothills belt within this map-area and along the boundary of the Forest Reserve the elevation varies from 4,700 feet in Bragg creek and the Elbow river, to 5,600 feet above sea level north of Sullivan creek.

Drainage

The Bow river has not always occupied its present position. This drainage started at some time long before the glacial age and soon after the uplift began which formed the Rocky Mountains. It is apparent that much of the Bow drainage, before the advance of the ice sheets, was in the vicinity of the preglacial Bow valley which in places included much more than the present valley. One of the most prominent old drainage courses extended from the Bow south of Cochrane, through Glenbow flats, along the Elbow to Turner station three miles south of Calgary, south to Midnapore, DeWinton and through Wilson coulee to Sheep river two miles west of Okotoks. South of Sheep river this abandoned channel extends close to the fifth meridian, passing west of the Sitook-Spagkway to Tongue creek, and then to the position of the town of High River. The main channel south of High River was along the Little Bow

PLATE 33

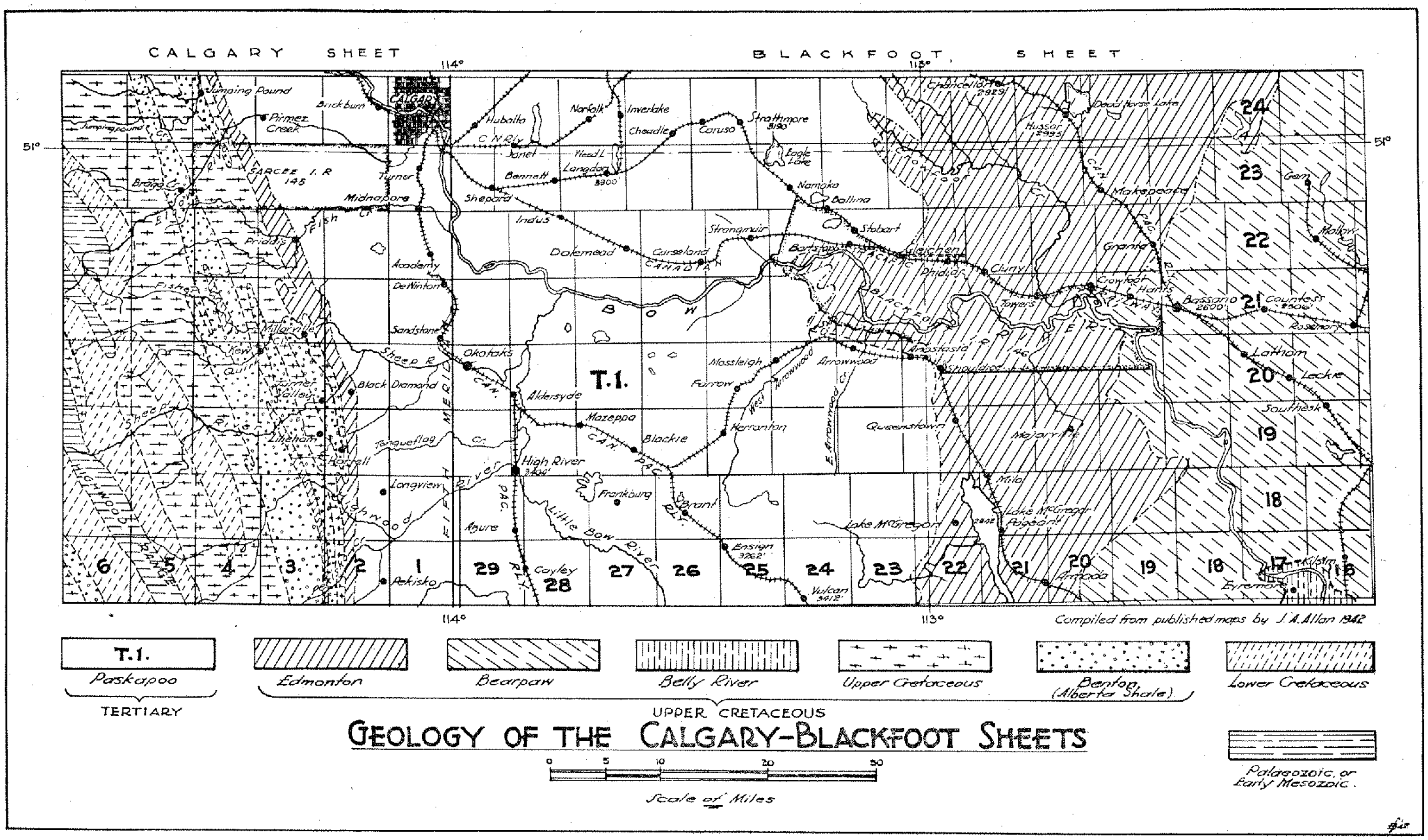
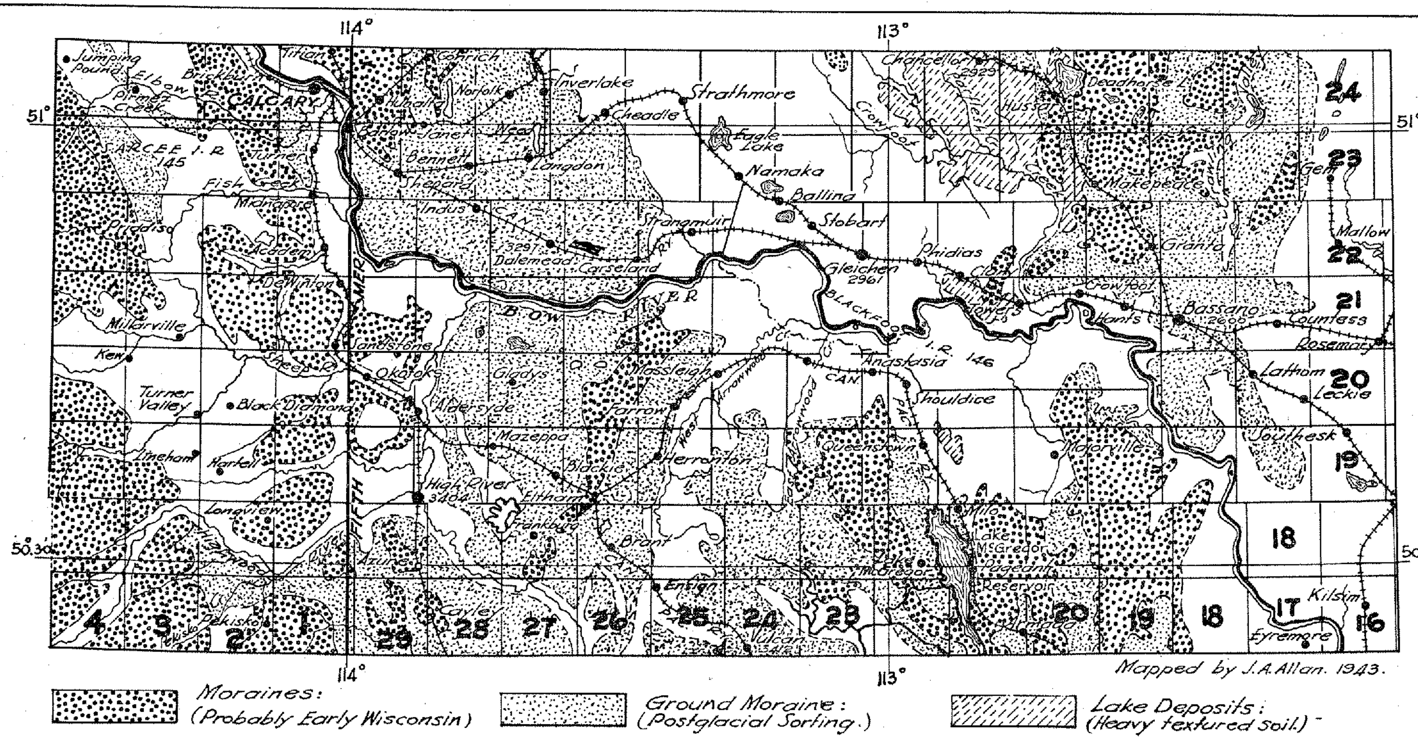

CALGARY SHEET
BLACKFOOT SHEET
114°
113°
51°
Calgary
High River
Okotoks
Strathmore
Gleichen
Bassano
Vulcan
T.1.
Compiled from published maps by J. A. Allan 1942
T.1.
Paskapoo
TERTIARY
Edmonton
Bearpaw
Belly River
Upper Cretaceous
Benton (Alberta Shale)
UPPER CRETACEOUS
Lower Cretaceous
Palaeozoic, or Early Mesozoic.
GEOLOGY OF THE CALGARY-BLACKFOOT SHEETS
0 5 10 20 30
Scale of Miles

PLATE 34



GLACIAL GEOLOGY OF THE BLACKFOOT SHEET.

Scale of Miles: 6 0 6 12 18

where it passes from the map-area in range 26. There are two other smaller drainage channels south of Highwood river, one follows through range 29, two miles west of Cayley into Mosquito creek, and the other extends from the Little Bow two miles south of High River, south to Silver lake flat east of the railway at Connemara. The town of High River is situated on the old buried channel where at one time most of the water from the Highwood river flowed south by the Little Bow. This point is of considerable importance because there is a grave chance that the Highwood when in flood might again follow this old course to the Little Bow, unless this danger is averted by artificial means. The record flood of May 1942, showed that the change of course of the Highwood into the Little Bow is possible, without a properly constructed dike to keep the water in the Highwood north from the town.

Crawling valley in the northeast of the map-area, north of Bassano, and the valley of Crowfoot creek were at one time much larger drainage courses than at present. Snake creek draining into Lake McGregor was formerly much larger than at present. Frank lake basin, seven miles east of High River, is an obliterated lake which about glacial time covered at least twelve sections. This lake drained originally into the Little Bow between sections 32 and 33, township 17, range 27, but during the last century at least has had no surface outlet. Three miles north of Ensign there was once a lake covering about six sections in postglacial time, drained by the West Arrowwood creek, but this is another example of an obliterated lake. The Southesk flat in township 19, and the north part of township 17, range 16, at one time was occupied by a lake which drained southwards into the Bow valley east of Eyremore. There has been a marked change in drainage along the east side of the map-area, north of Rosemary in the Gem flat and in the vicinity of Matzhiwin creek. Lake McGregor is now an artificial lake as it is used as a reservoir, but formerly there was a large lake extending north to the Queenstown flat. It is quite probable that there was an old drainage course extending from Lake McGregor in a northeasterly direction to Bow valley, southwest from Cluny. There have been marked changes in the drainage in the vicinity of Lloyd lake in township 22, range 2, west of the fifth meridian. At one time there were drainage ways from Lloyd lake northwest to Pirmez flat and Jumpingpound flat.

Eagle, Namaka and Stobart lakes, southwest from Strathmore are only remnants of a much larger proglacial lake, that is, a lake that was formed at the front of the ice sheet when it occurred in this position. Chestermere lake is in a former drainage way that extended south to the Bow valley. Many other evidences of early drainage might be cited from this map-area but those cited will be sufficient to emphasize the fact that present drainage is only a passing phase of the drainage history of the map-area.

Some of the former lakes have disappeared through a number of factors of which three may be mentioned. (1) Since the appearance of settlement, artificial draining has removed the surface water. (2) Cultivation, causing increased evaporation, has possibly removed a part of the water in some cases. (3) Climatic changes are of major importance. Cyclic variations in the annual precipitation have changed the water table and have caused lakes to disappear and reappear. Several cases might be cited of lakes in Alberta that were at lower levels about the beginning of the century than at present. Unfortunately meteorological data over a period of years are sadly lacking in Alberta. If this interpretation is correct, then it is reasonable to anticipate a rise in the water table and ultimately the reappearance of lakes in some areas as the cycle progresses with increased precipitation.

Sub-surface Geology

The areal geology of the Blackfoot and Calgary sheets is shown on the small scale map (Plate 33) accompanying this report. This information is taken from the geological map of Alberta prepared by the writer and published in 1937.

The geological formations which occur at the surface or immediately below the unconsolidated deposits in the plains and foothills belt in the Blackfoot and the eastern part of the Calgary sheet east of the Forest Reserve boundary, are Cretaceous and Tertiary in age. Older Mesozoic and Paleozoic rocks outcrop within the inner foothills belt and in the east side of the Rocky Mountains.

On Plate 33 nine geological units are shown. It is not necessary to discuss each of these units in detail but mention will be made of some of the chief lithological characteristics of each group. The outcrops of these various rocks are limited in area on the Blackfoot and east part of the Calgary sheets, and are confined largely to the eroded areas shown on the soil map. In other areas the information on the rock formation has been obtained from the records of dug or drilled wells.

The rocks in this map-area, in order of age from the youngest to the oldest, are as follows:

Period	Formation	Character of Rock
Tertiary	Paskapoo (Willow Creek and Porcupine Hills)	Sandstones, soft grey, clayey, and calcareous, and clay shales.
Upper Cretaceous	Edmonton (St. Mary River)	Sandstone, shale and coal.
	Bearpaw	Shale, dark coloured with sandy beds, some bentonite, marine.
	Belly River	Sandstone and shales interbedded, coal seams in upper part, fresh and brackish water deposition.
	Alberta (Benton)	Shales, dark with ironstone concretions, marine.
Lower Cretaceous	Blairmore-Kootenay	Sandstones, grey, greenish and dark coloured. Shales, grey, green and maroon. Coal seams occur near the top of the Kootenay. Non-marine.

The oldest rocks shown on the geological map (Plate 33) are grouped as the Paleozoic and early Mesozoic. Several formations are grouped and these outcrop in Highwood range and in Moose mountain within the Forest Reserve. It is known that several of these older formations occur under the plains at depth, but they do not affect the soil types in this map-area.

The Lower Cretaceous (Blairmore-Kootenay) formations are composed essentially of hard grey, greenish and dark coloured sandstones. In the Kootenay formation which is the lower, there are several coal seams. There is no coal being mined from the Kootenay in this map-area, but a very large reserve tonnage has been proven by prospecting in the Highwood valley west of the

Highwood range in range 6, and in the valley of Sheep river in range 7, west of the fifth meridian.

The strata in the lower part of the Upper Cretaceous are represented by the Alberta shale formation which includes what was formerly known as the Benton shale. This formation consists chiefly of dark grey shale of marine deposition. The shale is interbedded with thin beds of sandstone and several thin beds of bentonite which is also known under the name of gumbo. These shales occur as a narrow band in Turner Valley between Tongue creek and Millarville. Another narrow band occurs at the north boundary of the map, west of Jumpingpound, and extends southeast into the north side of Sarcee Indian Reserve. The largest belt of these rocks occurs from Pekisko creek in the east half of range 3, and on the west side of range 2, northward across the entire width of the Calgary sheet, and across Jumpingpound creek to the west side of township 24, range 5. Where these rocks form residual clays, the soil type is a heavy clay or clay loam.

The Belly River strata are of freshwater deposition and consist chiefly of grey, greenish and buff sandstones interbedded with grey, greenish and carbonaceous shales. Crossbedding caused by deposition in shallow water, is common in the sandstone. The Belly River strata are exposed in a small area in the southeast corner of the Blackfoot sheet on the Bow river in the vicinity of Eyremore. Strata of this age extend under the entire Blackfoot sheet below the younger formations.

Within the foothills it has not always been possible to differentiate between the Upper Cretaceous formations for mapping purposes, so the bands of such strata are mapped in a single unit. Where it has been found possible the Alberta shale and the Edmonton have been mapped separately, but elsewhere in the foothills the Upper Cretaceous is shown in one unit.

The Bearpaw formation consists chiefly of dark grey clay shales and sandy shales of marine deposition. In some areas there are numerous limestone concretions and some of the shale beds contain marine fossils of which the cephalopods as *Baculites* and *Placenticeras,* are quite common. These fossils are usually coated with an iridescent layer of lime carbonate known as "mother-of-pearl". These fossils are segmented and are frequently considered to be fish vertebrae, but they are not fish.

There is one large belt of Bearpaw along the east side of the Blackfoot sheet. It extends across the south boundary of the map from ranges 16 to 20. The upper contact crosses Bow river near Crowfoot, and at the north boundary of the map it extends to the west side of range 16. These shales form heavy soils and are frequently salty. Good well water has not been found in the Bearpaw shales in any part of Alberta. Water from these shales is usually highly alkaline and not suitable for domestic use. This formation is over 300 feet thick in the vicinity of Bassano, but it thins to the west and does not occur as a separate formation in the foothills. There is an exposure of dark shaly rocks at the crossing of Highwood river south of Turner Valley, that are correlated with the Bearpaw formation.

The Edmonton formation corresponds in time age to the St. Mary River formation in southern Alberta and represents the uppermost Cretaceous strata. It consists of non-marine highly calcareous sandstone, light grey sandstone and sandy shales. Crossbedding and irregular bedding are common structural features. Soils which have been influenced by these strata have a high lime content. Freshwater oyster shells and other freshwater fossils are common in this formation. A broad band of Edmonton strata occurs across the Blackfoot sheet from township 17, ranges 20, 21 and 22, includes Lake McGregor and extends north to township 24, ranges 17 to 22, west of the fourth meridian. The upper contact of this formation crosses Bow river in range 24, 8 miles northwest of Arrowwood. There is a narrow band of Edmonton strata extending along the east side of the foothills belt across the Calgary sheet from Pekisko, through Black Diamond, Priddis and to the north boundary of the map in the west side of range 4. Plate 32B shows a typical outcrop in the Edmonton southwest of Bassano. It also shows the irregular weathering in the hard and soft belts. The position of this formation indicates in general the line between the plains and the foothills in this map-area.

The youngest rocks in the Blackfoot and Calgary sheets belong to the Paskapoo formation which is Tertiary in age. This formation corresponds to the Porcupine Hills formation and the Willow Creek formation in the Macleod and Pincher Creek sheets. The formation consists of soft, grey, clayey sandstone and clay shale of freshwater deposition. The lower Willow Creek beds have mauve, red and grey hues.

The Paskapoo strata have the widest distribution in the map-area and occur as the surface formation in the western half of the Blackfoot sheet, and the eastern one and one-half to three and one-half ranges in the Calgary sheet. These Tertiary rocks occupy the trough-like depression known as the Alberta syncline, so the older rock formations come to the surface both to the east and to the west of the Paskapoo band. These rocks have had a marked influence on many of the soils east of the foothills in Alberta.

Origin of Surficial Deposits

The mineral composition of a soil and the source from which the mineral grains have been derived are geological problems. Frequently the origin of the material making up the unconsolidated deposits can be determined.

It is not always possible to determine the origin of the surface deposits in certain areas because frequently the unconsolidated material is of mixed origin. This is particularly true in the case of reworked deposits such as outwash plains, alluvial and marginal deposits.

The soil differs from underlying deposits upon which it is developed in that weathering agents have changed its original texture, color and composition. In some soils the accumulation of organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. In most cases the surface leaching has deprived the soils of certain original minerals, and often the mineral content of the subsoils has been changed.

The general character of the surface of the Blackfoot and Calgary sheets indicates to some degree the origin and distribution of the unconsolidated deposits. In the plains area, rock outcrops are confined chiefly to the eroded areas and represent about three per cent of the total map-area of about three and one-third million acres. Almost three-quarters of the map-area has a level to gently rolling surface in which the unconsolidated deposits consist largely of more or less well sorted glacial moraine and alluvial material, and a very small part of residual soil. More rolling topography, representing about 10 per cent of the map-area, occurs along the outer foothills and the western edge of the area underlain by the Paskapoo formation, chiefly on the eastern edge of the Calgary sheet (Plate 32C). Similar surface conditions usually occur marginal to the principal morainal areas. The real hilly areas, representing about 12 per cent, occur within the foothills where the ridges consist largely of rock formations, and also in the undisturbed morainal ridges, such as, east of Hussar, east of Lake McGregor and in the Buffalo Hill moraine.

The unconsolidated surface deposits in the Blackfoot and Calgary sheets can be classified under four major types:

(1) Residual and sorted residual deposits.
(2) Glacial deposits—moraine, till, boulder clay.
(3) Resorted glacial deposits.
(4) Transported deposits of alluvial, lacustrine and dune or eolian origin.

The first type includes the residual soils formed by erosion processes from the underlying rock formation. Soils formed in this way will have a composition somewhat similar to the composition of the underlying rock from which the soil has been formed, except in cases where solutions have removed a part of the more soluble constituents. More frequently the residual soils have been resorted or affected in some way by various transporting agents of erosion and in such cases the composition of the soil is not similar to that of the underlying strata.

Residual soils formed from dark marine shales are more readily recognized in the field than those from sandstone and shale of freshwater deposition. Only a few narrow belts of residual soil were observed in the map-area and these are associated with underlying Bearpaw and Alberta shale formations of marine origin. Residual soils, more or less sorted, on the underlying Bearpaw formation, occur on the east side of the Bow valley between Eyremore and Lothian. The largest area of residual soil was observed in Turner Valley, Kew Valley, and in the depressions west to the Forest Reserve boundary between ridges of harder sandstone formations. These soils are produced from the underlying bands of Alberta shale. In the valley which extends from Sheep river at Black Diamond, northwest to Priddis and about two miles north of Priddis creek, residual soils have been formed on shales that correspond to the Bearpaw formation.

The second major type includes those deposits of glacial origin which occur in the form of terminal moraine as irregular hills or undulating ridges, often quite thick, or as ground moraine, usually thin or represented by scattered glacial boulders and pebbles.

The distribution of glacial deposits in the Blackfoot sheet and the eastern part of the Calgary sheet was mapped with considerable detail. Plate 34 shows the distribution of the morainal deposits or unsorted glacial material, and the sorted glacial material which has been subjected to some postglacial sorting. The original moraine occurs in ridges, hills or rolling broken topography with numerous sloughs and in places kettleholes. The sorted or reworked glacial material forms lower relief and the surface in those areas is usually more plain-like. There has been some laking between the morainal areas. The larger lake basins are shown on Plate 34. The largest basin is along Parflesh creek south of Chancellor.

The glacial deposits have been derived from one of two sources. The mountain or alpine glaciers originated within the Rocky Mountains and proceeded eastward over the foothills and plains, carrying rock debris from the rock formations within or possibly west of the front ranges of the Rocky Mountains; and the Keewatin or Continental glaciers originated in the vicinity of Hudson Bay, bringing with them a very different kind of rock debris derived from the Precambrian rocks in the Canadian Shield and also the rock material from the plains over which the glaciers passed. No attempt will be made to discuss in detail the glacial history or the deposits of glacial origin which were left in this part of Alberta.

The morainal material transported from the mountains consists largely of limestone, dolomite, shale, slate, quartzitic sandstone some of which is phosphatic, and dark chert pebbles.

The detrital material transported from the northeast by the Keewatin glaciers consists largely of igneous and metamorphic rocks such as granite, gabbro, gneiss, schist, argillite, greenstone, etc., and locally of harder sandstone from the younger rock formations under the plains over which the ice moved.

The glaciers from the Rocky Mountains extended down the valleys and spread out over the intervening ridges in the foothills belt. Boulders and gravels carried by the glaciers were left when the ice melted. The mountain glaciers extended eastwards until the ice met the Keewatin glaciers from the Hudson Bay area. The most easterly extension of the mountain glaciers in this map-area was about the position of the fifth meridian.

On the top of Sitook-Spagkway (Middle Heights) four miles west of Aldersyde in the northwest quarter of section 32, township 19, range 29, three Keewatin boulders were observed and many smaller boulders from the mountain glaciers. The finer material has been washed out of the moraine from the top of this hill. Two Rocky Mountain boulders and at least one Keewatin boulder were observed in the east slope of this hill in section 3, township 20, range 29. East of this point the boulders are from the Keewatin glaciers, while west of the hill the boulders are from the mountains.

The large boulder known as the "Big rock", on the north side of the highway, eight miles west of Okotoks in section 21, township 20, range 1, has been deposited there by the mountain glaciers. It consists of quartzitic sandstone.

The largest glacial erratic of mountain origin and the farthest from the mountains observed by the writer, is in the valley of Nose creek, close to Beddington siding and on the east side of the railway about five miles north of Calgary. The exact location is in the northeast quarter of section 26, township 25, range 1, west of the fifth meridian. The Beddington boulder (Plate 35A) measures 24 feet long, 23 feet wide and 15 feet above the surface of the ground. This boulder consists of quartzitic sandstone, well bedded with some layers of pebbly sandstone, smoothly polished from animals rubbing against it and in part from wind abrasion. The rock is similar to that in other large glacial erratics west of Okotoks and in the foothills and western edge of the plains in southwestern Alberta, such as shown in Plate 25A. Other smaller boulders of the same kind occur to the south in range 1 and farther west around Longview.

South of the Highwood river many Keewatin boulders were observed in the vicinity of the fifth meridian. The farthest west Keewatin boulder observed is on the side of the highway in section 5, township 18, range 1. This indicates that the soil types west of the fifth meridian in this map-area do not contain much of the Keewatin glacial debris. But on the other hand, considerable mountain debris has been carried westward by streams into the Blackfoot sheet.

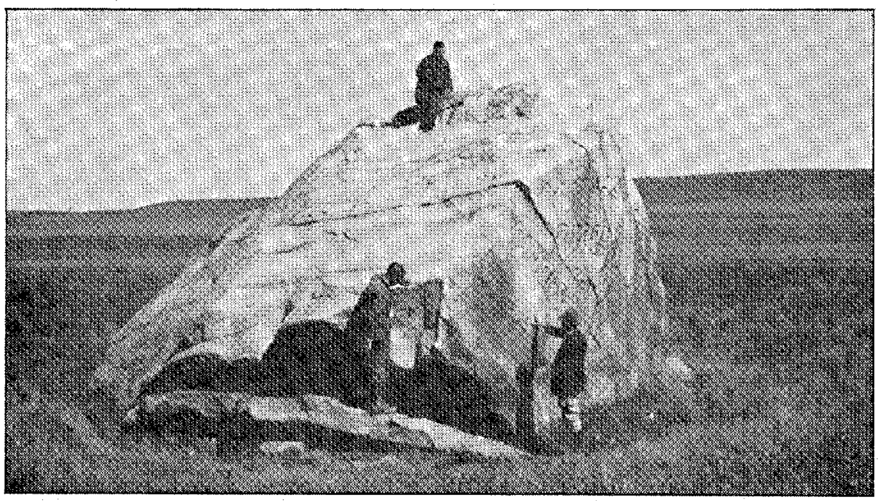
It is probable that the glaciers from the west and from the east covered the whole of the area included on Plate 34, even the highest points. Glacial debris was observed on the top of Buffalo hill and other high points in the Arrowwood district. Over one-half of the surface of the Blackfoot sheet consists of glacial material either as unsorted glacial moraine or as sorted glacial debris.

There are several prominent morainal ridges and lower areas in the Blackfoot sheet. There is a large morainal area extending across the eastern side of the Blackfoot sheet from north to south. At the north boundary of the map this *Hussar moraine*, either terminal or lateral, extends from Hussar east to Crawling valley, a distance of about fifteen miles. It occurs around Granta in township 22, range 19, and extends west into range 20. From the Bow river valley south to the boundary of the map-area, the moraine covers almost all of range 19 and the west side of range 18. To the west, the hills on the east side of Lake McGregor are glacial moraine, which also extends to the west of the lake as a narrow band in township 17, widening to about five miles in township 18, and reaching a maximum width of about eight miles in Buffalo hill and the ridge to the northeast. Another belt of moraine extends from the Little Bow river south of Frankburg, northeast between Blackie and Brant in range 26, and east of Dinton and Glenview to the centre of township 21, range 25. On the west side of the Blackfoot sheet there is glacial moraine from the edge of the Bow valley at the city of Calgary, eastward for about six miles, with a small area northwest of Chestermere lake. A morainal ridge occurs between DeWinton and Okotoks in the area between the Bow and Sheep rivers. In the southwest corner of the Blackfoot sheet between the Highwood river and Mosquito creek, there are several isolated morainal islands at Azure and Cayley and west of the meridian.

