THE GEOLOGY OF THE RED DEER AREA, ALBERTA, With Particular Reference to the Geomorphology and Water Supply.

by

A. M. STALKER.

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Department of Geological Sciences
McGill University

April 1950

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MAP INDEX.

The following index gives the locations on the map of various towns, villages, stations and post offices, and lakes, mentioned in the thesis. These locations are given by quarter section,section, township and range, all west of the Fourth Meridian, Alberta.

Towns, Stations, Post Offices.

Name	Quarter	Section	Township	Range
Alix	NW	36	39	23
Ardley	N	I6	38	23
Big Valley	NE	26	35	20
Blackfalds	SW	26	39	27
Botha	SW	33	38	I8
Burbank	SE	24	39	27
Byemoor	NW	6	35	I6
Clive	N	30	40	24
Delburne	NW	2I	37	23
Elnora	NE	I0	35	23
Endiang	SE	35	34	I6
Erskine	SW	6	39	20
Fenn	NE	35	36	20
Gadsby	W	27	38	I7
Hackett	NE	36	36	I8
Halkirk	NE	24	38	I6
Haynes	SE	4	39	24
Heatburg	SE	3	39	23
Huxley	NW	I7	34	23
Innisfail	NW	2I	35	28
Joffre	SE	9	39	25
Labuma	SE	I9	38	27
Lacombe	S	30	40	26
Leo	NW	34	35	I7
Lousana	NW	23	36	23
Mirror	S	28	40	22

MAP INDEX. Continued. Towns, Stations, Post Offices.

Name	Quarter	Section	Township	Range
Nevis	NE	I	39	22
Penhold	W	36	36	28
Red Deer		I6	38	27
Red Willow	SW	20	40	I8
Rumsey	SE	24	33	2I
Scollard	NW	I9	34	20
Stettler		5	39	I9
Tees	SE	25	40	24
Trochu		I7	33	23
Warden	SW	I3	38	20
Wimborne	SW	35	33	26
		LAKES		
Blackfalds			39	26
Buffalo			40	20, 2I
Delburne			37	23
Davey			2I, 22, 28-35	27
Ewing			37	20, 2I
Farrell			33	I7
Foxall			37	2I
Ghostpine			36	24, 25
Goosequill			35, 36	23
Gough			35, 36	I7, I8
Gull			40	28
Hummoch			35, 36	23
Lacombe			40	27
Lanes			37	I4
Lonepine			37, 38	I8
Lowden			36, 37	I9
Marion			37	I7, I8
Mikwan			36	23
Shooting			37	I7
Sullivan			34, 35, 36	I5

PREFACE.

The glacial geology of the Province of Alberta has received comparatively study and only a small amount has been published on the subject. Most of the work that has been done has been in southern Alberta, near the United States border, and in the foothills of the Rockies. Much of the material published on glacial geology in the Province is very general. The author does not know of any detailed work or publication about the glacial geology of the region described in this thesis.

The writer has visited all parts of this Red Deer map-area and has seen everything in it about which mention is made in the thesis. Practically all the material contained in the thesis has been collected by the writer on the spot, and the deductions from it, and the conclusions reached, are his own.

THE GEOLOGY OF THE RED DEER AREA, ALBERTA, With Particular Reference to the Geomorphology and Water Supply.

CHAPTER I. INTRODUCTION.

During the field seasons of 1946, 1947, 1948 and 1949 the writer was engaged in mapping the Pleistocene and Recent geology and studying the water resources in certain areas of central Alberta. This work was done for the Geological Survey of Canada, the Chief Geologist of which has kindly given permission to use in this thesis information collected during these summers. The Pleistocene and Recent deposits were to be mapped as they affected water supply, and some study was also given to the bedrock for its effect on water supply.

Mr. B. A. Latour, assisted by the writer, commenced the survey in the field season of 1946 and mapped the region around the towns of Red Deer, Lacombe, Innisfail, and others. In 1947 the writer expanded this work northward to the town of Ponoka, and eastward as far as the towns of Alliance, Galahad, Castor and Stettler, and to the district north of the towns of Byemoor and Endiang. In 1948 a region between Stettler and Big Valley, as far east as Byemoor, and including Delburne and Elnora to the west, was covered. In the past summer (1949) the survey was continued west of Rumsey and Scollard as far as Innisfail, Olds and Didsbury.

Up to the present Mr. Latour and the writer have studied the water supply and mapped the Pleistocene and later deposits in that area contained in Townships 35-42, Ranges 13-28, and in Townships 31-35, Ranges 21-29, inclusive, west of the Fourth Meridian, Alberta. It is expected that this work will be continued to the south in future field seasons, until the remaining area in Townships 27-35, Ranges 13-29, has been surveyed.

The information gathered in these surveys is to be published in two ways. Water-supply papers, dealing almost entirely with water-supply but with some information on the bedrock and unconsolidated deposits, are being published. Each of these covers an area of I6 townships, or 576 square miles, in a block of four townships by four. At present the mapping has been done and water supply studied in eleven of these blocks, or about 6336 square miles. The water-supply papers on five of these areas have been published (see numbers 8, II, I2, I3, I4 in bibliography), and the other four are under preparation.

It is also planned to publish a memoir dealing with the area of I2 of these water supply papers. In this the Pleistocene and Recent deposits will be more fully discussed, and less emphasis will be given to water supply.

This thesis will cover only part of that area mentioned above, more specifically that region included in the Red Deer map area. The Red Deer sheet, Sectional Map No. 2I5, west of the Fourth Meridian, Alberta, drawn at the office of the Surveyor General of Canada, includes that area lying between Latitudes of approximately 5I 48' and 52 30' N, and Longitudes II2 00' and II4 00' W. The area includes, approximately, Townships 33 to 40, Ranges I5 to 28, inclusive, west of the Fourth Meridian, Alberta. The area includes about II2 townships of 36 square miles each, or a total of about 4032 square miles.

Acknowledgments. The writer wishes to thank the Chief Geologist for the permission to use in this thesis information collected under the Geological Survey. Mr. B. A. Latour, of the Geological Survey, mapped and studied about 32 of the townships in the northwest of the map-area (Townships 35-40, Ranges 25-28; Townships 39 and 40, Ranges 2I-24). The writer, who assisted him in this mapping and who

has made use of some of Mr. Latour's notes on this area, wishes to express his gratitude to him. The information on water supply in Townships 39 and 40, Ranges 15- 20, was collected for the Geological Survey by Dr. R. L. Rutherford of the University of Alberta. Thanks should also be expressed to the late Dr. J. S. Stewart of the Geological Survey, Dr. P. S. Warren of the University of Alberta, and to Drs. J. E. Gill and T. H. Clark of McGill University for their suggestions.

Topography. The surface of this area has a general slope downward to the northeast. Near the Battle River it lies at about 2,400 feet elevation, whereas in the southwest it is generally over 3,200 feet elevation. This gives an average slope of about ten feet to the mile, but it is by no means regular and between these points much of the ground is extremely rough and hilly. The lowest point, where the Battle River leaves the eastern edge of the area, is slightly above 2,100 feet elevation, while the highest points, in a north-south ridge in Range 26, reach to about 3,500 feet.

About 15 miles east of the western edge of this area, and almost entirely in Range 26, a belt of higher land strikes almost due north. This higher ground is composed of bedrock that rises usually 200 or 300 feet above the surrounding country. This higher ground has, for the most part, a rough, hilly surface, and some of the higher hills reach an altitude of more than 3,400 feet. This belt of higher ground has a general width of five or six miles, and the land slopes away from it on both sides for long distances. This ridge of higher land has a large influence on the drainage system in the western half of the area, which has established itself since the departure of the ice-sheets. It is crossed by only one stream, the Red Deer River, which cuts southeastwards through it in a deep valley five miles east of the city of Red Deer, and this ridge is elsewhere the chief drainage divide in the western half of the area. It also seems to have had an important influence on the ice-sheets and on their formation of moraines and glacial lakes, as will be shown later. In pre-glacial time it also doubtless was an important feature of the topography. This belt of higher ground will often be mentioned in this thesis, where it will be called the 'Range 26 Ridge'.

In the northeastern districts and in some other regions the surface is fairly smooth, except for scattered streams and gullies. In a few places broad bedrock hills or ridges form gentle slopes, and the remainder of the area is largely covered by a rough, sharply-rolling surface with numerous small hills and valleys.

Rivers and Streams. The Red Deer River flows through this area, and its valley is the chief feature of the topography. Altogether about I35 miles of its course lies in the area being described. As shown on the map, this river crosses the Fifth Meridian to enter this area in Township 36, and thence follows a northeast course to about six miles northeast of the city of Red Deer, where it is joined by the eastward-flowing Blindman River, its only tributary of any size in the area. Thus far the Red Deer is in a broad valley with gently-sloping sides, with the land surface sloping towards the river for many miles on either side. Though this broad valley continues to the northeast past the towns of Lacombe and Ponoka, the Red Deer River leaves it after being joined by the Blindman, and the broad valley to the north now contains no sizable stream. The Red Deer River turns more than I20 degrees to flow southeast for several miles, and in this southeast stretch it cuts through the Range 26 Ridge in a narrow valley which is more than 550 feet deep in places. After this it turns to flow more or less eastward to the vicinity of Ardley, from where it flows north for about five miles, and then eastward again for about eight miles. Along these eastward and northward flowing stretches of the river, its valley is fairly shallow, usually about 150 feet deep, and fairly wide. But the river now makes a nearly right-angled turn to flow southward, and it is once again in a narrow valley, one or two miles wide, and usually more than 300,and in places more than 500, feet deep. Further along its course the river tends more and more to flow southeast, till just southwest of the town of Big Valley, where it makes another right-angled turn to flow southwest for about ten miles. Making yet another right-angled turn, east of Trochu and Huxley, it once more follows a southeast course more or less parallel to that farther north, and leaves the southern edge of the map-area in Range 21. Along all this latter part of its course the river retains the narrow, deep valley it has farther north.

The only other river in the area, besides the Red Deer and Blindman, is the short section of the Battle in the extreme northeast. This has a valley two or three miles wide and between 200 and 250 feet deep.

The more important streams include Ghostpine, Big Valley, Threehills, Kneehills, Parlby, Tail and Paintearth Creeks. All of these but Paintearth and Big Valley Creeks are in the western half of the area, where the drainage system has reached a higher stage of development, and where the precipitation is slightly greater, and evaporation less, than in the east. Ghostpine Creek flows southeast from Ghostpine Lake in a broad valley. Big Valley Creek lies in a somewhat flat-floored and often steep-walled valley that heads rather suddenly at Foxall Lake and continues southeast through Ewing Lake towards the Town of Big Valley, where it turns nearly 90 degrees to flow southwest into the Red Deer River. Threehills and Kneehills Creeks follow quite wide and deep parallel valleys southeast. Parlby Creek, after flowing southeast in most of its course, near the town of Alix turns to flow north past the town of Mirror into Buffalo Lake. Tail Creek is a small stream that drains Buffalo Lake into the Red Deer River through a large valley. Paintearth Creek, which lies in the northeast of the area, is a collection of large, flat-floored gullies, about 225 feet deep, quite as might be expected in a semi-arid region with youthful drainage on weak bedrock.

These streams and valleys will be discussed in the chapter on the drainage system (Chapter 6).

Lakes. The three largest lakes, Sullivan, Buffalo and Gull, lie only partly in this area. Others of importance are Gough, Ghostpine, Ewing, Foxall, Marion, Lonepine, Farrell, Goosequill, Mikwan, Lowden and Blackfalds. Some of the lakes, especially those in the east, have been known practically to disappear in dryer years. While those in the western half of the map-area may fluctuate greatly in water-level, they almost always contain a fair amount of water, and are relatively stable when compared with those in the east.

Sloughs, ponds and smaller lakes are also common enough, except in the flatter regions to the northeast and the dryer areas to the southeast.

The lakes and ponds in the west contain fairly fresh water. As one proceeds eastward the water contains more alkali, till large quantities are contained in some of the lakes in the very east. Generally the water does not contain enough alkali to prevent its use by cattle, but in dry seasons, as the water-level falls, the salts are concentrated, and glistening white salts are deposited around some of the ponds. At these times much of the water is not fit for use.

Climate. Records of precipitation have been kept at a number of points in this area and in surrounding districts. Among the towns where records are, or have been kept, are Halkirk, Alix, Lacombe, Penhold and Olds. Several private persons have also kept records. The average yearly precipitation in this area is about I6 I/2 inches, with about three-quarters of the precipitation in the form of rain. The total amount of precipitation seems to decrease slightly from northwest to southeast. While it is fairly evenly spread through the year, much of the winter downfall is lost through the spring run-off.

Along with precipitation the rate of evaporation has an important role, and the strong evaporation in the southern and eastern districts of the area is partly responsible for the small number of ponds and lakes, and for the lack of trees, there. The slight decrease in precipitation could not, itself, explain the differences in these features between here and further northwest.

The direction of the prevailing wind is most commonly from the northwest or west. East and southeast winds are also common.

This region has characteristically warm summers and cold winters, with July on the average being the warmest month and January the coldest. The rather long, cold winters greatly decrease the rate of weathering in the region.

Trees. Cottonwood and aspen are the chief varieties of trees. A few spruce occur in the northwest, but are rare elsewhere. They are most common in sandy districts and in valleys, and an occasional spruce may be seen in any part of the Red Deer valley within the map-area. The poplars grow thickest and largest in the northwest and in the valleys. They decrease in number and size to the south and east, and are not found in the very southeast. Except near sloughs few trees grow east of Range 19 or south of a line that runs near the towns of Trochu, Wimborne and Big Valley. Small willow, serviceberry and other bushes are common in much of the area.

Glaciation. All this region has been covered by the continental or Keewatin ice-sheets, but no evidence of mountain or piedmont glaciation was seen. Indeed, the nearest indications of mountain glaciation are in the vicinity of Rocky Mountain House and near the Clearwater River, about 30 miles from the western edge of the map-area. The continental ice had sufficient thickness to cover the highest points in this area, those of about 3,500 feet elevation.

The glacial geology of the area has several outstanding characteristics. As far as could be determined no eskers are present either in this or surrounding districts. No drumlins were noticed, and it is unlikely that these, roche moutonnee or crag-and-tail forms are present in any number. This is a region in which large quantities of recessional moraine were deposited, and more than one-third of the area has knob and kettle morainal topography. Over considerable areas glacial erosion seems to have been very active. Extensive areas, chiefly in the east, but to a lesser extent elsewhere, have only a thin covering of drift. As would be expected, the glaciation has had a strong effect on the drainage system and pattern, and few streams now follow a pre-glacial course.

Some features of the glacial geology are a result of the nature of the local bedrock. No glacial striae were seen, and none could be expected. The bedrock is of an extremely soft character, and even in the unlikely event of such bedrock having been host to many striae, it could not preserve them well, as it consists for the most part of weak or uncemented shales and sandstones, as shown in Table I. Most striae formed by the ice-sheets would be destroyed almost immediately, either by the ice itself or by water from the ice, while continued erosion and weathering would be hard on any surviving. The character of the bedrock, especially its weakness and lack of joints, also works against plucking and sapping, and thus roche moutonnee, crag-and-tail forms and rocdrumlins could seldom be formed.

The most important effect the bedrock has had on the glacial geology is, however, its influence on the composition of the drift. Most of the material composing the drift was collected locally, and as the local bedrock formations consist primarily of shales and clays and secondarily of fine and coarse sandstones with, in addition, a few ironstone layers and coal seams, the drift, especially where thin, is generally of a clayey type. In places it is more sandy, particularly over the Paskapoo formation. Small pieces of coal are generally scattered through it. Pebbles and boulders are fairly numerous, but the number varies from region to region.

The pre-glacial topography also has had an important, though indeterminable, effect on the ice-sheets and thus on the glacial geology. It has certainly played an extremely important role in determining locations of recessional moraines and in which regions glacial erosion would be active. Also the general slope of the surface to the northeast has been a major factor in causing the formation of glacial lakes and streams.

General. The Buffalo Lake moraine strikes more or less northwest in a broad path through the centre of this area. This is a complex system of hills, ridges and valleys, formed by recessional moraine, and showing very little pattern. Its western boundary is largely along the Range 26 Ridge, while in the east the boundary, as indicated on the map, runs from south of Sullivan Lake, south around Gough Lake, to the west of Ewing and Foxall Lakes north to Erskine, and then northeast past Red Willow.

Northeast of the Buffalo Lake moraine are districts of fairly flat ground moraine, bedrock and lake sands, while west and south of it are regions of glacial-lake deposits and ground moraine. The Buffalo Lake moraine and the areas on either side of it form the three main divisions in the glacial geology of the area.

About I,770 square miles of the map-area have a covering of ground moraine, while I,460 square miles have the irregular topography of recessional moraine. Lake sands cover about 475 square miles, in about I2 of which they have been formed by wind into fair-sized dunes. Water covers another I40 square miles, and in slightly more than IOO square miles bedrock is either exposed or covered by less than three feet of drift. Gravels of various types cover about 20 square miles, while lake clay and silt has a surface of about 70 square miles. Some of this lake clay and silt is varved. The lake sands and clays also lie over other glacial deposits, of course, such as recessional and ground moraine.

After a short chapter on the local bedrock, this thesis will have three chapters on the region west of the Buffalo Lake moraine, on the Buffalo Lake moraine itself and the lakes included in it, and on the region northeast of the Buffalo Lake moraine. A chapter on the drainage system of the area follows, and then two chapters on the economic geology, the second dealing entirely with water supply. A concluding chapter discusses multiple glaciation in this area, and gives conclusions about this and certain other matters.

Chapter 2. Bedrock.

The bedrock formations that outcrop in central Alberta are of Tertiary and Upper Cretaceous age, and consist almost entirely of soft shale and sandstone, with some coal and ironstone layers. They are tabulated below.