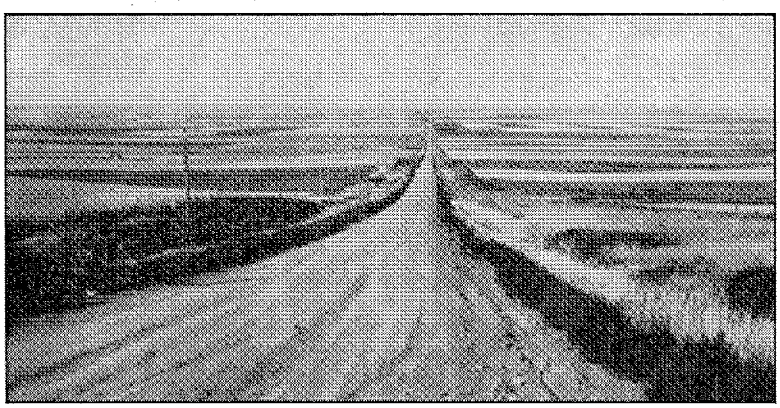
In the Calgary sheet glacial moraine covers most of the area south of the Tongue creek in range 1, between Tongue creek and Sheep river, and in ranges 1 and 2 between Sheep and Bow rivers.

The sorted or reworked glacial deposits in the third type have a wide distribution within and around the moraine. The surface of this type of glacial deposit is shown in Plate 35B in the Vulcan area. The largest area occurs in the Blackfoot sheet in ranges 26, 27, 28 and 29, or west of a line drawn from Ensign, north to Carseland and Cheadle (Plate 36A). The unconsolidated deposits are all sorted glacial from Carseland to Shepard, and from Dinton west to the Highwood river. In the Calgary sheet numerous small irregular areas occur within and about the glacial moraine. Gravelly outwash from the glacial deposits occur in a few small areas, chiefly

PLATE 35

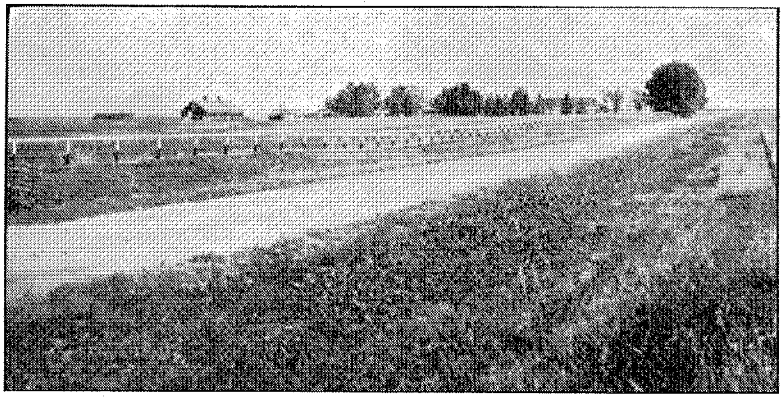


A.—Beddington erratic. A glacial boulder of quartzitic sandstone, 24 feet long, 23 feet wide and 15 feet above surface of ground, transported by ice from Rocky Mountains, to Nose creek valley, section 26, township 25, range 1, west of fifth meridian, about five miles north of Calgary.

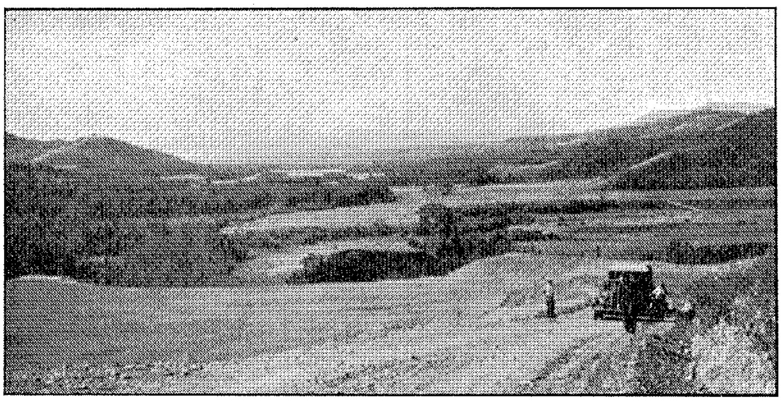


B.—Sorted glacial deposits forming dark brown loams in the Vulcan area. Looking north across Snake creek valley in range 23, about six miles east of Vulcan.

PLATE 36



A.—Sorted glacial deposits west of Sheppard, typical of area between Calgary and Carseland.



B.—Looking southwest up Highwood river valley from Sullivan creek hill, showing alluvial terraces and foothill topography.

C.—Alluvial plain at Gem, looking south from northeast corner of section 8, township 23, range 16, west of fourth meridian.

where there is low land adjoining high land capped with glacial moraine, as along drainage courses. Part of the city of Calgary is situated on the gravel outwash from the high banks along the Bow valley.

The fourth type of surface material includes the *transported deposits*. The transporting agents are wind and running water, either along stream courses or as runoff. The former gives rise to dunes or eolian plains, the latter to alluvial flood plain and lacustrine deposits. Transported soils are bedded in character due to the sorting action of the transporting agents. The sand and clay may occur in separate layers or lenses, forming a sandy soil or a clay soil. These deposits may be a mixture of sand and clay with varying proportions of each, giving rise to a sandy clay or a clay loam or a sandy loam soil. It is not always possible to distinguish the fourth type, that is the transported deposits of recent origin, from the resorted or transported glacial deposits.

Transported deposits may be derived from two main sources. There are the gravel, sand and clay that are carried down the slope along major river courses for considerable distances. These are alluvial and fluviatile deposits that are directly associated with river transportation.

In the Blackfoot and Calgary sheets the river-carried alluvial and fluviatile deposits are distributed along the valleys of the Bow, Highwood and Sheep rivers, Priddis creek and other small creeks, and along some of the old abandoned drainage courses such as Crawling valley (Plate 36B).

The second type of transported deposits includes the deposits that have been washed down from higher levels to lower levels, possibly in a lake basin. These form alluvial and lacustrine plains. In this type the finer particles will be carried farther than the coarser material. Fine clays and silt will grade into sand, and the sand will grade into gravel. This class of material is widely distributed in the Blackfoot sheet. One large area of alluvial and eolian deposits occurs at the east side of the sheet, east of the Bow from township 19 to the top of the map-area. Much of the surface east of Bassano and Gem contains this type of deposit (Plate 36C). The alluvial plain between Gem and Crawling valley, and the east side of the Hussar moraine, consists of a mixture of alluvial and glacial material which is known as glacio-alluvial deposits. A much larger area of transported deposits occurs in the central part of the Blackfoot sheet between the Hussar moraine on the east and the glacial plain west of Carseland.

In general the surface deposits are coarser on the west and become finer to the east indicating a sorting due to transportation. Sand and coarser sediments predominate on the west of the map, north of the Bow from about range 25, but silts and clays predominate in range 21 in the Cluny and Ouelletteville areas. The finest particles of transported material occur as heavy clay in the Parflesh plain, south of Chancellor (Plate 37A).

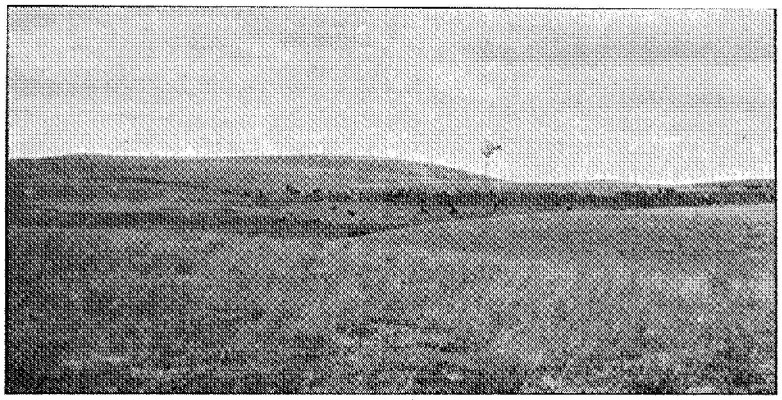
There is another large area of transported material south of the Bow. Extending north from about the centre of township 17 in the Lake McGregor area, there is a narrow band of mixed alluvial and glacial material derived from the adjoining unsorted moraine. Between Queenstown and Milo the transported deposits broaden rapidly towards the Bow and include all the area westward from the Majorville district in range 20 and flanking the north slope of Buffalo hill to West Arrowwood creek in range 25. A narrow band of alluvial material has been deposited along the West Arrowwood drainage southward to the Ensign district and towards Vulcan. There are several small irregular areas of alluvial material on the west side of the Blackfoot sheet such as the Frank lake basin that fingers out to the northwest, and the High River-Aldersyde basin that extends from the centre of section 2, township 19, range 28, west to about the centre of range 29. From DeWinton east to the mouth of Highwood river, there is another alluvial area flanking the ridge north of Okotoks. In the Calgary sheet the largest alluvial area occurs in the Sarcee Indian Reserve extending from Lloyd lake and Fish creek in range 2, northwest to the Elbow river and includes the Pirmez silt loam flats. A similar type of soil occurs in range 3, north of Elbow river. These silt loams have been derived largely from the adjoining glacial deposits and from the underlying clay shale and sandstone in the Paskapoo formation.

There are several flats in this map-area that are of glacio-lacustrine and postglacial origins. These old lake basins represent areas where the earlier drainage was dammed by ice or by glacial moraine and lakes were formed, then later the basins were filled in with clays, silts and sands. *Chancellor flat* (Plate 37A) is the largest of such proglacial lake basins, that is, a lake formed at the front of the ice. This basin extends from Hussar westward for about 10 miles, and from Ouelletteville north beyond the boundary of the Blackfoot sheet, which is township 24. This lake was formed against the ice sheet that left the *Hussar moraine* (Plate 37B). Much of the clay and silt was washed into this basin from the west during the glacial age. The *Cluny flat* represents a lake basin formed on the side of the Bow river, when the valley was filled with glacial ice (Plate 34). Deadhorse lake occupies a kettle hole which is a depression formed in the moraine when the glacier melted. There is another small lake basin about two miles wide and six miles long, east of Crowfoot creek between townships 22 and 23. Drainage courses sometimes become obstructed and lakes are formed. One small lake was formed in this way between Queenstown and Milo along the drainage from Lake McGregor. Eagle, Namaka and Stobart lakes were at one time connected, but alluvial material washed into this drainage basin has caused the present three lakes. This basin may have at one time extended northwest to the vicinity of Strathmore. Lloyd lake, five miles southwest of Midnapore, is the remnant of a much larger lake basin. There is evidence of considerable laking represented by *Jumpingpound flat* north of Elbow river in range 4. This old lake basin at one time extended north at least as far as Jumpingpound creek in township 25, and possibly was connected with *Glenbow flat,* the south end of which occurs north of Elbow river in range 3.

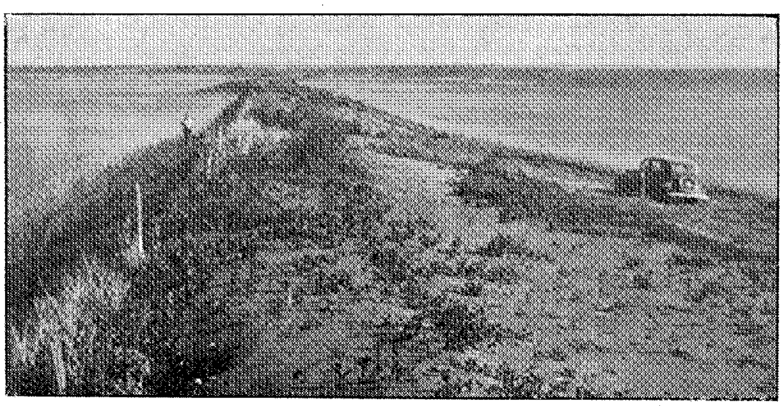
In almost every case old lake basins can be recognized by the flatness of the surface, and by the fineness and uniformity of the clay or silt, unless the fine soil has been piled up by wind action to form dunes, such as occurs south of Cluny. Eolian deposits in the form of dunes, or as narrow ridges (Plate 37C) may be found on any surface material that is fine enough to be transported by the wind. There are several small dune areas but in no place are the areas large.

PLATE 37

A.—Looking south across Parflesh creek from section 24, township 24, range 21, west of fourth meridian, showing part of Chancellor flat.



B.—Hussar moraine about four miles east of Deadhorse lake in township 24, range 19.



C.—Eolian deposit as a drift on a roadway crossing the Little Bow valley, 3 miles southeast of High River.

Water Supply

The term *water supply,* according to common usage, refers to the water that occurs on or beneath the surface and is available for domestic, industrial or irrigation uses. But this term has a broader meaning as it includes the water or moisture in the soils, so necessary for all plant life. Rivers, creeks and lakes form the *surface water* supply, and this water may have been carried long distances from the melting of glaciers, or the run-off from higher lands. A part of the surface water may be supplied from local precipitation.

Underground water includes water that occurs in the rock formations beneath the surface or in the unconsolidated deposits that occur over the bedrock. It is most important to realize that all the underground water supply has been derived from surface precipitation and therefore comes from the surface. A grave mistake has been made in many parts of Alberta by draining off the surface water and by cutting off the brush and forest in order to add a few acres for agricultural purposes. So often by so doing the water supply has been depleted, and in many instances the well water supply has become inadequate for domestic purposes. If man does not allow the surface water to enter the surface deposits, then the underground water supply in that district will be reduced just that amount.

The best advice that can be given on the problem of water supply is to retain all possible precipitation on the surface. Do not drain lakes and sloughs, and do not remove brush and woods from the plains area or even from the foothills. By removing water from the surface, some water wells in that district will have a depleted supply. This water problem is so important that it deserves a separate report, but this subject will not be discussed here.

Artesian water differs from the ordinary underground water in that the water has entered the rocks many miles distant from where the artesian water is encountered by deep drilling. All flowing wells are not artesian wells. Most shallow flowing wells are man-made springs where the water is flowing from an orifice on the side of a hill, or on or at a point where the water is under a head because of higher ground in the vicinity. Flowing wells were observed in several localities including those in section 5, township 20, range 27, also in section 33, township 19, range 27, in section 24, township 19, range 28 and in section 5, township 18, range 29. Several springs were observed around Buffalo hill, the Arrowwood hills, Sitook-Spagkway and along the Highwood valley especially west of the town of High River, both on the south and on the north sides of the river.

There is no serious water problem in this map-area. There are many wells with a large supply of good water and there are many flowing wells, some of which were encountered within fifty to two hundred feet from the surface. With the exception of the more compact clay soils, water can be expected in most of the unconsolidated deposits, especially where there are lenses or beds of sand or gravel. There are also good chances of water horizons occurring within the bedrock. Sandstone and sandy shale are sufficiently permeable to form good water horizons. The Paskapoo formation contains many beds suitable for water reservoirs. The Edmonton or St. Mary River formation also contains many feet of strata suitable for the accumulation of water. The geological map (Plate 33) indicates that these formations have a wide distribution in this map-area.

It has been pointed out that the Bearpaw shales are of marine deposition. Attention is drawn to the important fact that good water or a good water supply cannot be expected from the Bearpaw strata. There is no use drilling or digging a well into the Bearpaw shales for good water as it does not exist. Any water from the Bearpaw shales will be unsuitable for domestic use or for stock use because of the high content of dissolved salts from the marine shales. In that area where the Bearpaw formation underlies the unconsolidated deposits, it is necessary to obtain well water from the surface unconsolidated deposits, or else to drill through the Bearpaw shales that are about 300 feet thick, into the underlying Belly River formation which contains strata suitable for water horizons.

The composition of well water varies widely, depending upon the percentage of soluble salts dissolved in the water. Some water is soft, and some water is hard because of the dissolved lime in the water, but both hard and soft water can be used for domestic or industrial purposes. Other water may contain alkalies, or alum, or iron, depending upon the amount of these soluble minerals in the surface soil or underground rock formations through which the water passes. A small quantity of highly saline water with alkalies and the like, can spoil a good water by mixing with it. This is why it is most important in digging or drilling a well to shut off all impure water from entering the well in which good water is encountered at a lower level.

A word of caution is given on the danger from gas during the digging of water wells. Throughout the plains in Alberta small quantities of gas may be encountered in almost any of the surface formations and particularly those designated Paskapoo and Edmonton. In a hand-dug well gas may accumulate while the well is being dug. Fatal accidents have occurred as a result of gas accumulation during digging operations. It is most dangerous to enter any excavation more than ten feet deep before testing for the presence of gas. Odorless gas or gas with a slight odor is most dangerous as it cannot be detected as readily as a strong sulphurous odor.

SOIL GEOLOGY IN ROSEBUD AND BANFF SHEETS

Introduction

The map-area discussed in this report includes the whole of the Rosebud sheet, townships 25 to 32 and ranges 16 to 29 inclusive, west of the fourth meridian, and that part of the Banff sheet east of the boundary of the Rocky Mountains Forest Reserve, principally within ranges 1 to 7, west of the fifth meridian, and townships 25 to 32 inclusive.

The geological map (Plate 38) shows the distribution of the geological formations. Plate 39 shows the distribution of the glacial deposits and the major lake deposits associated with the moraines in the Rosebud sheet. The interpretation of the glacial deposits in this area, is based on field investigations by the writer in 1940 and 1941, and on the classification of soil types carried out by the P.F.R.A., Dominion Department of Agriculture in co-operation with the Soils Department at the University of Alberta.

Physical Features

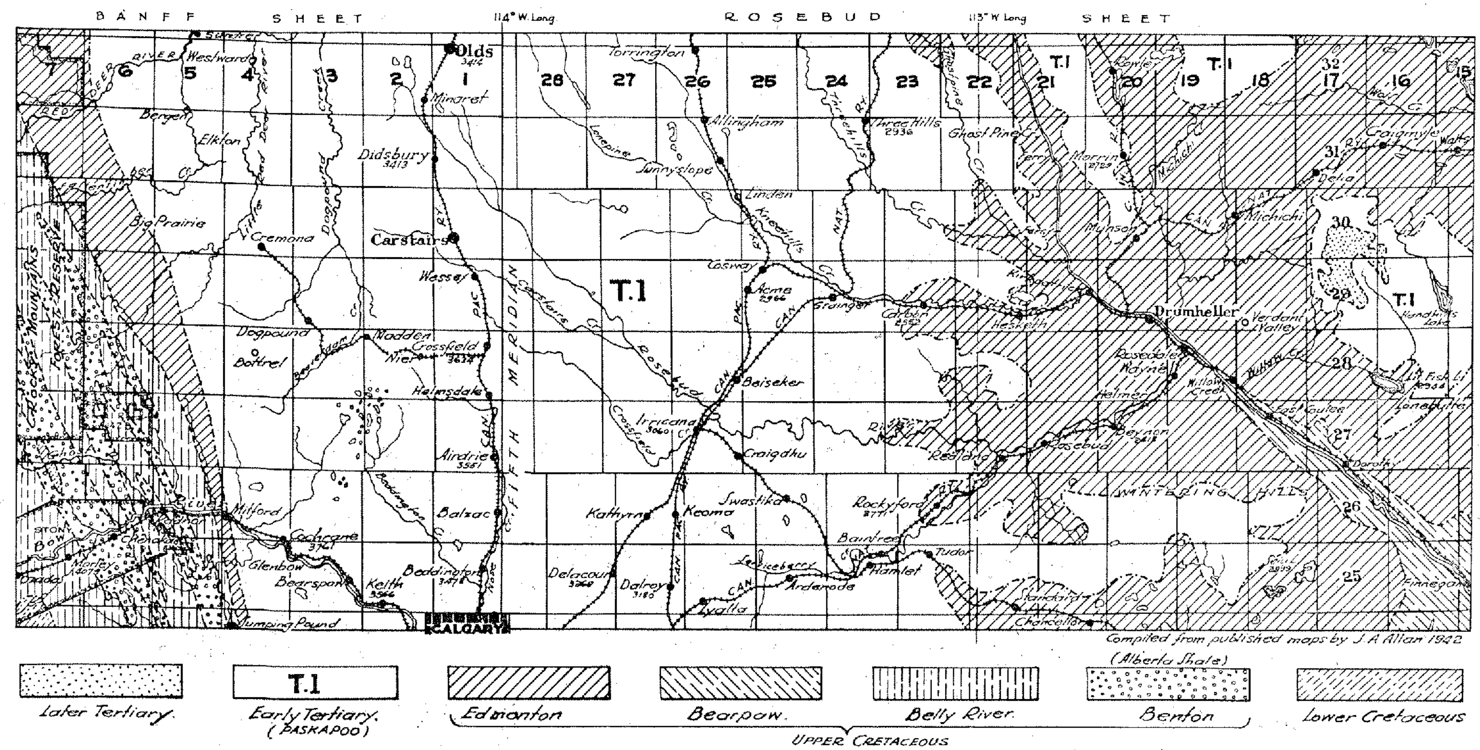
The surface of the Rosebud sheet lies entirely within the plains area with elevations ranging from 2,150 feet at the southwest corner, and 2,600 feet at the northeast corner of the map-area, to 3,550 feet at the southwest corner, and 3,350 feet above sea level at the northwest corner of the sheet. There are two prominent hills in the Rosebud sheet; these are the Hand hills, east of Drumheller in townships 29 and 30, range 17, west of the fifth meridian, with a maximum elevation of about 3,550 feet above sea level, and Wintering hills, south of Drumheller in township 27, ranges 19 to 22, with a maximum elevation of about 3,400 feet above sea level. The highest part in the Rosebud sheet is close to the fifth meridian in townships 27 and 28, range 29, between Airdrie and Crossfield where the tops of two hills each have an elevation of about 3,725 feet above sea level.

The surface of that portion of the Banff sheet included in Plate 38 consists of the western edge of the plains area and the eastern edge of the foothills belt. There is a sharp change in the topography between the plains and the foothills, but the western edge of the plains is approximately along a line drawn from the junction of Jumpingpound creek and the Bow river in range 4, northwest along Grand Valley, across Little Red Deer river in the vicinity of Big Prairie in range 5, and across Red Deer river to the west of Bearberry Prairie in range 6, west of the fifth meridian. In this portion of the Banff sheet the elevations range from 3,300 feet to 5,300 feet above sea level.

Almost the entire area of the Rosebud sheet with the exception of the south slope of Wintering hills, and that portion of the Banff sheet north of township 27 is drained by the Red Deer river and its several tributaries. The Red Deer passes north out of the Banff sheet at Sundre in range 4, west of the fifth meridian, 23 miles west of Olds, and enters the Rosebud sheet at the west side of range 21, west of the fourth meridian, 48 miles east of Olds. The incised preglacial valley of the Red Deer river ranges from 300 to 500 feet in depth and one to two miles in width. Most of the tributaries to the Red Deer valley are also deeply incised for several miles from the mouth of each. Rapid erosion has developed badland topography along the Red Deer within the Rosebud sheet. The badlands are most extensive in the vicinity of Drumheller (Plate 12A). Many dinosaur fossils have been collected, more or less complete, from the badlands between Drumheller and the Morrin ferry in township 31.

There are two small streams entering the Red Deer river on the east side of the valley in the Rosebud sheet. Willow creek drains the south part of Hand hills and enters the Red Deer ten miles downstream from Drumheller. Michichi creek joins the Red Deer at Drumheller and drains the northwest slope of the Hand hills.

There are several larger tributaries entering the Red Deer from the south. Rosebud river with an extremely meandering course joins the Red Deer at Rosedale, five miles southeast of Drumheller and rises about six miles southwest of Olds. A smaller tributary of the Rosebud is Serviceberry creek which rises in section 36, township 25, range 27, between Dalroy and Keoma. Kneehills creek joins the Red Deer at Kirkpatrick, six miles northwest of Drumheller and rises in the vicinity of Olds and Innisfail. Threehills

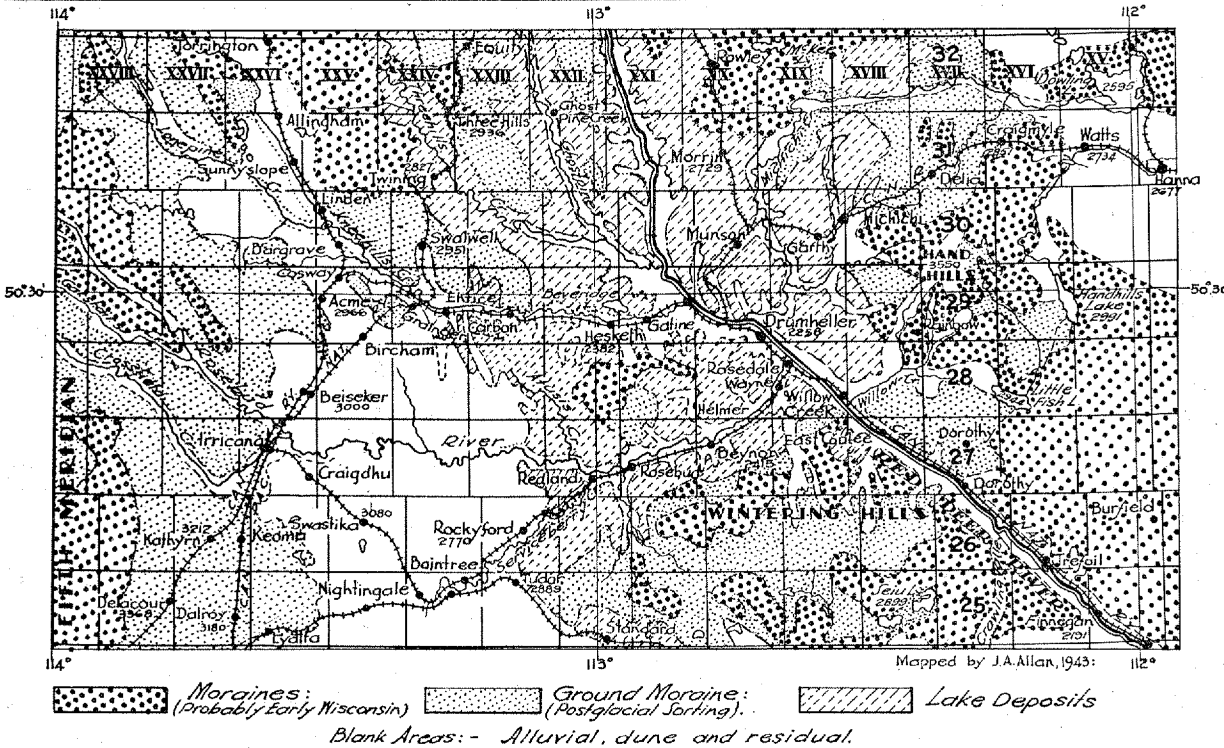


GEOLOGY OF THE BANFF-ROSEBUD SHEETS.

10 5 0 10 20
Scale of Miles.

AM '42

PLATE 39



Glacial Geology of the Rosebud Sheet.

Scale of Miles: 6 0 6 12 18

and Ghostpine creeks join in township 30 and as one stream enter the Red Deer between townships 29 and 30. These tributaries drain the area along the north side of Rosebud sheet, principally in ranges 24, 25 and 26. There are many dry coulees eroded into the upland along the sides of the main river and its tributaries (Plate 43B).

In the Banff sheet Beaverdam creek, Dogpound creek and Little Red Deer river drain northwards into Red Deer river. The larger tributary drainage of the Bow river includes Nose creek and Beddington creek north of Calgary, Bighill creek which enters the Bow at Cochrane, Horse creek, Grand Valley creek and Spencer creek, each of which drains less than ten miles from the Bow. Ghost river enters the Bow in range 6, eleven miles west of Cochrane. The headwaters of the Ghost river are within the Rocky Mountains, north of Banff. The Ghost river in preglacial times was the outlet for the Bow river from Banff by way of Minnewanka lake.