Table I.

Age	Formation	Thickness
Tertiary	Paskapoo	800 feet more or less.
Upper Cretaceous	Edmonton	I,000 to I,200 feet.
	Bearpaw	300 to 600 feet.
	Pale and Variegated beds.	600 feet more or less, a maximum of I,000 feet.
	Birch Lake	I00 feet.
	Grizzly Bear	I00 feet maximum.
	Ribstone Creek	325 feet maximum.
	Lea Park	950 to I,I00 feet.

Only three of these formations - the Paskapoo, Edmonton, and Bearpaw - outcrop in this area. As these are the only ones that have any influence on water supply or have affected to any extent the glacial geology here, these are the only formations which need concern us.

The Paskapoo formation reaches a thickness of more than 500 feet towards the western part of the area. It is essentially composed of freshwater sediments, mostly shale and sandstone. A few thin coal seams are present, and towards the base of the formation are some siliceous limestone beds. The material composing the formation is usually weak, and much of the sandstone is practically uncemented. Some harder beds of sandstone and shale are present, however. The sandstone is usually buff, yellow or of a rusty colour, whereas the shale renges from grey to black in colour. Crossbedding is common, and the beds are often massive. The formation has many good exposures in the area.

The Edmonton formation has a thickness of more than I,IOO feet in parts of this area. It also is composed essentially of freshwater sediment, mostly shale with lenses of sandstone, the sandstone being finer grained on the average than that of the Paskapoo formation. Coal seams and ironstone layers are also present. The formation is generally weak and soft, but some harder beds of sandstone are included in it. The shale ranges in colour from white to green, blue, brown and gray, whereas the sandstone is mostly white or gray. The formation is poorly bedded with much crossbedding. Characteristic of the formation is a large content of bentonite which, too, is largely responsible for the white, gray, green and blue colours. This material causes the beds containing it to be very sticky when wet, and the amount of it contained in the drift of the area is the main reason for the stickiness of the drift when wet. This formation is excellently exposed in this area.

The Bearpaw formation is fairly thin in this area. It consists mainly of shales of marine origin, which are usually green in colour. In places the formation contains sand, bentonite and thin coal seams. This formation outcrops little in the area.

The bedrock dips in general a little south of west, at a rate, in most of the area, of about 15 to 20 feet to a mile.

The Geological Survey of Canada has published maps of the bedrock geology, on a scale of four miles to an inch,

NE quarter, section 26, Township 40, Range 16,

Strip coal mine in Edmonton formation. The coal seam is about eight feet thick. Note fold in background.

About section 30, Township 39, Range 15.
Erosional remnant of Edmonton formation in Paintearth Creek. Note folds in the bedrock. Month of July.

which cover practically all the area of the Red Deer Sectional Map No. 2I5 (Stettler Map number 503A and Red Deer Map number 504A, the geology of both by R. L. Rutherford). Allan and Sanderson have published a report (see number 3 in bibliography) on the geology of the area included in this map and the Rosebud sheet to the south.

The larger part of this area is underlain by the Paskapoo formation, which overlies the Cretaceous practically everywhere west of Big Valley Creek, and Ewing, Foxall and Buffalo Lakes. The Bearpaw is the uppermost formation only in a very small area of the northeast, where it is uncovered towards the bottom of Battle River and Paintearth Creek valleys. Elsewhere the Edmonton formation overlies the Bearpaw, being either directly under the surface deposits or, as in the west, under the Paskapoo formation. Near the line of contact, where the Paskapoo begins to overlie the Edmonton, the land surface usually rises I00 or 200 feet, with the surface of the ground over the Paskapoo being higher than that over the Edmonton. Though this rise is almost always close to where these two formations meet, it does not necessarily follow the line of juncture, but is often a mile or more, generally east, of this line.

<u>Bedrock Outcrops.</u> Outcrops of bedrock are fairly common, especially in stream valleys, in this area, and are caused by several different means. Bedrock is widely exposed in the valleys of the three rivers: along all that section of the Battle River in the area, at scattered points on the Red Deer Valley above where the Blindman enters it and continuously from there on, and along much of the Blindman River. It is pretty continuously exposed along

much of Big Valley Creek, and is also seen in many other valleys, especially the post-glacial and, to a lesser extent, the inter-glacial ones. Gullies entering the Red Deer River usually contain excellent exposures, as does Paintearth Creek with its flat floor, steep walls and many branching gullies.

In the eastern third of the area most of the streams cut into, and uncover, bedrock, and it is also generally exposed for a mile or two back from Sullivan Lake and all its inlets. Bedrock is widely exposed around Marion, Lonepine, Gough and Ewing Lakes, especially the first, and some of the smaller lakes and ponds. Also present in the eastern third of the area are large regions in which the drift is either missing or intermittent, and in broad districts surrounding these regions the bedrock is only a foot or two below the surface. These areas of exposed or shallowly-covered bedrock comprise more than IOO square miles.

Bedrock is also exposed in regions of concentrated gullying and strong erosion, which has caused the active removal of the surface deposits. These regions (such as just south of Ewing Lake and three miles northeast of Lowden Lake) comprise perhaps five square miles. Outcrops are also common on the bedrock ridges and hills, where a thin drift cover often permits a small amount of erosion to reveal the bedrock.

The large amount of road-building and grading work presently being done in the area results in many outcrops. Almost any road across a valley or a bedrock ridge has bedrock in its ditches. In many of the flatter regions of the eastern third of the area, bedrock often appears in roadside ditches, especially in those districts just mentioned where bedrock is near the surface. In the eastern part of the area, too, coal mines, especially the strip mines, often produce interesting outcrops.

Many of the above types of outcrop, and especially those made by road building, are rapidly destroyed by slump, vegetation covering and weathering, and after four or five years they may no longer be of use as outcrops. Outcrops along the railways, too, have mostly been destroyed in these ways, as the railways have generally been built for some time.

Proportion of Paskapoo to Edmonton Outcrop. Though the Paskapoo formation covers the larger area, most outcrops expose Edmonton formation. There are many reasons for this. The Paskapoo overlies the Edmonton in the west, as previously mentioned, where the average annual precipitation is slightly greater, and the evaporation less, than in the east. This promotes a thicker covering of vegetation and soil, causes quicker weathering and slumping, and thus the quicker destruction of outcrops in the Paskapoo regions. Much of the west also has a covering of lake deposits which hides the bedrock. As the drainage system in the west is mostly older and better developed than in the east, it has thus more gently-sloping valley walls and, consequently, less bedrock is there exposed. In addition, the unconsolidated deposits are generally thicker in the west, which also decreases the opportunities for widespread outcrop there, and most of the districts with no, or only a thin, covering of unconsolidated material are in the east.

Another factor increasing the proportionate amount of Edmonton formation outcrop is that the Red Deer River, while flowing south in the centre of the map-area over land nominally underlain by Paskapoo, has worn through this Paskapoo and cut deeply into the Edmonton formation. As the Paskapoo is thus removed from much of the sides of the valley, it is seldom seen to outcrop here.

Thus most of the factors that make for widespread outcrops are missing in the western districts but present in the east. However, the greater amount of exposed Edmonton, as compared with that of Paskapoo, must be partly caused by differences in the formations themselves. Large portions of the Paskapoo formation are cemented either poorly or not at all, and on exposure may resemble ordinary sand deposits and thus not be recognized as bedrock, especially if the traces of bedding have vanished. The Edmonton formation, however, seems to be more easily gullied, and thus gives valleys with steeper walls and more bedrock outcrop. Also, in the Edmonton formation a greater alternation in strength of successive strata causes stepped slopes with resulting greater bedrock exposure. Water also has greater difficulty in seeping into the Edmonton formation than into the Paskapoo, which increases the proportion of it running off the surface of the former formation and increases the rate of valley and gully erosion on this formation.

Distinction Between Bedrock and Till. In places, in those regions underlain by the Edmonton formation, and especially where the surface covering is thin, some difficulty arises in distinguishing the bedrock from the till. Often both have the same colour and are composed of much the same material, for the till was largely derived from the local bedrock. Often, too, neither shows much weathering, but the bedding near the surface of the bedrock has often vanished. The presence of foreign rock fragments scattered through the till is perhaps the best method of distinguishing them, but even this is, in places, rather uncertain, as the Edmonton formation contains scattered concretions and pieces of ironstone and as so many of the rock fragments in the till have been gathered locally from this formation. On removal of the weathered surface, the bedrock exposures generally show poor bedding and crossbedding, in contrast to the till. Coal seams also are very helpful in distinguishing between bedrock and drift, as are the small pieces of coal usually present in the drift.

It is seldom easy for a driller to determine when he is through the drift and into bedrock. Often the first indication of bedrock is a coal seam or a thick ironstone layer. Pieces of igneous and metamorphic rock (except quartzites), unless they have fallen from above, will show that he is still in the drift. Drilling in the drift and in the Edmonton formation is about equally easy.

The bedrock was chiefly studied for its influence on quantity and quality of water supply, and for the material it supplied to the drift.

Chapter 3.

The Regions West and South of the Buffalo Lake Moraine.

The north striking Range 26 Ridge roughly determines the western edge of the Buffalo Lake moraine, though some recessional moraine also occurs southwest of it. From this ridge the land slopes west down towards the old valley of the Red Deer River, which the present river occupies to about five miles north of the city of Red Deer. Whereas the river here swings sharply east, the old valley continues north past Lacombe and out of the map-area. In the south, recessional moraine is also absent from some districts between the Range 26 Ridge and the Red Deer River in Ranges 22 and 2I, and these districts will be included in this chapter.

Glacial-lake Red Deer. West of the Range 26 Ridge much of the region has a covering of sand, silt and clay, and large parts of it, when seen from nearby hills, look flat and smooth. Most of this old valley of the Red Deer River was occupied by a lake while the last ice-sheet in the region was melting. As the city of Red Deer lies near the centre of the old lake bed, and as this lake occupied the valley of the Red Deer River, the name'glacial-lake Red Deer' will be used in the remainder of this thesis in referring to this lake.

The area presently covered with lake deposits, as indicated on the map, does not, however, include the whole former extent of this lake. In some parts of it no sediment may have been deposited. In other parts of its bed, mainly the higher regions, only a little sediment seems to have been deposited, and this was easily removed by later erosion. From other places large amounts of the lake sedimenthave been removed by erosion, often by wind, and redeposited elsewhere. Thus the area originally covered by these deposits does not altogether coincide with their present-day remains as shown on the map, and much of the surrounding district was, no doubt, at one time under the waters of this lake.

The lake sediment continues out of this map-area southwest of Innisfail and also north of Lacombe. The size of that section of the Red Deer valley which the lake occupied southwest of Innisfail has not been determined, but it is likely as large as that section covered by the lake water in this map-area. North of Lacombe the lake deposits occupy the valley as far as the town of Ponoka, but they lower in altitude and occupy a narrower strip. On both sides of this lake, and in the districts south of the Buffalo Lake moraine but east of the Range 26 Ridge, ground moraine forms the surface. It will be discussed later in this chapter.

A topographic map shows that an ideal situation is here present for the formation of a lake in front of an ice-sheet advancing from, or retreating in, a northerly direction. There is, first, this long, broad valley with very gently-sloping sides that normally drains north. In addition, the Range 26 Ridge prevents drainage to the east, while a surface that steadily rises away from the valley prohibits drainage to the west. Further, the valley rises in elevation to the south and west, which leaves little possibility of drainage in that direction. Therefore, as the ice melted north, northwest or northeast, a lake would result before the ice-front, unless sub-glacial or underground drainage developed.

<u>Southeast Outlets of Glacial-lake Red Deer.</u> The lake seems to have followed a retreating ice-front north

as it slowly replaced the ice in the valley. The water would, of course, rise to the elevation at which an outlet could be formed, and three possibilities for outlets were present. The water could, perhaps, have found a course to the north through, or over, the ice, but no signs of its having done so are apparent, and, in any case, this would probably just lead to higher ice beyond. Or it could have sought a path through the Range 26 Ridge and spilled eastwards into one of the pre- or inter-glacial, southeast-flowing streams on the lower ground beyond. This was not done (except later when the Red Deer River re-assumed its course through the ridge), though for a while the water must have come close to doing so. The other possibility, and the one which the water made use of, was to find a course south or southeast from the vicinity of Innisfail, over the edge of the old Red Deer valley and onto lower land about 30 miles southeast. To do this, the lake water had to cross a surface that now lies at about 3,200 to 3,250 feet elevation. Two outlets were here formed, the western one being the shallower, never having been cut below 3,I50 feet, whereas the channel of the more easterly one is everywhere below a present elevation of 3,I00 feet.

These outlet valleys are now practically streamless. They are steep-walled, flat-floored valleys carved into bedrock, which contain only what till has slumped from the sides, and no boulders, save for pieces of the local bedrock. Some sand is present on their floors, but there is little other surface deposit, and the bedrock is everywhere near the surface, seldom being covered by more than the soil. Much of the sand probably came from the local Paskapoo formation, which is here to a certain extent unconsolidated. Bedrock outcrops at a number of points on the valley walls and in the ditches of roads across tham.

The valleys seem to be post-glacial and formed during the melting of the last ice-sheet in this area. Among the features indicating this are their flat floors, steep walls, lack of drift, southeast direction of flow, steep gradient and the absence of any general slope towards these valleys in the surrounding districts, such as is present near other neighbouring valleys, most of which are pre- or inter- glacial. Supporting this evidence is the fact that they drained a post-glacial lake. No valley in a weak formation, such as the Paskapoo, could retain some of the above features any length of time, even in a region of light rainfall such as this, and these valleys are post-glacial, and remain practically as they were when glacial-lake Red Deer ceased to drain through them.

The size of these valleys, which are carved into bedrock to a depth of more than 100 feet in the western case, and 150 feet in the eastern, would seem to indicate fairly long erosion by a considerable volume of water. But it must be remembered that the Paskapoo formation, into which they are cut, is often not much more than loose sand and can be worn down quickly. These valleys also have a high gradient, in both cases more than seven feet to a mile, which would have greatly aided their erosion. Thus these outlets may not have been in use as long, or have carried as great a volume of water, as would at first appear.

The eastern outlet is the lower, and thus probably remained in use later than the other. Some difficulty arises, however, in explaining why two outlets should have been formed so near one another, and several causes for this are possible. Both outlets may have started about the same time and competed until the eastern one captured all the drainage. Or the western outlet may have become jammed with drift and ice, or blocked by a small re-advance of the ice-sheet, which allowed the formation of a second one. Possibly the eastern outlet was the earlier, but a re-advance of the ice blocked it, causing the formation and temporary use of the western one. Or, again, stagnant ice from a re-advance may have kept an all-completed western outlet blocked while the eastern one was cut. Although there seems to be no means of determining the true cause of two outlets, some re-advance of the ice seems likely, as mentioned in the chapter on the Buffalo Lake moraine (chapter 4), since recessional moraine occurs near these valleys.

The presence in the western outlet of a flat-topped island, several miles long and rising to the general level of the country near the valleys, is also difficult to explain. No evidence is now present to explain why the outlet should divide into two almost equal branches (the eastern branch is slightly larger), but perhaps ice jamming, blocking and overflow are the answers. The island itself is singularly flat-topped, level and unaffected by stream erosion.

If the outlets commenced to erode at above 3,200 feet (present) elevation, as seems likely, the lake must have stood, for a short time at least, at about this level. Little of the lake sediment lies above 3,100 feet at present, however, and thus it was either removed from the higher parts of the lake bed or never deposited there. No doubt these higher deposits were only thin and were quickly washed into the lake after it had lowered from its first high margins, and thus the total original size of the lake was greater than its sediment now indicates. Little evidence of these early high margins, such as beaches or old shore-lines, now appears, and the lake level probably fell more or less continuously for a time, without any long halts. Floating ice on the lake may also have helped prevent the formation of beaches. Most of the lake bed below 3,000 feet present elevation has a covering of the lake deposits, however, and the rate of fall of the lake level probably decreased as the eastern outlet was reaching its base of around 3,050 feet elevation. This would allow a much greater length of time during which the lake water could deposit the sediment below 3,000 feet, and would permit a much greater accumulation of this sediment in the lower parts of the lake bed.

Chigwell and Ponoka Outlets. The Range 26 Ridge seems to have kept ice ffom entering the lake from the east or northeast, though some meltwater probably entered from these directions. Thus the ice to the north and the depth of outlet would alone govern the size of the lake and its spread northward.

As the lake water replaced the ice northward past the city of Red Deer no new outlet became available, since the eastward course of the Red Deer River through the ridge would be blocked by ice moving to the ridge from the east. Gull Lake, in the northwest of the map-area, and Sylvan Lake, west of the area, were then connected with glacial-lake Red Deer, and these lakes are now the main remnants of this glacial lake.

No new outlets were found, as the ice retreated northward, until minor outlets were formed near Chigwell and a major outlet developed near Ponoka (I2 miles north of the map-area), running past Tees and through Parlby Creek valley to the vicinity of Buffalo Lake. With this outlet, glacial-lake Red Deer had finally found a passage through the Range 26 Ridge, this being at a spot near Ponoka where the old Red Deer River had worn it down. Glacial-lake Red Deer was now connected with Buffalo Lake (which then stood higher than at present), and the old outlets to the south were quickly abandoned. These new outlets were formed over ground that now generally is of less than 2,900 feet elevation. in the case of the Ponoka outlet and 3,000 feet in the region of the Chigwell one. The Ponoka outlet has been worn below 2,700 feet present elevation.

As it retreated northwards in the old Red Deer valley, the ice-front did not leave any evidence indicating halts in its retreat in this area. If any such halts occurred, the indications of them have been obliterated by erosion or by burial under the lake sediments. Just north of the area and about three miles west of Morningside, some rather severe, if local, recessional moraine appears. Its edges are buried under lake sediment and sand dunes, but it may, in the past, have connected with that recessional moraine to the southeast, and perhaps represents a halt in the retreat of the ice fronting the lake.

Diversion of the Red Deer River. It is interesting to notice that glacial-lake Red Deer and its outlets indicate that the eastward diversion of the Red Deer River from its old course occurred earlier than the last ice advance. If there had been no valley of the Red Deer through the Range 26 Ridge, no post-glacial valley would have formed here, as the river would naturally have followed the lake drainage system and have flowed by the Ponoka outlet or those southeast of Innisfail. It would not have cut through this ridge while these lower outlets were available.

A Previous Glacial Lake. The question naturally arises as to whether any lake existed in the region of glacial-lake Red Deer during the retreat of previous ice-sheets. Though there is no way of deciding this definitely, certain evidence points to there having been such an earlier lake. The strongest evidence is the eastward, rather than northward, course of the Red Deer River after the Blindman joins it, and the ideal situation here present for the formation of such a lake. Other evidences are the positions of Davey Lake, and Kneehills and Threehills Creeks. Any previous lake would not necessarily have, of course, the same outlets or boundaries, but it would likely have occupied much the same part of the Red Deer River valley.

The eastward diversion of the Red Deer cuts through the Range 26 Ridge where it has a present elevation of more than 3,200 feet, and in doing this the river has carved a valley more than 500 feet deep. As mentioned above, this channel was developed prior to the last glaciation. Thus, at one time, water in the Red Deer valley must have stood high enough, perhaps over 3,200 feet elevation, to have spilt eastward across the ridge. To do this the river must have been blocked, and a lake formed which raised the level of the water. Further, the situation is so favourable for the formation of a lake that, no matter in what direction, except southwards, a glacier was retreating, a lake would be formed in much this position.

Drainage to the southeast from such a former lake, before the diversion of the Red Deer, may be partly responsible for Kneehills and Threehills valleys, and for the valley in which Davey Lake lies. These valleys are of a size to have once carried a considerable volume of water, and perhaps they once drained such a lake. To drain into these valleys, however, the lake water would have had to cross a surface that is now 3,200 to 3,250 feet elevation. Thus, even with these outlets, the water would still be able to spill east along the present course of the Red Deer River, once the ice had melted that far north, for a lower surface would be there available than that presented by these southern outlets.

The Lake Deposits. The sediment found in the bed of glacial-lake Red Deer is generally a fine sand. This, in places, grades into silt, and in some districts a clay, occasionally varved, with lenses of silt and sand, is present.

The thickness of the lake deposits varies greatly, but it generally increases towards their centre and near the river. That they are seldom more than 50 feet thick we learn from wells, and they are often thinner than IO feet. Information from wells also indicates that the lake sediment is usually underlain by till, which in some places shows at the surface and in stream cuts. In a few places the lake sediment lies directly on the bedrock, and, beside a stretch of the river from south of Red Deer to where it turns east, it lies on gravel, which in its turn lies on the bedrock. This gravel is discussed in the chapter on the economic geology (chapter 7).

The lake clay is found mostly towards the centre of Township 36, Range 27, where it covers about II square miles, and along the west side of the Red Deer River in Townships 36, 37 and 38, where it covers about 13 square miles. Other lake clay, not connected with glacial-lake Red Deer, lies in the valleys of Kneehills, Threehills and Ghostpine Creeks, covering in all about 45 square miles. The clay west of the Red Deer River and in Kneehills Creek shows some varving.

Thickness of the Drift. The combined thickness of lake deposit and the drift it covers is usually less than

50 feet. The following table gives general figures for this combined thickness in those townships which have lake deposits:

Table 2.

Township	Range	Average Thickness	Greatest Thickness	Usually Thinner Than
36	27	feet	45 feet	20 feet
36	28	30	50	
37	26		50	20
37	27	40	I80?	50
37	28	70	II5?	
38	27	50	70	
38	28	30		50
39	26	50		70
39	27	35?		40?
40	26	35	I00?	50
40	27	40	I00?	

Note I. Figures for certain of the items have been omitted in those cases where adequate information was lacking.

Note 2.'Greatest Thickness' refers to the maximum average thickness of any half-square mile area in the township concerned.

Note 3. 'Usually Thinner Than' gives a thickness that is surpassed in only a few small areas.

It must be remembered that the above figures are only approximate. They are determined partly from well information which, as will be explained in the chapter on water supply (chapter 8), is not always completely accurate.

They will, however, serve to give a general idea of the thickness of the drift in this area. As the drift and bedrock often have many similarities, drillers cannot always determine when they reach bedrock, and thus their figures for the thickness of the surface deposits are more apt to be too large than too small. The figure of I80 feet given under 'Greatest Thickness' is almost certainly too high, as is probably the II5 foot figure, even if, as seems likely, the drift at this point is filling a former channel of the Red Deer River. Nonetheless the above figures show a greater thickness of drift here than anywhere else in the map-area outside of the recessional moraine areas, and indicate how the lake deposits have added to the total thickness of drift; especially when one considers that the country around the lake margins has a covering of only about IO or 20 feet of till. The lake sediments have probably increased the average thickness of the unconsolidated deposits in the area of glacial-lake Red Deer by about 30 feet.

The clay west of the Red Deer River is mostly thinner than IO feet, and that in Township 36, Range 27, has an average thickness that is only slightly greater. A ring of thin lake deposits, mostly sand, surrounds Gull Lake, representing the higher level of this lake just after the melting of the last ice sheet.

Sand Dunes. The lake sands have, in places, been duned by wind. The main areas of dunes are as follows:

East of Lacombe Lake and about three miles south-west of the town of Lacombe, dunes cover an area of about one square mile.

North of the Blindman and Red Deer Rivers, south-east of the town of Blackfalds and about seven miles north of the city of Red Deer, dunes cover about three square miles.

About two and one-half miles south of the city of Red Deer along the Calgary highway, sand dunes occupy about six square miles. The land around them, especially to the east, is flattish.

Two miles southwest of the town of Innisfail, sand dunes cover about two square miles.

Thus, altogether, sand dunes overlie about 12 square miles of the bed of glacial-lake Red Deer in this map-area. Further north, but still in the old lake bed, dunes near Morningside cover about 2I square miles, and some others,about six miles west of Morningside, cover about seven square miles.

These areas consist of now stagnant dunes, usually from 20 to 50 feet high, scattered at random, forming knolls and basins. Aerial photographs indicate that the winds forming the dunes came largely from the southeast, though probably their direction varied a great deal. This is nearly opposite to the direction of the presently prevailing winds (p. 7), and may indicate either a subsequent change in wind direction, or that the strongest winds at that time came from the southeast.

These dunes are at present considered wasteland, and are, of course, useless for farming, due to their rolling nature, tendency to 'blow', and the poor soil they form. Nevertheless, these areas support more tree growth than the surrounding country, and this is often spruce, which is sparse elsewhere. Good supplies of water can also often be obtained in these areas, the presence of this water being, naturally, the chief reason for the greater growth of trees.

The aforementioned are the only sand dune districts in this map-area. Wind has, of course, affected other parts, stripping sand from some areas and spreading it widely, with the formation of local dunes in some places, as at Leo. Much of the margin of glacial-lake Red Deer was cleared of the lake sediment by wind, leaving till exposed.

The lake sediment lowers in elevation to the north. This may be partly due to a greater thickness of it having been deposited in the south, where the water stood longer, than in the north where ice was present during the early part of the existence of glacial-lake Red Deer, with the consequent result of easier and quicker removal of the sediment from some of the northern districts after the lake had drained. This northward lowering of the lake deposits does not seem to be alone due to a steady lowering of the lake level, for this would have required a continuous and fairly uniform wearing down of the outlets, or the steady discovery of new ones.

Other districts further east in the map-area are also covered with lake sediment, the larger of such districts being around Buffalo Lake; southwest of the town of Stettler; around Delburne Lake; and around Ghostpine Lake. Smaller areas of lake sands are also common. These sands will be discussed in the chapters on the Buffalo Lake moraine and on the area east of it (chapters 4 and 5).

Ground Moraine. That part of the map-area west of the bed of glacial-lake Red Deer (mostly in Range 28) is almost entirely covered with ground moraine, the only parts not so covered being the valley of the Blindman River and a few bedrock outcrops. Bedrock has here the chief role in shaping the topography, and it is responsible for the broader and higher hills and ridges. The drift is thin, seldom being more than 50 feet thick and usually much less. It is IO to 20 feet thick in Township 39, Range 28, and about the same or slightly thicker in Township 40, Range 28. In the west of Township 38, Range 28, it has an average thickness of not much more than five feet, and is less than 50 feet thick everywhere in this township and in the part of Township 37, Range 28, west of the Red Deer River.

The region lying west of the Buffalo Lake moraine as far as the bed of glacial-lake Red Deer is generally covered with ground moraine. Some outwash gravels in Township 36, Range 28, will be discussed in the chapter on economic geology (chapter 7). The ground moraine covers the Range 26 Ridge, together with most of the area between it and the lake deposits, and is present practically everywhere under the lake sediment itself. It is nearly everywhere thin. For instance, in Township 34, Range 28, it is usually less than IO feet thick, and in Township 33, Ranges 27 and 28, it is of much the same thickness, or even somewhat thinner. On the Range 26 Ridge the ground moraine is often less than two or three feet thick, and most roadcuts here expose bedrock. Elsewhere between the ridge and the glacial-lake deposits, the till is generally between IO and 30 feet thick, and below the lake deposits it is usually less than 30 feet thick.

In that district south of the Buffalo Lake moraine, in Ranges 22, 23, 24 and 25, the ground moraine is usually from IO to 20 feet thick.

The thinness of the ground moraine is rather surprising, but it will be found that it is of greater average thickness here than in the ground moraine districts east of the Buffalo Lake moraine. Its thinness is difficult to explain, but the position of the Range 26 Ridge, long periods when the ice was stagnant, and a general ladk of debris in the ice, may all be partly responsible. Even in the recessional moraine areas of the map-area it will be found that the drift is often unexpectedly thin.

Description of the Till. The drift composing the ground moraine in these regions west of the Buffalo Lake moraine is usually a yellowish-brown till of a sandy clay composition, though it has a wide range in both colour and composition. It contains a limited number of pebbles and rather few boulders, while a few small lenses and pockets of sand and gravel are present. It is largely composed of sand and clay from the Paskapoo formation. The proportions of sand and clay vary considerably, and in some regions the till is of a very clayey type. Small pieces of coal, one-half inch or so in diameter, are scattered fairly evenly through it.

The majority of the pebbles and boulders, often more than four-fifths of them, are rounded pieces of quartzite or very hard sandstone. These betoken the nearness of the Rocky Mountains, from which they originated, and the amount of gravel brought down by streams before glaciation. Not all the pieces of quartzite came from the west, however, and some, especially the larger boulders, have been brought from the northeast by the Keewatin ice-sheets. These latter are usually less well rounded. The gravel from the west, which will be further discussed in the chapter on economic geology (chapter 7), consists almost entirely of pieces of hard sandstone and quartzite, for the weaker material was inevitably weeded out during transportation by the swiftly moving streams. A few limestone pebbles are present in places.

Pieces of rock of other types, beside the quartzite, are also present in the till. These are chiefly granites and granite gneisses, biotite schists, diorites and gabbros, dolomites and other fragments brought by the Keewatin ice, and in places, especially farther west, the limestone pebbles from the west. The mica schists and basic rock fragments are at times more weathered and crumbly than the other types.

Generally less than one or two per cent of the volume of the till consists of pieces greater than one inch in diameter, and there are districts in which they form less than one-tenth of one per cent of the till's volume. Boulders over two feet in diameter are rare.

In places the till contains a large number of slabs of sandstone and ironstone from the Paskapoo formation. This, as a rule, indicates that the drift is only a few feet thick, as these piesce of Paskapoo are too weak to be carried farther than a short distance without crumbling.

Towards the east, in Ranges 24, 23 and 22, the ground moraine becomes lighter in colour and generally more clayey, due to an increased proportion of material from the Edmonton formation. The number of pebbles and boulders decreases to an extent as one proceeds east.

Chapter 4.

The Buffalo Lake Moraine.

Introduction. About I,450 square miles of the map-area are covered with the knobs and kettles, ridges and hollows, of recessional moraine. A glance at the map discloses that the area so covered is large, and it is actually well over one-third of the total map-area. More than 75 townships contain large amounts of this moraine, and about 50 of these are more than half covered by it. Then, too, in other areas that were once covered by such moraine, it has been so altered and modified by erosion, with development of drainage systems, as to be now scarcely recognizable as moraine. These latter areas are comparatively small, however, and are mainly situated near rivers and streams, as in the example near Threehills Creek.

The map shows that the recessional moraine occurs in some widely scattered and irregular patches, A main, massive section, much broken but generally about 20 miles wide, strikes northwest through the centre of the area. This has an irregular outline, with many outlying, almost disconnected, parts, some of which are of fairly large size.

All this recessional moraine, however, including the outlying patches near Innisfail, is part of the Buffalo Lake moraine. This was named from Buffalo Lake in the north of the area, a large lake (nearly 20 miles long) which this moraine entirely surrounds and near which it is strongly developed.

The Buffalo Lake moraine, being large, is obviously of extreme importance in its effect on farming, tree growth, roads, railroads and drainage, and it is also the outstanding feature of the glacial geology. The Buffalo Lake moraine has, perhaps, its greatest development in our map-area.

Further south it dies out or becomes more moderate in detail, while 10 or 15 miles north of the area it again apparently dies out.

In the map-area itself, however, the moraine has the most extreme variations. Not only are its boundaries uneven and irregular, with large scattered patches outside the main mass, but the main portion itself has many open areas, small patches of ground moraine with comparatively smooth surface, rivers and streams cutting through it, and several large lakes and valleys. The largest of the valleys is the one containing Buffalo Lake itself. Further, this moraine shows the greatest variation in development and relief. A few knolls and hills in it rise about 200 feet above the nearby valleys, while heights of 150 feet above the kettles are present in several areas. Heights greater than 100 feet are common, and in wide regions the average height of the hills is more than 50 or 75 feet above the kettles. In other wide districts the knobs are low and broad, perhaps 20 or 30 feet high, and the kettles wide and shallow. These variations in the moraine, along with others, will be more apparent when the moraine is discussed in greater detail.

Drift Composing The Buffalo Lake Moraine. This recessional moraine is composed of ordinary till, which is surprisingly little different from that forming the ground moraine to the east and west. The till is usually of a clay or sandy-clay variety. Sandy till is not often seen, and pockets of sand and gravel, while present, are not as common as might be expected. The till is mostly buff, light-yellow, grey or brown in colour, with the darker colours being more prevalent in the west over the Paskapoo formation, whereas in the east the white or light-grey till derived from the bentonitic shales of the Edmonton formation is prominent. The pebbles and boulders in the till of the recessional moraine are of the same types as those found in the ground moraine regions; i. e., mostly quartzite or sandstone pieces from the mountains, with igneous and metamorphic fragments brought by the Keewatin ice next in amount, and also some pieces of local bedrock. Pebbles and boulders are only a small part of the volume of the till, often not more than two or three per cent, and are scarcely more common than in the ground moraine. Boulders over two feet in diameter are not common, and any over four feet in diameter are practically absent. The largest boulder observed anywhere in the whole area was not more than eight feet in its greatest dimension.

The small proportion of coarse material in this recessional moraine is rather unexpected. Certainly immense amounts of ice melted during its deposition, and the water run-off must have been large. One would expect that, in so running off, the water would transport and deposit elsewhere much of the finer material, such as clay, silt and sand, thus leaving a gravelly or sandy residue. But few signs of such a removal of fine material are evident anywhere in the area, and the best example of such a residue is that perhaps three miles west of Erskine (section 9, Township 39, Range 2I and vicinity), where large quantities of boulders and gravel are present and fine material is largely missing.

Though much of the ice may have disappeared by ablation and evaporation, nevertheless large quantities of water must have run out from the ice, either over, through or under it, yet there is no trace or sign of the material that such running water would be expected to deposit. Some of the water probably drained to the southeast under the ice in the large, southeast-trending valleys to be described later (in the chapter on the drainage system, chapter 6), though little sign of any gravel connected with such streams is present.

In certain sections of the Buffalo Lake moraine, a thin deposit of varved clay and silt, for the most part much slumped, is often present on top of some of the knobs, but is noticeably absent from the nearby kettles. Such layering (unlikely to be yearly) could only have been formed by water standing in depressions in the ice, and receiving material from the surrounding ice. The fillings of these depressions now, of course, form the knobs, and stand higher than the surrounding area with the layers of clay and silt near their tops.

Boundaries, Influence of Topography. The western boundary of the Buffalo Lake moraine was, to a great extent, determined by the north striking Range 26 Ridge, which seems to have been an effective western barrier stemming temporary re-advances of the ice during its total retreat. Only in the south, where this ridge is lower, does the ice seem to have been able to re-advance any distance past it. With the ridge having decided the western edge of the moraine, the material deposited behind it seems to have continually forced the front of the still-moving ice back towards the east, thus forming the main mass of the moraine towards the centre of the map-area.

The eastern boundaries were determined by many smaller topographical features, and in many instances without apparent reference to topography at all. Towards the centre of the map-area, near Ewing Lake, the town of Nevis, and further southeast, the eastern edge of the moraine is near the contact of the Edmonton and Paskapoo formations. This line of contact, as previously mentioned (p. I4), is often marked by a nearby ridge, with higher ground towards the west. Generally, indeed, the eastern boundary of the moraine is where bedrock rises towards the west, perhaps partly due to glacial erosion having worn down the bedrock in the east while this recessional moraine was being deposited. For the locations of other sections of the eastern boundary, however, no topographical features can be offered as an explanation. Climatic control of the ice, while being probably the main influence everywhere on the formation of the moraine, must have been all-important in determining the locations of these stretches of boundary.