The Bow river was dammed by the Calgary Power Company, Limited, in 1928 at the mouth of the Ghost river so the reservoir formed by this dam, 108 feet high, extends up the valley of the Ghost for two miles and up the Bow valley for eight miles to Morley. This reservoir lake with a maximum width of one mile has been designated Gaherty lake by the writer after G. A. Gaherty, President of Montreal Engineering Company and Calgary Power Company, Limited, who has been largely responsible for hydro-electric development throughout Alberta.

The south side of Bow valley is drained by Jumpingpound creek which enters the Bow about two miles west of Cochrane, and Chiniki creek which drains the slopes south of Morley.

The drainage pattern in the western half of the Rosebud sheet and in the northeast corner of the Banff sheet, has a definite northwest and southeast trend, which represents successive drainage courses at the front of the retreating ice sheet. Many of these drainage ways are abandoned and do not now contain streams, but nevertheless the pattern indicates the former drainage.

There are no large lakes but there are numerous small lakes and slough lakes within the map-area. Many of the lakes shown on the map have become dried up or greatly reduced in size. Handhills lake (2,981 feet) and Little Fish lake (2,944 feet) on the slopes of Hand hills at the east side of the Rosebud sheet are the largest, but these have become reduced in size in recent years. Handhills lake is now only a shallow alkaline slough lake. Much of the basin of Beveridge lake in township 29, north of Kneehills creek at Hesketh, has been under cultivation for several years. It is evident that in the Rosebud sheet as in many other parts of Alberta, the volume of surface water has become greatly reduced in the past two decades.

Several factors may have contributed to the disappearance of former lakes, but chief among these are climatic changes, cultivation causing increased evaporation, and artificial drainage following settlement. Cyclic variations in the annual precipitation have changed the water table and have caused lakes to disappear and reappear. It is regrettable that meteorological data in Alberta over a period of years, are lacking. It would appear that the decrease in annual precipitation has been a major force. If cylic variations in the annual precipitation are occurring in Alberta, then it is reasonable to anticipate a rise in the water table and ultimately the reappearance of lakes in some areas. Indications that even within the past three years the water table has risen slightly and water has appeared in some former lake basins, or the water level in certain lakes has risen, point to the correctness of this interpretation.

SUB-SURFACE GEOLOGY

The geological formations that occur at the surface or immediately below the unconsolidated deposits in the plains and foothills belt in the Rosebud sheet and eastern part of the Banff sheet east of the Rocky Mountains Forest Reserve, are Cretaceous and Tertiary in age. On the geological map (Plate 38) seven geological units are shown. Some of the chief lithological characteristics of each group will be mentioned, but detailed descriptions will not be given.

The outcrops of these various rocks are limited in extent particularly on the Rosebud sheet, and are confined largely to the eroded areas along the Red Deer river and its tributaries, and along the Bow river and its tributaries. There are several outcops around the slopes of Hand hills and Wintering hills, and along several of the ridges within the foothills belt. In other areas the information on the rock formations has been obtained from the records of dug and drilled wells, from coal mines and in part from outcrops outside of the area shown on Plate 38.

The rocks in this map area, in order of age, from the youngest to the oldest, are as follows:

Period	Formation	Character of Rock
Later Tertiary	Handhills conglomerate	Conglomerate, loosely cemented wtih sand and clay.
Early Tertiary	Paskapoo	Sandstone, soft grey, clayey and calcareous, and clay shales.
Upper Cretaceous	Edmonton	Sandstone, shale, several coal seams and bentonite beds.
	Bearpaw	Shale, dark coloured to grey, with sandy beds, some bentonitic, marine.
	Belly River	Sandstone and shale interbedded, coal seams in upper part, fresh and brackish water deposition.
	Alberta (Benton)	Shales, dark grey to almost black, with ironstone concretions, sandy shales and a thin sandstone member (Cardium), marine.
Lower Cretaceous	Blairmore-Kootenay	Sandstone, grey, greenish and dark coloured. Shales, grey, green and maroon. Coal seams near top of the Kootenay. Non-marine.

The oldest formations, the Lower Cretaceous, Benton and Belly River, outcrop only within the foothills belt in the Banff sheet. The entire area of the Rosebud sheet is represented by the Bearpaw, Edmonton and Tertiary formations.

The Lower Cretaceous is represented in Plate 38 by one small area in the extreme southwest corner of the map-area and in a narrow band extending across Ghost river in range 7.

The foothills lying west of a line drawn from Jumpingpound near the west side of range 4, to the Red Deer river at the west side of range 7, consist of several folded and faulted bands of Benton and Belly River strata. The strata in the lower part of the Upper Cretaceous are represented by the Alberta shale formation which includes what was formerly called the Benton formation. This formation consists chiefly of dark grey shale, in some parts almost black, and sandy shales of marine deposition. Towards the centre of this formation there is a band of sandstone and conglomerate which thickens to the northwest and is known as the Cardium sandstone or conglomerate (Plate 44B). This harder member frequently forms prominent outcrops along the ridges in the foothills. The shale members are interstratified with thin beds of sandstone and in places, with several thin bands of bentonite which represents decomposed volcanic glass.

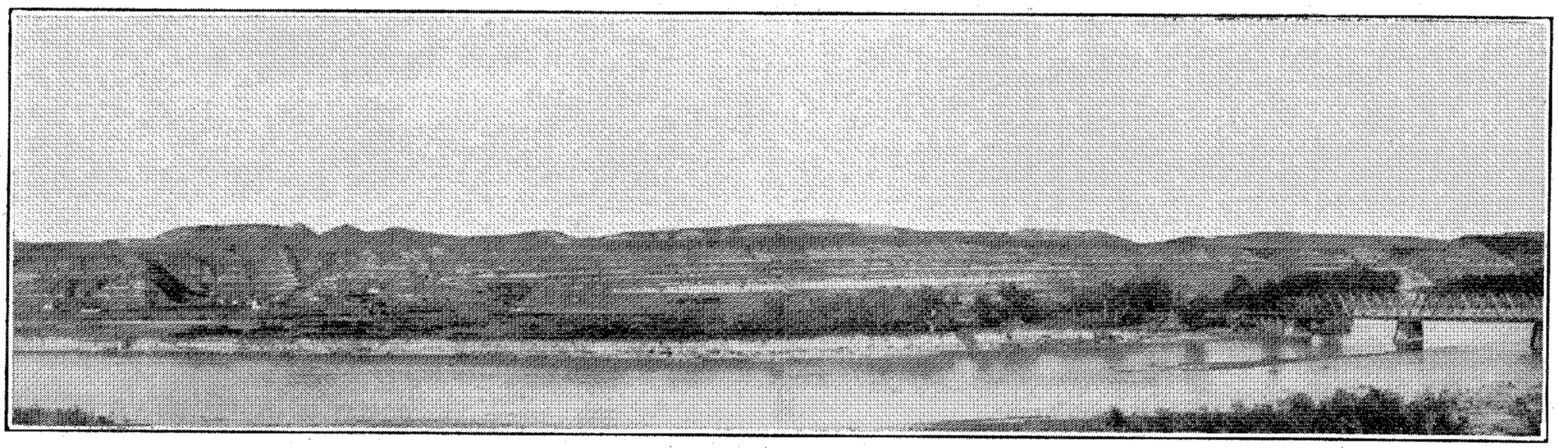
The Belly River starta are of freshwater deposition and consist chiefly of grey, greenish and buff sandstones interbedded with grey, greenish and carbonaceaus shales. Crossbedding caused by deposition in shallow water is common in the sandstones. The sandstones are more extensive and because they are more resistant to weathering, they frequently form the ridges within the foothills belt. The broadest band of Belly River strata in this map-area extends across the Bow river valley in range 7 between Morley and Ozada. The other narrower bands of Belly River rocks occur as bands separated by Alberta or Benton strata where the older formations have been thrust through the younger by faulting or folding.

The Bearpaw formation consists chiefly of dark grey clay shales and sandy shales of marine deposition (Plate 10A). There are several thin beds of light grey bentonite interstratified with the shales, particularly in the lower part of the formation. In some areas there are numerous limestone concretions. Some of the shale bands and the concretions contain marine fossils of which the cephalopods, such as *Baculites* and *Placenticeras*, are common. The former are straight shelled and the latter are coiled shelled cephalopods. The largest *Placenticeras* observed by the writer in the Rosebud sheet, measured forty-two inches in diameter. These fossils are usually coated with an iridescent layer of lime carbonate known as "mother-of-pearl".

The only exposure of Bearpaw strata in the Rosebud sheet is along the sides of Red Deer valley from the mouth of Willow creek, eight miles below Drumheller in section 12, township 28, range 19, west of the fourth meridian, downstream to the southeast corner of the map-area. At Dorothy ferry the Bearpaw outcrop is about one and one-half miles wide across the valley but the outcrop of these shales widens rapidly and rises above the top of the Red Deer valley at Finnegan. The Bearpaw formation along the Red Deer valley is about 550 feet thick, but it thins to the west and to the north. There is no Bearpaw exposed in the Banff sheet. This formation has not influenced the soils in the Rosebud sheet.

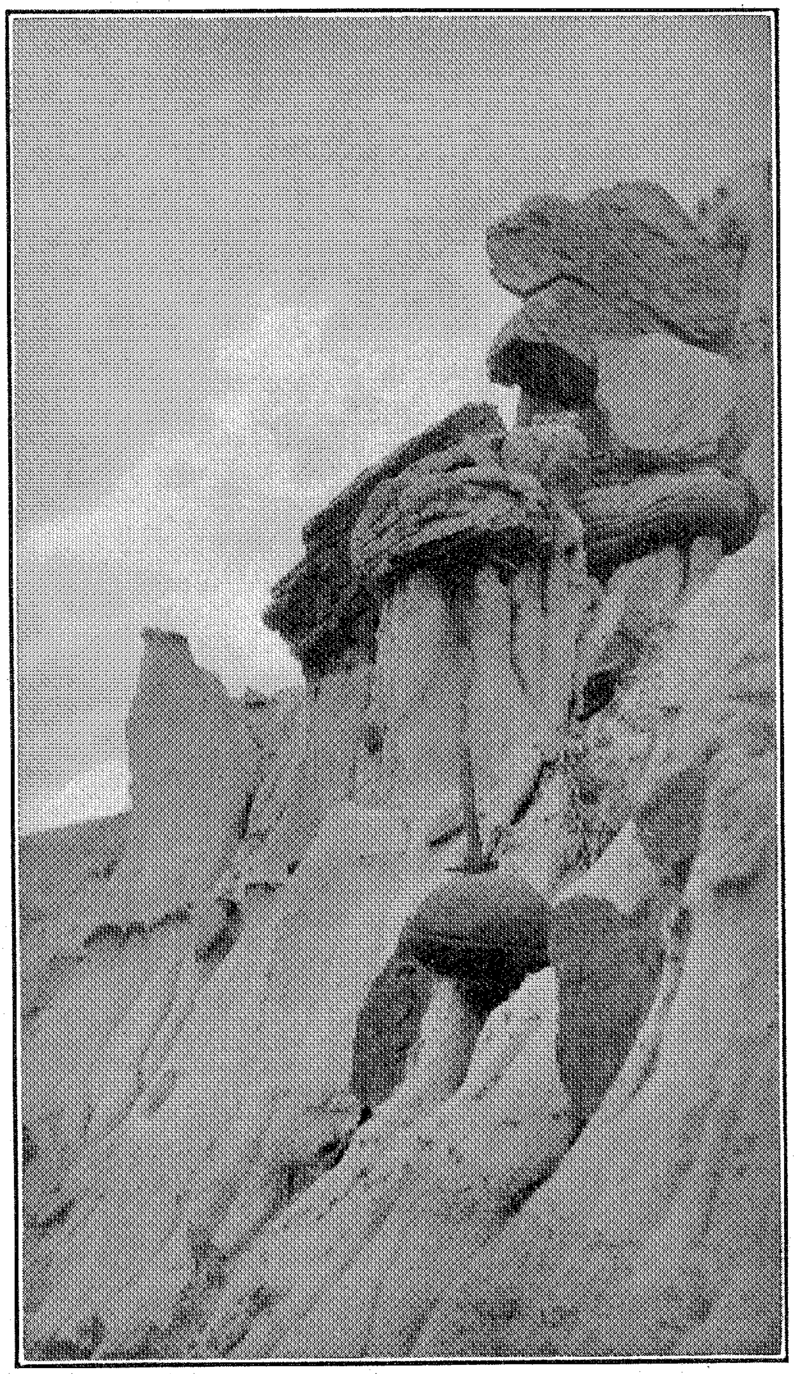
The Edmonton formation represents the uppermost Cretaceous strata. It consists largely of sediments deposited under fresh and brackish water conditions, in shallow freshwater basins, or in estuaries and deltas, or in littoral zones along the border of an advancing or retreating sea. Some of the members in this formation were deposited on mud flats and along flood plains that were exposed above the water level for short spaces of time, possibly

PLATE 40



East side of Red Deer valley looking northeast from Rosedale station. Lense of white bentonitic sandstone above No. 1 coal seam shows in centre.

PLATE 41



Spherical and irregular nodules of siliceous shale in white bentonitic sandstone between No. 7 and No. 8 coal seams, south of Newcastle Junior mine.

seasonal. Some of the beds, particularly those containing carbonaceous material, originated in enclosed basins or swamps. Cross-bedding, current marks, lensy structure, nodular masses, ironstone bands, erosion during deposition, younger beds enclosing fragments of older beds and especially those immediately under, are a few of the characteristics that prove the continental origin of the sediments in the Edmonton formation.

The composition of the strata in this formation varies greatly, both laterally and vertically. The Edmonton formation in this map-area consists of fine-grained sandstones, highly calcareous sandstones, sandy shales, bentonitic sandstones and shales, bentonite, ironstone bands, carbonaceous shales and coal. Bentonite is the prevailing constituent throughout the whole series of beds. There are thin beds of pure bentonite from a fraction of an inch up to a few feet in thickness, and many beds are classed as bentonic clays, shales and sandstones.

The sandstone members contain more or less bentonite and clay. The bentonitic sandstones are white on the eroded surface and give a pronounced banded appearance to the escarpments (Plate 40). Other hard bands of silicious shale in the bentonitic sandstone weather into flattened or spherical nodules that are more resistant to erosion (Plate 41). Many specimens of silicified fruit and fossilized plant fragments, including *Cunninghamites* sp., have been collected by Mr. W. R. Fulton from various horizons in the Edmonton formation in the vicinity of Drumheller.

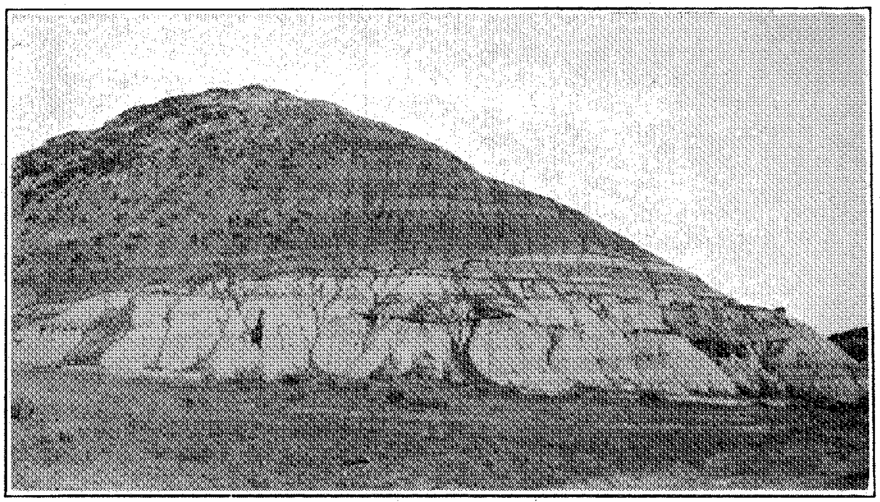
There are no true sandstone members in the formation except possibly certain hard flaggy sandstones that occur in well-defined horizons. On account of their resistance to erosion these hard thin sandstone layers form ledges and cap the mesas, buttes and the numerous irregular outliers in the badlands along the valley of the Red Deer river (Plate 44A).

Bands of ironstone and clay ironstone nodules are common throughout the Edmonton formation. These bands are seldom more than four inches in thickness and consist of hard irregularly rounded or flattened nodules that are red, brown or black on the weathered surface depending upon the iron content in the nodules. The surface of the nodule is frequently marked into small irregular polygons and they are known as septarian nodules. The markings are due to contraction cracks formed in the ferruginous muds during consolidation.

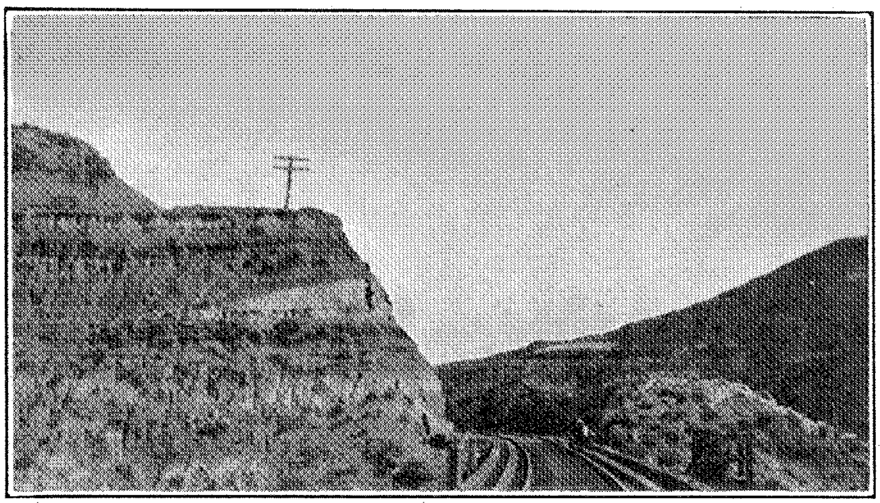
The Edmonton formation is transitional into the underlying marine Bearpaw. There is usually a sharply defined contact between the light-coloured basal sandstone in the Edmonton formation and the chocolate brown marine shales in the Bearpaw formation (Plate 10). In some outcrops beds of Bearpaw marine shale overlap the brackish-water Edmonton sandstones, indicating that the marine Bearpaw sea advanced shorewards and deposited marine muds on top of the brackish and freshwater sands (Plate 42A).

The Edmonton formation is the surface formation throughout much of the eastern half of the Rosebud sheet, east of range 23. Almost continuous outcrops extend along the slopes of the valley of the Red Deer river and along the slopes of the tributary valleys. The strata are nearly flat-lying and erosion has developed badland topography. The badlands are best developed along the gorge-like valley of Red Deer river from the north boundary of Rosebud sheet,

PLATE 42

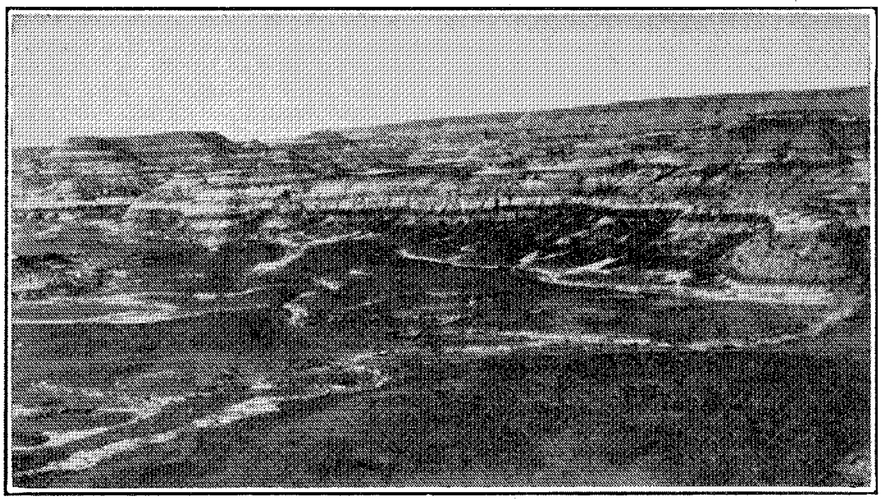


A.—Transitional beds between the Edmonton and Bearpaw formations in the Red Deer valley near Willow creek. Marine Bearpaw shales locally overlap brackish-water Edmonton sandstones.

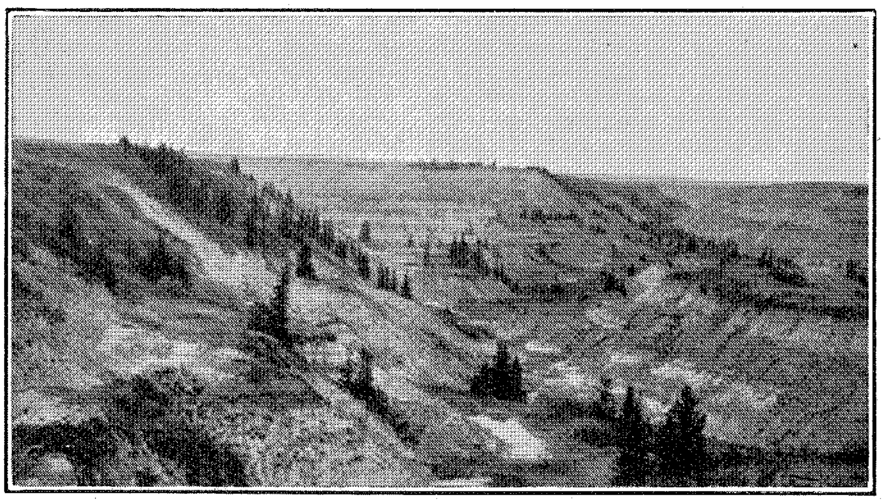


B.—Lense of white bentonitic sandstone on top of No. 6 coal seam along Rosebud river south of Wayne. Typical structure in the Edmonton formation.

PLATE 43



A.—Badland topography, Red Deer valley near Drumheller, looking northwest in southwest quarter of section 1, township 29, range 20, west of the fourth meridian. No. 5 coal seam showing in foreground.



B.—Looking down a typical coulee from upland south of Kneehills creek. Shows type of vegetation in badlands.

township 32, downstream to Dorothy in township 25. This area is often referred to as the dinosaur Drumheller badlands because these strata contain dinosaur bones. Fossil mollusks are common in this formation. The badlands have the greatest width in the vicinity of Drumheller (Plates 40 and 43A). This area is also known as upper Red Deer or Drumheller badlands because there are badlands as extensive and as varied in appearance, developed in the Belly River formation, especially from Steveville down the Red Deer valley for about twenty-five miles. These are the lower badlands or Steveville badlands.

A complete section of the Edmonton formation is exposed along the Red Deer valley between Ardley in township 38, which is north of the Rosebud sheet, and Willow creek in township 28, eight miles downstream from Drumheller. This complete section of the Edmonton formation measures 1,224 feet in thickness (Allan, 1924).

The Edmonton strata are the youngest of the three important coal-bearing formations in Alberta. This formation contains at least twelve coal seams, having an aggregate thickness of sixty-two feet. Eight of these seams are mined, with an aggregate thickness of 52 feet of coal.[9 10] This does not mean that wherever these coal seams occur in this area there will be a uniform thickness of coal of commercial quality because the lateral variation in quality and thickness in these coal seams is very great and all parts of any particular seam are not of equal market value. The coal is classed as of subbituminous rank. Some of these coal seams are shown in Plates 11, 43A and 44A.

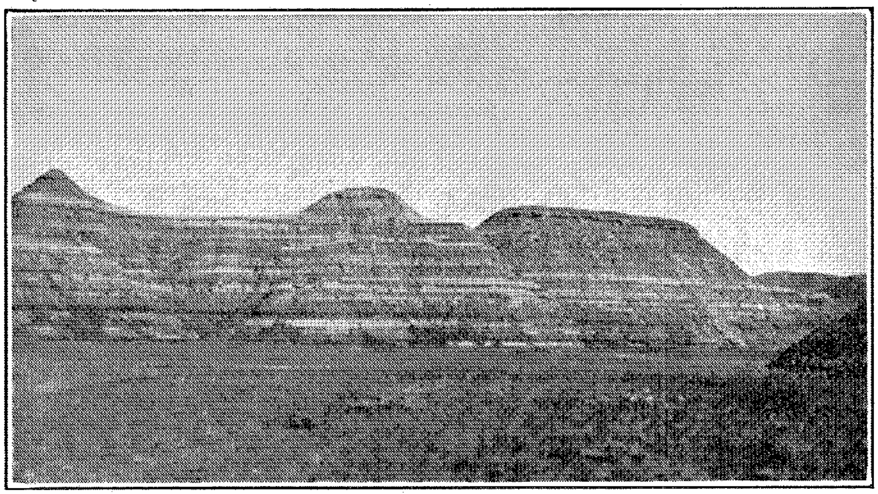
There is a narrow band of Edmonton strata extending through the Banff sheet from the vicinity of Jumpingpound in range 4, where the band is about one mile wide, to the Red Deer river in range 7, at the northwest corner of the map-area where the band is about six miles wide.. The rocks in this band close to the foothills, are more sandy with a lower bentonite content, but with about the same amount of lime. Soils which have been formed from or influenced by these strata are high in lime and frequently high in bentonitic clay or gumbo.

The youngest rocks in the Rosebud and Banff sheets are Tertiary in age. The Paskapoo which is Early Tertiary in age, consists chiefly of soft, grey, clayey sandstones, soft shales and clays slightly indurated. The formation is of freshwater deposition and contains freshwater fossil shells, chiefly mollusks.

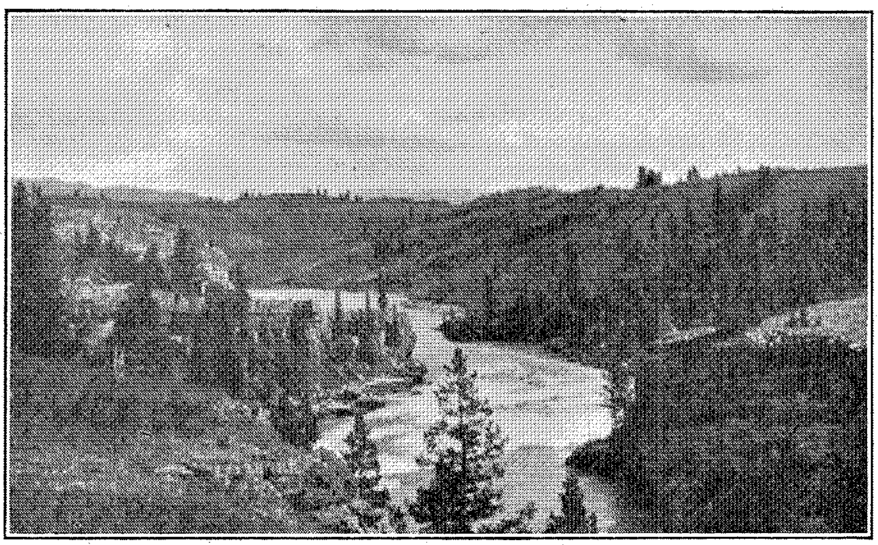
The Paskapoo formation has a wide distribution in the map-area (Plate 38) and occurs as the surface formation in the western half of Rosebud sheet, chiefly west of range 22, and the eastern four to six ranges west of the fifth meridian in the Banff sheet. This formation occupies a trough-like depression known as the *Alberta syncline* in which the older rock formations come to the surface both to the east and to the west of this band of Paskapoo which is about sixty miles wide. This rock formation also caps Wintering hills and Hand hills at the eastern side of the map-area. A narrow band of Paskapoo occurs on the east side of the Red Deer valley from Munson north to beyond the north boundary of the Rosebud sheet.

The youngest rocks in this map-area and in fact, in Alberta, occur on top of Hand hills and are Late Tertiary in age. These rocks are here named the *Handhills conglomerate* and consist of a

PLATE 44



A.—Three types of buttes, north side of former golf course at Drumheller. Hard thin sandstone bed caps flat-topped butte and is underlain by No. 7 coal seam. No. 5 coal seam is prominent near the bottom of the escarpment.