While topography had a role in deciding its edges, it had little influence on the main mass of the moraine after the western limit was determined. The highest of the hills and the deep, broad valleys were indiscriminately covered with a complex pattern of knob and kettle moraine. The open areas, surrounded by the moraine but where the knob and kettle topography is missing, do not seem to be the result of topographical influences, and their edges generally cannot be linked to any feature of the topography. In this, the rim of the knob and kettle moraine around these areas differs to an extent from the main, outside boundaries of the moraine.

A little more should be said about the influence of topography on deposition of recessional moraine in the area. The main masses of it, those that are the thickest, the most widespread and have the most extreme morainal development, have usually been deposited in areas where bedrock relief is high, and where some barrier (such as the Range 26 Ridge) limited the ice. In several smaller areas the recessional moraine is limited to valleys (Ghostpine Creek near Elnora) and lower areas (some sections west of Big Valley). While usually the moraine is likely to be more prevalent on slopes rising away from the ice, in a few places patches of the moraine are present only on slopes down away from what was probably the position of the ice (as in areas east of Gough Lake and west of Byemoor). There also remains the very large number of instances where no special topographical feature is associated with the moraine.

Outliers of the Buffalo Lake Moraine. What may perhaps be called 'outliers' of the Buffalo Lake moraine are present in the southwest of the map-area, mainly in Township 33, Ranges 27 and 28. These are in the form of ridges two, three, four or more miles long, from 20 to 50 feet high, and perhaps 100 feet wide. Since they are by no means straight, even ridges, however, but a series of convex and concave lobes with very uneven top, they might better be described as winding lines of small hills. The till composing these moraines is little, if any different from that in the ground moraine on either side (as described on p. 33).

These ridges are probably small moraines formed by the ice during its general retreat, and they consist of material either dropped by it during a short halt or shoved ahead of it during a local re-advance of the ice-front during its general retreat. Though in some areas they may be annual moraines, no method of estimating the length of time represented by each one was discovered.

In general these ridges trend northwest, but many variations are present. However, they offer some of the best evidence for the position of the ice-front during the melting of the last ice-sheet. Though only a few of them are in the area under discussion, many more may be seen further south, in Townships 31 and 32, Ranges 25 to

28, where they increase greatly in number, size, and definiteness of form.

Other, and larger, patches of recessional moraine are also present in the southwest, such as those east and west of, and to a certain extent within, the town of Innisfail. Here some of the knobs may rise 20 or 30 feet above the nearby kettles. In a strip of more highly developed recessional moraine to the south of Davey Lake, in Township 34, Range 27, some scattered hills are over 50 feet high. Davey Lake itself seems to be the result of damming of a valley by this moraine.

Wimborne Section of the Buffalo Lake Moraine. The above-mentioned areas of recessional moraine, west of the Range 26 Ridge, are of only minor importance as compared with the main mass of the Buffalo Lake moraine. In the 30 miles east of this bedrock ridge the moraine covers about four-fifths of the surface. In parts of this area its development is mild and the drift is thin; indeed, almost everywhere the drift is thinner than at first appears. For example, whereas the knob and kettle moraine around Wimborne has many knolls and undrained hollows, some of fair size, the drift here is thin, often under 20 feet, and usually less than 30 feet thick. Some of the hills, while appearing to be composed entirely of drift, seem to have a bedrock core or base, and the bedrock under the drift certainly has an uneven top.

The knob and kettle area around Wimborne is also largely separate from the main mass of the Buffalo Lake moraine, and the larger part of its boundaries are indefinite. In the northwest it disappears as the higher hills of the Range 26 Ridge become commoner, and elsewhere stream and gully erosion have graded and drained some of the knob and kettle areas, so modifying them that they now appear little different from ground moraine, and making their boundaries indefinite. The knob and kettle development is greatest south and east of Wimborne, where hills rise 30 to 50 feet above the nearby basins. Elsewhere the development is mild. The drift composing this moraine is little different from that described for the ground moraine to the west (p. 33).

The thinness of the drift in this part of the Buffalo Lake moraine is doubtless partly due to the lowness of the Range 26 Ridge, which allowed the ice to advance farther west and southwest, there building small moraines and thus dispersing the drift. In addition, it is one of the outermost parts of this moraine, and perhaps was formed before the deposition of the remainder was well started.

If erosion had not modified some of the knob and kettle moraine several miles east of Wimborne, the continuation here of the moraine north of Threehills Creek could be better observed, for then the eastern edges of the two sections would be approximately in line, and their correspondence better observable. The main valley of Threehills Creek contains little trace of knob and kettle topography, except in sections 20 and 21 of Township 34, Range 25, where the recessional moraine crosses the whole width of the valley except where it is breached by the winding stream channel, which is narrow here. This strip of moraine seems to have temporarily dammed the stream and to have caused the formation of a lake to the north. In this lake silt and clay was deposited to a level perhaps 25 to 50 feet higher than in the valley to the south.

<u>Sections of the Buffalo Lake Moraine North of Red Deer River.</u>

North of the Red Deer River, and west of Buffalo

Lake, other areas of recessional moraine are present which it might be as well to describe before proceeding to the large mass in the centre of the area. These regions have a moderate morainal development. The moraine south of Haynes is low, with the knolls generally 20 or 30 feet high, and with shallow kettles. Though low or shallow, these knobs and kettles are broader than those usually seen, and have gentler slopes. Nearly all of these kettles contain water, and poplars grow thickly. The till in some small areas is sandy, but mostly it has the same content as in the ground moraine to the west (p. 33).

The moraine stretching from four miles east of Lacombe, past Clive and Tees, to Alix and Buffalo Lake, has many of the same characteristics. It is usually of a mild development, especially towards the west where it disappears amongst the bedrock hills of the Range 26 Ridge, or elsewhere grades without definite boundary into a slightly-pitted, gently-rolling ground moraine. The knob and kettle character increases to the east towards Mirror and Alix. The hills may rise to 10 or 20 feet in the west, and some in the east rise to 50 feet. They are generally broad, and, especially in the west, have comparatively gentle slopes, and the kettles are mostly shallow. These recessional moraine areas are largely wooded with poplar, especially in the east where most of the kettles contain water.

The drift composing the recessional moraine is a till of much the same type as that found further west in the ground moraine (p. 33). It is seldom coarser here than in the ground moraine areas, and gravel and sand are uncommon. The thickness of the drift is mostly less than 50 feet. In that section south of Haynes it probably has an average thickness of less than 30 feet; in Township 40, Range 26, of about 20 feet; and further east of 40 to 60 feet with some small areas where there is 70 or 80 feet of drift.

Central Mass of Buffalo Lake Moraine. That mass of recessional moraine stretching north from Threehills Creek to the Red Deer River, and from west of Ghostpine Lake east also to the Red Deer River, is of much greater intensity, roughness and importance. In most of this area the morainal hills are higher and broader, the undrained valleys wider and deeper, and the slopes steeper than in the areas previously mentioned. This section of the Buffalo Lake moraine covers much of the higher land of the map-area, including the highest altitudes in the region.

-Ghostpine Lake Sands. An area around Ghostpine Lake, entirely surrounded by the recessional moraine, is marked as lake sands on the map. The knob and kettle development actually continues through this district right up to the lake itself, and so no break is here present in the mass of the Buffalo Lake moraine, as might appear from the map. Sand was deposited over the nearby moraine by the waters of the lake at a time when it stood higher. The present outlet of this lake is a narrow, quite steep-walled channel, trending southeast, and it is easily seen how the lake could have been formerly dammed in this section. These lake sands are characteristically coarse. In many places the morainal hills appear where the sand has been removed, or where it perhaps was never deposited, and thus these lake sands are patchy.

-Delburne Lake Sands. Similar characteristics are shown by the sands near Delburne Lake, which were also deposited over knob and kettle moraine at a time when Delburne Lake stood higher, and which are also patchy. The present Delburne Lake has no surface outlet, but when it stood at its higher level it probably drained northwest into the Red Deer River.

There is much variation in the intensity of development of the Buffalo Lake moraine in the various townships. In the west of this central mass, in Townships 36 and 37, the knob and kettle development commences near the Range 26 Ridge, with the bedrock hills of this ridge slowly giving place to the morainal ones. Further south, along the east side of Threehills Creek, the western boundary of this knob and kettle moraine shows a rather abrupt commencement of the moraine. The eastern boundary of this section of moraine just northeast of Threehills Creek, and south of the main mass, is perhaps the best example of a definite recessional moraine boundary in the map-area. For a distance of about six miles in a north-south line the morainal hills rise suddenly to a height of perhaps 30 or 40 feet from the fairly flat ground moraine to the east. From here east to the Red Deer River the southern boundary of the Buffalo Lake moraine is less distinct, with generally a slow gradation from a gently-rolling ground moraine in the south to the knob and kettle moraine, which is usually mild for a mile or so from its edge. Along the northern edge of this central part, from west of Hillsdown east to Delburne, the moraine is of a moderate nature for several miles back, and along part of it the recessional moraine really is continued across the river in that section south of Haynes. The recessional moraine, near its edge from Ardley east to the river, is of a mild development for a width of several miles, as the drift slowly changes from a gently-rolling ground moraine in the north to a highly developed knob and kettle type further south. Along the southward-flowing part of the Red Deer River the Buffalo Lake moraine has only a moderate to mild development, and it is really continued on the opposite side of the river.

From the edges of this moraine we proceed to the central parts which are almost everywhere of extreme morainal development. West and north of Ghostpine Lake the roughness of the morainal surface is accentuated by an uneven bedrock surface beneath it. The few and winding roads the map shows for these regions give an indication of this roughness. Some difficulty occurs in trying to determine the extent to which the hills are due to bedrock or to moraine, both here and in other regions. In this region many hills rise more than 75 feet above the nearby basins. Southwest of Ghostpine Lake the rolling hills are of corresponding height, but the drift is more sandy and gravelly than in most areas.

Northeast of Ghostpine Lake and Ghostpine Creek the knob and kettle topography is as extreme as anywhere in the map-area, with many hills over 100 feet high. From here towards the town of Delburne, and north towards the Red Deer River, although the moraine still has an extreme development, the hills are lower but still rise in places to heights of 50 to 75 feet. Directly east of Ghostpine Lake and Ghostpine Creek the moraine continues to be extreme east to the town of Lousana, and to Goosequill and Mikwan Lakes. Hills here are commonly more than 75, and in places more than 100, feet high, while a few miles west of Mikwan Lake they rise to 150 feet. From the vicinity of Elnora east to within a few miles of the Red Deer River the morainal development is also strong, with hills in some districts more than 100 feet high. In the region so far mentioned the recessional moraine is continued across several large, southeast-trending valleys, which apparantly have had no effect on the moraine, neither increasing nor decreasing the intensity of its development.

Towards the river from east of Lousana, Mikwan Lake, and the northern part of Goosequill Lake, the knob and kettle development is more moderate, and even practically disappears in some parts, leaving in its place a gently-rolling till covering with some shallow kettles. Elsewhere in this region the knobs are around 20 to 50 feet high.

East and southeast of Delburne towards the river, the morainal development is once more extreme, save close to the river itself. Some hills here are more than I00 feet high. North to the river from Wood Lake the moraine becomes milder in character, the hills being generally less than 30 feet high.

Bedrock has been mentioned as accentuating the knob and kettle development in the west near the Range 26 Ridge. Its effect elsewhere is less obvious. Interesting bedrock exposures are present near the crossroads at the southeast of section 28, Township 36, Range 24, where a new road grade cuts through what, from the surface, appear to be morainal knobs. The cuts show, however, that these seeming knobs are composed almost entirely of flat-lying and undisturbed beds of the Paskapoo formation with a till covering that is only a few feet thick. How many other knobs in the region are formed like these is not known, but these are almost certainly not exceptional. Valleys worn into bedrock, before deposition of the moraine, also increase in several districts the apparent height of the knolls beside the valleys, as in the northwest of Township 35, Range 23. Large, pre-glacial hills found in several areas, as in sections I5 and I6, Township 36, Range 23, may also accent the morainal development. Nevertheless,it is clear that the recessional moraine in this area is highly developed into knob and kettle arrangement.

The drift in this central mass of the Buffalo

Lake moraine usually has a range in thickness of from 20 to 100 feet, with a general average of about 50 feet. It is thickest towards the centre of this area. North and east of Delburne it ranges between 20 and 60 feet in thickness, west and north of Ghostpine Lake from 40 to 90 feet in thickness, while south and southeast of Goosequill Lake it has an average thickness of about 60 feet. In that area lying east of Ghostpine Lake, towards Delburne and Goosequill Lakes, the drift is mostly between 40 and 100 feet thick, with an average of about 50 or 60 feet. Further east, towards the river, the drift is thinner, with an average thickness of about 30 or 40 feet.

In most places the till composing the moraine is of a clay variety, of a type that water will not easily soak into. Occasionally, as southwest of Ghostpine Lake, the moraine is gravelly and sandy. Many of the ponds and sloughs, which are numerous, contain water through all the year, and some lakes are present. The recessional moraine, except where cleared, is characteristically wooded with cottonwood and aspen, some of large size for this part of Alberta, and often in dense growth.

Recessional Moraine South and East of Buffalo Lake.

South and east of Buffalo Lake the map shows a large area of the recessional moraine. Further north this moraine extends westward, practically surrounding Buffalo Lake. Except for the strip which runs through the town of Stettler, and that near Red Willow and Leahurst, this moraine is strongly developed. The hills are highest, and the valleys deepest, towards Buffalo Lake and further south towards Nevis and Erskine, where many hills are over 75 or 100 feet high. The map reveals that roads are few and generally winding, and that ponds are numerous. In general, this knob and kettle topography is as strongly developed here as anywhere in the map-area. Once again the recessional moraine is characteristically wooded with aspen and cottonwood, which become thinner towards the east. The sloughs, particularly in the west, often contain water all year.

Near Buffalo Lake, the edge of the moraine, which is strongly developed right to the lake, is covered with sand deposited when the lake stood at a higher level. Generally the moraine is composed of till of a clayey texture, though in a few places it is sandy. The drift is about 30 to 50 feet thick in the east, near Leahurst and Red Willow, and has an average thickness of nearly 100 feet in places near Buffalo Lake and Nevis. The drift here is much like that composing the ground moraine farther east (chapter 5).

Southeast trending branches of this moraine extend through the town of Stettler and just east of Erskine. Towards the south these become lower and disappear.

Section Between Red Deer River and Big Valley Creek.

The mass of recessional moraine between the Red Deer River and Big Valley Creek is separated from that above by the valley running northwest past the town of Nevis. Immediately south of this valley the morainal character is strong, with many hills over 50 feet and yet higher hills towards the south. Between Ewing and Foxall Lakes and the Red Deer valley many of the hills rise to more than 75 or 100 feet, and the terrain is extremely irregular. Further south the morainal hills are lower, and they gradually die out near Scollard.

North of Foxall Lake a rolling ground moraine gradually increases in roughness towards the west and becomes knob and kettle moraine. Elsewhere, to the west of Big Valley Creek, the knob and kettle moraine appears to begin suddenly. This is partly, of course, due to the continuation of the moraine on the opposite side of Big Valley Creek Valley, so that the real boundary of the moraine is farther east.

From Big Valley Creek westward the surface rises until it is 300 or 400 feet above the valley. This gives a first impression of a great thickness of moraine, but closer examination discloses that the higher ground is largely due to rising bedrock, and that the drift here, as elsewhere, is seldom as thick as at first indicated. Indeed, near the river west of the town of Big Valley the drift cover is quite thin.

In Township 35 and in the southern half of Township 36, the morainal character is strongest in the east near Big Valley Creek, where some hills are around 75 feet high. Further west, towards the Red Deer River, the recessional moraine is largely confined to valleys.

In most of this region between Big Valley Creek and Red Deer River the drift cover has an average thickness of more than 50 feet. The till is here becoming lighter in colour than on the other side of the Red Deer River, due to the growing influence of material from the Edmonton formation. It is mostly of a clay type with a few more sandy areas in the north. As in the ground moraine farther east, pebbles and boulders are not in great number, and the proportion of quartzite fragments is decreasing as compared with farther west.

Most of this region of the recessional moraine is wooded with aspen and cottonwood, though they become fewer towards the south. Sloughs and ponds are numerous, especially in the north where many of the kettles hold water the year around, but lakes of any considerable size are few.

Southeast Section of Buffalo Lake Moraine.

One large mass of recessional moraine in the map-area yet remains to be discussed, namely the irregular-outlined mass in the southeast.

The part of this moraine in Townships 33 and 34, Ranges I5 to 20 inclusive, has not received as much study as the rest, and its outlines are partly drawn from aerial photographs.

This recessional moraine is separated from that just described by the large valley of Big Valley Creek, and is more or less a continuation of both that section and the knob and kettle moraine west of the Red Deer River.

The knob and kettle development is strong practically everywhere in the central part of this mass. Its boundaries are usually indefinite, with the recessional moraine slowly grading into a low, rolling ground moraine. The few places where the boundary is more distinct include the sections south and east of Gough Lake, near Lowden Lake, and near Big Valley Creek where, as mentioned, the moraine continues on the other side of the valley.

East of Ewing Lake, in the region near Fenn and around Lowden Lake, the morainal development increases southward until hills rise 50, 75 or in some places even 100, feet above nearby valleys. This stronger character continues south through Townships 36 and 35, with numerous hills above 50 feet high, and some even over I00 feet. West of Rumsey the moraine is more moderate and varied, and the hills are mostly from 20 to 50 feet in height.

An area the size of several townships, in which no roads and few contour lines are shown on the map, lies about five miles east of Rumsey and Scollard. This is, at present, given over to cattle ranging. All this region, and some of the recessional moraine adjacent to it, possesses certain pecularities. Most of the hills rise to heights of 30 to 50 feet, have a rounded form and are all of about equal breadth. Their tops, being at much the same altitude, form a fairly even horizon. One may look from the top of one of these hills, and see for several miles nearly all the hills rising to an approximately horizontal line. Every here and there, however, one hill rises about 100 feet higher, but intermediate heights are uncommon. These higher hills are sometimes flat-topped. The reason why the moraine in this region should have these pecularities is not known.

Knob and kettle moraine of a moderate type extends east in Township 34, and then to the southeast corner of the map-area with fairly strong development.

The map shows a northward projection of the Buffalo Lake moraine in the east, stretching north in a broad mass past Byemoor and Endiang, to the west of Sullivan Lake. The boundaries of this recessional moraine are rather indefinite, with the rolling ground moraine of surrounding districts gradually changing to a most irregular and complex system of morainal hills towards the centre of this mass. What are probably the highest and largest morainal hills in the map-area lie in Township 35, in the west of Range 15 and in the eastern part of Range 16. Some of these hills rise to more than 150 feet above the nearby valleys, and a few are nearly 200 feet above the kettles. These heights are rather startling when the comparatively small size of this projection of the Buffalo Lake moraine (about 50 square miles) is realized.

Most of the drift composing the recessional moraine in this region east of Big Valley Creek in the southeast of the map-area is a clayey till. In several places, such as east of the town of Big Valley, it is more sandy. The influence of the bentonitic shales of the Edmonton formation is seen in the light colour of much of the moraine. The number of boulders and pebbles is moderate, and the pieces of quartzite, while decreasing in proportion, still are in greatest number.

Kettles are exceedingly numerous throughtout this section of recessional moraine, but sloughs and ponds are fewer than in the other knob and kettle areas mentioned, probably mostly because of a greater rate of evaporation and slightly less annual precipitation here. The area east of Rumsey is practically without ponds, as is also the area east, south and west of Scapa. Although more numerous elsewhere, they are never so common as in the parts of the Buffalo Lake moraine described previously.

Except near sloughs, trees are completely lacking in the southern and eastern parts of this section of the Buffalo Lake moraine. They are more numerous in the northern and western parts, but never as numerous as in recessional moraine areas further west and north.

Chapter 5.

The Areas East and Northeast of the Buffalo Lake Moraine.

The Buffalo Lake moraine ends in the east with a boundary that is in places distinct and elsewhere has a gradation into ground moraine. The area to the east, including about 27 townships, has certain prominent characteristics. Among these are the thinness of the drift covering; the youthful stream and gully system; the number of broad, shallow basins without outlet; a fairly arid climate and a general lack of trees.

Only a small part of this region lies above 2,800 feet elevation, and this higher country is in the south and west in the vicinity of the Buffalo Lake moraine. From these higher regions the surface slopes away at a general rate of about I5 feet to a mile, and in the extreme north-east it is lower than 2,400 feet.

The drift is surprisingly thin over this area. Indeed,it is thin as far as the Viking moraine, about 50 miles east of the Buffalo Lake moraine, and this region of thin drift constitutes what is known as the Torlea Flats (see number 20 in bibliography). In that district west of Warden, to the north of Ewing Lake and south of Erskine, the drift, including glacial-lake sands and outwash, is generally from 20 to 50 feet thick, while in the east of the area it is generally thinner than 20 or 30 feet. Indeed, in areas comprising over I00 square miles, bedrock outcrops fairly continuously.

This whole area is underlain by the Edmonton formation except for the small sections of Bearpaw, along Battle River and Paintearth Creek, previously mentioned (p. I4).

Description of the Till. The till in this area is typically white or light grey; it is generally of a clay composition and contains few pebbles or boulders. These characteristics are produced chiefly by the large content of material from the Edmonton formation, and in some instances it much resembles this formation except for its lack of bedding and its content of pebbles. As the Edmonton formation is mostly weak, only pieces of the ironstone layers, small pieces of coal, and a little of the harder sandstones can retain a fair size in the till and not crumble. Thus this formation supplies few pebbles or boulders to the drift, and the high content of Edmonton formation is partly responsible for the small proportion of rock fragments in the drift.

Here again the pieces of rock are largely quartzites, granites, schists and dolomites, along with the above mentioned pieces of Edmonton. The proportion of quartzites is much smaller than in the western part of the map-area. This is probably due to there having been fewer pre-glacial deposits of gravel here than in the west. This decrease in quartzites partly accounts for the smaller percentage of pebbles and boulders in the till.

Lakes and Glacial Erosion. The lakes in this area include Foxall and Ewing Lakes, which are really part of Big Valley Creek; Sullivan Lake, the largest; and Gough, Marion, Lonepine, Lowden, Shooting, Lanes and Beltz Lakes. A number of small lakes and sloughs are also present in the areas of glacial-lake sands, but there are few in the north and northeast where better drainage has developed.

Ewing and Foxall Lakes are mainly caused by glacial deepening and blocking of Big Valley Creek. The other lakes have various causes, but they lie mostly in bedrock basins having no outlet. Gough Lake is characteristic of them. It is about eight miles long and four miles wide at its greatest, but is only shallow. It lies near the centre of a gap in the Buffalo Lake moraine. No surface outlet is noticeable, and bedrock is near the surface everywhere around it. This lake seems to lie in a basin carved into bedrock, and does not seem to be due to other causes, such as glacial damming of a valley. Lowden Lake has similar characteristics, also being in a gap in the Buffalo Lake moraine. While Lonepine and Marion Lakes are farther from the moraine, they also are in bedrock basins. Bedrock is exposed nearly right around these lakes, which show no sign of being in former valleys, nor does the topography around suggest previous valleys that could have been dammed. That these broad, shallow basins in the bedrock were carved previous to the retreat of the last ice from this region is indicated by the till lying in them, and they were certainly formed by ice erosion. Wind is the only other agent that could have formed such basins, but their irregular shape, and the fact that they would have, in order now to contain till, to have been formed before the last glaciation, which would have filled and modified them, rejects formation by wind. As the last glaciation has erased all traces of previous ones from this region, and has also much modified and eroded the bedrock, these basins must result from the last ice-sheet. These bedrock basins, the absence of till from previous glaciation, bedrock modifications, along with the small amount of drift, all indicate that this was a region of active erosion by the last glaciation. This is further supported by the large amount of material from the Edmonton formation contained in the drift, both here and farther west, which could have been picked up only in the strip about 40 miles wide, from east to west, that is underlain by the Edmonton formation, and which lies mostly in this region.

The time of this active ice erosion, if it was more or less limited to any stage, is, of course, uncertain. The most likely period seems to be when the Buffalo Lake moraine was being built, with the actively-moving ice carrying the eroded material farther west and southwest.

Ground Moraine. Ground moraine, composed of the till described previously (p. 54), covers the largest part of this region. The next largest portion is covered with lake deposits, mostly sand, showing reworking by the wind. Other areas have exposed bedrock or are covered by water.

Ground moraine is shown on the map as covering about 680 square miles northeast of the Buffalo Lake moraine. As it also underlies most of the lake sands, and as some of the areas marked as bedrock have a thin covering of moraine, this figure is but approximate.

The ground moraine areas are often flattish, or reflect underlying broad bedrock hills and ridges through the thin till covering. In a few districts the moraine itself causes a more hilly surface, as near the town of Halkirk; north of Marion and Lonepine Lakes; between Battle River and Paintearth Creek in the east of the area; south and southeast of Stettler; and near Ewing and Foxall Lakes. Among the areas which have a very smooth moraine surface are the districts south of Gough Lake; west and northwest of Gough Lake; around Hackett; and near Gadsby.

The following table gives approximate figures for the thickness of the drift northeast of the Buffalo Lake moraine.

Table 3.

Township	Range	Greatest Thickness	Least Thickness	Usually Thinner Than	Average Thickness
35	I5	5 feet	0 feet	feet	0 feet
36	I5	I0	0	5	4
37	I5	I5	0	5	2-3
38	I5	I5	0	I0	7-8
39	I5	I5	0	I0	7-8
40	I5	I5	0	I0	7-8
36	I6	I5	0	I0	5
37	I6	I0	0	I0	5
38	I6	20	0	I5	6-7
39	I6	20	0	I5	8-9
40	I6	40	0	20	I5
35	I7	40	0	20	I5
36	I7	40	0	20	I2
37	I7	30	0	I5	I0
38	I7	20	2	I0	7-8
39	I7	20	2	I5	I0
40	I7	40	2	I5	I2
35	I8	20	0	I0	7-8
36	I8	20	2	I5	8-9
37	I8	20	0	I5	5
38	I8	30	2	25	I2
39	I8	30	I0	25	I5-20
40	I8	40	I0	25	20
37	I9	50	0	40	20
38	I9	45	0	30	I8
39	I9	50?	30	40?	35?
37	20	70-80?	30	60?	40?
38	20	70?	5	40	30
39	20		5	40	25?
38	2I	60	I5	50	30.

Notes. 'Least Thickness' and 'Greatest,Thickness' refer to the smallest and greatest average thickness found in any area of about one-half square mile.

'Usually Thinner Than' gives a thickness that is surpassed in only a few small areas.

It must be remembered that these are approximate figures, and give only a general idea of the thickness of the drift. As figures can be given only for those areas where information could be obtained, thicker drift of such features as valley fillings, though such are here very unlikely, could easily have escaped notice. Also a thin layer of drift may cover the bedrock so effectively as to appear to be of greater thickness.

Certain features stand out from the above figures. First, of course, is the striking thinness of the drift over broad districts. In 23 of the 30 townships mentioned the average thickness of the drift (not including the recessional moraine areas) is less than 20 feet. The second feature is the thickening of the drift to the west and the northwest, which is, in places, accentuated by a covering of lake deposits.

The thinness of the drift requires some explanation. As previously mentioned (p. 56), this must have been a region of active ice erosion during the formation of the Buffalo Lake moraine. The ice must later have stagnated, leaving only the material it then contained to be deposited, without addition from outside. This would partly account for the thinness of the drift, and also partly explain the lack of glacial features in the Torlea Flats.

While erosion after retreat of the ice no doubt has had some effect, it cannot, except locally, have removed much of the till, for the stream system in the areas of thinnest drift is very poorly developed and could not possibly have carried off much of the drift. Erosion would also have removed proportionately more of the finer material, and left behind a concentration of the coarser, but boulders and pebbles are generally few. Several districts have deposits of gravel and concentrations of boulders, such as near some seasonally active streams north of Sullivan Lake; near Battle River to the north; and in the shallow lake area, to be shortly mentioned, northeast of Red Willow. But post-glacial erosion cannot be used as a major factor in explaining the thinness of the drift in much of the area, and its thinness must be largely original with the drift. This region of little drift (Torlea Flats) includes most of the district from the Buffalo Lake moraine to the Viking moraine, a distance of more than 50 miles.

<u>The Lake Sands Near Stettler and Lowden Lake.</u> The lake sands are present in patches of varying sizes, but the largest and most important is about six miles southwest of the town of Stettler. It includes about 65 square miles and has a greatest thickness of about 50 feet. It seems everywhere to be underlain by a gently rolling till. In the north the sand is coarse to fine, but it becomes finer towards the south where it grades in places into silt.

This sand area is important as a source of water, which is usually at shallow depth. This water supports a growth of poplar trees that is heavy for the district, and in many cases the edges of the sand areas are shown accurately by where the trees cease. (The ordinary till of the region does not generally have tree growth, as water from the small precipitation runs off the clayey till without soaking in, as in the sand areas. Trees often grow on till near those ponds and sloughs which hold water most of the year, and on recessional moraine.)

The surface of this sand area is gently rolling, with hills IO, 20 or 30 feet high; it is most hilly in the south near the recessional moraine and least so in the north. Swamps and sloughs occupy many of the hollows. This rolling surface is not caused primarily by the sand, but is a reflection of the top of the underneath till or, in the case of the broader hills, of the bedrock. The sand covering the till is discontinuous, with the till often showing, and in some parts of this lake sands area the sand is present only in scattered patches. In the lower ground the sand is often 20 to 50 feet thick.

This sand has been reworked by the wind, being carried from some areas, especially in the north, and settling mainly farther south, and much of that section of the Buffalo Lake moraine north of Big Valley Creek has a covering of sand.

The outlet for the water which deposited most of this sand seems to have been along the valley past Nevis, due west to the Red Deer River. Later some water may have drained to the east. This sand is connected to that around Lowden Lake.

The sand near Lowden Lake, which was once more extensive, has been partly reworked by wind, probably settling over the recessional moraine to the south and east, which in places has a covering of sand. The sand was probably deposited after this portion of the Buffalo Lake moraine was formed, between the moraine and the stagnant ice which blocked drainage to the northeast.

Sands Northeast of Red Willow. Another area of lake sand lies along the northern edge of the map-area, in Township 40, Ranges I6 to I8. This area, as shown on the map, comprises about 60 square miles, and it continues further north. This is a district of low relief, with a general slope to the northeast, and with some gentle hills that are lower than 10 or 20 feet. The ground moraine seen in the vicinity and composed of the till previously described (p. 54) continues through this area. Overlying it are discontinuous patches of sand which in a few places have a thickness of 20 feet, but which are usually much thinner. There is no way of foretelling where these patches of sand will be found. In a few cases they are found on higher ground, sometimes on slopes and in many instances on lower places. Around these patches of sand the till has often been partly reworked with consequent removal of much fine material, leaving pebbles and boulders on the surface.

These sands most likely result from deposits in a number of separate, short-lived, shallow lakes, formed after much of the ice had melted, with perhaps some stagnant ice remaining and supplying material, and with drainage largely blocked. This region still has not developed a good drainage system, and many swamps remain. However, though drainage and erosion of this area would be slow, the present sand areas do not properly represent these lakes, as the sand has certainly been removed from some areas by water and wind, and redeposited elsewhere. (No sign of dunes or other wind deposits was seen in the surrounding districts, however.)

As it is practically impossible to outline the separate spots of lake deposits, all this region of intermingled patches of sand and till has been mapped together, with the edge drawn about where the sands are first common. It will be noticed that this boundary corresponds little to contours.

<u>Other Lake Sand Areas.</u> Another area of lake sands, near

Shooting Lake, has generally coarse sand with some gravel. Another area of lake sands lies east of Gough Lake, and near Leo some of this sand has been duned by wind to a height of perhaps 30 feet. Thin lake sands of much the same type are also present south of the Buffalo Lake moraine, surrounding and in the vicinity of Farrell Lake. These sand areas are of only minor importance, however, but now and then some water is obtained from them for local use.

Other Types of Surface Covering. Among the types of surface covering in this area not yet mentioned are the water surface and the three or four different varieties of bedrock outcrop. The area covered by water is extremely variable, and may in years of little precipitation decrease to one-third or one-half of normal. The part of this region usually covered by water is, however, about 65 square miles (east of Buffalo Lake moraine up to the edges of the map-area). Most of the lakes are in areas of thin ground moraine, and they lie either on a thin layer of ground moraine or directly on the bedrock. The lakes are all shallow.

In more than 100 square miles, as shown on the map, bedrock is either at the surface or covered by only a thin, lessthan three feet thick, layer of till, with the patches of bedrock and thin till covering intermingled. As the nearness of bedrock to the surface is here the important factor in water supply, these areas of thin till and exposed bedrock are mapped together. These areas not only are barren of trees, but often have practically no vegetation whatever.

Various causes are responsible for the different areas of bedrock outcrop or extremely thin drift. In some broad regions, as around Lonepine and Marion Lakes, and in

About section 4, Township 36, Range I5.
West shore of Sullivan Lake, showing exposed Edmonton formation. Cliffs about 30 to 40 feet high in foreground, perhaps 20 feet high in middleground. No such cliffs are present on the east side of the lake, but only a smooth, gentle slope is present. Some water of the lake is present in the background, this is very shallow and dries up in dry years. At high water the lake comes right to these cliffs. Shortly after I900, coal seams in the bedrock along this shore were burning. Note barrenness of area, with no trees and scanty grass.

Townships 37 and 38, Range I6, the drift seems never to have been thick, even if it was ever continuous. In other districts the drift cover seems to have been removed by erosion, as over wide areas north of and near Sullivan Lake. Other outcrop appears in beds of ordinary streams, as with many streams in the vicinity of the town of Gadsby, and in the valley of the Battle River, where the thin till covering has been removed. Other outcrop is present where a medium thickness of till has been removed from an area by a complex system of gullies (sections II, I3, I4, Township 37, Range I9, and in the gully and stream system of Paintearth Creek).

The bedrock regions often have less than two inches of soil over the bedrock, or even none at all. Though often naturally deficient of vegetation, some of these bedrock regions are farmed, the soft Edmonton formation being ploughed up, and if precipitation is large a heavy crop may result. These districts are being steadily abandoned, however. Township 37, Range I6, is now mostly deserted; only a part of the bedrock area north of Sullivan Lake is still being farmed; while some of the region near Lonepine and Marion Lakes was never much used. Thus these bedrock regions seldom make successful farms.

Chapter 6.
The Drainage System.

Introduction. The map shows that a majority of the streams in the area follow a generally southeast course. The few exceptions include most of the Red Deer River's course, those of the Blindman River, Battle River and Big Valley Creek; in other words the largest valleys. Of these exceptions, the last third of the Red Deer River's course in the area is nearly southeast, most of that of Big Valley is southeast, while both the Blindman and Battle Rivers have a slight southeast tremd.