B.—Looking down Bow river west of Ozada, showing rapids and restricted stream channel caused by hard Cardium beds.

flat-lying series of gravel loosely held together with sand, clay and iron oxide. This conglomerate is about 150 feet in thickness and forms an escarpment along the west face of Hand hills. This formation is considered to be Oligocene in age and is similar to a conglomerate capping Cypress hills in southeastern Alberta and the Swan hills south of Lesser Slave lake.

Origin of Surficial Deposits

It is not always possible to determine the origin of the surface deposits in certain areas because frequently the unconsolidated material is of mixed origin. This is particularly true where the deposits have been reworked, such as outwash plains, alluvial and marginal deposits. In other areas the origin of the unconsolidated surface material can be determined.

The surface soil differs from the underlying deposits upon which it is developed because weathering agents have changed its original texture, color and composition. In some soils the accumulated organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. Often the surface leaching has deprived the soils of certain original minerals, and often the mineral content of the subsoils has been changed.

The origin and distribution of the unconsolidated deposits in the Rosebud and eastern part of the Banff sheets are indicated to some extent by the character of the surface. Soils in comparatively flat or gently undulating plains are of different origin from soils on rolling or hilly topography. In the plains areas rock outcrops are confined largely to the eroded areas along the drainage ways, and represent less than five per cent of the Rosebud sheet. Almost ninety-five per cent of the Rosebud sheet has a mantle of unconsolidated material of different origins which varies in thickness from a minimum up to at least seventy-five feet. The thickness of the surficial deposits on that part of the Banff sheet east of the foothills may be greater than it is on the Rosebud sheet and may exceed one hundred feet in some places. Some of the ridges in the foothills belt have a thick mantle of glacial material while others are almost free from till or other rock debris.

The unconsolidated surface deposits in the Rosebud and Banff sheets are classified under four major types:

(1) Residual and sorted residual deposits.
(2) Glacial deposits—moraine, till, boulder clay.
(3) Resorted glacial deposits.
(4) Transported deposits of alluvial, lacustrine and dune or eolian origin.

Residual soils are formed by erosion processes from the underlying rock formation. There are no large areas of soil of residual or sorted residual origin in the Rosebud sheet. A few small areas of sorted residual soil were observed along Jumpingpound creek in range 5 in the Banff sheet. Residual soils partly sorted and mixed with a thin mantle of till occur on the upper slopes and on the tops of the ridges along the west side of the map-area in ranges 5 and 6. Where the surface is wooded or covered with vegetation, the origin of the surface material is uncertain.

The second major type includes those deposits of glacial origin which occur in the form of terminal or end moraine as irregular hills or undulating ridges, often quite thick, or as ground moraine, usually thin or now represented by scattered glacial boulders or pebbles. It is not always possible to distinguish the undisturbed moraine in this type from the sorted or reworked glacial deposits included in the third type.

The distribution of the glacial deposits in the second and third types, based on observations and on the soil classifications within the Rosebud sheet, is shown on Plate 39. It is possible that some of the areas mapped as end or ground moraine, may extend into those areas that are mapped as sorted or reworked glacial deposits. The writer has mapped as undisturbed till and boulder clay only those areas where there is no doubt about the origin of the material.

The glacial deposits have been derived from one of two sources. The mountain or alpine glaciers originated within the Rocky Mountains and proceeded eastward over the foothills and plains, carrying rock debris from the rock formations within or possibly west of the front ranges of the Rocky Mountains; and the Keewatin or Laurentide ice sheets that originated in the vicinity of Hudson Bay, bringing with them a very different kind of rock debris derived from the Precambrian rocks in the Canadian Shield and also the rock material from the plains over which the glaciers passed.

The morainal material transported from the mountains consists largely of limestone, dolomite, shale, slate, quartzitic sandstone some of which is phosphatic, and dark chert pebbles.

The detrital material transported from the northeast by the Keewatin glaciers consists largely of igneous and metamorphic rocks such as granite, gabbro, gneiss, schist, argillite, greenstone and locally of harder sandstone from the younger rock formations under the plains over which the ice moved.

The glaciers from the Rocky Mountains extended down the valleys and spread out over the intervening ridges in the foothills belt. Boulders and gravels carried by the glacier were left when the ice melted.

There is no sharp line of demarcation between areas covered with debris from each of these sources. It would appear that the mountain ice sheets advanced eastward across the Banff sheet at an earlier time, and that later the Keewatin or Laurentide ice sheets advanced from the east and even moved westward over the eastern edge of the mountain debris. In a soil survey it is the unconsolidated material at or close to the surface that is related directly to the soil types.

Rock debris from the mountain ice sheets is distributed as far east as the fifth meridian at Calgary. Large glacial erratics and smaller glacial boulders of quartzitic sandstone were observed by the writer from the southeast corner of the Banff sheet at Calgary, north through the centre of range 1, across MacPherson coulee to the top of township 28, three miles west of Crossfield; in a northwesterly direction to Cremona and north to the Little Red Deer river at Elkton in township 31, range 4, west of the fifth meridian. In some places the drift is thin and boulders are close to bedrock.

The largest glacial erratic observed in this map-area is the Beddington boulder (Plate 35A) which occurs close to Nose creek on the east side of the Canadian Pacific railway, in legal subdivision 9, section 26, township 25, range 1, west of the fifth meridian, five miles north of Calgary. This erratic consists of quartzitic sandstone, with rose and opalescent quartz grains, well-bedded and possibly derived from Lower Cambrian strata within the Rocky Mountains to the west. Rutherford (1941) has suggested ice-borne transportation for these erratics east of the foothills belt.[11]

This glacial boulder measures 24 feet long, 23 feet wide and 15 feet high above the surface of the ground. The depression in which the boulder occurs is eight feet deep and has been formed by wind action and by the tread of animals around the boulder. The lower edge of the boulder is polished by the animals rubbing against the rock. Other boulders of similar quartzitic sandstone were observed by the writer at the following places along the roadway in:

Sections 33 and 34, township 25, range 1.
Sections 28 and 33, township 26, range 1.
N.E. section 33, township 26, range 1 (three-foot boulder of Rocky Mountain Quartzite).
Sections 24 to 32, township 27, range 1.
L.S. 8, section 17, township 28, range 1 (5×6×10 feet).
N.W. section 34, township 28, range 2.
N.W. section 3, township 29, range 2.
N.W. section 23, township 29, range 4.
Section 8, township 30, range 4.
Section 23, township 30, range 5.

Drift from the Keewatin or Laurentide ice sheets was distributed over the eastern edge of the boulder debris from the mountain ice sheets. Evidence of ice debris from the northeast has been reported as far west as Jumpingpound creek and Grand Valley creek, but the writer has not observed drift of eastern origin as far west as Cochrane.[12]

The glacial deposits in the Rosebud sheet (Plate 39) are widespread. There are two major morainal areas, the one at the eastern side and the other at the western side of Rosebud sheet and extending over much of the area of the Banff sheet to the foothills. The eastern morainal area extends from Rowley in township 32, range 20 to the east side of the map-area, south through ranges 15, 16, 17 and part of 18, to Willow creek in township 28, then southwest along the north slope of Wintering hills to range 22 in the vicinity of Standard and Tudor. This moraine extends across the preglacial valley of Red Deer river from the mouth of Willow creek to Finnegan at the southeast corner of Rosebud sheet. There are twenty-eight townships or about 1,000 square miles in the eastern part of the Rosebud sheet where the surface material is either undisturbed till and boulder clay, or soil in which there has been some sorting action as determined by composition and structure of the soils.

At the western side of the Rosebud sheet, the morainal belt includes much of the area from the east side of range 26, west to the fifth meridian, north to the north boundary in township 32, and east to the east side of range 27. This belt of glacial and sorted glacial deposits occupies about eighteen townships or about 650 square miles.

There are three smaller areas of till or sorted glacial material between these two large belts. One of these areas occurs on the north side of Kneehills creek from Carbon to the north boundary of the map-area in township 32. There is an esker-like ridge about a quarter of a mile wide extending eastward in township 32, from the east side of range 25 to Three Hills where it joins the upland of sorted glacial material between Threehills creek and Ghostpine creek. The upland between Ghostpine creek and the Red Deer river is also capped with sorted till. The third small area of moraine and sorted till occurs on Kneehills creek in the vicinity of Hesketh, and Rosebud river near Rosebud railway station.

It will be necessary to extend the field investigations on the glacial deposits beyond this map-area to the north before it will be possible to interpret the relationship between all these morainal areas or to interpret the drainage topography related to the moraines. These glacial deposits are considered to be of Early Wisconsin age. The glacial deposits at the east side of the Rosebud sheet are all of Keewatin origin. Those deposits in the vicinity of the fifth meridian and west in the Banff sheet are in part of Keewatin origin and in part of mountain origin. The true relationship has not yet been determined.

The fourth type of surface material includes the transported deposits which have been moved to their present position by running water or by wind. Transported deposits may be derived from two main sources. Alluvial and fluviatile deposits, consisting of gravel, sand and clay, are associated with river transportation. The second class of transported deposits includes the rock debris that has been washed down the slopes from higher levels into lake basins.

In the Rosebud sheet there is a broad belt consisting largely of alluvial material, extending through the map-area from south to north and separating the eastern moraine from the western moraine. This belt of alluvial deposits at the south of the map-area, occupies ranges 23, 24 and 25 in township 25, and extends north across Rosebud creek. In township 29 the alluvial plain extends from Grainger to Acme and as a narrower band, extends to Sunnyslope and north along Spruce creek to the north boundary of the map-area in the west half of range 26. There are also transported deposits distributed along the sides of the lower postglacial valley of Red Deer river and its several tributaries. These deposits in the river valleys are of quite recent deposition since the disappearance of the ice sheets.

The lake deposits in the Rosebud sheet are of considerable importance. A large proglacial lake was formed when the drainage down the preglacial Red Deer valley below Willow creek was obstructed by ice. These lake deposits occur on both sides of the Red Deer valley from the north boundary of Rosebud sheet in township 32, down to the position of Willow creek. This large area containing lake deposits is here called Lake Drumheller. The south boundary of this large proglacial lake extends from the mouth of Willow creek, in a southwesterly direction, between Rosebud creek and Wintering hills, to Tudor in range 23, a distance of thirty-five miles. The east boundary of Lake Drumheller extends from Willow creek, in a northerly direction through range 18 to township 31, then it turns west across the north branch of Michichi creek, passing within two miles north of Morrin. In section 30, township 31, range 20, west of the fourth meridian, the old shore line turns sharply to the north, passing Rowley and Mortimer lake, to the north boundary of the map-area in section 33, township 32, range 20. The west shore line of Lake Drumheller extends from Tudor across Serviceberry creek, two miles east of Rockyford, and across Rosebud river on the east side of range 23. It crosses Kneehills creek at the east side of range 24, then swings eastward to one mile east of Carbon where it turns north for three miles. From section 2, township 30, range 23, this shore line extends in a northwesterly direction, sub-parallel to Threehills creek, passes two miles west of Twining and reaches the top of the Rosebud sheet in section 35, township 32, range 25. With the exception of a ridge of moraine between Threehills creek and Ghostpine creek, and another ridge between Ghostpine creek and Red Deer river, the deposits at the north boundary of Rosebud sheet extend from the centre of range 20 to the east side of range 25, a distance of about twenty-eight miles.

This glacial lake, known as Lake Drumheller, occupied approximately eleven hundred square miles on the Rosebud sheet (Plate 39). The soils in this old lake basin are quite uniform through this area and are chiefly clays high in lime. These lake deposits vary in thickness because of the irregular original floor of this lake basin. In some places the lake deposits are as much as fifty feet deep, and may be much deeper in some parts of the basin.

In the vicinity of Standard in township 25, range 22, occurs the north end of Lake Chancellor which extends south to township 23 in the Blackfoot map-area (Plate 34). This proglacial lake, which the writer designates Lake Chancellor, extends from Hussar on the east side of range 20, westward for ten miles, and from Oueletteville at the south edge of township 23, north to the centre of township 25, about two miles north of Standard.

The highest level of the Drumheller lake deposits is between 2,850 and 2,900 feet above sea level. There appears to have been two outlets to Drumheller lake, possibly both were not active at the same time. There is a small narrow high level outlet extending from Tudor to Standard in township 25, ranges 23 and 24. Well-sorted alluvial deposits extend along this old glacial drainage way which today has a surface elevation of about 2,900 feet and which was gorge-like when active. The main outlet to Drumheller lake during its later stage was along the eastern end of Wintering hills in the vicinity of the present Red Deer valley, and southward in range 17 through Crawling valley towards the Bow valley in the vicinity of Bassano. The highest point in this glacial drainage way along Crawling valley, is about 2,650 feet above sea level three miles south of Red Deer river in section 36, township 25, range 17, west of the fourth meridian. The bottom of this drainage way is no doubt at a much lower level. Much of the water from Drumheller lake could have been drained along this channel through the end moraine east of Willow creek, before the drainage became diverted down the Red Deer valley in range 16 which has been the post-glacial drainage way.

In the Banff sheet there is a small lake basin, irregular in outline, in the vicinity of Jumpingpound creek in township 25, ranges 4 and 5, west of the fifth meridian. This Jumpingpound lake extends about four miles south to the Elbow river in township 24. There has been some laking in the old drainage way between Crossfield and Airdrie on the west side of the fifth meridian. This long narrow lake basin contains heavy clay and clay loam soils.

No attempt has been made to discuss in detail in this report the distribution or origin of the various types of superficial deposits, forming the mantle of unconsolidated material in the Rosebud and Banff sheets.

REFERENCES CITED

[1]Beach, F. K., Schedule of Wells Drilled for Oil and Gas to 1941, Dept. Lands and Mines, p. 65.

[2]Bulletin 31, University of Alberta, College of Agriculture, 1938, pp. 81-102.

[3]Warren, P. S., The Significance of the Viking Moraine, Trans. Roy. Can. Institute, Vol. 21, No. 46, 1937, p. 301.

[4]Rutherford, R. L., Some Aspects of Glaciation in Central and Southwestern Alberta, Trans. Roy. Soc. Can., Vol. 35, Sect. 4, 1941, p. 115.

[5]Stewart, J. S., Geol. Surv. Can., Mem. 112, 1919, p. 22.

[6]Geology of Southern Alberta Plains, Geol. Surv. Can., Memoir 221, 1940, p. 97.

[7]Dowling, D. B., Geol. Surv. Can., Memoir 93, 1917, p. 121.

[8]Geology of the Southern Alberta Plains, Geol. Surv. Can., Memoir 221, 1940, p. 97.

[9]Allan J. A., Geology of the Drumheller Coal Field, Research Council of Alberta, Report 4, 1922, 72 pp.

[10]Research Council of Alberta, 5th Ann. Rept., No. 12, 1924, p. 37.

[11]Rutherford, R. L., Trans. Roy. Soc., Can., Vol. 35, 1941, Sec. 4, pp. 115.

[12]Nichols, D. A., Trans. Roy. Soc. Can., Vol. 25. 1931, Sec. 4. p. 49.

RESEARCH COUNCIL OF ALBERTA

GEOLOGY

REPORT NO. 34, PART IV—PAGES 149 TO 157

Relief Model of Alberta and its Geological Application

By J. A. Allan

PLATE 45

Edmonton, Alberta

1943

Part IV.

RELIEF MODEL OF ALBERTA AND ITS GEOLOGICAL APPLICATION

By J. A. Allan

Introduction

It is assumed that a map is used to enable one to visualize more clearly the geographical and physical features present in the area covered by the extent of the map. If this is not accomplished in part, then the effort in producing the map has been futile. A part of the earth's surface is represented on a plane with a greatly reduced scale.

The scale of a map means the distance between two points on the map, compared to the distance between the same two points on the ground. For example, a map on a scale of one inch to one mile, means that a linear measurement of one inch on the map represents one mile in the field. Or if the scale is one inch to eight miles, then a linear measurement of one inch on the map represents eight miles in the field. This may be illustrated in another way. The linear measurement between Edmonton and Calgary is twenty-two inches and the map is on a scale of one inch to eight miles, then the linear distance between Edmonton and Calgary is 176 miles. On the other hand if the map scale is eight inches to one mile, then these two cities on a map of this scale would be 1,408 inches apart or over 117 feet. Naturally then the accuracy of details on the map, will depend on the scale of the map.

Surface relief may be represented on a plane or map by means of contour lines, hachures and isohypses, or on a relief model which is a three dimensional map. A contour line is a line drawn through points at equal elevation with reference to a datum line. The contour interval is the difference in elevation between two contour lines. For example, if the contour interval on a map is 100 feet, then the vertical distance between the points on the ground represented by one contour is 100 feet higher or lower than those points represented by the other contour line. Contour lines on a map therefore, will represent the amount of relief in the area represented by that map. Hachures are short lines on the map to represent the direction of slope on the surface of the ground. Isohypses are shadings or tints on a map where each tint represents one elevation with reference to the datum line which is usually sea level. In the relief model, the irregularities on the surface of the ground are shown in three dimensions. For example, one can readily observe on the relief model the depth, width and length of a valley, or the height, length, width and irregularities along the slopes of a mountain. To most individuals surface perspectives can be more readily interpreted on a relief map than on a contour map.

For almost a century ground photography has been used in surveying. A photograph taken from each of two points on the ground, a known distance apart, can be used in a stereoscope and any point in the photograph can be plotted in three dimensions when the two photographs are observed in stereoscopic projection.

Similarly photographs taken from known points in the air, a known distance apart are used in the same way to obtain ground perspective. Photographic surveying or photogrammetry as it is known today, was not used extensively until after the First Great War. Ground photography was introduced into Canada in 1888 by Captain E. Deville, Surveyor-General of Canada.

In recent years aerial photography has made it possible to reproduce relief accurately in a very limited area of a few square miles by means of vertical photographs taken in stereoscopic projection, but this method of observing relief is limited in scope, although useful in the preparation of the relief model.

In the construction of a relief model it is necessary to have contour maps from which the data for the model may be obtained. The accuracy of the relief model will depend on the completeness of the contour data. Only those areas that are mapped topographically can be shown accurately in relief. Where levels have been run along stream courses or along surveyed lines, like base lines or meridians, it has been possible to extend contour lines over adjoining unsurveyed areas for the purpose of preparing a relief model.

Preparation of Relief Model

Since the organization of geological survey investigations under the auspices of the Research Council of Alberta in January 1921, the writer realized the value of a relief model of the whole of Alberta, on which the known surface relief could be shown. In 1936 the writer compiled the data and constructed the relief model of Alberta (Plate 45). The horizontal scale of the model is one inch to eight miles and the vertical scale is one inch to 1,600 feet. The greatly exaggerated vertical scale was used to bring out a distinction between plains, foothills and mountains, and particularly to represent more clearly the profile along the mountains from south to north.

This relief model is constructed on a base consisting of seven-ply board and is ninety-eight inches long and fifty-four inches wide. It is mounted vertically and is on exhibit in the geology museum at the University of Alberta in Edmonton.

In the preparation of the relief model of Alberta, the incompleteness of topographical detail and contour data have been fully appreciated. All available survey data have been utilized in the preparation of this relief model, and no apologies are offered for the inaccuracies in relief in various parts of Alberta as shown on this model.

Only about one-half of the surface of Alberta has been surveyed topographically and represented by contour maps. These contour maps have been compiled by the Topographical Survey of Canada. In the northern half of Alberta very little topographical mapping has yet been done. The base lines which are twenty-four miles apart, have been surveyed in whole or in part and levels have been recorded along these lines. The Fourth meridian which is the east boundary of Alberta, had been surveyed and levelled as far as the south shore of Lake Athabaska. Since this model was constructed the Fourth meridian has been surveyed from Lake Athabaska to the north boundary of Alberta which is the 60th parallel of latitude. The Fifth meridian which is longitude 114 degrees, has been levelled to latitude 58 degrees. The Sixth meridian which is longi-

PLATE 45

Photographed from a relief model in the Geology Museum, University of Alberta. Model on horizontal scale, 1 inch to 8 miles; vertical scale, 1 inch to 1,600 feet.

tude 118 degrees, has been levelled to the north boundary of Alberta. All the level data along the base lines and meridian lines have been used in compiling this model. In addition to this information, use was made of the contour maps prepared from the Alberta-British Columbia boundary survey; the numerous topographical maps of small areas issued by the Geological Survey of Canada; railway surveys; irrigation surveys; and certain private surveys of special areas. The contour lines from these various areas where levelling surveys have been made, have been extended into the intervening areas in order to complete a contour map of the whole of Alberta from which the model could be made. Naturally the accuracy of the relief shown on the model in the unsurveyed areas is reduced, but unless this procedure had been followed the model could not have been compiled.

The model does not show anything that is not on the contour map but it was possible to accentuate relief features by increasing the vertical scale.

Alberta has an area of approximately 255,285 square miles and extends from the 49th parallel which is the International Boundary line, north to the 60th parallel of latitude, a distance of 756 miles. The outline of Alberta may be described as a terrestrial rectangular area in which the lower left hand corner of the rectangle is missing. On account of the curvature of the earth the width varies with the latitude. The narrowest part of Alberta is the south boundary where the width is 182 miles. The widest part of Alberta is at latitude 53°40′ along a line which passes about 15 miles north of Edmonton. In this position the width is 404 miles. On the north boundary the width of Alberta is 342 miles.

The surface elevations of Alberta range from a minimum of 565 feet above sea level on the north boundary at Fort Smith, to a maximum of 11,874 feet in Mt. Alberta at the headwaters of Athabaska river. This represents a difference of 11,309 feet between the lowest and highest points shown on the relief model or a maximum relief of seven inches on a vertical scale of one inch to 1,600 feet.

Construction of Relief Model

The method of construction of this model was both simple and quick and, of necessity, had to be inexpensive. The base map used for the compilation of topographical data was on a scale of one inch to eight miles.

The base consists of three squares of seven-ply board each fifty-four inches by thirty-two and three-quarter inches. The model is built in three parts for convenience and no reinforcing was required. These three blocks are mounted on two four by four inch supports and set up as a vertical panel. As no plaster or water was used, there is no danger from warping or twisting of the model.

The procedure in building up the model was simple. A geographical map on the scale of one inch to eight miles was used, on which the 400-foot contour lines were plotted and drawn from all available topographical data. These lines were shown in different colored inks to make a sharp distinction between any two contour lines. A 400-foot contour interval was selected instead of a smaller V.I. (vertical interval) for two reasons; it was quicker and cheaper, and the vertical scale required was 1,600 feet to one inch, which represented four layers of three-ply board, each one-quarter of an inch in thickness. All the 400-foot contour lines from 1,000-foot to 9,000-foot were drawn on the map. The only exception was the inclusion of the 800-foot contour line which brought out certain details of relief in the northeast corner of Alberta in the vicinity of Lake Athabaska along Athabaska river and Peace river.

Each contour line, beginning with the lowest, was traced from the map to a sheet of 3-ply board by means of a wooden pencil and sheets of carbon paper. The next higher contour line was also traced on the same board and this line was used as a guide for the next layer above. For example on the 1,000-foot contour board, the 1,400-foot contour profile was also marked, while in the 1,400-foot contour board the 1,800-foot line was also drawn, and so on. This was necessary, especially where there were several small island-like areas on that contour level. The lower contour profile was then cut out with a jig saw with a 14-inch arm.

In the next step each contour profile layer was nailed or glued securely to the model base in its proper position. If the edges of the profile were too narrow or too slender to nail, these parts were glued to the under layer. Longer nails were used in the thicker part of the model to make the mass more rigid. The areas above the 9,000-foot contour line were too small to cut out conveniently, so the peg system was used above this elevation. Fine wires were cut to scale for the individual mountain peaks. Cotton batting soaked in liquid beeswax was wrapped around the wire and shaped to the particular mountain as shown on topographical maps. These wires were inserted and glued to the wood base. This proved to be an economical and quick method of building up the mountain peaks where the vertical scale was so greatly exaggerated.

When the model was completd, liquid brown beeswax was applied with a paint brush and the angles between the contour profiles were filled in. Slopes were smoothed or scraped when the wax was cool, and small ravines and depressions were carved and shaped with modelling tools. In the preparation of the model, seven pounds of beeswax were used.

The surface of the model was shiny and reflected the light, so a layer of dull shellac was added which improved the surface appearance. The river courses were then painted in light blue and the lakes in darker blue. The effect on the relief model is quite pronounced but the lakes do not show up distinctly on the photograph (Plate 45).

It was not economically possible to add the culture to this model in the form of names, cities, towns, lines of longitude, latitude, etc., so a similar panel base has been placed beside the model. On this panel a geographical map is attached on which the areas in the intervals between the contour levels have been colored differently. By placing the colored lines representing longitude and latitude on the model and the panel, any locality on the map can be readily determined on the relief model.

In the preparation of this relief model the writer was assisted by William J. Reid, a student at the Edmonton Technical School, who operated the jig saw and applied the beeswax. The construction of the model required a total of about 300 man hours and the cost for the materials and assistance was $240. The construction of this relief model was made possible by a grant from the Carnegie Corporation of New York.

The above details are given on the methods and procedure followed in the construction of this model which covers 30 square feet, because the statement is commonly made that relief models are expensive and slow to construct and in fact are often scarcely worth the effort and expense. The writer differs with this view especially where the relief model is going to be used for demonstration purposes or for instruction in the classroom. Further points on the value are cited below.

This task was undertaken by the writer, partly to become more thoroughly acquainted with the topographical expressions within Alberta and, largely, with the hope that a relief model could be constructed from which plaster casts could be made cheaply for use in the teaching of geography in the schools of Alberta. It is hoped that this end will yet be achieved.

Value of a Relief Model

There are many details on the geomorphology of Alberta that are not apparent on the photograph because it has not been possible to add geographic names to the model and only the names of Edmonton, Calgary, Lethbridge, Medicine Hat, Waterways and Peace River are shown on Plate 45. If the reader is not familiar with the geography of Alberta, the writer suggests the use of the geological map of Alberta or any larger scale map for reference. On the other hand, there are features which show up on the photograph of the relief model and which would not be recognized on a topographical map of an area of a quarter of a million square miles if such were available.

In Alberta there are four major physical divisions, namely: mountains, foothills, plains and that portion of the Precambrian Shield which occurs in the extreme northeast corner of Alberta, with an area of about 8,000 square miles. The entire Precambrian Shield occupies an area of about 2,500,000 square miles of Canada.

The total area of Alberta is 255,285 square miles. The mountain division occupies approximately 15,000 square miles or six per cent of the total area, a quite small part of Alberta but one with important economic potentialities from tourist traffic to Canada and as a source of surface water supply to the plains in central Canada. The foothills belt represents about 12,000 square miles, or four per cent, and the Precambrian Shield, 8,000 square miles or 3 per cent. The remainder of Alberta, or an area of approximately 220,000 square miles, which is 87 per cent of the total area, is represented by the plains division. Alberta is, therefore, truly a "plains" province.

These first three divisions, namely: mountains, foothills and plains, are clearly differentiated on the relief model. There are three drainage basins in Alberta from which the water reaches three oceans. Sixty-three per cent of Alberta or 160,000 square miles are drained by the Mackenzie basin into the Arctic ocean, 36 per cent or 92,000 square miles are drained eastward into Hudson Bay. The remaining 3,000 square miles are drained by the Milk river to the south into the Gulf of Mexico.

The lowest part of Alberta above sea level is in the northeast corner between Lake Athabaska (699 feet) and Fitzgerald (665 feet). The lowest point is on Slave river at Fort Smith, close to the north boundary, with an elevation of 565 feet above sea level. No topographical survey with levels has been made of the Precambrian Shield area but from personal observation there are very few places in this area where the elevation is over 800 feet above sea level.