It has been mentioned (p. 3) that this area and the surrounding country have a general slope to the northeast. Thus the trend of the streams is nearly perpendicular to the surface slope and to the direction in which they might be expected to flow. Two explanations of this are possible:- control by bedrock or control by glaciation. The theory of bedrock control has several attractions. The southeast trend of the valleys is roughly parallel to the strike of the bedrock. Again, near several of the valleys, outcrops give indications of local bedrock dips toward the centre of the valleys from both sides. As a large proportion of the valleys are cut into bedrock and the drift is often thin, the opportunities for bedrock influence on the streams are increased. The nature of the bedrock, with very soft, uncemented beds alternating with harder ones, would also tend to increase the bedrock's influence on the streams once they had cut down to it.

However, a number of other factors oppose bedrock control of the stream directions. The oldest valleys, which should show most bedrock control, seldom have a southeast course, and the Range 26 Ridge, which is pre-glacial, gives no indication of an early southeast drainage pattern. The large amounts of soft material in the bedrock formations over wide districts would also weaken bedrock control of the streams. The bedrock, also, could exert little control on streams still running on the driftcover, as a number of the southeast-flowing streams do, and it could have little influence on the direction new streams being formed on the drift would take.

The factors mentioned above as working against bedrock control of streams and the direction of their valleys tend to support glacial control. The main evidence for glacial control of stream direction are the following: Many of the southeast-flowing streams were formed during glacial time. The southeast direction of stream flow is more or less parallel to what is thought to have been the approximate ice-front during the advance and retreat of the ice-sheets. The northeast slope of the land would have forced the water to find a passage around the ice, and the most likely direction for it to take would be to the southeast. Altogether, the direction of the streams is as might be expected of any formed under the influence of glaciation.

The map discloses that the southeast trend of the streams is best developed in the western half of the area, and particularly in that region closed on three sides by the Red Deer River. It should be mentioned that several other valleys having a southeast trend, not apparent on the map, are present in this region. The main exceptions to the southeast drainage pattern are west of the Range 26 Ridge, along the broad, old valley of the Red Deer River, and in the east where the precipitation is smaller and where stream valleys are not yet well developed.

Pre-glacial stream valleys differ in several respects from those formed during or after glaciation. They had long periods of time in which to carve valleys, and to adapt themselves to the general slope of the land and to variations in the bedrock. They have had time to carve broad valleys, often many miles in width, which slope gently towards the stream with few or no steep slopes or cliffs. These streams often have broad flood-plains which contain gravel and sand having evidence of pre-glacial deposition. The divides from these streams are well back from them, and generally parallel with them.

Post-glacial stream valleys, on the other hand, are generally narrow with steep walls and cliffs; they tend to have high gradients and are usually in the youthful stage of development. Their tributaries are short with steep gradients, and are often gully-like. Some such valleys were in use only during the melting of the ice, and these now contain practically no streams. One other important characteristic of post-glacial valleys is the general absence of drift in them.

Inter-glacial valleys are intermediate in character, though perhaps tending more towards that of the post-glacial ones. The sides of their valleys usually have a covering of till, which the stream has not as yet been able to remove. In those instances where the stream has been diverted from these valleys, practically none of the till has yet been removed.

It must be remembered that the base-level to which the streams in this map-area are tending (as set by the elevation of water in the Red Deer and Battle Rivers) is several hundred feet below the general land surface. Thus the stream valleys tend to be deep.

Individual Valleys.

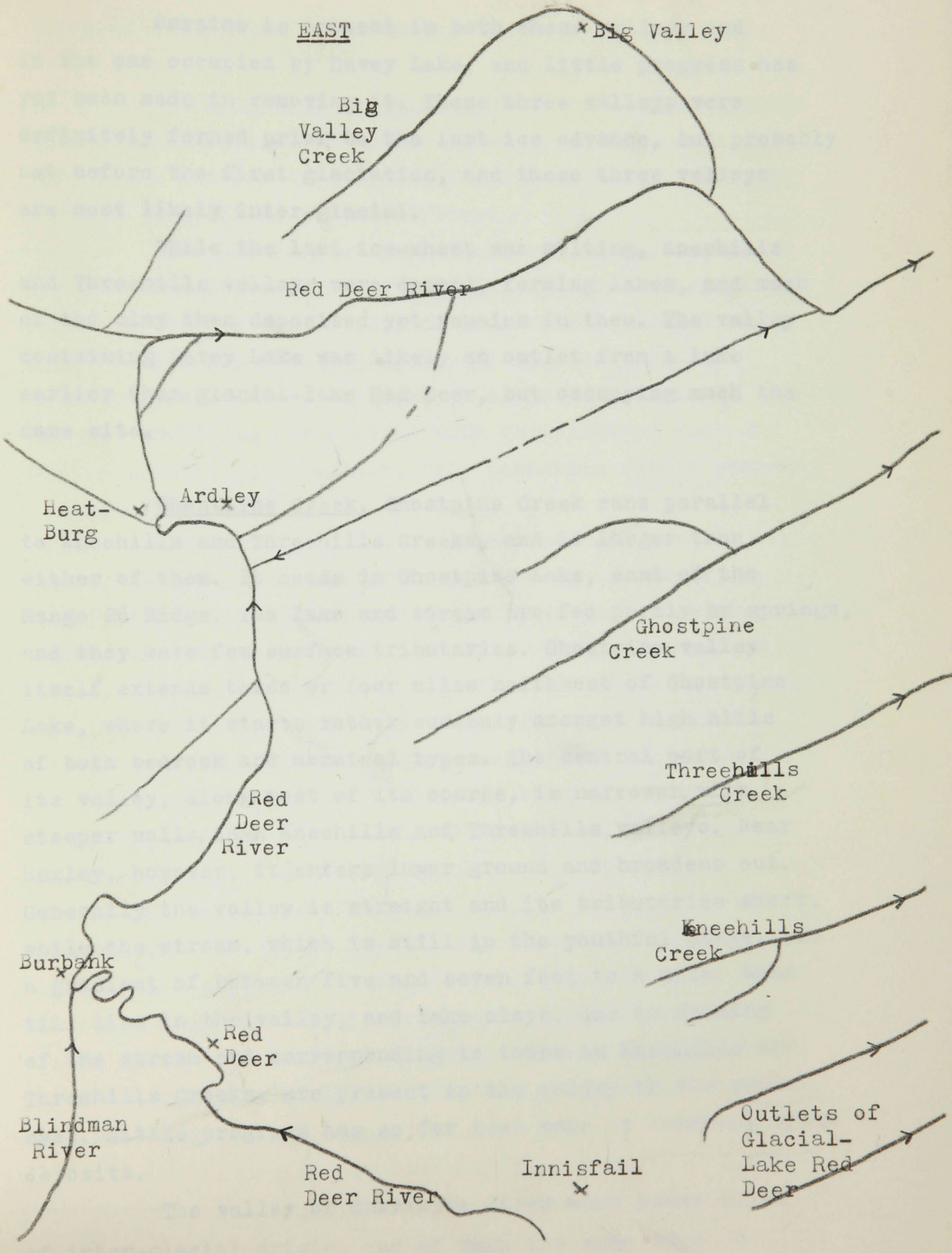
Outlets of Glacial-lake Red Deer. The main valleys will now be examined individually, commencing in the southwest. The first valleys here are the two former outlets of glacial-lake Red Deer, which have been mentioned in the discussion of that lake (p. 20). These are characteristic of post-glacial valleys which were in use only during the retreat of the ice. They are flat-floored, steep-walled, straight, deep (100-250 feet in depth), and have only short streams or gullies as tributaries. Moraine seems entirely absent from the valleys. Most of the depth of the valleys is in bedrock, as the drift cover in the neighbourhood is usually less than 10 feet thick. The gradient of these valleys is from five to ten feet in a mile. These are the best examples of post-glacial valleys in the area.

Davey Lake, Kneehills Creek, Threehills Creek. Davey Lake lies in a valley that has been blocked by recessional moraine, causing the formation of a lake with an outlet to the side of, and at a higher level than, the old valley. This valley joins that of Kneehills Creek, and is comparable in size to it above their junction.

Kneehills and Threehills valleys have many similarities. Both head in the Range 26 Ridge and follow parallel courses southeast. The valleys are straight, V-shaped, several miles wide, and have moderately steep walls and short tributaries. The gradient is rather high, being about five feet to a mile in both cases.

There is some indication of a local dip of bedrock towards the centre of Threehills valley, but nothing very definite could be observed. If the direction of any of the valleys has been controlled by bedrock it is most likely in these two cases, though even here bedrock control is doubtful.

Drainage Pattern of Eastern two-thirds of Red Deer Map-Area.



Scale: about six miles to an inch.

WEST.

moraine is present in both these valleys and in the one occupied by Davey Lake, and little progress has yet been made in removing it. These three valleys were definitely formed prior to the last ice advance, but probably not before the first glaciation, and these three valleys are most likely inter-glacial.

While the last ice-sheet was melting, Kneehills and Threehills valleys were dammed, forming lakes, and much of the clay then deposited yet remains in them. The valley containing Davey Lake was likely an outlet from a lake earlier than glacial-lake Red Deer, but occupying much the same site.

Ghostpine Creek. Ghostpine Creek runs parallel to Kneehills and Threehills Creeks, and is larger than either of them. It heads in Ghostpine Lake, east of the Range 26 Ridge. The lake and stream are fed partly by springs, and they have few surface tributaries. Ghostpine valley itself extends three or four miles northwest of Ghostpine Lake, where it starts rather suddenly amongst high hills of both bedrock and morainal types. The central part of its valley, along most of its course, is narrower, with steeper walls, than Kneehills and Threehills valleys. Near Huxley, however, it enters lower ground and broadens out. Generally the valley is straight and its tributaries short, while the stream, which is still in the youthful stage, has a gradient of between five and seven feet to a mile. Much till lies in the valley, and lake clays, due to damming of the stream and corresponding to those in Kneehills and Threehills Creeks, are present in the valley to the south-east. Little progress has so far been made in removing these deposits.

The valley of Ghostpine Creek also seems to be of inter-glacial origin, and of much the same type as

Threehills and Kneehills Creeks.

Various Unnamed Valleys. Several unnamed valleys are next in order to the east. These are in the main now streamless and are largely filled with moraine. They also show thr prevailing southeast trend.

The most westerly of these valleys is tributary to Ghostpine Creek just north of the town of Huxley. Its course is marked by a string off small lakes, formed by morainal damming of a valley two miles wide and about 200 feet deep. This also seems to be an inter-glacial valley, and it is now covered with the hills of knob and kettle moraine. This valley, too, commences rather suddenly to the northwest.

The next valley to the east has gentler-sloping valley sides, and is larger, longer, broader and mostly deeper than the one last-mentioned. This valley now has no continuous stream, but its course is marked by a series of lakes, the largest of which are Mikwan, Hummock and Goose-quill in Townships 35 and 36, Range 23. This valley is fairly long, and, surprisingly, reaches the Red Deer River at both ends. In the south it joins this river near the right-angled bend in Township 35, Range 22, while in the north it joins it just west of Ardley in Township 38, Range 24. It has lately been deepened at both ends by streams flowing into the river in opposite directions. The floor of the valley rises from both ends and reaches its highest altitude near the town of Lousana and near Mikwan and Goose-quill Lakes. The Canadian National Railway's line between Trochu and Alix uses this valley for a low route through the surrounding higher land.

This valley is generally more than two or three, and is in places four, five or even more miles wide. It is usually more thwn I50 feet deep, and in the south, where recent cutting has occurred, more than 300 feet. It is usually covered with, and partly filled with, knob and kettle moraine, and mile after mile of rolling topography is present. This is best seen to the west of the valley, south of Hummock Lake, where broad stretches of round hills, some reaching I00 feet above the nearby kettles, occur. Some gravel and sand deposits are present under this moraine; the amount is not known but is probably small.

While this valley is definitely not post-glacial, little else is certain. It is probably inter-glacial. The connection of both ends of the valley to the same river requires some explanation, and possibly the Red Deer River ran through it for a time, either before the river assumed its present course or when it was temporarily blocked. The curves taken by the river at both places where this river joins it may be evidence for this valley being older than that section of the Red Deer River to the east, and this is also indicated by the shapes of the two valleys. Another possibility is that the valley was chiefly formed by a southeast-flowing stream, with its northern part being carved by a more recent stream that is slowly intruding on the older valley and capturing it. The newer stream would, of course, choose the low ground of the old valley up which to advance its head. It should, however, be mentioned that no evidence of this valley is present on the north side of the Red Deer River in Township 38, as might be expected if this valley were older than the Red Deer.

The next valley to the northeast, a lesser one, is also connected at both ends with the Red Deer River. From the Red Deer River in the west of Range 23 it runs north to the same river in the northern part of Township 36. It is comparatively shallow, and often rather narrow, and its sides have low slopes. No stream now runs in this valley, but several lakes, the largest of which is Delburne Lake, are present. The valley practically disappears in sections 5 and 6, Township 37, Range 22. Its floor never reaches as high an altitude as that of the last valley described. It possibly carried the water of the Red Deer River for a short while.

This valley is definitely not post-glacial as it is often deeply covered with knob and kettle moraine, and it most likely was formed in inter-glacial time.

Further northeast, in Township 38, Range 22, a shortcut once taken by the Red Deer River in a southeast direction is probably responsible for a small valley and some gravel deposits there present.

Valleys North of Red Deer River. A few streams north of the Red Deer River have much the same southeast direction of flow, but these are mainly small streams with small valleys. Parlby Creek is the only one with a large valley, and it flows southeast for the first part of its course. Though this stream changes direction near Alix and flows north, the valley running to the southeast past Nevis has the same strike as, and is perfectly aligned with, that part of Parlby Creek flowing southeast. The origin of Parlby Creek seems to have been influenced not only by glaciation, but also by the fact that it is connected with the northern outlets of glacial-lake Red Deer (p. 24).

The southeast trend of valleys is less characteristic of the eastern third of the map-area. Sullivan Lake and its inlet from the northwest are aligned in a southeast direction, while the upper part of Bigknife Creek continues the strike of Sullivan Lake. This latter creek is post-glacial, and Sullivan Lake probably also owes its formation to the last glaciation.

Big Valley Creek. One of the larger valleys yet remaining to be discussed is that of Big Valley Creek. This valley starts rather suddenly northwest of Foxall Lake, and has a southeast trend for the first half of its course. It then makes a nearly right-angled turn to flow southwest into the Red Deer River. Few tributaries are present, and the stream is fed partly by springs.

The valley is large, and must have once carried a large volume of water, though at present it is nearly dry during the summer months. Characteristically, it has a flat floor about a mile wide, with a total valley width of several miles. Usually the valley is about IOO feet deep, and its walls, which are generally higher on the west side, are steepest near the town of Big Valley. No source for the large amount of water needed to carve this valley is evident, though it may have been supplied by a temporarily blocked Red Deer River, or from drainage of a glacial lake north of Ewing Lake. However, both these sources seem unlikely, the former as the valley has no connection with the Red Deer River in the north, and the latter as the amount of water it would supply would not likely prove adequate.

The valley seems to have originated previous to the last glaciation, as morainal hills stretch into it in places, and moraine covers some gravel deposited in it. Its course seems to be partly controlled by bedrock, with the southeast-trending section lying near the contact between the Edmonton and Paskapoo formations. The Paskapoo formation lies chiefly to the west, and the higher banks on that side may be partly due to its greater ability to withstand erosion. The valley is carved almost entirely in bedrock, mostly the Edmonton formation, and good outcrops, including coal seams, are noticeable, especially from the town of Big Valley south.

Other Large Valleys. The larger remaining valleys are those of Paintearth Creek and the Blindman, Battle and Red Deer Rivers. The Blindman River follows a fairly straightforward course down the broad slope of the old Red Deer valley in the western part of the map-area. It is largely the outlet of Gull Lake, and drains the adjacent territory through a short valley about 200 feet deep and a mile or so wide. Only a short section of the Battle River is present in this area, and it occupies a steep-walled valley about 250 feet deep. Paintearth Creek is a collection of gullies, about 220 feet deep and steep-sided. Both it and the Battle River are cut almost totally into bedrock, as the drift cover in the neighbourhood is mostly less than ten feet thick. Both are good examples of valleys formed in weak rocks in nearly semi-arid regions.

Red Deer River. The largest river in the area, and also the one with the largest associated problems, is the Red Deer. At first, after entering this area, all is straightforward; it is a river flowing in a valley it has occupied for a long time. The valley has the expected characteristics, being broad, with the surrounding country sloping gently towards the river for eight, ten or more miles on either side. It is true that after the last glaciation the river recommenced its flow on lake deposits and drift and now has incised meanders(well seen in and around the city of Red Deer), but with only a few minor exceptions it is now following the same course as before the first glaciation. This section of the river is mostly in a late

About section 32, Township 38, Range 26.
The Red Deer River just after cutting through the Range 26 Ridge. The valley is over 400 feet deep at this point, and less than a mile wide.

About section 13, Township 38, Range 26.
The valley of the Red Deer River during its eastward course. Valley about 200 feet deep here. Taken during low water. Month off August.

youth stage, and has a fairly high gradient.

Near Burbank, however, the river swings suddenly from its old course to flow southeast, and its whole pattern changes. Thence it runs through a narrow valley, little more than a mile wide and almost 600 feet deep, and it is here that the problems begin to arise.

The Red Deer River has chosen to cut through the Range 26 Ridge in one of its higher sections. Either lake water west of the ridge once reached the altitude of this section of the ridge (at present about 3,200 feet) and so started to pour over it, or a stream (either tributary to the Red Deer or flowing east or southeast) had earlier carved a valley, however small, which enabled the lake waters to find a passage across the ridge at a lower elevation. Since at several other points the ridge can at present be crossed at 50 or 100 feet below 3,200 feet, it thus seems likely that a former valley tributary to the old Red Deer, determined the point at which the new diversion of the river crossed the ridge. Because this small stream likely flowed northwest into the Red Deer like a normal tributary, this would partly explain why the Red Deer swings so sharply to flow southeast, and not east, for a stretch.