The plains division varies in elevation from less than 800 feet above sea level in the lower Peace river district and about 1,000 feet in the Hay lake district in northwestern Albert, to about 3,500 feet above sea level along the eastern edge of the foothills belt. There are several "hills" or prominences rising several hundred feet above the surrounding plains. These are *residual hills* formed by the erosion of the surrounding rocks.

There is no sharp line of demarcation between the plains division and the foothills belt, but it is apparent from the relief model that the foothills belt widens northwards and becomes merged into the plains north of Athabaska river. The foothills belt consists of rolling topography with many long narrow ridges representing broken and folded strata, and intervening sub-parallel valleys which have been eroded into the softer rocks. The valleys and ridges have a trend which corresponds to the direction of the mountains. Elevations within the foothills belt range generally from 3,000 to 5,000 feet above sea level. There are many ridges which rise locally to higher altitudes than the average elevation of 4,000 feet, particularly north of the Bow. There are prominences such as the High Divide ridge between the Brazeau and Athabaska which are capped by a gravel deposit, and which closely resemble the residual hills in the plains. Such hills may form a criterion to interpret quite recent uplift.

The mountains division occurs as a narrow belt fringing the southwestern side of Alberta and representing only 6 per cent of the total area of Alberta. The mountains are narrowest in the Crowsnest area and also in the centre of Alberta, west of Smoky river. The widest part of this mountain belt is west of Edmonton along the Watershed between the Mackenzie basin and the Hudson Bay drainage. At this position the mountains are 54 miles wide (Plate 45).

The elevations in this division range from 3,500 feet along the valleys leading to the Crowsnest pass and Yellowhead pass, up to a maximum of 11,870 feet in Mt. Assiniboine, 11,874 in Mt. Alberta at the head of Athabaska river and about 12,900 feet in the Mt. Robson district northwest of Yellowhead pass. The profile of the mountains shows more clearly in the relief model than on any topographical map, the gradual increase in altitude from Waterton lake and Crowsnest pass district northwest to the Mt. Robson district where the mountains pass out of Alberta into British Columbia.

The relief model indicates many structural features within the Rocky Mountains. One of the most outstanding features shown in the model, is the remarkably straight narrow trench which extends from Jasper southeast to Bow valley at Lake Louise station, a distance of 160 miles. It is along this trench that the scenic Jasper-Banff highway has been constructed. This highway was opened to tourist travel in 1937.

The drainage pattern, the depth, width and trend of valleys, or the irregular interstream areas are important and useful criteria in interpreting the geological structure. An exaggerated vertical scale will sometimes indicate the geological structure and its relation to the topography more clearly than if the vertical scale approaches the natural scale.

It is contended that a relief model of a large area, if based on sufficient topographical data, will enable the geologist to recognize, or at least suspect, broad structural features which will not be apparent on a topographical map of a small area no matter how excellent that map may be.

Residual Hills in Alberta

It has already been pointed out that in the plains area of the relief model there are several hills or prominences rising several hundred feet above the surrounding plains. These are *residual hills* formed by the erosion of the surrounding plains. Some of these hills have been modified by glacial erosion, some have been capped by ice and others have remained above the ice even during maximum glacial distribution. The more prominent residual hills in the plains belt in Alberta are the following, from north to south:

Name	Location Tp.	Rg.	Mer.	Elevation (Approx.) (in feet)	Elevation above surrounding area (in feet)	Deposits on Top
Ninishith hills	124	19	W. 4th	1,200	200	Glacial
Caribou mountains	113	5-10	W. 4th	3,200+	1,700	Glacial (?)
Watt mountain	111	21	W. 5th	2,300+	1,000	Non-glacial (?)
Naylor hills	99	24	W. 5th	2,800+	1,100	Non-glacial (?)
Buffalo Head hills	94-102	11-14	W. 5th	2,800+	1,100	Non-glacial
Birch mountains	97-102	12-16	W. 4th	2,700+	1,000	Glacial
Trout mountains	89	2-3	W. 5th	2,600+	800	Glacial
Clear hills	88	9	W. 6th	3,600+	1,100	Thin glacial
Birch hills	77	1-3	W. 6th	2,500+	600	Glacial
Saddle hills	75	6	W. 6th	3,100+	900	Glacial
Pelican mountain	76	23-24	W. 4th	3,100±	800	Glacial
Marten mountain	75	5	W. 5th	2,900+	......	Glacial
House mountain	70	11	W. 5th	3,950	1,000	Non-glacial
Swan hills	67-68	10-12	W. 5th	4,230	1,000	Non-glacial
Whitecourt hill	58	12	W. 5th	2,700	700	Non-glacial
Hand hills	29-30	17	W. 4th	3,550+	600	Glacial in part
Wintering hills	26	19	W. 4th	3,400+	500	Glacial
Cypress hills	7-8	1-3	W. 4th	4,600	1,600	Non-glacial

All of these hills are shown on the relief model. The writer has examined or observed all of these hills south of the latitude of Peace River and Waterways, and most of these more northerly hills have been visited by some of the members of the Research Council of Alberta. It would appear that most of these residual hills in the northern half of Alberta rise from 800 to 1,000 feet above the surrounding country. The relief is considerably greater where some of the major drainage courses pass close to the remnant of erosion, for example, Peace river at Fort Vermilion is 2,000 feet lower than the top of Caribou mountains, Athabaska river is 1,600 feet lower than the top of Birch mountains, and the top of Buffalo Head hills is 1,600 feet higher than Peace River at Carcajou Point.

There is a thin gravel deposit on top of Caribou mountains, and there is a heavy morainal deposit at the head of Bushe river between Caribou mountains and Watt mountain. It would appear that the glaciers at one time covered Caribou mountains. On the other hand, Belly River sandstone outcrops on the top of Buffalo Head hills so that at least the top of this residual hill has not been affected by ice. It is apparent that these outliers represent one or more plateaux. There is a marked accordance of levels in the tops of the hills in the surrounding country between Naylor hills on the west of Peace river, and the Buffalo Head hills and Birch mountains between the Peace and the Athabaska. Watt mountain is 400 feet lower and this hill may have been lowered by glacial erosion.

Glacial drift has been reported on the top of Watt mountain. Approximately the same amount of erosion is noted around Saddle hills, Trout mountains and Pelican mountain. This feature is significant whatever the explanation may be.

The flat-topped Swan hills on the south side of Lesser Slave lake rise 2,300 feet above the lake but about 1,000 above the surrounding country. In the Geological Survey Summary Report, Part C., 1918, the writer recorded the bedded gravels capping these hills. There is no indication that the ice sheets ever covered these hills. These gravels are of Tertiary age and quite similar lithologically to the gravels capping Cypress hills in the southeast corner of Alberta which are older than the Miocene uplift.

The erosion plateau south of Lesser Slave lake in the vicinity of Whitecourt hill, Hand hills, east of Drumheller, and Wintering hills, south of Drumheller, occur at about 3,000 feet above sea level. On the top of Hand hills at the north end, there is a consolidated gravel which is believed to be early Tertiary in age, but on the lower easterly slopes there is a heavy Keewatin moraine. There are a few scatterd boulders on the highest part of Hand hills but no ground moraine so that the ice has not modified these hills to any great extent. The top of Cypress hills is not glaciated, and this upper plateau appears to correspond to the Swan hills plateau. The origin or dates of the plateaux of Tertiary and Quaternary ages in Alberta will not be discussed, but the model indicates that these plateaux are quite widespread especially in the northern half of Alberta.

RESEARCH COUNCIL OF ALBERTA

GEOLOGY

REPORT NO. 34, PART V—PAGES 161 TO 196

Coal Areas of Alberta

By J. A. Allan

TABLE OF CONTENTS

MAP NO. 18

Edmonton, Alberta

1943

PART V.

COAL AREAS OF ALBERTA

By J. A. ALLAN

INTRODUCTION

Coal is one of the most important of the mineral resources in Alberta. The coal-bearing formations have a wide distribution throughout Alberta. Coal is being mined at a number of centres in the plains, foothills and mountains in the southern half of Alberta. When the Research Council of Alberta was organized in 1920, it was apparent that a map was needed outlining coal areas based on geological formations. Such a map was needed for the classification of coals according to chemical analyses, and also for the marketing of coal where it is advisable to indicate the district from which the coal has been mined.

Previous to 1923 the Federal Mines Branch and the Research Council of Alberta had been designating coals according to the Alberta mine inspection districts, which were based on geographical rather than on geological factors. This resulted in the same kind of coal in the same coal basin, being classified in two or sometimes in three different mining districts, and a certain amount of confusion arose.

The first map of Alberta on which was shown various coal areas, was compiled by the writer in 1924, and published in Report No. 10 which is the Fourth Annual Report of the Scientific and Industrial Research Council of Alberta. This map was printed on a scale of one inch to thirty miles, and on it 36 coal areas were defined. In the following year, 1924, the coal areas map was revised and nine new coal areas were added where some coal was being mined. This made a total of 45 coal areas where coal mining was being carried out in Alberta. These areas are described in Report No. 12, the Fifth Annual Report of the Scientific and Industrial Research Council of Alberta, 1924, page 44.

The Coal Sales Act, 1925, Statutes of Alberta, 1925, Cap. 21, assented to April 10, 1925, legalized these coal areas in so far as they are used in the sale of coal. The same classification of Coal Areas in Alberta was accepted by the Dominion Mines Branch. Since that date coal statistics used and published by both the Federal Government and the Alberta Government are arranged according to the coal areas as named on the Coal Areas Map of Alberta.

Considerable additional geological information has been obtained on the coal deposits in Alberta since 1924 so that a revised coal areas map was essential.

In 1940 a revised Coal Areas Map of Alberta was compiled by the writer. This map was drafted and produced through the co-operation of the Department of Lands and Mines, Province of Alberta.

COAL AREAS MAP OF ALBERTA, 1940

The Coal Areas Map of Alberta, Map No. 18, based on geological formations and produced in 1940, accompanies this report. This map is made on a scale of one inch to twenty miles and includes the townships and ranges, the geography and all the railway lines up to date. There are 49 coal areas grouped in four different colors to differentiate the areas that are underlain by the different coal formations.

Before discussing the different groups of areas shown on the map, a few observations on the coal formations are necessary. The coal deposits in Alberta occur in rocks of Cretaceous age. The divisions of the Cretaceous in Alberta are given below from the youngest to the oldest.

Table of Cretaceous Formations in Alberta

UPPER CRETACEOUS	Edmonton or St. Mary River	Continental	Coal
	Bearpaw	Marine	
	Belly River Series		
	Pale Beds	Continental	Coal
	Foremost	Continental	Coal
	Pakowki	Marine	
	Milk River	Continental	
	Alberta (Colorado)	Marine	
	Crowsnest Volcanics		
LOWER CRETACEOUS	Blairmore	Continental	Coal
	Kootenay	Continental	Coal

Coal-bearing beds in Alberta occur in three different horizons, namely, the Edmonton, the Belly River, and the Blairmore-Kootenay. The first two horizons are in the Upper Cretaceous and the third is in the Lower Cretaceous. The number of coal seams and thickness of the coal seams varies in different localities. A coal seam that is workable in one area may be too thin or too dirty to mine, or may be absent in another area where the same formation occurs. For example, the Edmonton formation where it is exposed along Red Deer river has a measured thickness of 1,224 feet, and includes over a dozen coal seams, but only about six have been found to be suitable to mine. Then again, erosion may have removed much of the coal-bearing formation and only a part of the whole formation occurs in an area. This applies to all three coal horizons in Alberta.

The Bearpaw formation separates the Edmonton from the Belly River coal-bearing horizons. The Bearpaw consists chiefly of marine shales which do not carry coal but these shales thin and finally disappear to the west and also to the north of the North Saskatchewan river. In some parts of Alberta where the Edmonton and Belly River formations come together it is not known where the contact should be drawn, and, if there are coal seams near this contact, it may not be possible to distinguish between Edmonton and Belly River coal. Certain coal areas on the map include such conditions, where the coal seams might be in either of these two coal-bearing formations.

Below the Belly River there is a thick series of marine shales grouped in the Alberta formation, formerly called in part, the Benton. These shales do not include coal. This formation appears to have a wide distribution and to underlie the whole of the southern half of Alberta. This is the lowest member in the Upper Cretaceous.

In the Lower Cretaceous there is the Blairmore-Kootenay coal horizon. In the mountains and foothills it is possible to recognize two formations, the Blairmore, underlain by the Kootenay. To the east, extending under the plains, the Lower Cretaceous is referred to as the Blairmore-Kootenay or sometimes as the Kootenay alone.

For the present purpose, it is only necessary to recognize the three coal horizons in Alberta, namely, *Edmonton, Belly River* and *Blairmore-Kootenay.*

Coal consists largely of plant material. The accumulated plant material becomes more compact with time so that coal is a mineral product which is always getting older, and with age the character of the coal changes. It is important to understand that the two chief factors that determine the rank of the coal are *age* and *pressure.* In general it is a fact that the older coals are more mature or "harder" than the younger coals. This is one reason why Nova Scotia coals, which are Carboniferous in age, are more mature than Alberta coals which are Cretaceous in age. Even in Alberta, the Blairmore-Kootenay coals of Lower Cretaceous age are more mature than most of the Belly River or Edmonton coals that are of Upper Cretaceous age. On the other hand, pressure will mature a coal more rapidly. That is why the rank of most Alberta coals increases from east to west, that is, from the plains to the foothills and mountains. For example, a Belly River coal at Wainwright is less mature than a Belly River coal at Cadomin or Luscar or Mountain Park. This explains why the Lethbridge coal is of higher rank than the Redcliff coal, although the coal seams in the two areas are of the same age. The coal seams in the Lethbridge area are closer to the mountains and have been affected to a greater degree by the mountain-building forces, than have the coal seams in the Redcliff area.

The structure in southern Alberta is synclinal. There is a trough or depression extending in a north-south trend to about latitude 52 degrees in the vicinity of Red Deer where the structure turns to the northwest. The Edmonton formation is exposed along the eastern and western sides of the trough. The older Belly River formation is deeper in the trough and outcrops at the surface on the plains on the east side, and also along the foothills belt on the west side of the trough. The Blairmore and Kootenay strata outcrop along only the front ranges of the Rocky Mountains and along the west side of the foothills belt. With these points in mind, the distribution of the coal areas will be considered.

There are 49 coal areas shown on the accompanying map (Map No. 18). Fifteen of these areas are underlain by the *Edmonton coal-bearing formation* and are distributed in a north-south band. Fourteen of these areas are the same as on the previous map, and only one new area, Mountain House, has been added. These areas have been named as follows:

Whitecourt	Castor	Sheerness
Pembina	Wetaskiwin	Drumheller
Edmonton	Ardley	Gleichen
Tofield	Big Valley	Champion
Camrose	Carbon	*Mountain House

The *Belly River coal horizons* are included in 13 coal areas distributed across the plains of southern Alberta and northward to Slave lake. These areas have been named as follows:

Lethbridge	Redcliff	Wainwright
Taber	Empress	Pakan
Magrath	Brooks	Rochester
Milk River	Steveville	*Slave
Pakowki		

The third group of coal areas is designated "Belly River (including Edmonton) Coal". This group includes the Belly River coal seams along the foothills belt and in some places coal seams in the basal beds of the Edmonton formation where the two coal horizons are not yet mapped separately. This group also includes the coal seams that have been prospected in the Grande Prairie district and also north of Edmonton at Westlock.

There are eleven coal areas in this group and these are named as follows:

Pincher	Prairie Creek
Pekisko	Halcourt
Morley	Sexsmith
*Red Deer	*Valhalla
Saunders	*Westlock
Coalspur	

The Lower Cretaceous or *Blairmore-Kootenay coal horizon* includes the same 10 coal areas shown on the earlier coal areas map. These ten coal areas are distributed along the eastern face of the Rocky Mountains and in southern Alberta extend to the west boundary of Alberta which is also the continental divide. These areas have been named as follows:

Smoky River	Panther
Brule	Cascade
Mountain Park	Highwood
Nordegg	Oldman
Clearwater	Crowsnest

Those coal areas marked with an asterisk (*) are new areas on the accompanying map. There are five of these new coal areas: Mountain House, Slave, Westlock, Valhalla and Red Deer.

Each of the 49 coal areas is named after some mining centre, town or geographical feature occurring within its boundaries, which enables the reader to associate the coal area with a particular part of Alberta.

Insofar as it is possible, three factors are considered in defining the boundaries of the areas. These factors are the distribution of the geological formations that have been recognized to date; the positions of mines and prospects in the area; and the character and classification of the coal as indicated by comparable chemical analyses.

It will be noted that the boundaries of these coal areas follow north-south and east-west survey lines, or in the case of the coal areas in the mountains and foothills belt, by straight oblique lines joining points where the coal formation is known to occur. The continental divide defines the western boundary of the Crowsnest, Oldman and Highwood coal areas. Of course the geological formations do not follow surveyed lines or other straight lines on any map. On this account it is not possible to show precisely the extent of the coal-bearing strata in all of the areas. For example, there may be some Kootenay or Lower Cretaceous coal extending beyond the eastern boundary of the Kootenay coal areas, but this is only a minor detail that can be corrected when more exact field data are obtained.

It will also be noted that the coal areas on the accompanying map do not include the whole of Alberta, but only those areas where coal mining is in progress or where coal seams have been prospected and some coal removed. Additional areas may be added when the occasion arises. Of course there are extensive areas in Alberta where there are no coal-bearing strata or areas where the coal seams are not of commercial quality, or where the geography will not warrant commercial development of the coal seams, or where the coal seams occur at too great a depth for commercial mining. Such areas are advisedly omitted from classification on the map.

COALS FROM ALBERTA COAL AREAS

Coal analyses are not included in this report but the table given below has been supplied by Edgar Stansfield, Chief Fuel Research Engineer, Research Council of Alberta:

TABLE 1

New Canadian Classification of Alberta Coals by Rank as per Specification D 388.38 of American Society for Testing Materials

Where more than one rank of coal has been mined in an area, the rank or ranks principally mined are listed first, but ranks of secondary importance are listed as also mined. In a few cases classifications are still doubtful and changes may be required when more information is available. The fact that a rank of coal is listed for an area does not necessarily mean this rank is now being mined in that area.

Kootenay Areas

Brule—Low volatile bituminous
Mountain Park—High volatile A bituminous and Medium volatile bituminous
Nordegg—Low volatile bituminous
Cascade—Low volatile bituminous, also Semianthracite
Highwood—Low volatile bituminous
Oldman—Medium volatile bituminous
Crowsnest—Medium volatile bituminous, also High volatile A bituminous

Belly River Areas

Halcourt—High volatile C bituminous, also Subbituminous B
Prairie Creek—High volatile B and High volatile C bituminous
Coalspur—High volatile C bituminous
Saunders—High volatile C bituminous
Morley—High volatile B bituminous
Pekisko—High volatile B bituminous
Pincher—High volatile B bituminous, also High volatile A and High volatile C bituminous
Magrath—High volatile B bituminous, also High volatile C bituminous
Lethbridge—High volatile C bituminous
Milk River—Subbituminous A and Subbituminous B
Pakowki—Subbituminous C and Lignite
Taber—Subbituminous A and Subbituminous B
Redcliff—Subbituminous C
Brooks—Subbituminous B
Sexsmith—Subbituminous C
Westlock—Subbituminous C

Edmonton Areas

Pembina—Subbituminous B
Edmonton—Subbituminous B and Subbituminous C
Tofield—Subbitmuinous C
Camrose—Subbituminous C, also Subbituminous B
Castor—Subbituminous C, also Subbituminous B
Ardley—Subbituminous B
Big Valley—Subbituminous B
Carbon—Subbituminous B, also Subbituminous A
Sheerness—Subbituminous C
Drumheller—Subbituminous B
Gleichen—Subbituminous B
Champion—Subbituminous A, also Subbituminous B
Wetaskiwin—Subbituminous B
Whitecourt—Subbituminous B

It will be noted that there is no anthracite coal in Alberta and according to the new classification of coal, there is no lignite coal in the coal areas as defined in Alberta, with the one exception of a coal seam in Pakowki area. In Table 2 is given the definition of each of these groups as used in the new classification:

TABLE 2

Classification of Coals by Rank*

Legend: F.C.=Fixed Carbon. V.M.=Volatile Matter. B.T.U.=British thermal units.

Class	Group	Limits of Fixed Carbon or B.t.u., Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitec	1. Meta-anthracite	Dry F.C., 98% or more (Dry V.M. 2% or less)	
	2. Anthracite	Dry F.C., 92% or more and less than 98% (Dry V.M. 8% or less and more than 2%)	
	3. Semianthracite	Dry F.C., 86% or more and less than 92% (Dry V.M. 14% or less and more than 8%)	Non-agglomerating(a)
II. Bituminous (c)	1. Low volatile bituminous coal	Dry F.C., 78% or more and less than 86% (Dry V.M. 22% or less and more than 14%)	
	2. Medium volatile bituminous coal	Dry F.C., 69% or more and less than 78% (Dry V.M. 31% or less and more than 22%)	
	3. High volatile A bituminous coal	Dry F.C., less than 69% (Dry V.M. more than 31%) and moist(b) B.t.u. 14,000(d) or more	
	4. High volatile B bituminous coal	Moist(b) B.t.u. 13,000 or more and less than 14,000	
	5. High volatile C bituminous coal	Moist B.t.u. 11,000 or more and less than 13,000(d)	Either agglomerating or non-weathering(e)
III. Subbituminous	1. Subbituminous A coal	Moist B.t.u. 11,000 or more and less than 13,000(d)	Both weathering and non-agglomerating
	2. Subbituminous B coal	Moist B.t.u. 9,500 or more and less than 11,000(d)	
	3. Subbituminous C coal	Moist B.t.u. 8,300 or more and less than 9,500(d)	
IV. Lignitic	1. Lignite	Moist B.t.u. less than 8,300	Consolidated
	2. Brown coal	Moist B.t.u. less than 8,300	Unconsolidated

(a) If agglomerating, classify in low-volatile group of the bituminous class.

(b) Moist B.t.u. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

(c) It is recognized that there may be non-caking varieties in each group of the bituminous class.

(d) Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of B.t.u.

(e) There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and non-weathering; Variety 2, agglomerating and weathering; Variety 3, non-agglomerating and non-weathering.

*Standard Specifications for Classification of Coals by Rank. A.S.T.M. Designation D 388-38. 1938 supplement to Book of A.S.T.M. Standards.

In order to simplify the discussion on each of these several coal areas, Table 3 shows important information on the thickness of coal seams, dip of coal seams, the depth of cover and the annual production of coal from those areas where mining operations are carried on. Table 1 shows the rank of coal in each area, according to the new accepted coal classification.

TABLE 3

Tabulated Data on Coal Seams by Areas

1.—Kootenay Coal Areas

Area	Thickness of seam (feet)	Depth of cover (feet)	Dip	Output (tons) 1941	1942
Smoky River	3.5-18		20°-70°	....	....
Brule	6 -10	The depth of	0°-40°	....	....
Mountain Park	27 -36	cover depends	15°-60°	985,751	932,403
Nordegg	7 -16	on the dip of	10°-12°	341,549	367,064
Clearwater	....	the coal seams		....	....
Panther	....	in the mount-		....	....
Cascade	7 -10	tains and the	10°-15°	322,202	337,659
Highwood	3 -38	foothills	50°-80°	700	271
Oldman	....		....	....	....
Crowsnest	7 -18		10°-50°	2,021,155	2,170,222
		Total		3,671,357	3,807,619

2.—Belly River Coal Areas

Area	Thickness of seam (feet)	Depth of cover (feet)	Dip	1941	1942
Halcourt	1.5- 2.3	0-150	....	3,595	2,403
Sexsmith	3	30- 40	....	88	....
Valhalla	....	....	....	....	....
Prairie Creek	3 - 6	0-425	8°-15°	16,988	....
Coalspur	8 -11	0-600	22°-45°	509,933	658,061
Saunders	4 - 5	0-1500	10°-50°	50,732	64,094
Red Deer	....	....	....	....	....
Morley	....	....	....	....	....
Pekisko	3 - 9	0-200	10°-30°	6,977	10,786
Pincher	2 -12	0-100	20°-50°	823	606
Magrath	2 -12	0-100	low (undulating)	21	....
Lethbridge	3 - 5.5	50-350	low (undulating)	339,579	470,065
Milk River	2 - 5	0- 75	low (undulating)	3,848	1,368
Pakowki	1 -11	0-200	low (undulating)	635	469
Taber	2 - 4.5	0-160	low (undulating)	14,852	13,191
Redcliff	4 - 6	200	horizontal	25,837	24,969
Brooks	4 - 5	0-150	horizontal	11,446	14,097
Steveville	....	....	....	....	....
Empress	....	....	....	....	....
Wainwright	....	....	....	....	....
Pakan	1 - 4	0-100	horizontal		....
Rochester	....	....	....	1,980	3,289
Westlock	3 - 7	0-100	horizontal	1,314	....
Slave	....	....	....	....	....
		Total		988,648	1,263,398

3.—Edmonton Coal Areas

Area	Thickness of seam (feet)	Depth of cover (feet)	Dip	1941	1942
Pembina	4 -25	0-310	....	66,746	58,980
Edmonton	3.5- 7.5	0-400	....	477,637	514,479
Tofield	5 - 8	10- 50	....	56,485	73,368
Camrose	4 - 7	15-300	....	54,786	47,627
Castor	4 -10	0-128	....	43,006	42,482
Ardley	4 - 6	30-100	....	10,916	5,938
Big Valley	3 - 6	0- 60	....	4,006	4,708
Carbon	4 - 5	50-200	....	57,207	63,750
Sheerness	2 - 9	10-100	....	39,205	50,490
Drumheller	3 - 7	0-550	....	1,458,455	1,785,021
Gleichen	3 - 4	50-150	....	25,642	21,979
Champion	2 - 4	100-150	....	13,203	12,369
Wetaskiwin	4 - 7	0- 60	....	2,546	1,783
Whitecourt	3 -10	0- 50	....	219	288
Mountain House	1 - 3	0-200	....	....	....
		Total		2,310,059	2,683,262

LOWER CRETACEOUS COAL

The oldest coal-bearing strata in Alberta are Lower Cretaceous in age. The Lower Cretaceous strata are of non-marine or continental deposition and consist chiefly of sandstones, shales and several interbedded and extensive coal seams. The Lower Cretaceous formations are exposed within the Rocky Mountains and along the western edge of the foothills belt. In the southern part of Alberta, chiefly south of Bow river, the Lower Cretaceous consists of two formations, the Kootenay which contains a number of coal seams, overlain by the Blairmore which does not contain coal seams. In the Crowsnest Pass district within the mountains and foothills, the Kootenay is separated from the Blairmore by a band of conglomerate, interbedded with sandstones. This band varies from 50 to 70 feet in thickness. This heavy conglomerate bed, known as the Blairmore conglomerate, is taken as the base of the Blairmore. The coal seams in the Crowsnest district and north to the Bow, are below the conglomerate and are therefore, in the Kootenay formation. This conglomerate band thins to the east and where the Kootenay and Blairmore cannot be determined, the strata are grouped as Lower Cretaceous.

In the Crowsnest district there are several coal seams in the Kootenay but only three seams are of sufficient thickness and purity to warrant development. In most of the mines, only two seams are being worked.

In the Bow valley at Canmore and Bankhead, ten or possibly twelve different coal seams have been recognized in the Kootenay formation, but most of the coal mined has come from four of the thicker seams.

Between the North Saskatchewan valley and the Athabaska valley in the foothills and front ranges of the Rocky Mountains, the important coal seams occur higher in the Lower Cretaceous than in the Crowsnest district. The coal seams that have been developed, occur above a conglomerate band known as the Cadomin conglomerate, which by many is considered to be the equivalent of the Blairmore conglomerate in the south. According to this interpretation, the coal seams northwest of the area between the Bow and North Saskatchewan rivers in the foothills and mountains, occur in the upper part of the Lower Cretaceous and in the series of beds, the equivalent of the Blairmore in southwestern Alberta. In the Mountain Park area, the coal seams occur in the Luscar formation which is underlain by the band of Cadomin conglomerate about 20 to 35 feet in thickness. If the Cadomin conglomerate and the Blairmore conglomerate are of the same time equivalent, then the coal from Nordegg northwards would correspond in age to the Blairmore formation in southern Alberta.