After passing the Range 26 Ridge the river flows more or less eastward for about 15 miles. In this stretch the country on either side slopes towards the river from several miles back. Near the river itself the valley walls drop quite steeply about 150 feet, and the appearance is of the river having incised its way below an older valley.

At Ardley the river swings again to flow north for several miles, and then once more flows east for about ten miles. The river still has much the same appearance, that of a steep-walled valley cut 100 or 200 feet below an older valley which is many miles wide with gently-sloping sides. Then at Nevis the river suddenly swings south, and the character of its valley changes completely, as described later.

Sections are given in the chapter on economic geology (chapter 7) that show what apparently are Saskatchewan gravels lying below two tills. This gravel presently lies at an elevation of less than 2,650 feet, about 150 feet lower than the Saskatchewan gravels near the city of Red Deer, which are at an elevation of about 2,800 feet. As shown in the sections, these are fairly coarse, river-laid gravels, generally 10 to 20 feet thick. These gravels immediately raise questions. If they are pre-glacial, as seems likely from their character and from their position under the tills, they indicate that a sizable pre-glacial stream flowed in this region. The comparative elevations of these gravels and those near the city of Red Deer would indicate that this stream could be the Red Deer River, but, as previously mentioned (p. 25), the evidence indicates that the river has used this section of its course only since the coming of glaciation diverted it from its old course. If, however, the Red Deer was first turned from its old course by mountain glaciation, the gravels at Ardley could still have been deposited by the Red Deer and yet contain only pebbles and boulders of mountain and local origin. No evidence has been noted, however, which indicates that western glaciation ever advanced far enough east (p. 8) as to interfere with the Red Deer River in this region.

Another possibility is that the Red Deer River was diverted very early in the Glacial Age, and this seems likely, before many igneous and metamorphic boulders had been brought this far west by the Keewatin ice, and as a result the gravels were deposited while the river was carrying practically none but mountain type boulders. The drift of later glaciations would then be deposited over the gravels. This would require three Keewatin glaciations altogether, and no drift from such an early glaciation seems to be present. This, however, means little, as the best remnants of drift from intermediate glaciations are in this valley, which, by this hypothesis, would not have been present to retain till from such an early glaciation.

A third possibility is that the gravels were laid down by a stream other than the Red Deer. This immediately raises some difficulties, both as to where the stream could collect such gravel (mostly of mountain origin), and the stream's course. If the present course of the Red Deer River is excepted, no valley exists, and none seems ever to have existed, that could have been the means of bringing the gravel directly from the mountains. It is also unlikely that the gravel could have been collected locally from earlier, higher deposits and then redeposited here (from Oligocene? gravels such as are presently seen on the Hand Hills, further south, at an elevation of about 3,500 feet). For not only is there no valley system present that could have collected these gravels, apart from the Red Deer, but also, any stream to do this would have to wear its valley below 2,650 feet elevation to deposit the gravels at that altitude, and all the surrounding area is appreciably higher. The course of such a stream away from Ardley is also puzzling. It would have to be lower than 2,650 feet elevation, and this is impossible to the south and west. There are only two possibilities:- through the valley southeast of Nevis, or through the region of Buffalo Lake. The former can be rejected, for further east the water has no means of escape from this valley at an altitude of less than 2,700 feet. Drainage through the Buffalo Lake region is just possible if drift has filled up a previous channel, but no such

About section 13, Township 36, Range 22.
The Red Deer River in its southward course, east of Lousana. Edmonton formation bedrock in foreground. Typical of the Red Deer valley during its southward course. River in background, gully in foreground.

NW quarter of section 16, Township 31, Range 21.
The valley of the Red Deer River from a distance of about one-half mile. Shows sudden drop of the valley from prairie level during river's southward course.

filled channel seems to be present, and in any case its gradient would have to be nearly nil. Thus it is difficult to see how these gravels could have been deposited by any other agency but the Red Deer River, after it had been diverted from its old valley.

The Red Deer River, as it crosses Ranges 24 to 22, has several tributary valleys. Those joining it from the south, of which the one containing Delburne Lake is the largest, have been described earlier. Near Heatburg a large valley enters from the north, and whereas it now has only a small stream, it seems previously to have been related to Parlby Creek and Buffalo Lake. Another tributary from the north is the large valley containing Tail Creek, which is a northward continuation of that valley which is used by the Red Deer River to flow southward in Range 22. This valley of Tail Creek must at one time have carried a large volume of water.

It should be remarked that for that section of the Red Deer River so far described there is no evidence of bedrock having played any large role in controlling the course of the river.

In that section of the river flowing east from Heatburg no Saskatchewan gravels are apparent. A section, given in the chapter on economic geology (chapter 7), has river gravels lying over the lower till. Though whether or not the Red Deer River formerly flowed north towards Alix and then south in the valley of Tail Creek, before using this southern shortcut, is indefinite, the river must have used this shortcut at a fairly early time, for a valley was present in which the lower of the tills was deposited.

For about 30 miles south of the town of Nevis the Red Deer River has a south to southeast course. Then, after turning and flowing southwest for about 10 miles, it again swings back to a southeast course. In all this distance its valley is seldom more than three miles wide, and in some places less than one. The valley is deep, however, the depth being almost everywhere greater than 400 feet, and in places (across Townships 36 and 37) nearly 600 feet deep. In its passage through this region the river seems to have disregarded easier courses for its present one, and is not affected by topographical features but has cut its valley indiscriminately through ridges and valleys, past higher and lower ground, and has not confined itself to the course that would be indicated by the land surface. Near the earlier-described sections of this river the country for several miles back tended to slope towards it, but no such tendency is evident here. In truth, the land a mile or so back is singularly unaffected by the nearness of the river, and has no general slope towards it, and has, it seems, more or less the same topographic features as were present before the river had its present course. This part of the river has not yet had time to influence the nearby country, and the topography indicates that in choosing its present course the river was almost independent of surface features. For instance, the ground through which the valley was cut is almost entirely above 2,800 feet present elevation, and mostly above 2,900 feet. But if the river had taken a course through Buffalo Lake it would nowhere have had to cross land higher than 2,700 feet, and if through the valley south of Nevis none over 2,750 feet elevation. Also a southward course a little farther east would have taken advantage of the much lower average surface over the Edmonton formation. The Edmonton formation, too, would probably have been easier to cut into. But the river has ignored all these advantages and given preference to its present route.

Probably several factors operating together caused the choice of this route. Amongst these would be blockage of the 'more favourable' routes by ice and drift, and the presence of an earlier small valley or valleys along its present course which the river could appropriate. Bedrock may in places have played a large role in determining which route the river would follow.

It should be mentioned that only the upper till (see sections in chapters 7 and 9) is present in this section of the valley, and that the only appearance of Saskatchewan gravels (in sections 29 and 32, Township 33, Range 22) seems entirely unconnected with the river. The modern till and moraine, however, enters the valley in places, mainly farther south, and parts of the valley show some effect of planing by the ice. This section of the river course seems to have been chosen previously to the last glaciation here, but its relation to earlier ones is uncertain.

It seems certain that earlier streams had carved small valleys in the present river course before the appearance of the Red Deer. Along most of this section of the river a bench, usually between 2,700 and 2,800 feet elevation, appears on both sides. This seems to represent an older stream valley, shallow but comparatively wide, below which the modern valley is cut sharply several hundred feet. There were probably two of these old valleys, one of which flowed north into Tail Creek, while further south along the valley another probably flowed to the south. These old valleys had almost certainly cut through the Paskapoo formation along all this section, thus simplifying the work of the later Red Deer. These old valleys apparently were close to a base-level, and later cutting by the Red Deer River to a new base-level has rejuvenated the tributaries, such as Big Valley Creek.

Blockage by ice lying to the north and east certainly played a large part in determining the location of this section of the Red Deer. The blocking of the area to the northeast would greatly limit the outlets (closing off the Buffalo Lake and Nevis routes) open to the waters of the Red Deer, and could have made these small valleys mentioned just above the best escape route. Once the water had commenced flowing here, it would have little trouble in cutting a deep valley into the Edmonton formation with a large volume of rapidly-moving water, a valley deep enough to retain the water after the blocking ice to the northeast had melted.

From Burbank on, the river is in a stage of late youth. It is at present reaching a base-level determined by the level of the South Saskatchewan River at the point where the Red Deer enters. The valley is cut almost entirely in bedrock, as the covering of drift in the neighbourhood is thin. The amount of control exercised by the bedrock on the river's direction is not known, but it may have been great.

The two right-angled turns of the river, in Townships 34 and 33, may be inherited from the former streams. Their most likely cause is stream capture. As the above-mentioned bench is lower in the south than in the north, the most likely possibility is the capture of part of a valley flowing towards Tail Creek by a branch of a stream flowing southward in the valley now occupied by Goosequill Lake (p. 70) and the part of the Red Deer valley running southeast out of the area to lower land beyond. Other causes for these turns are possible, however, as exceedingly little is known of pre-glacial drainage in the area, and especially in that region east of this part of the Red Deer River, where glacial erosion was very active.

Chapter 7. Economic Geology.

Introduction. This chapter will deal almost exclusively with those economic deposits of glacial or later origin, and with the effect of the drift covering upon the value of economic deposits in the bedrock.

Economic deposits in the unconsolidated cover consist mainly of gravel, sand and clay, stone for building and fill, and, often the most important, aquifers containing water. The value of the soil is also largely determined by the nature of the glacial drift. In some areas, though nowhere here, saline lakes collect valuable salts from the drift. The drift cover also affects the economic geology of the bedrock, increasing the difficulty and expense of finding and developing some deposits, while protecting others from destruction by weathering and erosion. As an example, the amount of coal that could be strip mined with profit would be doubled, trebled or even quadrupled if no drift had to be removed, and at present all the strip mines in the region are in places where there is only a thin drift cover. The covering of drift, however, often slows the weathering of the coal, and thus preserves its value. On the other hand, the drift increases the difficulty of finding the shallow coal seams, and necessitates more drilling to determine if strip mining would be profitable. In water supply, the drift cover forces deeper drilling if bedrock water is desired, and a clay till, such as is usually present here, increases run-off, diminishing the amount of water entering the bedrock. As this thesis deals primarily with glacial geology, bedrock economic deposits will not be discussed further.

As water supply is described elsewhere (chapter 8), only the economic deposits of the unconsolidated cover will be discussed here.

Gravel. Gravel is the chief economic product of the unconsolidated cover in the area. The gravel deposits differ much in quantity, types and sizes of the fragments contained, sorting, and method and time of deposition. The deposits range in size from small ones containing less than I,000 cubic yards to those containing several million cubic yards. Their composition ranges from completely quartzitic sandstone gravels to complex mixtures of quartzites, hard sandstones, granites, gneisses, schists, boulders of other igneous and metamorphic types, and pieces of local bedrock. Some deposits have fair to good stratification, bedding, crossbedding and sorting, whereas others are nothing but a heterogeneous drift containing more pebbles and boulders than the ordinary moraine and having no trace of bedding. Some of the gravel has been transported long distances by water and contains well-rounded pebbles and boulders. Other of the gravel has suffered little water transportation, whereas some of the gravel has had practically no water transportation at all, but is the result of removal of finer material.

The gravel deposits may be classified according to time of deposition, as follows:-

pre-glacial (mostly Saskatchewan) gravels.
glacial gravels
inter-glacial gravels
post-glacial gravels

The first type (pre-glacial) is the only one that does not contain igneous and metamorphic boulders brought from the east by the Keewatin ice-sheets. The glacial gravels are the only ones connected directly with the ice. The inter-glacial and post-glacial gravels are water-laid, but contain boulders brought into the area by the Keewatin ice.

Glacial, pre-glacial and post-glacial gravels are definitely represented in this area, while some inter-glacial gravel is probably present.

Pre-glacial Gravels. The only pre-glacial gravels of importance in the area are those of the Saskatchewan type (see bibliography, reference number I5). These are gravels and sands of post-Cretaceous and post-Miocene? age found at scattered localities in Alberta and Saskatchewan. They were first named the South Saskatchewan gravels by McConnell (see number 9 in bibliography), and the name Saskatchewan was later extended to similar gravels in Alberta. In this area these gravels consist almost entirely of quartzites or hard sandstone pieces, along with minor amounts of other material, such as the local bedrock. Pieces of igneous rock are characteristically absent. The pebbles and boulders forming this gravel are nearly always well-rounded, and the gravels are well sorted and bedded. The individual fragments are usually of smaller diameter than six inches, though some are larger. This gravel is essentially composed of material originally transported from the west (Rocky Mountains), and the gravels are chiefly found near present and past river channels.

These gravels were certainly more widely distributed before glaciation. Enormous quantities of them were picked up by the ice, and their quartzites and hard sandstones are the chief types of boulders found in the drift. A previous wide distribution is also indicated by the scattered patches of them still remaining.

In this area these gravels are most commonly found along the valleys of the Red Deer and the Battle Rivers, though what are probably Saskatchewan gravels, or redeposited Saskatchewan gravels, are also present in several other places. These gravels also supplied much of the material presently in the glacial and later gravel deposits.

Inter-glacial Gravels. Inter-glacial gravels are doubtless present, though they are more difficult to recognize. Much of that gravel along the section of the Red Deer River flowing east of Heatburg is probably inter-glacial.

Post-glacial Gravels. Post-glacial gravels are found, usually in minor amount, along modern rivers and streams, both as new deposits and as reworking of previous ones.

Glacial Gravels. Glacial gravels are present everywhere in the area, though usually in small and widely scattered deposits. In a few areas these deposits are of a fair size. These gravels vary more in composition, sorting, stratification, size of the fragments and size of the deposits, than the other types of gravels.

Individual Gravel Deposits.

Gravel Near Red Deer and Blindman Rivers. The Red Deer River has large deposits of gravel beside its northeastward and eastward flowing sections. During the river's south or southeastward course in Ranges 22 and 21 practically no gravels are present beside it.

A fairly coarse gravel, with boulders that are usually less than six inches in the longest dimension, lies along all the Red Deer's present channel. Little use has been made of this gravel, and it would be costly to gather.

Apart from that in the channel itself, gravel is commonly present along the Red Deer's valley. On the west bank, for ten or so miles northward from where the river enters this area northwest of the town of Innisfail, scattered deposits of gravel collected from reworking of the till by water are present. Some of these deposits are fairly large, such as those near the bridge west of Penhold. This gravel contains igneous and metamorphic boulders brought by the Keewatin ice, along with the pieces of quartzite.

The largest gravel deposits in the map-area are near the city of Red Deer. These extend along the river and back from it, north to past Blackfalds, west along the Blindman River, east to Burbank, and south past Labuma where the gravel is well exposed on the west bank of the Red Deer River. This gravel is the source of much of that in the river channel itself. At present it is being dug from several small pits in and around the city of Red Deer, and from a large pit south of the Town of Blackfalds, and in the past it has been much used by railroads.

These gravels are practically all quartzitic sandstones, along with a few pieces of local bedrock. Along the Red Deer River the gravel contains no boulders brought by the Keewatin ice, except for the few in cuts which have been dropped from the overlying till. The gravel in the pit south of Blackfalds, however, although still predominantly quartzites, contains a great number of igneous boulders. Though most of this gravel seems to be of the pre-glacial, Saskatchewan type, in some areas it evidently has been reworked by water after the advent of the Keewatin ice, with the addition of foreign boulders.

These gravels seem everywhere to be river laid, as they are much crossbedded and the rock pieces are well rounded and sorted. The boulders have a wide range of sizes, but they are usually less than six inches in the longest dimension (though larger ones are present), and lenses of sand and fine gravel are present.

A few sections may help indicate the position and size of these deposits.

Bank of Red Deer River.

SW quarter, section I9, Township 38, Range 27, West of the Fourth Meridian.

5 feet	Varved silts and clays, containing no pebbles.
20 feet	Sandy till, containing numerous pebbles, some brought by Keewatin ice.
0-I foot	Fine gravel and sand, representing a former stream bed.
I8 feet	Clayey till of a dark colour, containing numerous pebbles of granite, schist, quartzite types, also coal fragments.
20 feet	Gravel. Fine sand to boulders, coarsely sorted, and containing no granite or schist pebbles, but nearly all quartzite.
63-64 feet	Total thickness of unconsolidated deposits.
30 feet	Paskapoo formation exposed.
93 - I03 feet	Total thickness.

Bank of Red Deer River.

W half of section 7, Township 39, Range 26, West of the Fourth Meridian.

I0 feet	Varved clay and silt, containing no pebbles.
25 feet	Sandy till of buff colour, containing pebbles brought by the Keewatin ice.
20 feet	Clayey till of black colour, containing many boulders brought by Keewatin ice.
25 feet	Gravel, consisting almost entirely of quartzites, with a few igneous types on the surface, probably fallen from overlying tills.
80 feet	Total thickness of unconsolidated deposits.
30 feet	Exposed bedrock, sandstone and shale of the Paskapoo formation.
IIo feet	Total thickness.

Bank of Blindman River.

NE quarter, section 13, Township 39, Range 27, West of the Fourth Meridian. (Due south from Burbank).

30 feet	Fine lake sand.
25 feet	Gravel, up to ten inches, containing no boulders brought by the Keewatin ice.
	Exposed bedrock. Shale, sandstone and coal of the Paskapoo formation.

These sections indicate that the gravels are earlier than the Keewatin glaciation, as the gravels are below any present till, and lack Keewatin ice-brought pebbles.

Gravel has recently been drawn from a pit just south of Blackfalds for use on the Calgary-Edmonton highway. At present this pit is about 650 feet long, 500 feet wide and 20 feet deep, and is everywhere in gravel. Thus more than 150,000 cubic yards have already been removed from this pit, and the gravel has a much wider extent. It is mostly coarse, up to six inches in diameter, but sand lenses are present. As previously explained (p. 86), this gravel, while basically of Saskatchewan type, seems to have been redeposited during or after an advance of the Keewatin ice, with the addition of some foreign boulders. The relation of this gravel at Blackfalds to the tills was not observed, for the tills are absent at this point and lake deposits cover the surrounding districts.