On the accompanying map (Map No. 18) showing the position of the coal areas, the Lower Cretaceous coal is designated as in the Kootenay coal horizon.

The Lower Cretaceous (Kootenay) coal areas are distributed along the western side of the foothills and within the eastern belt of the Rocky Mountains, where the Lower Cretaceous strata including coal seams, occur at the surface.

There are a number of coal seams in the Lower Cretaceous strata north of the North Saskatchewan valley, but most of the coal mining operations have been on two or three different seams, and in some places only one seam has been mined.

There are ten coal areas shown on the accompanying map where there are Lower Cretaceous coal seams at the surface or close enough to the surface to be mined to date. It will be understood that some of these coal seams will extend east of the Kootenay coal areas, at greater depth and under the younger formations, but up to date mining operations have not been extended east of the coal areas as shown on the accompanying map. Most of the Lower Cretaceous coal produced in Alberta has been from the Crowsnest, Cascade, Nordegg, Mountain Park and Brule coal areas. Important coal deposits have been prospected or are known to occur in the other coal areas, namely, Oldman, Highwood, Pincher, Clearwater and Smoky River.

The coal in the Lower Cretaceous (Kootenay) strata within these ten coal areas, is of the highest rank in Alberta, ranging from low volatile bituminous up to semianthracite. The higher rank of coal is due to the greater age and especially to the metamorphism resulting from greater pressures on the coal by mountain-building forces. In general, the coals are more mature in the mountains and western foothills than they are in the eastern foothills and under the plains in Alberta. The Lower Cretaceous coals must be regarded as mostly of bituminous rank. Only at one locality in the Cascade coal area, namely at Anthracite, five miles east of Banff, is there coal of semianthracite rank.

A few notes are given below on several of the coal areas where coal is being mined today or where the geology has been worked out in greater detail.

Crowsnest Area

In the Crowsnest Pass the Kootenay formation varies in thickness from 800 to 584 feet at Coleman to 360 feet at Burmis. There are at least five seams in the formation but only three seams are of importance and only two are being mined at any one place. The seams are numbered 1 to 5 from top to bottom.

In the Crowsnest coal area, coal is being mined from the Kootenay formation at Coleman, McGillivray creek, Blairmore, Bellevue, and until recently at Hillcrest. Coal has also been mined at Frank and Burmis. The rank of coal in the Crowsnest area, has been determined as medium volatile bituminous and also some high volatile A bituminous (see Table 1).

The following table shows the correlation of the coal seams and the thickness of strata between the coal seams at the different collieries in this area[1]:

TABLE 4

Kootenay Coal Seams in Crowsnest Coal Area

Thickness of Coal Seams, Their Local Numerical Designations, and the Stratigraphic Intervals at Different Collieries

	International Coal and Coke Company, Coleman	McGillivray Creek Coal and Coke Company, Carbondale	West Canadian Greenhill Mine, Blairmore
	Feet	Feet	Feet
Thickness as obtained from mine workings:			
Interval to top of formation	0-22		
Coal seam	No. 1: 0- 3		
Interval	30	30	0- 4
Coal seam	No. 2: 4-17(a) Av. 14½	No. 2: 5-17(a) Av. 9½	No. 1: 0-17 (a) Av. 12
Interval	5-90	85	40-85
Coal seam	No. 4: 7-10(b)	No. 4: 4-10(b)	No. 2: 10(b)
Interval	220	230	230
Coal seam	No. 5: 5-17(c)	No. 5: 5-20(c)	No. 4: 4- 6(c)
Interval	300-450	300-450	225
Estimated total thickness of formation from outcrop	584-800	650-800	560

	Franco-Canadian Company, Frank	Hillcrest Collieries, Hillcrest	West Canadian Collieries, Bellevue
	Feet	Feet	Feet
Thickness as obtained from mine workings:			
Interval to top of formation			
Coal seam	No. 1: 10-25(a) Av. 12	No. 1: 0-18(a) Av. 12	No. 1: 4-14(a) Av. 12
Interval	38	34-53	35-50
Coal seam	No. 2: 6	No. 2: 9-13	No. 2: 5-16(b)
Interval	125	135	125
Coal seam	No. 3: 7(c)	No. 3: 6-13(c)	No. 4: 7(c)
Interval	220	220	220
Estimated total thickness of formation from outcrop	450	430	430

	Maple Leaf Collieries No. 1 mine, Maple Leaf	Leitch Collieries & Byron Creek Collieries, Byron Creek	Mohawk Bituminous Mines	Burmis Mining Co. Mine No. 153
Thickness as obtained from mine workings:	Feet	Feet	Feet	Feet
Interval to top of formation				
Coal seam	No. 1: 0-8(a)	No. 1: 0	0	No. 1: 3¾
Interval	56	35	35	40
Coal seam	No. 2: 5-14(b)	No. 2: 4-10 (a) Av. 6	No. 2: 6-12(a)	No. 2: 4½(a)
Interval	135	110	110	100
Coal seam	No. 4: 8½(c)	No. 3: 7	No. 4: 7(b)	No. 5: 5½-8(c)
Interval	210	220	200	200
Estimated total thickness of formation from outcrop	425	380	360	360

(a) Principal coal seam which has been or is being mined.
(b) Coal seam partly mined.
(c) Impure coal prospected but not mined.

Highwood Area

In the Highwood coal area, the Kootenay coal seams have been prospected extensively along the valley of Highwood, particularly on Cat creek on what is known as the Ford property, on Flat creek in the foothills, and also along the Sheep river valley on what is known as the Burns property. Details on these coal basins have been given by Allan[2].

There are two main bands of Kootenay strata with coal seams. The eastern band is in the foothills along the east side of the Highwood range. Two coal seams, six and sixteen feet in thickness, have been opened up on Flat creek where the cover over the coal seams varies from the outcrop to a thickness of about 400 feet. The larger and more important band of coal-bearing strata extends along the Highwood valley west of the Highwood range, in range 6 and the west side of range 5. This band of Kootenay strata branches in township 18, near the junction of Storm and Mist creeks. The narrower of the two branches follows up the valley of Storm creek on the west side of Mist mountain to the pass at the head of Pocaterra creek which flows into Kananaskis river. Coal prospects have been opened up on this creek but these coal-bearing beds pinch out in Pocaterra creek about two miles above the junction with the Kananaskis.

The eastern branch of this band of Kootenay strata extends up the valley of Mist creek on the east side of Mist mountain and on the west side of Highwood range. It extends over the divide and follows up the south side of Sheep creek valley where the Burns coal field is situated. This narrow band of coal-bearing strata extends across the head of Elbow river drainage and across Kananaskis valley to join the Cascade coal basin.

The Ford coal field covers the coal-bearing strata, chiefly along the northeast side of the Highwood valley from the north side of township 16, diagonally across range 6 into township 18. The Burns coal field includes the extension of these coal seams to the northwest and on the south side of Sheep river valley in township 19, range 7, west of the fifth meridian.

Numerous prospect tunnels and test pits have been opened up on the Ford property. On Cat creek fourteen coal seams are exposed and have been prospected for a distance of about a mile across the strike of the formation in which the strata are dipping steeply, and intensely crushed and broken by faulting. These coal seams have been examined by the writer but considerable prospecting work has been carried out since the examination was made. Beginning at the most easterly prospect, the seams are described as follows:

No. 000. About four feet of badly crushed coal containing considerable bone, but many lensy fragments of solid coal with high lustre. The limestone outcrops a few yards east of this prospect.

No. 00. About eight feet of solid coal and four feet of badly crushed coal.

No. 0. Seven feet six inches of good-looking coal.

No. 1. Five feet glossy compact coal and about four feet badly crushed coal.

No. 2. Twelve feet glossy and blocky coal, fourteen inches of bone, three feet six inches fair coal.
This seam, which is eight feet from No. 1, dips at 53 degrees west and strikes north 39 degrees west.

Nos. 3 and 4. Very little work has been done on numbers 3 and 4, so that the exact width of these could not be determined but the seams are four to five feet thick.

No. 5. Thirty-three feet made up as follows: 11 feet coal, 4 feet shale and coaly shale, 18 feet coal. This is one of the best seams on the property and contains much coal of good marketable quality. The strike of the seam is north 39 degrees west and the dip 85 degrees southwest.

No. 6. Ten feet wide, has been opened up about fifty feet below No. 5. It appears to represent the upper part of No. 5 whereas the lower part of No. 5 at this level appears to have pinched out considerably.

No. 7. Twelve feet of very good coal has been opened up seventy feet below the level of No. 6. The strike here is north 42 degrees west and the dip 88 degrees west to 88 degrees east.

No. 8. A five-foot seam of badly crushed coal opened up five feet below No. 7. No blocks could be obtained from this seam but the prospect does not extend beyond the weathered portion of the coal. The strike of this seam is north 62 degrees west and the dip 65 degrees northeast. There is a fault between 7 and 8.

No. 9. Seam opened up half-way down the canyon of Cat creek. The prospect exposes four feet six inches of fine-textured but clean coal. The strike is north 38 degrees west and the dip about 80 degrees west.

No. 10. Between the camp and the mouth of the canyon there are two seams. The upper one, No. 10, is about seven feet wide and the coal is mined for camp use in small but angular blocks.

No. 11. Within a few feet of No. 10, but on account of the crushed character of the seam, only twelve feet can be readily measured.

This is an important undeveloped coal field which is quite accessible and in which the coal is classed as low volatile bituminous rank.

Coal of a similar rank occurs in the Sheep river coal basin. Considerable prospecting has been carried out in this basin by the P. Burns Coal Mining Company, particularly between Sharp creek and Rickert creek. A tunnel 1,800 feet long, commonly referred to as the Burns mine, has been driven to the southwest across the coal measures. Practically no further development work has been done on this coal basin in the past twenty years.

The section of the coal-bearing strata measured in the tunnel, is characteristic of the coal seams in this basin. The section is as follows:

950 feet sandstone and shale, strike north 27 degrees west, dip 70 degrees west.
35 feet coal, Burns seam.
375 feet sandstone and shale.
38 feet coal, Sharp seam.
140 feet shale and sandstone.
18 feet coal.
133 feet sandstone.
7 feet coal.
60 feet sandy shale.
3 feet coal (end of tunnel).

This is not a complete section of the coal measures because along Sharp creek, a few hundred yards west of the adit to the tunnel, six seams were examined. In the prospect pits and short tunnels along Sharp creek and Rickert creek, the coal seams examined represent at least eighty-six feet of coal in nine separate seams. This important coal property is readily accessible by road up Sheep creek, west from Turner Valley oil field.

Cascade Area

The Cascade coal area extends from township 21 in Kananaskis valley to township 28 at the head of the Cascade creek valley. The geology of the entire Cascade coal basin was investigated and described by D. B. Dowling in 1910 and 1923. The structure in the vicinity of Canmore coal mine was mapped in 1933 by B. R. MacKay. Mining operations have been carried out in this basin at Bankhead, Anthracite and Canmore. The mines at Bankhead opened in 1888, and the former workings at Anthracite have been abandoned for several years. More recently the Wheatley mine has been opened up on the east side of the former workings at Anthracite. The coal seam being worked is about 9 feet in thickness with a cover up to about 400 feet. The Canmore mines have been in continuous operation since 1888.

In the Cascade area there are at least twelve coal seams within a section of about 1100 feet of Lower Cretaceous strata. Several of these seams are quite thin and are useful only as markers.

At Canmore there appears to be eight important coal seams which according to Dowling[3] are as follows from the top downwards:

Stewart seam, 7 to 8 feet, highest seam worked (No. 2 mine).
Sedlock seam, 5 feet 6 inches (No. 1 mine).
No. 6 seam, not mined.
Cary seam, mined (No. 1 mine).
No. 4 seam, 3 feet (No. 1 mine).
No. 1 seam, 5 feet 8 inches.
No. 3 seam, 4 feet 8 inches.
No. 2 seam, 5 to 6 feet.

MacKay shows 12 coal seams on the structure sections published by the Geological Survey of Canada, but it is unfortunate that no report on the area mapped or description of the seams has been published to date. The order of the seams in about 300 feet of strata, is noted as follows:

Section 7000 feet, southeast of No. 2 Entry	Section below Three Sisters mountain
Upper marker seam	Upper marker seam
Marker seam	Marker seam
Stewart seam	Stewart seam
Morris seam	Morris seam
Sedlock seam	Upper Marsh seam
Carey seam	Lower Marsh seam
No. 4 seam	Cairnes seam
No. 1 seam	Joe seam
No. 3 seam	Dirty seam
No. 2 seam	Wind Creek seam
No. 0 seam	
Marker seam	

As shown in Table 1, the coal in Cascade coal area is classed as in the low volatile bituminous rank. There are small pockets of semi-anthracite in this area where the coal has been more intensely metamorphosed, but the volume of this rank of coal is not large.

Nordegg Area

The Nordegg coal area includes the present mines of the Brazeau Collieries and the Bighorn coal basin which lies west of the Bighorn range.

The coal seams occur in the Lower Cretaceous formation, known as the Luscar, and above a band of conglomerate known as the Cadomin conglomerate. If this conglomerate is correlated as the time equivalent of the Blairmore conglomerate, then the coal in the Luscar formation is younger than the Crowsnest coal which is in the Kootenay formation. There are at least five coal seams and posibly more, in the Luscar formation. In the mines of the Brazeau Collieries, two seams are being worked. No. 2 seam is about 6 feet thick and No. 3 seam is about 13 feet in thickness. The average dip of the coal seams is about 12 degrees to the southwest and the cover varies from the outcrop to over 1000 feet in thickness.

The coal in the Nordegg area is classed as low volatile bituminous in rank.

Mountain Park Area

In the Mountain Park coal area the coal seams occur in the Luscar formation which is underlain by the Cadomin conglomerate about 35 feet in thickness. The coal is in the upper part of the Lower Cretaceous. There are several coal seams, but two are of particular importance, each of which varies in thickness from about 25 feet to about 40 feet.

Mining operations are at four centres, Mountain Park, Cadomin, Luscar and at K. and D. mine on Mary Gregg river. The Mountain Park basin is west of Nikanassin range of Paleozoic rocks. Three seams have been opened up. The No. 1 or Kennedy seam is 25 feet in thickness. The cover varies from the outcrop to 1200 feet. No. 2 seam is 8 feet and No. 3 seam is 32 feet in thickness.

The Cadomin basin is situated on the east side of Nikanassin range and strata are steeply dipping, in places overturned, and the coal is intensely crushed. The main seam being mined, is 32 feet in thickness with a cover varying up to about 2000 feet in depth.

The Luscar-K. & D. basin is the continuation of the Cadomin basin and is also situated close to the east face of Nikanassin range. Most of the coal is mined from one seam which varies from 30 to 35 feet in thickness in cover from the outcrop to about 1500 feet.

The coal in the Mountain Park area is classed as of high volatile B bituminous and medium volatile bituminous ranks.

Brule Area

In the Brule coal area, coal seams in the Luscar formation have been mined at Brule mines, east of the front of the Rocky Mountains, and at Pocahontas and Bedson, west of the front range of Paleozoic limestones[4]. Mining operations at these places ceased several years ago. The coal at all these centres is intensely crushed under the weight of the overthrust mountain block lying close to the west of the coal basins. The coal is classed as of low volatile bituminous rank.

Smoky River Area

The Smoky River coal area is situated in the vicinity of Smoky river, a tributary of Peace river, and the Berland river, a tributary of Athabaska river. This area is known to contain a very large reserve of Lower Cretaceous coal which is classed as low volatile bituminous and medium volatile bituminous rank. Details on these coal seams have been given by J. McEvoy[5].

A summary of the coal seams is given by McEvoy (p. 10) as follows:

	Feet	Inches
Seam A, of workable quality and thickness	5	0
B, " " "	4	0
C, " " "	9	0
D, " " "	5	6
E, " " "	8	1
H, " " "	18	0
I, " " "	13	0 (up to 14 ft.)
Total	62	7
Seam F, of doubtful commercial value	3	6
G, " " "	6	11
Total	10	5

or a grand total of 73 feet of coal

BELLY RIVER COAL

The Belly River strata are grouped about the middle part of the Upper Cretaceous and are considerably younger than the Lower Cretaceous coal-bearing formation. It follows, therefore, that the coal in the Belly River formation is less mature and metamorphosed to a lesser degree than the Lower Cretaceous coals because these young coal seams occur further removed from the east front of the Rocky Mountains.

The Belly River coal areas shown on the accompanying map (Map No. 18) include two groups, namely those designated "Belly River Coal" and "Belly River (including Edmonton) Coal". The reason for making this distribution is given below. There is a trough-like structure, referred to as the Alberta syncline, extending northward through central Alberta with younger rock of Tertiary age at the surface along the centre of the trough and with older rocks coming to the surface along the edges of this trough. The Belly River strata occur at the surface along the foothills belt, then dip eastward into the Alberta syncline and then rise to the surface again along the east side of Alberta. In the Magrath area at the south end of the trough, the Belly River formations occur at the surface.

Along the eastern side of this saucer-like depression the Belly River formations are separated from the younger Edmonton coal-bearing formations by a series of marine shales in the Bearpaw formation so where this condition exists there is no difficulty in distinguishing the coal seams in the Belly River from those in the Edmonton. The Bearpaw marine shales become thinner and finally disappear so that along the foothills there is no Bearpaw formation. As a result of this condition the Belly River coal-bearing strata within the foothills are directly overlain by the Edmonton coal-bearing formation, and it is not always possible to distinguish the uppermost Belly River coal seams from the basal Edmonton coal seams, because coal seams occur close to the contact of these two formations. Only in a few places within the foothills does this condition exist but it was considered advisable to draw attention to this fact by coloring slightly differently those areas where some basal Edmonton coal seams might occur very close to the Belly River coal seams. Coal seams close to the contact of the two formations occur at a few places in the vicinity of Grande Prairie, so the Halcourt, Valhalla and Sexsmith coal areas are shown to include some Edmonton coal. The Bearpaw shales also pinch out north of the North Saskatchewan river, so that in the Westlock area some of the coal seams are definitely in the Belly River, but in some places there is a coal seam at the base of the Edmonton, directly underlain by Belly River strata. When more detailed geological work has been carried out in some of these border areas, it may be possible to more definitely separate these coal seams along the contact of the two formations. In this discussion the coal areas within the foothills and those along the east side of Alberta will all be considered as of Belly River age.

In Table 1 it is shown that the rank of the coal in the Belly River coal areas varies between wide limits from high volatile A bituminous rank in Pincher coal area, down to subbituminous C coal in Pakowki, Redcliff, Sexsmith and Westlock coal areas, with some lignite in Pakowki area. All of these areas are far removed from the foothills and from the effect of mountain-building forces.

Halcourt Area

In the Halcourt coal area there are thin coal seams in the Belly River strata outcropping along the banks of Wapiti river, Red Willow creek and other smaller tributaries in the Grande Prairie district, but no thick seams have been observed. Where the coal seam has been opened up by mining or in prospect pits, the coal bed varies from seventeen to twenty-eight inches in thickness, but there may be thicker seams within this area which have not yet been found. The cover varies from the outcrop to over 150 feet. The coal from this area is classed as high volatile C bituminous, also subbituminous B rank.

Sexsmith Area

There are thin coal seams exposed along the valley of Smoky river in both the Belly River and the Edmonton formations, but no thick seams have been observed. A few tons of coal have been mined from a three-foot coal seam in the basal Edmonton beds, about fifteen miles northeast of Sexsmith. The coal from this area is classed as subbituminous C rank.

Prairie Creek Area

The Prairie Creek coal area includes the area along and adjacent to the Athabaska valley between Entrance and Obed. A coal seam three to six feet in thickness, dipping 8 to 15 degrees and with a cover varying from the outcrop along Athabaska valley to about 425 feet, has been developed by mining in the vicinity of Hinton. It is classed as high volatile B and high volatile C bituminous rank. There are several coal seams in the Belly River formation in this area.

Coalspur Area

The Coalspur coal area extends from the McLeod river valley to the Brazeau river. There are several coal seams in the Belly River formation in this area, and from three of these seams, called the Val d'or, Silkstone and Mynheer, about one-half million tons are produced annually from six mines along the Coal Branch of the Canadian National Railway in the vicinity of Coalspur. There are two large open pit strip mines operated at Sterco and Coal Valley, where the coal deposit varies from 50 to 120 feet in thickness. The cover where mining operations are carried out varies from the outcrop to about 600 feet. Coal from this area is classed as high volatile C bituminous rank.

Saunders Area

The Saunders coal area extends from the McLeod valley to the North Saskatchewan valley. Details on the geology of this coal basin have been given in an earlier report[6]. The strata have been designated the Saunders formation, the lower part of which has been correlated with the Belly River formations. Several coal seams occur within a thick band of about 250 feet. The coal seams mined at Saunders and Alexo are four and one-half to five feet in thickness, with dips of 10 to 15 degrees. The cover varies from the outcrop along the sides of the North Saskatchewan valley to about 1500 feet. The coal in this area is classed as high volatile C bituminous in rank.

The Red Deer and Morley coal areas contain thin coal seams in the Belly River and basal Edmonton strata, but there is no coal being produced from these areas at the present time.

Pekisko Area

The Pekisko coal area includes the foothills belt from Priddis to the head of Willow creek in township 13. The Turner Valley oil fields are within this area. Coal seams have been prospected at several places along the Highwood and Sheep rivers, and at present there are four mines with small production in the vicinity of Priddis in township 22, ranges 3 and 4, west of the fifth meridian. The coal seam that is mined varies from three to nine feet in thickness and the dip varies from nearly horizontal to more than thirty degrees with a cover up to about 200 feet. As this area is within the foothills, the strata in many places dip more steeply and are broken by faults. The coal in this area is classed as high volatile B bituminous rank.

Pincher Area

The Pincher coal area includes the much disturbed belt in the foothills from the north side of township 12 to the International Boundary. Almost all of the Upper Cretaceous formations occur within this disturbed area in which the strata are folded and faulted, including the Belly River coal horizons and the younger coal horizon in the St. Mary River formation which is correlated with the Edmonton formation. The north part of this area lies between the Livingstone range on the west which is an outlier of the Rocky Mountains, and the Porcupine hills on the east, an erosional residual ridge capped by flat-lying Tertiary strata.

There are two coal-bearing horizons in the Belly River formation. The lower coal horizon occurs within the lower part of the Belly River formation. Between Oldman river and Crowsnest river, these coal-bearing strata occur about 400 feet above the base of the Belly River formation. There are several coal seams ranging in thickness from a few inches up to about seven feet, but only one seam is thick enough to be worked. This coal bed has been prospected both on Oldman river in township 10, range 2, and on the Crowsnest river in township 8, range 2.

The upper coal-bearing horizon in the Belly River formation occurs within the upper 150 feet in the formation and corresponds in age to the Lethbridge coal beds. There are several thin coal seams in this horizon but only one workable seam has been opened up in prospect pits in township 10, range 2; township 7, range 2 and township 4, range 28.

Various attempts at mining have been made since 1903. The principal coal seams in this area are quite irregular in thickness and the coal bed pinches or thickens rapidly due to the effect of pressure from the mountains close to the west. At the Purdy mine in legal subdivision 15, section 26, township 7, range 2, the coal seam is between 7 and 8 feet thick and occurs near the top of the Belly River formation. At the Rhodes mines in legal subdivi-ion 16, section 23, township 7, range 2, the coal seam is about 6 feet thick, but in places thickens to about 10 feet. The cover over this coal seam that is being mined, is about 100 feet thick. The seam opened up in section 23 may be a lower seam than the one being mined in section 26. There appears to be a stratigraphic interval of about 50 feet between the coal seams at the two localities but this may be due to the disturbed character of the strata.

A recent report of the Cowley district has been prepared by Hage[7].

The disturbed character of the coal in this area is seen in the rank of coal which is classed as high volatile B bituminous, also high volatile A and high volatile C bituminous.

Magrath Area

The nine coal areas along the south and in the southeastern part of Alberta contain Belly River coal beds that are less disturbed from west to east than those in the foothills and closer to the mountains.

In the Magrath coal area the coal horizons in the Belly River have not been prospected thoroughly. The coal from this area is classed as subbituminous A and subbituminous B rank. Coal seams younger than the Belly River also occur in this area.

Lethbridge Area

The Lethbridge coal area is a most important Belly River coal-producing area in the plains. In 1941, the coal production from this area was 339,579 tons.

Oldman river follows an irregular course across the area, and along the sides of this valley the Belly River strata containing coal seams are exposed. The valley of the Oldman at Lethbridge is over 200 feet deep. Along the sides of this valley there is exposed the upper part of the Belly River strata overlain by the Bearpaw shales which, in turn, are overlain by interglacial gravels and glacial till.

The Belly River formations in southeastern Alberta have been subdivided as follows:

Pale beds or Oldman formation, containing the Lethbridge coal member at the top.
Foremost beds, with coal seams near the top.
Pakowki marine shales.
Milk River, chiefly sandstones.

In the Lethbridge area, coal seams occur within the upper 85 feet of the Pale beds formation which has recently been named the Oldman formation and includes the transition zone between the Belly River and the Bearpaw marine shales[8]. On the upstream side of the railway bridge at Lethbridge, lenses of Bearpaw marine shale are interbedded with the uppermost beds in the Oldman formation, but all the coal seams are in Belly River strata. The Oldman formation is about 380 feet in thickness and the coal seams occur in the Lethbridge coal member of the Oldman formation.

There are several coal seams in the Lethbridge coal member but only one seam is extensively worked. This coal seam varies in thickness from three feet to a maximum of about five feet six inches. The beds are nearly flat-lying and the cover over the coal seam varies from 250 to 350 feet in thickness, except where part of the cover has been removed by erosion along the sides of the valleys and coulees. There are several small faults and slips in the coal seam, some of these may have been caused by slumping or settlement of the strata along the sides of the deeply cut Oldman river valley and numerous tributary valleys and coulees.

According to the new Canadian classification, the coal in the Lethbridge area is high volatile C bituminous rank. This rank is considerably higher than that according to the former classification in which Lethbridge coal was grouped as subbituminous or as domestic in quality.

The lower coal-bearing horizon in the Belly River occurs at the top of the Foremost formation which underlies the Oldman formation. This lower coal horizon is not exposed in the Lethbridge coal area but it comes to or near to the surface east of Lethbridge in the Taber coal area where coal is mined. It is known that coal seams in this lower horizon in the Foremost formation, occur at depth within the Lethbridge coal area where the presence of these coal seams has been determined in holes drilled for oil.

Taber Area

In the Taber coal area, the surface formation is the Foremost which includes about 500 feet of strata below the Oldman formation where it is exposed along Oldman river. Numerous thin coal seams occur throughout the Foremost formation, but the principal coal-bearing horizon occurs near the top of the formation. Coal has been mined at a number of places, especially in the vicinity of Taber and along the Oldman river. The principal seam mined varies in thickness from about two feet to a maximum of 4 feet 4 inches. In three of the mines now in operation the seam is 3 feet 8 inches in thickness. The cover varies with the locality and in the vicinity of Taber is about 160 feet thick. The coal is classed as subbituminous A and subbituminous B rank.

Milk River Area

Along the valleys of Milk river and Etzikom coulee in the Milk River coal area, several thin coal seams outcrop throughout the Foremost formation. The seams where they have been prospected vary from 2 to 5 in thickness, with less than 75 feet of cover. At two places the coal seam has been opened up by stripping operations. The coal is classed as subbituminous A and subbituminous B rank.

Pakowki Area

The Pakowki coal area covers nine townships and eight ranges in the southeast corner of Alberta. This area includes part of the Cypress hills in Alberta. These hills are capped by Tertiary strata underlain by Upper Cretaceous strata in which both the Belly River and Edmonton formations are represented. There are several coal seams, most of them less than one foot in thickness, in both of these coal-bearing formations. Along the Milk river valley two to eight feet of coal occurs in the upper part of the Foremost formation, but along Lost creek and Sage creek and in the northern half of the area, there are thin coal seams in the Lethbridge coal member of the Oldman formation at the top of the Belly River. There is a coal seam eleven feet in thickness, opened up at Little Plume in section 2, township 9, range 5, west of the fourth meridian. This seam is in the Lethbridge coal member at the top of the Belly River. The coal in this area is classed as subbituminous C and lignite ranks. At Elkwater in section 23, township 8, range 3, there is a coal seam 5 feet 6 inches in thickness in the Edmonton coal horizon. This coal is less mature than the Belly River coal in the same coal area.

Redcliff Area

In the Redcliff coal area there are coal seams exposed in the valley of the South Saskatchewan river, Bullshead creek and in various coulees, especially where the upper beds in the Foremost formation outcrop. A coal seam about four feet in thickness is mined at Redcliff in section 5, township 13, range 6, at a depth of about 200 feet below the surface. The coal is classed as subbituminous C rank. There is a thin coal seam in the Lethbridge member of the Foremost formation in section 35, township 11, range 5, in the vicinity of Dunmore.

Brooks Area

In the Brooks coal area one coal seam 5 feet in thickness has been opened up in the Bow river valley at Eyremore. The seam is mined by stripping operations on a lower bench in the valley, and by a shaft 150 feet deep on the upland. The coal is classed as subbituminous B rank. There are a number of thin coal seams in this area, especially in the upper part of the Belly River.

Steveville and Empress Areas

The Belly River strata in the Steveville and Empress coal areas include several thin coal seams that outcrop along the valley of the Red Deer and South Saskatchewan rivers and along some of the tributary valleys, especially in the badlands along the Red Deer river downstream from Steveville. There is no coal production from these two areas.

Pakan Area

There are several thin coal seams in the Belly River strata exposed along the steep sides of the North Saskatchewan valley. Prospect pits have been dug into thin coal seams exposed close to the water-line at Pakan. These thin coal seams are in the Pakan formation which corresponds in age to the Foremost formation in southern Alberta. Older coal seams occur near the base of the Belly River, in the Brosseau formation which corresponds to the Milk River in southern Alberta. A tunnel has been driven into one of these coal seams near the top edge of the North Saskatchewan valley, north of Beauvallon, in sections 11 and 14, township 55, range 10, west of the fourth meridian[9]. Coal seams have been encountered at different horizons in the Belly River strata in wells drilled for oil, gas or water in the Pakan coal area.

Rochester Area

The Rochester coal area on the accompanying map, has different boundaries from the area by the same name in 1924[10]. That part of the original Rochester coal area in townships 58 to 60 and ranges 21 to 25, has been placed in the Westlock coal area which includes coal seams in the Belly River and also some seams in the basal beds in the Edmonton. The Rochester coal area now includes townships 61 to 64 and ranges 18 to 25 inclusive. There are thin coal seams in the Belly River strata in this area and the coal production is small at the present time.

Westlock Area

The Westlock coal area is defined on the accompanying map (No. 18), as including townships 58 to 60, between range 21, west of the fourth meridian, and range 3, west of the fifth meridian, inclusive, also townships 61 to 64 between range 26, west of the fourth meridian, and range 3, west of the fifth meridian, inclusive. This area includes coal-bearing strata in both the Belly River and the Edmonton formations. There are many coal prospects within this area in the upper part of the Belly River group of rocks. There is a small coal production from the Belly River horizon in township 60, range 21. The coal seam being mined varies in thickness from 5 feet to 6 feet 10 inches under a cover of about 50 feet. Test drilling might determine the occurrence of workable coal beds at other places within the Westlock coal area.

Slave Area

The Slave coal area includes the area about Lesser Slave lake between townships 70 and 75, ranges 5 and 15, inclusive, west of the fifth meridian. There is no coal production from this area, but these coal seams have been prospected along the south side of the lake in the upper part of the Belly River strata.

High Prairie Area

Since the accompanying map was printed a coal seam has been prospected close to Little Smoky river in legal subdivision 8, section 28, township 72, range 20, west of the fifth meridian. This coal seam occurs in the Wapiti formation which is Belly River in age. Other thin coal seams are known to occur in the Belly River horizon between the Slave and Sexsmith coal areas. It is here suggested that the High Prairie coal area shall include townships 69 to 75, range 16, west of the fifth meridian to range 1, west of the sixth meridian, inclusive. This is a Belly River area and will accommodate any other coal prospect that may later be opened up within the area as defined.

EDMONTON COAL HORIZON

The Edmonton coal-bearing formation has a much wider distribution than is indicated by the fifteen coal areas in central Alberta as shown on Map No. 18. The areal extent of the Edmonton formation is discussed in Part II, Report 34, and is also shown on the geological maps of Alberta, Maps No. 16 and No. 17. The Edmonton strata form the surface formation under fourteen of the coal areas from Champion to Whitecourt, but this formation extends westward under the Paskapoo formation and outcrops in the Mountain House coal area and along the eastern side of the foothills belt.

The Edmonton formation has been measured along the Red Deer valley where it outcrops in the Ardley, Big Valley, Carbon and Drumheller coal areas. The top of the formation outcrops in township 38, range 25, at the west side of the Ardley coal area, and the base of the formation occurs at the southeast corner of township 28, range 19, near the mouth of Willow creek. This measured section contains 1,224 feet of strata assigned to the Edmonton formation in which there are at least fourteen coal seams, having an aggregate thickness of 62 feet of coal. Table 5 given below, is a generalized section of the strata in the Edmonton formation. As the stratigraphic interval varies locally, the entire thickness of the section will also vary from place to place[11].

TABLE 5

Section of Edmonton Formation in Red Deer Valley

Feet	Description
	Contact overlain disconformably by Paskapoo
60	Sandstone and shale
20	No. 14 seam (Ardley)
50	Rock
3	No. 13 seam
170	Rock
1	Volcanic tuff
50	Rock
5	No. 12 seam (Thompson)
90	Rock
6	No. 11 seam (Carbon) (Paton)
155	Rock
3	*Corbicula* zone
20	Rock
3	*Ostrea* zone
85	Rock
	Ornithominus zone, 110 feet above No. 9
2	No. 10 seam (Marker seam)
60	Rock
1	No. 9 seam
15	Rock
2	No. 8 seam
100	Rock
4	No. 7 seam (Daly)
25	Rock
2	No. 6 seam
70	Rock
5	No. 5 seam (Newcastle)
15	Rock
1	No. 4 seam
10	Rock
1	No. 3 seam
10	Rock
3	No. 2 seam
30	Rock
6	No. 1 seam (Drumheller)
40	Rock
1	No. 0 seam
100	Rock
	Bearpaw shales at base
1,224	Total thickness of the Edmonton formation.

There is an erosional surface at the top of the Edmonton and as much as 450 feet of the uppermost beds in the Edmonton formation were removed along this disconformity, before the younger Paskapoo sediments were deposited[12]. On this account the coal seams that occur in the upper part of the formation are not present in all of the coal areas.

The coal seams, from the oldest to the youngest, have been numbered 1 to 14 respectivly. The thickness of the coal seams varies laterally throughout the formation, and several of the seams are too thin to be mined. The coal seams in this part of Alberta vary in thickness from less than one foot up to a maximum of about 20 feet. Mining operations have been undertaken along the Red Deer valley in seams numbered 1, 2, 5, 7, 9, 11, 12 and 14. The seams are numbered from the lowest to the highest. In some places No. 1 seam occurs about 140 feet above the base of the Edmonton formation in Drumheller basin, and No. 14 seam occurs about 60 feet below the top of the Edmonton formation in the Ardley coal area. The stratigraphic interval between the coal seams varies in different localities.

In most of the coal areas only the more accessible coal seams near the surface have yet been developed. In several areas coal seams at a greater depth in the formation have not yet been opened up.

In 1941, the coal production from the Edmonton formation was represented by 2,310,059 tons, of which 1,458,455 tons were produced in the Drumheller coal area, and 477,637 tons were produced in the Edmonton coal area.

A few notes are given below on each of the coal areas from which coal has been mined in the Edmonton formation.

Pembina Area

In the Pembina coal area, there are several coal seams in the upper part of the Edmonton formation. The thickest coal seam is known as the "Big seam" which outcrops in the valley of North Saskatchewan river at "Coal Arch" in legal subdivision 1, section 32, township 50, range 3, west of the fifth meridian. This coal seam in the North Saskatchewan valley is about 25 feet thick and occurs near the top of the Edmonton formation. The lower part of the same seam has been worked at the village of Wabamun where 7 feet 6 inches of coal are mined. At Gainford, west of Wabamun, almost 10 feet of coal have been mined from a seam that is lower than the thick seam mined at Lake Wabamun. At Evansburg on the Pembina river, two coal seams have been opened in a mine operated several years ago by the North American Collieries. The bottom of the upper or "Big seam" occurs at a depth of 270 feet below the surface and the top of the lower seam occurs in the shaft at a depth of 310 feet. The lower seam where mined is 5 feet 6 inches thick. The coal in the Pembina coal area is classed as subbituminous B rank. Full details on the coal seams in this area and their position in the formation, are given by Rutherford [13].

On the south side of the North Saskatchewan river, two coal seams outcrop along Strawberry creek in township 49, ranges 2 and 3, west of the fifth meridian. The upper seam is exposed in the southeast quarter section 32, township 49, range 2, and averages over 5 feet in thickness. The lower seam is best exposed in section 27, township 49, range 2, where it has an average thickness of four to five feet. This occurrence is about 30 miles west of Leduc.

These two seams probably represent the "Big seam" or "Pembina seam", occurring in the North Saskatchewan valley where it is, in places, 25 feet thick.

Edmonton Area

The Edmonton coal area includes townships 49 to 57, ranges 21 to 27, inclusive, west of the fourth meridian. The North Saskatchewan river has cut a valley almost 200 feet deep across this area. The Edmonton formation in which the coal seams occur is about 500 to 550 feet thick at the city of Edmonton, but the upper beds have been removed by erosion. West of Edmonton this formation is over 1,000 feet in thickness.

There are two main coal horizons in this uppermost Cretaceous formation. The coal seams mined in the vicinity of Edmonton occur in the lower coal horizon which includes the lower part of the Edmonton formation. A thick seam of coal occurs in the upper coal horizon which is close to the top of the Edmonton formation. This is the "Big seam" which outcrops on the North Saskatchewan river at Goose Encampment in section 32, township 50, range 3, west of the fifth meridian in the Pembina coal area. This seam does not occur in the Edmonton coal area.

The earliest discussion of the coal seams in the Edmonton basin was by Dowling in 1910[14]. According to Beach[15] who compiled data on the coal seams in the Edmonton coal basin in 1934, there are at least ten coal seams in this area. The seams are numbered from the base of the formation. These seams have not yet been correlated with the coal seams in the lower part of the Edmonton formation along the Red Deer valley in the vicinity of Drumheller. Several of the coal seams have been exposed in mining operations, some are outcropping along the sides of the North Saskatchewan valley and other smaller valleys, and other seams have been encountered in drilled holes.

The oldest seam is designated No. 1 and the youngest seam is No. 10. Three seams have been mined extensively throughout the area, namely No. 3 or "Lower seam", No. 4 or "Clover Bar seam", and No. 7 or "Weaver seam". Other coal seams have been prospected and worked in small operations.

No. 1 coal seam was encountered in a well drilled in the city of Edmonton on 98th Street near Jasper Avenue. This seam, reported to be 8 feet thick, occurs at a depth of about 475 feet below the surface, or at 1,750 feet above sea level.

No. 2 seam occurs about 70 feet above No. 1 and was also encountered in the bored well mentioned above.

No. 3 seam or "Lower seam", outcrops close to river level at Clover Bar in section 28, township 53, range 23, west of the fourth meridian. This coal seam varies from 10 inches to 5 feet in thickness and was at one time worked in the Standard, Ritchie and Parkdale mines.

No. 4 seam or "Clover Bar seam", about 25 to 40 feet above No. 3 seam, averages from 4 to 6 feet in thickness. This coal seam thickens to the north, and at St. Albert the seam is about 7 feet thick. This seam has been worked in several mines.

No. 5 seam is 35 feet above No. 4 and is seldom over three feet thick. It outcrops at water level close to the Low Level bridge at the base of McDougall hill in Edmonton.

No. 6 seam is less than 2 feet thick but it is a good marker seam and occurs about 50 feet above No. 5 seam.

No. 7 coal seam or "Weaver seam", is about 6 feet thick and 120 feet above the Clover Bar seam.

No. 8 seam is irregular in extent, but it is almost 3 feet thick where it outcrops opposite the mouth of White Mud creek.

No. 9 coal seam or "Big Island seam" occurs about 280 feet above the Clover Bar seam. This coal seam is about 2 feet thick at the High Level bridge in Edmonton, but it becomes thicker to the west and at Big island, the seam is about 5 feet thick.

No. 10 seam occurs about 50 feet above the Big Island seam. It outcrops near the top of the valley at Big island where it is about three feet thick.

It is not known how many seams there are in the upper coal horizon in the Edmonton formation. The "Big seam" occurs close to the top of the formation and there are thinner seams in lower beds within the Pembina and Tofield coal areas, but these may have been entirely eroded from the Edmonton coal area.

The coal in the Edmonton coal area is classed as subbituminous B and subbituminous C rank.

Tofield Area

In the Tofield coal area the coal seam near the top of the Edmonton formation has been mined extensively by stripping operations. This seam varies from 5 to 8 feet in thickness under a cover of 8 to 20 feet, where it has been mined. There are known to be other coal seams within this area corresponding to some of the seams in the Edmonton area on the west. There is a considerable amount of coal accessible to stripping operations under a cover of less than 30 feet, within this area.

The coal is classed as subbituminous C rank.

Camrose Area

In the Camrose area there are several coal seams throughout the Edmonton formation. Some are outcropping, others have been opened up by mining operations where the thickness of coal varies from 4 to 7 feet. Other seams lower in the formation have been encountered in drilling operations within 300 feet of the surface at Camrose. In a well drilled in the town of Camrose, a seam of coal 5 feet thick was encountered between 110 and 115 feet from the surface. Another seam one foot thick, in the same well, occurred between 165 feet and 166 feet from the surface. There is also a thin seam of coal in the same well at 255 feet from the surface. Some of the seams in the northern part of this area, may occur close enough to the surface to be worked by stripping operations, provided the seams are not too wet.

The coal is classed as subbituminous C, also subbituminous B.

Castor Area

The Castor coal area covers the entire width of outcrop on the Edmonton formation. There are several coal seams at various horizons in the formation within this area. There are about thirty small mines working seams that occur in the surface beds between the outcrop and a depth of 128 feet. There are several different seams being worked. The thickness of the coal seams in the area varies from 3 to 8 feet. At a few places the seam that is being mined, thickens to about 10 feet.

The coal in the Castor area is classed as subbituminous C, also subbituminous B rank.

Ardley Area

The Ardley coal area is underlain by the upper part of the Edmonton formation. At Ardley in township 38, the Ardley seam which is seam No. 14 in the Edmonton formation (see Table 5), is mined along the south side of the Red Deer valley. This coal seam is 5 feet 6 inches thick and there is a cover of about 90 feet. This seam corresponds to the Big seam at the top of the Edmonton formation in the Pembina coal area. The No. 11 or Carbon seam has been mined in section 11, township 39, range 22, near Nevis, where there are 4 to 5 feet of coal. Both the Carbon and Ardley seams outcrop in the sides of the valley of the Red Deer river in townships 37 and 38, range 22. At Delburne the Ardley seam is 5 to 6 feet thick.

The coal in the Ardley area is classed as subbituminous B rank.

Big Valley Area

In the Big Valley coal area the No. 14 or Ardley seam, the No. 12 or Thompson seam and the No. 11 or Carbon seam outcrop along the sides of the Red Deer valley. At Big Valley the No. 12 seam has been mined where it is about 6 feet thick.

The coal is classed as subbituminous B rank.

Carbon Area

The Carbon coal area extends from Rosebud river, north to the vicinity of Trochu. This area includes townships 27 to 29, ranges 22 to 24, and also townships 30 to 33, ranges 19 to 24. The deep valley of Red Deer river extends from north to south in range 21. The shallower valleys of Ghostpine, Threehills and Kneehills creeks and Rosebud river extend across the area from west to east. The upper portion of the Edmonton formation, containing coal seams, is exposed along the sides of these valleys. The surface formation overlying the Edmonton in the higher portion of the area is of Tertiary age.

Mining operations are being carried out in the vicinity of Carbon, Three Hills and Trochu on the west side of the Red Deer valley, and at Rowley on the east side of this valley. The seams that have been opened up in the Carbon area, are higher than those in the Drumheller coal area.

The Carbon seam or No. 11 seam has been opened up in the vicinity of Carbon and on Rosebud river, six miles north of Rockford. The coal seam is about 4 feet thick and the cover varies from the outcrop to about 200 feet.

The Ardley seam or No. 14 coal seam which occurs about 370 feet above the Carbon seam and near the top of the Edmonton formation, is mined in the vicinity of Three Hills, Trochu, Rowley and five miles west of Scollard. This coal seam is about 4 feet 6 inches to 5 feet thick at Three Hills under a cover of about 75 feet. On the east side of the Red Deer valley this coal seam is about 5 feet thick under a cover of over 100 feet. The coal in the Carbon area is classed as subbituminous A, also subbituminous B rank.

The Thompson seam or No. 12 seam, which occurs about 90 feet above the Carbon seam in townships 35 and 36 and is about 4 to 5 feet thick, may occur in some portions of the Carbon area.

Sheerness Area

The Sheerness coal area includes the Hanna district and the Handhills that are capped by younger Tertiary strata. This area includes the lower part of the Edmonton formation. The coal seams that have been observed or determined by mining, correspond to seams numbered 1 to 6 in the Drumheller area. No. 1 seam is mined by stripping operations close to Sheerness in section 19, township 29, range 12, where the coal seam is 6 feet 4 inches to 7 feet 3 inches thick, and in section 12, township 29, range 13 where the coal seam is 6 feet 3 inches thick. The cover that is removed varies from four to thirteen feet. At about ten other places in this area small scale stripping operations have been undertaken. There is a large volume of coal in the Sheerness coal area that can be obtained by strip mining where the cover does not exceed twenty-five feet.

In a coulee of badlands in the northeast quarter of section 18, township 29, range 12, seams No. 1 to No. 6 are exposed. No. 1 and No. 6 seams are only 3 feet 10 inches thick, and No. 5 seam is only 23 inches thick. This indicates how the coal seams in the Edmonton formation vary greatly in thickness even in a short lateral distance.

The coal in this area is classed as subbituminous C rank.

Details on the distribution and character of the coal seams in the Sheerness coal area have been given by Allan[16].

Drumheller Area

The Drumheller coal area is the most important coal-producing area in the Edmonton formation. In 1941 there were 1,458,455 tons of coal produced from about 25 mines. This represents 60 per cent of the entire output of coal from the Edmonton formation in that year.

This area as shown on the accompanying map, includes twelve townships, and it is cut diagonally from northwest to southeast by the valley of Red Deer river which is 300 to 400 feet deep. The Edmonton formation occurs at the surface throughout the area with the exception of two small areas on the west side of range 21 in the uplands between Rosebud river and Kneehills creek, and between Kneehills creek and Threehills creek, respectively. In these two small areas the Edmonton is overlain by the younger Paskapoo formation of Tertiary age. Along the bottom of the Red Deer valley from Willow creek to Dorothy ferry, the marine shales in the Bearpaw formation outcrop below the base of the Edmonton formation.

The maximum thickness of the Edmonton formation is 1,224 feet where it has been measured along Red Deer valley between the base of the formation at the mouth of Willow creek and the top of the formation where it is exposed at the river level in township 38, range 25, about 10 miles southwest of Ardley railway station[17]. (Table 5.)

In the Drumheller coal area, the entire Edmonton formation is only about 850 feet thick, between the base of the Paskapoo, exposed near Hesketh, less than one mile north of Kneehills creek, and the top of the Bearpaw, exposed in the Red Deer valley at the mouth of Willow Creek. The upper strata in the Edmonton formation was removed by erosion in this area before the Paskapoo sediments were deposited [12]. This is the explanation for the thinner section of Edmonton strata in the Drumheller district. As only the lower two-thirds of the Edmonton formation occur in this area, it follows that the coal seams that occur in the upper one-third of the Edmonton strata, will not be found in the Drumheller coal area. The highest coal seam observed in this area, is the Carbon seam or No. 11 seam which occurs in the northwest quarter of section 33, township 27. range 21, about 3 miles north of Rosebud river.

All of the coal seams from the lowest up to seam No. 9 are exposed along the sides of the Red Deer valley between East Coulee and the mouth of Kneehills creek, a distance of about 20 miles. Seam No. 10 is exposed along the sides of the valley of Kneehills creek from the mouth to Hesketh.

The geology and the relation, character, composition and thickness of the coal seams have been fully discussed by the writer in "Geology of the Drumheller Coal Basin"[18]. This report (No. 4) which is accompanied by a map and sections, is now out of print so that some of the details on the coal seams will be given here.

Since the preparation of Report No. 4, several mines in the vicinity of Drumheller have been closed and others have been opened up. A number of mines have been worked in the Rosebud valley at Wayne, but these have been closed for several years. More recently mining operations have been carried out down the Red Deer valley below Rosedale at Willow creek and at East Coulee.

In Table 6 is given a list of the mines now active. The location of each mine, the seam being worked and the thickness of the coal seam in each mine are shown in the table.

TABLE 6

List of Mines in Drumheller Coal Area

	Lsd.	Sec.	Tsp.	Rg.	W4	Seam	Thickness
Red Deer Valley Coal Co.	NE ¼	7	29	20	W4	1	5′0″
Monarch Coal Mining Co. Ltd.	7	8	29	20	W4	1	5′8″
Commander Coal Company	5	9	29	20	W4	1	5′6″
Midland Coal Mining Co.	10 & 11	9	29	20	W4	1	5′6″
Brilliant Coal Company	14	10	29	20	W4	1	6′0″
Hy-grade Coal Mining Co. Ltd.	13	11	29	20	W4	1	5′0″
The Minute Coal Company	2 & 7	14	29	20	W4	7	5′6″
Newcastle Collieries Ltd.	NW ¼	3	29	20	W4	1	5′0″
Ideal Coal Company Ltd.	16	1	28	20	W4	1	5′5″
Rosedale Collieries Ltd.	14	28	28	19	W4	1	4′ to 5′
Rosedale Collieries Ltd.	SE ¼ 7	28	28	19	W4	1	5′0″
Aetna Coal Company	1	22	28	19	W4	1	7′0″
Western Gem & Jewel Collieries Ltd.	NW 6	15	28	19	W4	1	5′0″
Empire Collieries Ltd. (Purity)	6 & 7	7	28	18	W4	1	3′4″ (bottom bench)
Empire Collieries Ltd. (Empire)	2	32	27	18	W4	2	5′6″
Maple Leaf Minerals	13	32	27	18	W4	2	5′6″
Comet Coal Company	12	28	27	18	W4	2	6′5″
Murray Collieries Ltd.	SE ¼	29	27	18	W4	2	5′2″
Regal Coal Company Ltd.	NW 13	21	27	18	W4	2	5′6″
Western Crown Coals Company	1	20	27	18	W4	2	5′6″
E. B. Foye	10	22	28	18	W4	5	3′6″
J. Hamilton	SE ¼ 15	23	28	18	W4	5	3′6″
E. Denio	13	33	27	21	W4	11	3′7″
Allen & Spray	3	6	28	20	W4	....	3′0″
B. Pickering	W ½ 2 & 3	6	28	20	W4	....	3′4″

The coal seams in the Edmonton formation have been numbered from the oldest to the youngest (see Table 5). The first important coal seam above the base of the formation at Drumheller, is designated No. 1 seam. The younger coal seams above No. 1 are numbered consecutively to the highest seam in the Edmonton formation, which is the No. 14 or Ardley seam, but this seam is not present in the Drumheller area. The youngest coal seam recognized in the Drumheller coal area is the Carbon or No. 11 seam. This coal seam has been opened up in section 33, township 27, range 21, about three miles north of Rosebud river. The same seam occurs at places along the north slopes of Wintering hills, one or two miles south of the Drumheller area.

In the vicinity of Rosedale there is at least one thin coal seam, designated seam No. 0, which is 30 to 50 feet below seam No. 1, and there may be other thin seams in some places between the base of the Edmonton formation and seam No. 1, in which the interval is represented by about 140 feet of sandstones and clay shales.

The various coal seams within the Drumheller coal area in the lower part of the Edmonton formation, vary greatly in lateral extent both in thickness and in purity of the coal. This is a characteristic of all the coal seams in the entire Edmonton formation. A coal seam may thicken or become thinner and even pinch out within a short distance. Some coal seams are known to treble in thickness within a distance of one or two miles. Other seams of two to five feet in thickness are known to change to bands a few inches in thickness, within a few miles. A parting in a coal seam at one place may thicken rapidly to a bed of rock a few inches or even to 8 or 10 feet within a mile. Such a condition of rapid change has been noted in seam No. 7 where it is exposed in Michichi creek. These rapid changes in the thickness of a coal seam make it difficult to describe accurately the characteristics of the coal, except at the place where the observation is made. Because of these conditions in the coal seam, important blocks of good coal may be overlooked in mining development, possibly through lack of adequate prospecting, and on the other hand, mining operations may become unprofitable because of the thinning of the seam or the presence of impurities in the coal seam.

Coal mining in this area has been confined largely to seams numbered 1, 2, 5, 7, and 11, but a few notes are here given on all of the coal seams recognized to date in the Drumheller coal area.

Seam No. 0. This seam outcrops close to the level of the Red Deer river below the entrance to the Rosedale mine, formerly the Star mine, in section 28, township 28, range 19. At this point, the seam is 14 inches thick, but it thins towards the east. The exposure of this seam continues to rise above the river level in a southeasterly direction and at the mouth of Willow creek, occurs about 100 feet above the river.

Seam No. 1. This seam was formerly known as the "Deep seam" or "Drumheller seam", because it is the lowest workable seam in the Edmonton formation. This seam occurs about 75 to 100 feet above the base of the formation, on the contact of the underlying Bearpaw marine shales. Coal from this seam is being extracted in 13 mines shown in Table 6, distributed along the Red Deer valley from Rosedale at the mouth of Rosebud river, to the mouth of Kneehills creek. The thickness of this seam in these mines, varies from 4 feet to 7 feet, with an average thickness of about five feet six inches. Downstream from Rosedale where the seam first outcrops at river level, the No. 1 seam becomes thinner and at Willow creek the seam is represented by a few inches of coal. The regional dip of the strata in the lower part of the Edmonton formation has been determined from the dip of No. 1 coal seam, which is at the rate of about 20 feet to the mile in a west-southwesterly direction. This rate of dip in the lower portion of the Edmonton formation extends beyond this area and across the Sheerness area to the east.

The most characteristic feature of No. 1 seam is its division into two benches by a band of bentonite varying in thickness from a fraction of an inch up to 20 inches. As a rule the bottom of this band is quite regular, but the top undulates. This observation applies to most of the prominent bands of impurities. In a number of mines along the Red Deer valley above Rosedale, the bentonite band is underlain by a band of bone or coaly bone or hard granular coal, and overlain by a few inches of grey granular coal. In Rosedeer and Western Commercial mines in the vicinity of Wayne in Rosebud valley, the bentonite band disappears and is replaced by bone, coaly bone, and hard granular coal which is frequently eliminated when mined. There is a zone from Rosedale southeast where the band of impurities between the upper and lower benches increases in thickness and reduces the amount of marketable coal.

The band of impurities between the two benches is in some places too wide to warrant its extraction in order to work the lower bench of coal. There is also a band of hard granular coal in several of the mines near the top of the lower bench. The texture of this coal is not attractive on the market, although analyses show that its heating value is just as high as much of the looser textured coal in this seam. The lower bench varies from 18 inches to 42 inches in thickness and in places contains a band of bone a few inches thick.

The upper bench varies in thickness from 5 feet to 6 feet 4 inches, and in places contains one or more thin bands of bone, shale or bentonite. The roof is shale and bentonitic sandstone. At a number of places a band of bone separates the coal from the roof, and in other places a lense of coal occurs between the bone and the true roof. In a few places the roof is soft and a few inches of coal are left on the roof for support.

The coal is bright in color when it is first mined, but assumes a dull lustre on exposure for a time to the air. The moisture content averages about 16 per cent and the ash varies greatly. Exposure to the air causes slacking as shown by numerous cracks on the surface, but this class of coal does not distintegrate easily, and with reasonable care in handling the percentage of slack is low. The coal from this seam can in most places be extracted in block form, the size of the block varying from two or three inches to twelve inches across the face. The main cleavage plane in this seam of coal trends north 43 to 50 degrees east. There are local areas where the coal is finer and in some cases rusty, but these areas might easily be avoided as they are usually associated with local rolls, slips or where the seam is shattered and moist. Much of this coal is glossy and amorphous. The jet-like lenses are formed from logs and massive blocks of wood. Such lenses are quite prominent in some parts of the seam, some are two inches in thickness and often the woody structure can be seen on the glossy surface. The amorphous coal is formed from smaller types of vegetation including leaves and bark. Specimens from Rosebud valley show a very intimate association of the two varieties of coal and a very finely laminated texture is present. So-called "nigger heads" are common in some areas in the seam. These masses of hard bone, represent the clay, sand and plant material, washed or blown into depressions on the floor of the basin in which the coal was being formed.

Another pronounced characteristic of No. 1 seam is the presence of numerous grey translucent and transparent crystals of selenite (gypsum) along the cleavage faces in the coal. This mineral does not lower the value of the coal but frequently produces a dull grey lustre on the surfaces of the blocks of coal when mined.

There is another distinct variety of coal in this seam which is called "granular coal" or "hard grey coal." Bands of this coal occur in some parts of this seam near the bottom of the upper bench and also below the bentonite parting in the lower bench. This granular coal is fine textured, hard, and a little heavier than the normal coal. The granular texture is due to the presence of innumerable conchoidal fracture surfaces, and not to individual grains of coal. This texture seems to have been caused by pressure and slight movement on a bed of coal material made up chiefly of plant seeds and soft structured vegetation, possibly grasses and other marsh growth.

Seam No. 2. This coal seam occurs 35 to 50 feet above No. 1 seam. At the mouth of Rosebud river between Rosedale and Wayne this seam varies from 22 inches to 40 inches in thickness, but the seam thickens to the southeast. There are now six mines working in this seam at Willow creek and East Coulee.

The writer is indebted to Gordon L. Kidd, mining engineer and geologist at Drumheller, for assistance and helpful suggestions in correlating coal seams at East Coulee and Willow creek with those in the vicinity of Drumheller. He first recognized that the important coal seam at East Coulee is the No. 2 seam[19].

The coal seam at East Coulee was formerly considered to be the No. 1 seam, until the correlation was made by Kidd. In a written communication, Kidd states that

> "No. 1 seam is intermittent in the East Coulee district. Shortly after the deposition of the material in No. 1 seam, a sand bar or wave beach formed in an almost north-south direction with open sea on the east of the barrier and a lagoon on the west side. This old bar attained considerable thickness and lasted until No. 2 seam time. During this time different local peat bogs formed in the lagoon and some of them are now represented by seams up to workable thicknesses locally. No. 2 coal seam owes its extra thickness to this condition since nearly half of the thickness of this seam was formed behind the barrier before the bog overgrew and spread eastward. The mouth of East Coulee is cut through this barrier but the No. 2 and No. 1 seams diverge to the south."

This is a reasonable explanation to the local thickening of the No. 2 coal seam at this locality. Similar explanations may apply to the rapid change in thickness in other coal seams in this area.

Seam No. 3. This seam is seldom more than one foot in thickness and is of no commercial importance, but it was used as a horizon marker and is exposed from the town of Drumheller eastwards. No. 3 seam is separated from No. 2 seam by 8 to 12 feet of sediments.

Seam No. 4. This seam occurs 10 feet above No. 3. It has a maximum thickness of one foot, but it is continuous and was useful for correlation purposes. No. 4 and No. 3 beds are exposed near the base of the outliers between Drumheller and Rosedale.

Seam No. 5. This coal seam was formerly known as the "Top seam" or "Newcastle seam" because it occurred at or close to the surface and above the Drumheller seam, and the Newcastle mine was the first to work this seam. This coal seam is described in detail in Report No. 4[18]. In 1921 there were eleven mines working No. 5 seam in the vicinity of Drumheller where the thickness of the coal varies from 3 feet 6 inches to 5 feet 5 inches, but the average thickness of the seam where mined, is about 4 feet 8 inches of clean coal. This seam thins to the east and to the south. Mining in this seam has been discontinued at Drumheller but there are two mines towards the head of Willow creek, working 3 feet 6 inches of coal in No. 5 seam, as shown in Table 6.

Seam No. 6. The thickness of this seam varies from 6 inches to 37 inches, but it can scarcely be called a coal seam as it contains very little coal and at many places consists entirely of black carbonaceous shale. The outcrop has been mapped and it has been given a number in the series, because it is a good horizon marker 70 feet above No. 5 seam. In Michichi creek No. 6 seam is 37 inches thick and consists of brown fissile shale, fossilized wood and black carbonaceous shale. The most prominent feature in this seam is a layer, seldom more than one inch in thickness, near the centre of the band, which consists of carbonized and silicified fragments of wood, bark, leaves, and even fruit. Many of the carbonized fragments are mineral charcoal and may represent the products of forest fires of Upper Cretaceous age.

Seam No. 7. This seam was formerly called the "Daly seam". It is worked in one mine near the mouth of Michichi creek in section 14, township 29, range 20, where the coal is 5 feet 6 inches thick. The No. 7 seam is a useful horizon marker as it occurs 20 to 28 feet above No. 6 seam and about 185 feet above No. 1 seam where sections have been measured. This seam indicates the rapid lateral change that may occur in the coal seams in this area. In section 36, township 28, range 20, and in section 32, township 28, range 19, it is less than one foot in thickness. At several places in Michichi valley, it has a thickness of 6 feet 8 inches, but this includes a shale parting 24 inches thick. The section at Brooks mine, now abandoned, shows 42 inches of coal with 13 inches of bone near the centre. Along the escarpment west of Michichi creek in section 10, township 29, range 20, No. 7 seam splits into two seams, separated by 10 feet of shale and sandy lenses, but in a coulee in the southwest quarter of section 15, township 29, range 20, the parting thins to 11 inches of shale. On the opposite side of the valley, south of the A.B.C. mine, now abandoned, the seam shows 18 inches of coal, and it lies within 18 feet of No. 6 seam, but this is only local. There is a dinosaur bone bed on top of No. 7 seam at this point. Between Monarch mine and Kneehills creek, No. 7 outcrops close to the base of the escarpment. In section 14, township 29, range 21, No. 7 seam is exposed at the edge of Kneehills creek. At this point the seam is about 3 feet 6 inches thick. A section of No. 7 seam near Wayne in Rosebud valley, shows one foot of coal separated by two feet of shale.

Seam No. 8. This is not an important coal seam but it is a good marker as it is persistent along the sides of the Red Deer and tributary valleys in this area. It occurs between 80 and 130 feet above No. 7 seam and varies in thickness from a fraction of an inch up to about 4 feet of clean coal.

Seam No. 9. This seam is useful as an horizon marker as at no place in this area was it observed to contain more than one foot of clean coal, but it appears to thicken up the Red Deer valley, north of this area.

Seam No. 10. This seam outcrops along the valley of Kneehills creek, as far as Hesketh and because it is a good horizon marker, it has been designated the "Marker seam".

Seam No. 11. This seam has been called the "Carbon seam" because it has been mined in the vicinity of Carbon which is west of the Drumheller area. This is the uppermost seam that has been recognized in the Drumheller coal area and occurs about 750 feet above the base of the formation. It is mined in section 33, township 27, range 21, about 3 miles north of Rosebud river where the coal seam is 3 feet 7 inches thick. The seam thickens to the north and at Carbon it contains 4 feet of coal.

There is a coal seam being mined in section 6, township 28, range 20, about two miles northwest of Beynon railway station in the Rosebud valley. The coal is about three feet thick and may represent either seam No. 11 or a lower seam.

The upper portion of the Edmonton formation is not represented in the Drumheller area because it was removed by erosion before the younger Tertiary sediments were deposited. There is therefore an erosion interval, or a disconformity represented by the contact of the Edmonton formation and the younger Paskapoo formation of Tertiary age. This contact occurs in sections 7 and 8, township 28, range 21, less than two miles to the northwest of where the Carbon seam is mined. This indicates that higher coal seams in the Edmonton formation can not be expected to occur in this area.

The Drumheller area is an important coal-producing area and it is reasonable to anticipate that much mineable coal has not yet been discovered within this area.

The coal in the Drumheller area is classed as subbituminous B rank.

Gleichen Area

The Gleichen coal area includes the whole width of outcrop of the Edmonton formation. There are three coal seams at various horizons in the formation. There are three mines with small production in the northern part of the area. In township 26, range 21, the coal seam is about 3 feet thick with a cover of 50 to 75 feet. In township 25, range 14, the coal seam opened up is 3 feet 10 inches thick. There is a mine operated by the Indians in the Blackfoot Reserve. The coal in this area is classed as subbituminous C rank.

Champion Area

The Champion coal area, like the Gleichen area, includes the whole of the outcrop of the Edmonton formation on the east side of the trough-like structure which is capped by younger Tertiary strata. The Edmonton formation in this area is about 1,000 feet thick in which there are a number of thin coal seams. Some of these coal seams, in different horizons in the lower part of the formation, outcrop along the valley of Little Bow river. There is a small coal production from northeast of Carmangay in townships 14 and 15, ranges 22 and 23, where the coal seams range from 2 to 3 feet in thickness. There is a coal seam 3 feet 8 inches thick southeast of Vulcan in township 16, range 23. The cover over these coal seams varies from about 100 to 150 feet. The coal in this area is classed as subbituminous A, also subbituminous B rank.

Wetaskiwin Area

The Wetaskiwin coal area lies west of the Camrose and Castor areas and north of the Ardley area. The upper part of the Edmonton formation occurs within this area and contains a number of coal seams. Erosion removed some of the upper beds in the Edmonton formation, including the greater part of the thick coal seams near the top, before the Paskapoo sediments were deposited. As a result of this erosion, the occurrence of coal in the upper Edmonton is patchy throughout the Wetaskiwin coal area. The thickest seam known in this area, averaging 5 to 7 feet, outcrops on the north shore of Wizard lake, seventeeen miles west of Millet, in section 3, township 48, range 27. This seam may correspond to a part of the "Big seam" exposed on the North Saskatchewan river and also to one of the two five-foot coal seams that outcrop along Strawberry creek in township 49, ranges 2 and 3, west of the fifth meridian in the Pembina area[20]. There may be considerable mineable coal in this or other seams in the Wetaskiwin area, that has not yet been determined.

The coal in this area is classed as subbituminous B rank.

Whitecourt Area

The Whitecourt coal area is the most northwest coal area indicated on Map No. 18. There is little known about the character or extent of coal seams in this area, but the area includes the upper part of the Edmonton formation in which there are a number of coal seams in the adjoining Pembina area.

The Edmonton strata containing coal seams occur at the surface north of a line drawn from about section 25, township 55, range 9, on the east side of the area, to the north side of Whitecourt hill in township 58, range 12. There are coal seams in the sides of the Athabaska valley below the mouth of McLeod river at Whitecourt. A seam about 3 feet thick outcrops about 140 feet above the Athabaska river in the southwest quarter section 34, township 59, range 10. Thin coal seams about the same horizon occur on the north side of the river below the ferry in section 1, township 60, range 12. A coal seam has been prospected on Whitecourt creek in legal subdivision 7, section 5, township 59, range 11. According to the Alberta Mines Branch Report, 1941, stripping operations are being carried out on a coal seam 6 feet 3 inches thick in legal subdivisions 12 and 13, section 19, township 59, range 10. This seam occurs about 200 feet above river level and may be higher in the formation than those outcropping along the side of the Athabaska valley to the north.

The presence of this and other coal seams in this district indicates that mineable coal may have a wide distribution in the Whitecourt coal area. Coal from this area is classed as subbituminous B rank.

Mountain House Area

The Mountain House coal area is the only area shown on the accompanying map (No. 18) to contain strata including coal seams in the Edmonton formation, outcropping on the west side of the trough-like structure and bordering the foothills belt. The western side of this area represents about the eastern margin of the foothills belt in which both the Belly River and Edmonton coal horizons occur.

This area includes the district in the vicinity of Rocky Mountain House about 50 miles west of Red Deer. The North Saskatchewan river has cut a valley over 150 feet deep through this area. No coal seams have been developed, but it is known that thin coal seams occur in the upper part of the Edmonton formation which outcrops along the sides of the North Saskatchewan valley west of Rocky Mountain House, and also along Prairie creek and Clearwater river. There is a thin coal seam outcropping close to the river level and close to the Edmonton contact with the Paskapoo, at Rocky Mountain House.

In Part V of this report, no attempt has been made to include all of the information available on coal seams in each of the 49 coal areas shown on the accompanying map. Only the occurrence, thickness and other characteristics of some of the coal seams that have been developed or observed in each area, are included. A more detailed discussion of the coal deposits in Alberta would require a much larger report.

Acknowledgements

Grateful acknowledgment is extended to the Honourable N. E. Tanner, Minister of Lands and Mines, Alberta, and to Mr. John Harvie, Deputy Minister of the same department, for co-operation in the preparation and publication of the Coal Areas of Alberta Map No. 18 which accompanies this report. The writer is especially indebted to T. W. Dalkin, Superintendent, Technical Division, Department of Lands and Mines, under whose direction this map was drawn.

The writer acknowledges with thanks the information kindly supplied by A. A. Millar, Chief Inspector of Mines for Alberta, without whose willing co-operation much data on the coal seams being mined, could not have been easily obtained. Thanks are due to Edgar Stansfield, Chief Research Fuel Engineer in the Research Council of Alberta, for helpful criticism and useful data on the composition and classification of Alberta coals supplied to the writer, and to R. L. Rutherford, Associate Professor of Geology, University of Alberta, for information on the geology and for helpful criticism in the preparation of this report.

References Cited

[1]MacKay, B. R., Geol. Surv. Canada, Sum. Rept., 1932, Pt. B, p. 37.
[2]Allan, J. A., Research Council of Alberta, Report No. 2, 1920, pp. 40-50.
[3]Dowling, D. B., Geol. Surv. Canada, Sum. Rept., 1923, p. 69B.
[4]MacKay, B. R., Geol. Surv. Canada, Sum. Rept., 1928, p. 1B.
[5]McEvoy, J., Smoky River Coal Field, Dom. Fuel Board, No. 7, 1925, pp. 1-19.
[6]Allan, J. A., and Rutherford, R. L., Research Council of Alberta, Report No. 6, 1922.
[7]Hage, C. O., Geol. Surv. Canada, Paper 43-1, 1943.
[8]Russell, L. S., and Landes, R. W., Geol. Surv. Canada, Memoir 221, 1940, p. 62.
[9]Allan, J. A., Geol. Surv. Canada, Sum. Rept., 1917, p. 13C.
[10]Allan, J. A., Research Council of Alberta, Report No. 12, 1924, p. 44.
[11]Allan, J. A., Research Council of Alberta, Report No. 12, 1924, p. 38.
[12]Allan, J. A., and Sanderson, J. O. G., An Upper Cretaceous Disconformity in Alberta (Abstract), Bull. Geol. Soc. of Amer., Vol. 36, 1925, p. 161.
[13]Rutherford, R. L., Research Council of Alberta, Report No. 19, 1928, p. 27.
[14]Dowling, D. B., The Edmonton Coal Field, Geol. Surv. Canada, Memoir 8E, 1910.
[15]Beach, H. H., unpublished thesis, University of Alberta, 1934.
[16]Allan, J. A., Research Council of Alberta, Report No. 33, 1935, p. 31.
[17]Allan, J. A., Research Council of Alberta. Report No. 12, 1924, p. 38.
[18]Allan, J. A., Research Council of Alberta, Report No. 4, 1921, pp. 1-72.
[19]Kidd, G. L., Notes on East Coulee Coal Area, Bull. Can. Inst. Min. and Met., No. 203, March, 1929, pp. 490-494.
[20]Rutherford, R. L., Research Council of Alberta, Report No. 24, 1928, p. 33.

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX

LIST OF PUBLICATIONS

of

RESEARCH COUNCIL OF ALBERTA

EDMONTON, ALBERTA

ANNUAL REPORTS OF COUNCIL

No. 3 (for the calendar year 1920); pp. 36. **(Out of print.)**
No. 5 (for the calendar year 1921); pp. 86. **(Out of print.)**
No. 8 (for the calender year 1922); pp. 64. **(Out of print.)**
No. 10 (for the calendar year 1923); pp. 76. **(Out of print.)**
No. 12 (for the calendar year 1924); pp. 66. **Price 35 cents.**
No. 16 (for the calendar year 1925); pp. 65. **Price 35 cents.**
No. 20 (for the calendar year 1926); pp. 53. **Price 25 cents.**
No. 22 (for the calendar year 1927); pp. 49. **Price 25 cents.**
No. 24 (for the calendar year 1928); pp. 53. **Price 35 cents.**
No. 25 (for the calendar year 1929); pp. 65. **Price 35 cents.**
No. 26 (for the calendar year 1930); pp. 76. **Price 35 cents.**
No. 27 (for the calendar year 1931); pp. 53. **Price 35 cents.**
Nos. 28, 29 and 32 (for the calendar years 1932-1934); pp. 90. **Price 35 cents.**
No. 33 (for the calendar year 1935); pp. 43. **Price 35 cents.**

There is a geological section in each of the annual reports.

REPORTS—FUELS

No. 10A (1923); COMBUSTION OF COAL FOR THE GENERATION OF POWER, by C. A. Robb. **(Out of print.)**

No. 14 (1925); pp. 64. ANALYSES OF ALBERTA COALS, with 18 maps and 2 charts. By E. Stansfield, R. T. Hollies, and W. P. Campbell. **(Out of print.)**

REPORTS—ROAD MATERIALS

No. 18. THE BITUMINOUS SANDS OF ALBERTA, by K. A. Clark and S. M. Blair.

Part I.—Occurrence, pp. 74. **Price 25 cents.**
Part II—Separation, pp. 36. **Price 25 cents.**
Part III—Utilization, pp. 33. **Price 25 cents.**

REPORTS—SOIL SURVEY DIVISION

No. 23 (1930); PRELIMINARY SOIL SURVEY ADJACENT TO THE PEACE RIVER, ALBERTA, WEST OF DUNVEGAN, by F. A. Wyatt and O. R. Younge; pp. 33 and colored map. Scale 1 inch to 4 miles. **Price 50 cents.**

No. 31 (1935); PRELIMINARY SOIL SURVEY OF THE PEACE RIVER-HIGH PRAIRIE-STURGEON LAKE AREA, by F. A. Wyatt; with colored map. Scale 1 inch to 4 miles. **Price 50 cents.**

REPORTS—GEOLOGICAL SURVEY DIVISION

By Dr. J. A. Allan, Professor of Geology, University of Alberta.

No. 1 (1919); pp. 104—A summary of information with regard to the mineral resources of Alberta. **Price 25 cents.**

No. 2 (1920); pp. 138+14. Supplements the information contained in Report No. 1. **(Out of print.)**

No. 4 (1921); GEOLOGY OF THE DRUMHELLER COAL FIELD, ALBERTA; pp. 72, and 6-color map (Serial No. 1). **(Out of print.)**

No. 6 (1922, Part I); GEOLOGY OF THE SAUNDERS CREEK AND NORDEGG COAL BASINS, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 76 and 2-color map (Serial No. 2). **(Out of print.)**

No. 7 (1922), Part II); AN OCCURRENCE OF IRON ON THE NORTH SHORE OF LAKE ATHABASKA, by J. A. Allan and A. E. Cameron; pp. 40; two maps (Serials Nos. 3 and 4). **(Out of print.)**

No. 9 (1923) GEOLOGY ALONG BLACKSTONE, BRAZEAU AND PEMBINA RIVERS IN THE FOOTHILLS BELT, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 48, and 6-color map (Serial No. 5). **(Out of print.)**

No. 11 (1924); GEOLOGY OF THE FOOTHILLS BELT BETWEEN McLEOD AND ATHABASKA RIVERS, ALBERTA, by R. L. Rutherford; pp. 61 and 8-color map (Serial No. 7). One inch to two miles. **(Out of print.)**

No. 13; GEOLOGY OF RED DEER AND ROSEBUD SHEETS, by J. A. Allan and J. O. G. Sanderson. Two geological maps in 8 colors. Scale, one inch to three miles. Serial No. 8 Red Deer Sheet and No. 9 Rosebud Sheet. Five structure sections. **(Report in preparation.) Maps and sections 50 cents.**

Map No. 10 (1925); GEOLOGICAL MAP OF ALBERTA, by J. A. Allan. In 14 colors. Scale one inch to 25 miles. **(Out of print.)**

No. 15 (1926); GEOLOGY OF THE AREA BETWEEN ATHABASKA AND EMBARRAS RIVERS, ALBERTA, by R. L. Rutherford; pp. 29 and 3-color map (Serial No. 11). One inch to two miles. **Price 50 cents.**

No. 17 (1927) GEOLOGY ALONG BOW RIVER BETWEEN COCHRANE AND KANANASKIS, ALBERTA, by R. L. Rutherford; pp. 46 and 9-color map (Serial No. 12). Scale 1 inch to 1 mile. **Price 75 cents, or map alone 25 cents.**

No. 19 (1928); GEOLOGY OF THE AREA BETWEEN NORTH SASGATCHEWAN AND McLEOD RIVERS, ALBERTA, by R. L. Rutherford; pp. 37 and 3-color map (Serial No. 13). Scale 1 inch to 3 miles. **Price 25 cents.**

No. 21 (1930); GEOLOGY AND WATER RESOURCES IN PARTS OF PEACE RIVER AND GRANDE PRAIRIE DISTRICTS, ALBERTA, by R. L. Rutherford; pp. 80 and 6-color map (Serial No. 14). Scale 1 inch to 4 miles. **Price 75 cents.**

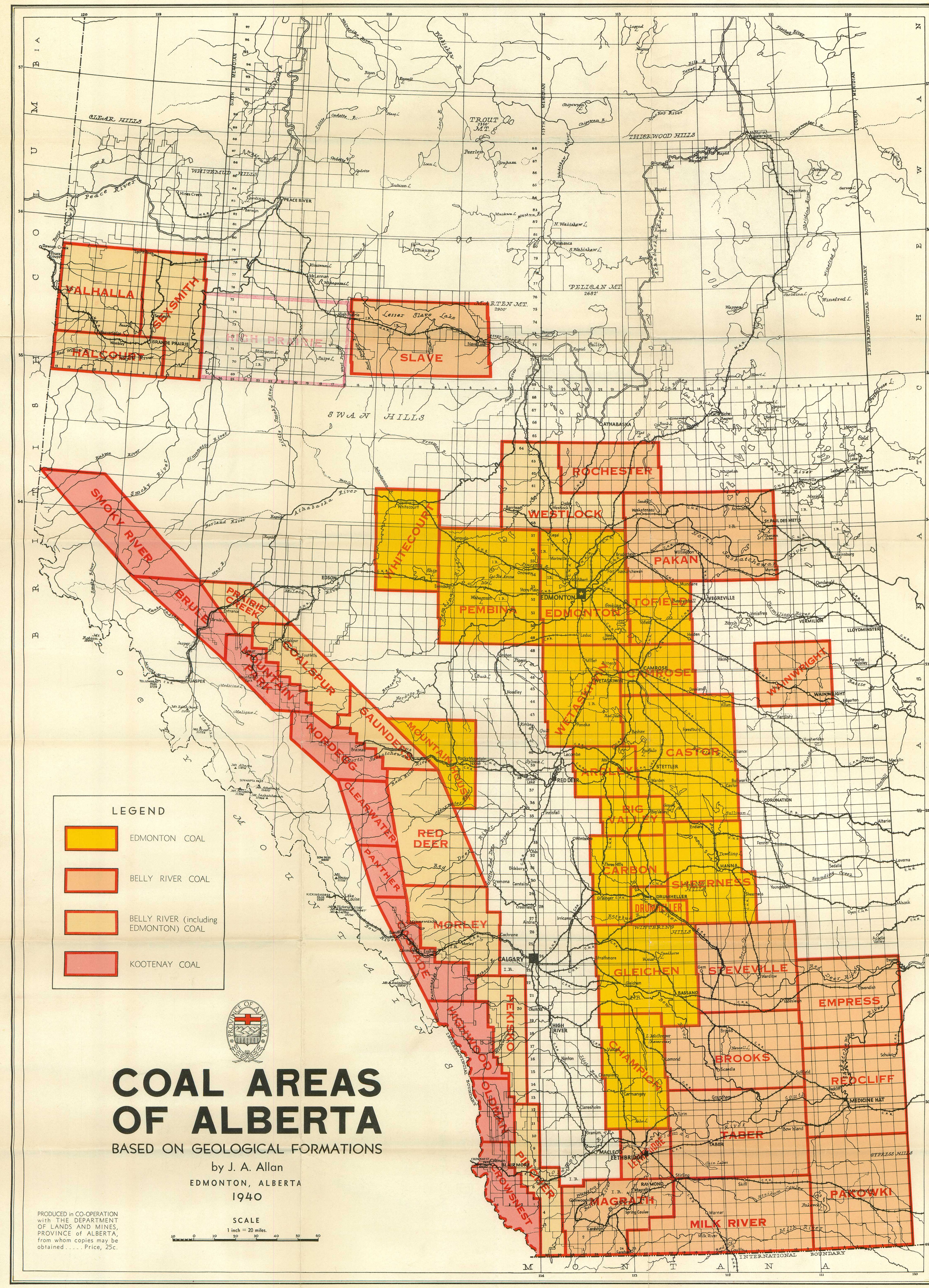
No. 30 (1934); GEOLOGY OF CENTRAL ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 41 and 10-color map (Serial No. 15). Scale 1 inch to 10 miles. **(Out of print.)**

Map. No. 16 (1937); GEOLOGICAL MAP OF ALBERTA (Coloured), by J. A. Allan. Scale 1 inch to 16 miles. **Price 75 cents.**
Map. No. 17 (1939); GEOLOGICAL MAP OF ALBERTA (Black and white), by J. A. Allan. Scale 1 inch to 32 miles. **Price 5 cents.**

Map No. 18 (1940); COAL AREAS OF ALBERTA, by J. A. Allan. Scale 1 inch to 32 miles. **Price 50 cents.**

No. 34 (1943), in five parts, by J. A. Allan; pp. 202. **Price $1.50.**

- Part I—General Geology of Alberta, pp. 37, and geological map No. 17, scale 1 inch to 32 miles. **Price 50 cents.**
- Part II—Rock Salt Deposit at Waterways, pp. 19.
- Part III—Geology of Alberta Soils, pp. 87. **Price 25 cents.**
- Part IV—Relief Model of Alberta and its Geological Application, pp. 9.
- Part V—Coal Areas of Alberta, pp. 36, and map No. 18, scale 1 inch to 32 miles. **Price 75 cents.**



DRAWN IN THE TECHNICAL DIVISION, DEPARTMENT OF LANDS AND MINES, EDMONTON, ALBERTA