An old railroad pit, which lies just southeast, shows the continuation of this gravel.

Gravel is present in the city of Red Deer itself, where several small pits are being used. One, in the southeast quarter of section 17, Township 38, Range 27, West of the Fourth Meridian, has the following section:

Variable thickness of varved clays and silts overlying the buff till locally.

10 feet	Buff till, containing numerous pebbles and boulders, including some brought by the Keewatin ice.
1/2 foot	Dark blue till, containing boulders brought by the Keewatin ice.
15 feet	Gravel, moderately coarse, composed essentially of quartzites, no igneous pebbles present.

It is practically impossible to estimate the amount of gravel present in these districts near the Red Deer and Blindman Rivers. The boundaries of this gravel are not known and are difficult to establish as the gravel is usually under lake deposits and one till, and often under two tills and the lake deposits. The amount is certainly large. In those places where it has been examined the gravel averages about 20 feet in thickness. The deposits seem to cover more than 10 square miles fairly continuously, though not perhaps to the same thickness, and certainly several million cubic yards are present.

The gravel is of good quality and suitable for most purposes for which gravel is used. Its chief advantage is that the boulders are of nearly uniform hardness, with weak stones few in number, which is an advantage in crushing. The quartzites are little weathered and seem resistant to the prevailing climate. As the gravel is rather coarse for most purposes, such as road gravel, it has to be crushed to the desired size.

Enough sand is usually present to fill the voids between the individual boulders, and it should thus be suitable for cement work, especially if the larger pieces are removed or crushed. The only possible disadvantage for this use is the greater hardness of the quartzites as compared to that of the cement itself. To supply small needs, beds of finer gravel can usually be found locally, making crushing unnecessary. These gravel supplies have proved of value in the past, and should be of ever-increasing value.

A large quantity of gravel is present in Township 36, Range 28, mainly in sections 17, 20, 21 and 28. The gravel is heaped into hills, as outwash from the ice. A few boulders are as large as 12 inches across, but most are between 3 and five inches, and much sand is present locally.

The fragments are mostly of quartzite, hard sandstone and chert, but igneous and metamorphic types such as were brought by the Keewatin ice are present in minor amounts. The gravel is coarsely stratified, with much cross-bedding, and the dip, though varying, often seems to be to the east in the places where this gravel has been examined. This gives indication of a late glaciation from the west, and is practically the only evidence for such a glaciation present in this map-area, and it is indefinite, for the general dip could not be well observed. This gravel is being drawn from several pits for use on roads.

While this gravel is more heterogeneous than that described previously, and contains more weak material, it is suitable for most purposes when crushed. The quantity present, though certainly fairly large, is not known. Information from wells indicates that it is more than 90 feet thick in some areas, and that it rests directly on the Paskapoo bedrock.

Somewhat similar gravel is present in the west of sections 19 and 30, Township 35, Range 28, West of the Fourth Meridian, where it forms rolling hills. It is crossbedded, and has a general eastward dip in much the same manner as the last gravel deposit described. It is fairly well sorted, and much sand is present. The material composing this gravel is much the same as that just described in Township 36, Range 28, though generally finer. This is also glacial outwash gravel, containing many boulders from the Saskatchewan gravel that were picked up locally. The quantity is not as large as in Township 36, Range 28.

In Township 35, Range 25, gravel is present, chiefly in sections 2I, 22, 27, 28, with some found through sections 2,II, I5 of Township 34, Range 25. The till in the neighbourhood is sandy and contains many pebbles and boulders. The number of these pebbles and boulders gradually increases towards the sections mentioned above until a poorly-sorted, poorly-stratified gravel, containing much clay and sand in parts, is present. Generally it may be classified as a very gravelly drift. The gravel is heterogeneous, containing pieces of weak, local bedrock, besides boulders from the Saskatchewan gravel and material brought by the Keewatin ice. The individual fragments are of the size usually found in the local till:- some boulders up to a foot or so in diameter, most less than six inches, with much fine material present. A small quantity of good gravel is present in several pockets, and this is mostly being used. Large quantities of low-grade gravel are available, but it needs to be sorted for most uses, and the amount of weak material makes it poor for crushing. It may be suitable for such purposes as road foundations and perhaps road gravel.

A small gravel deposit, containing several thousand cubic yards, lies in the northwest quarter of section 34, Township 37, Range 25. The gravel is composed of local sandstone; granites, gneisses and quartzites brought by the Keewatin ice; along with the quartzites from the Saskatchewan gravels. The components of the gravel, which is poorly sorted, range in size from sands to boulders. The gravel is of glacial outwash origin, and has the mixture of material and the drawbacks usual in such gravels. Thus it is not very suitable for cement work, but may be used for roads and other like purposes.

Gravels Near Big Valley Creek. Several gravel deposits, some of large size, are present along Big Valley Creek. The largest of these lies about five miles south of the town of Big Valley, in sections 3, 4, 9 and 10, Township 35, Range 20, and in sections 32 and 33, Township 34, Range 20. The next in size is four miles south of the town of Fenn, to the west of the creek, in sections 12, 13, 14 and 23, Township 36, Range 20. More gravel is present west of Big Valley Creek, two miles north of Scollard, in sections 31 and 32, Township 34, Range 20, and in sections 25 and 36, Township 34, Range 21. Each of these areas of gravel possesses characteristics peculiar to itself. Descriptions follow.

Sections 3, 4, 9, 10, Township 35, Range 20.
Sections 32, 33, Township 34, Range 20.

This gravel deposit is best examined from a pit of the Canadian National Railways, from which large amounts of gravel have been taken. This pit, which is in the form of a long cut with gravel walls more than 15 feet high, is about one-half mile long.

The gravel is composed of many types of rock fragments, with quartzites and pieces of hard sandstone seemingly in the majority. Pieces of the local Edmonton bedrock are present, and also pieces of schist, granite and gneiss brought by the Keewatin ice. Although the gravel near the pit shows much variation in the sizes of the individual pieces, from coarse sand to boulders of three or four feet diameter, most of the boulders are three or four inches in diameter. Many of the rock fragments are noticeably angular, particularly the pieces of Edmonton bedrock and the schists. Some of the granite pieces are also fairly angular. Those from the quartzites or hard sandstones are most nearly rounded, probably because the ice picked them up already rounded from earlier stream deposits, perhaps from Saskatchewan gravels.

The gravel beside this pit has noticeably little bedding. The lower part of the gravel has none whatever, while in the upper part it is only faint and probably due to later reworking by streams. Such a division between upper and lower parts is also found in the gravel south of Fenn (Township 36, Range 20).

The surface of the gravel is fairly smooth, and is covered in places with six or more feet of what appears to be a buff-coloured till. Large boulders are scattered over the surface, as if finer material had been removed.

This gravel deposit has a wide extent, and another pit is present in it in the northeast quarter of section 32, Township 34, Range 20. The gravel here is finer, mostly ranging in size from coarse sand to larger pieces one or two inches in diameter, with a few boulders as large as six or seven inches. The top part of this gravel is stratified, and the dip is roughly south. The material composing the gravel near this second pit is similar to that in the first. Some of the pieces of granite and schist here appear much weathered.

The whole gravel deposit is more than one and one-half miles long in a north-south direction. Its width is uncertain, as the limit on the east is not known, but it should be wider than one mile at the widest, as the gravel seems to extend up to the recessional moraine, and even under the edge of it. Information gained from wells, and given by persons in the neighbourhood, indicates that the gravel is usually more than 20 feet, and in places as much as 50, feet thick. The quantity of gravel, although difficult to estimate, should well exceed 12,000,000 cubic yards.

The gravel is mostly of good quality, though more heterogeneous and of less uniform hardness than the Saskatchewan gravels. These factors lower its value for crushing, which is necessary for most purposes as so much of the gravel is coarse. For such purposes as road foundations and railroads it can be used directly. The value of the gravel increases to the south, as it becomes finer and better sorted due to farther transportation by water. Gravel from this area should prove suitable,just as it is, for many uses such as road gravel.

This gravel is, as yet, little used, due mostly to the presence in the neighbourhood of other gravel, more accessible and of slightly better quality. Also little demand for large quantities of gravel exists in the locality at present, but this gravel will yet prove a valuable resource.

Sections 12, 13, 14, 23, Township 36 Range 20, West of the Fourth Meridian.

Gravel from this area is being used at present, being drawn mostly from section 14, Township 36, Range 20, in that area between the Canadian National Railways line, and the present highway, from Stettler to Big Valley.

This gravel is similar in some fearures to that just described. Once again it contains a wide mixture of material, including the quartzites and hard sandstones from the Saskatchewan gravels, igneous and metamorphic rock fragments brought by the Keewatin ice, and pieces of local bedrock. As the latter are pieces of the weak Edmonton formation which could only be carried a short distance without crumbling, they indicate that this gravel was not transported far by water.

The lower part of this gravel shows no bedding or sorting, and the pebbles and boulders are only moderately rounded, as in the lower part of the deposit just described. A definite break occurs between this lower gravel and the upper five feet, which is bedded with a dip roughly east. The upper part of the gravel is mostly fine, with individual pieces up to about an inch diameter, while the lower part is coarser. Thus while the upper gravel can often be used directly, the rest of the gravel needs crushing for many uses. The quality of the gravel is good, though not as high as in the Saskatchewan gravels, and pits dug into it are now as deep as 20 feet. The quantity is fairly great, the deposits being as much as 1,000 feet wide and 20 feet thick, and stretching for several miles discontinuously along the west side of Big Valley Creek. While the total amount is hard to estimate, more than 1,000,000 cubic yards of gravel is likely present.

Sections 31, 32, Township 34, Range 20.
Sections 25, 36, Township 34, Range 21.

Patches of gravel, usually as a thin layer under the sod, are present in these sections. The gravel lies on both sides of Big Valley Creek, and is partly a continuation of that described to the northeast. It is composed of a mixture of igneous and metamorphic rock fragments brought by the Keewatin ice, boulders from the Saskatchewan gravels, and a few pieces of local bedrock. It is seldom more than three or four feet thick, and the quantity, while fairly large, is not as great as in the two deposits described just above. The quality is moderately good.

Sections 29, 30, 31, 32, Township 35, Range 19.

The gravel present in this general area is of a very mixed type, containing the igneous and metamorphic rock pieces brought by the Keewatin ice, boulders from the Saskatchewan gravel, and pieces of local bedrock. It is little sorted, and contains sand-sized particles along with boulders of sizes found in the ordinary till. It is seldom of much value, but in a few of the better sorted spots it is more useful. Although pits have been dug in several of these spots and some of the gravel is used locally, it will not be of great importance as long as the better gravel in the neighbourhood lasts.

The limits of this gravel are difficult to determine, as in some places it grades into the brown, gravelly moraine of the area, and in other places it seems to extend under this moraine. Wells dug through the till often enter gravel in the surrounding districts, and all this gravel is probably connected.

The thickness of the gravel varies greatly, but wells indicate that it is sometimes greater than 30 feet. This gravel may join the deposit, previously described, lying five miles south of the town of Big Valley, and the total amount, while unknown, may be large. The quality is only fair to poor.

Other Gravel Deposits.

Vicinity of Sections 28, 29, 32, 33, Township 38, Range 22, West of the Fourth Meridian.

Parts of these sections and some of the surrounding districts, as indicated on the map, contain gravel. Some of the gravel has been used, mostly on roads, with the main pits being in the northwest quarter of section 28, where the gravel is best suited for this purpose.

These pits show a fine gravel, composed of pebbles that are usually less than one inch in diameter, though sizes range from four inches down to that of sand. It has fair stratification, with the beds horizontal or dipping or dipping southeast. The pebbles and boulders are moderately rounded, and include igneous and metamorphic types brought by the Keewatin ice, quartzites from the Saskatchewan gravels, and pieces of the local Edmonton formation. The latter are weak, and could not have been carried far. The gravel near these pits is as much as 25 or 30 feet thick.

The gravel is fairly widespread, though seldom noticeable at the surface. Wells sunk into it have indicated a thickness in places of as much as 60 or 70 feet (northeast quarter of section 32), though it is usually thinner. The amount of gravel present seems large, though difficult to estimate. The quality is fairly good, and is probably highest to the southeast where it is finer and better sorted.

This gravel seems to have been deposited during a diversion of the Red Deer River (p. 72).

Sections 13, 14, 23, 26, 27, 34, 35, Township 38, Range 22, West of the Fourth Meridian.

This gravel is largely composed of a mixture of pebbles and boulders taken from the Saskatchewan gravels and those brought by the Keewatin ice sheets, ranging from sand size up to eight inches in diameter. Very little stratification is noticeable. The gravel overlies buff-coloured till, and is covered by a few feet of water-deposited sand, such as covers much of the surrounding region.

The gravel is from two to fifteen feet thick, but the quantity is uncertain, mostly because of the sand covering.

The amount, while more than is usually present in pockets in moraine, is not large. The quality is rather poor, due to the mixture of sizes and materials, but some of the gravel has been used in the past, and as the area to the east has little gravel it is likely to continue to be used. Other deposits lie under the lake sands, and a well in section 2I obtains water from gravel at a depth of 75 feet.

Farther north a thin layer of gravel, one to three feet thick, lies over the knob and kettle moraine east of Nevis.

Sections 29, 32, Township 33, Range 22.

Several gravel deposits are present in this vicinity. The gravel consists chiefly of quartzitic sandstones (including pink arkoses), with a few pieces of limestone. Igneous boulders and those of other types that were brought by the Keewatin ice are noticeably absent, except for the few that have slumped from the overlying till. The gravel ranges from sand size to three or four inches in diameter, and is well sorted into lenses of sand and gravel. The pebbles and boulders are much rounded, but many of them have been cracked into two pieces subsequent to deposition, forming an angular edge and giving the pieces a half-spherical shape.

The largest of the deposits is more than 300 feet long and has a greatest thickness of more than 20 feet. It contains a moderate quantity of high quality gravel, but crushing would be helpful for most purposes. The gravel has been drawn from several pits for use on nearby roads. It seems, in places, to be overlain by the buff till. Other, smaller patches of gravel lie discontinuously in the five miles to the north of it.

Township 38, Range 23.

Saskatchewan gravels are present at other points along the Red Deer River besides those previously mentioned, mostly on the west bank of that section flowing northward in Township 38, Range 23. They consist almost entirely of quartzites and hard sandstones, and any boulders of the types brought by the Keewatin ice are probably due to later reworking by water or ice of the top few feet of the gravel, or to slumping from the overlying till. No Saskatchewan gravels have been noticed near the river from where it turns south in Township 38, Range 22, to where it leaves the area.

This gravel is much the same as the Saskatchewan gravel described near the city of Red Deer (p. 86). The following section from the north bank of the river in section 32, Township 38, Range 23, will indicate the position of this gravel.

5-15 feet	Buff till, containing igneous and metamorphic pebbles brought by Keewatin ice.
15 feet	Dark-blue till, containing igneous and metamorphic pebbles brought by Keewatin ice.
20 feet	Coarse gravel, mostly quartzites and sandstones.
	Edmonton bedrock. Shale, snadstone, coal.
40-50 feet	Total unconsolidated deposits.

The amount of gravel in these deposits is fairly large, and the quality is good, being similar in quality to the gravel near the city of Red Deer (p. 86).

NW quarter, Section 35, Township 38, Range 23.

Fairly good gravel is present in this section on the south side of the Red Deer River valley. It is best seen in a strip mine located there, from where the following section is taken.

	Thin covering of sandy till, containing pebbles brought by Keewatin ice.
I0 feet +-	Gravel, containing boulders brought by the Keewatin ice.
20 feet	Hard, blue-black till, containing pebbles brought by Keewatin ice.
————	Bedrock, shale and coal of the Edmonton formation.
30 feet +-	Total of unconsolidated deposits.

It will be noticed that this gravel lies over the dark-coloured till, and seemingly under the buff till, and that it contains Keewatin boulders and pebbles. This may be an inter-glacial gravel deposit. The quality is good, and the gravel seems to be river deposited. The quantity is difficult to determine, but the deposit is probably of medium size.

Sections I6, I7, I8, Township 38, Range 23.

Fair-size deposits of medium quality gravel are present here. This gravel is composed of a mixture of little sorted material, and seems to be of glacial outwash origin.

Sections 24, 25, 26, 35, Township 40, Range I6.

Over a large part of these sections a layer of gravel, usually between one and four feet thick, lies at the surface. It is composed largely of quartzites, hard sandstones, and the granites and other types brought by the Keewatin ice. Little stratification or sorting is present, and the gravel contains a broad mixture of sizes, including many fairly large boulders. It is of rather poor quality, due to its content of weak material and its size variation, while the thinness of the layer makes it difficult to use. Though the gravel has a wide extent, the total amount is not large.

This gravel is best seen in the northwest quarter of section 25, whence some has been removed. Here it is three to seven feet thick and lies over fairly fine, stratified sand. This sand is as much as 50 feet thick, and is probably Saskatchewan sand, corresponding to the Saskatchewan gravels.

SW quarter, Section IO, Township 35, Range I6.

Here unstratified gravel forms several hills which reach to a height of more than IOO feet. It is mostly composed of quartzites and hard sandstones, along with igneous and metamorphic rock fragments brought by the Keewatin ice. The individual particles are generally under two inches in diameter, but some larger ones are present near the surface. This gravel, though glacial outwash, is of good enough quality. Well information indicated that gravel is present in much of the surrounding district, at a varying distance under the surface, Thus, while the quantity of gravel is impossible to estimate, it would seem to be rather large.

Various Small Gravel Deposits.

Many small pockets of glacial gravel are present in the area. These range in size from less than one thousand to several thousand cubic yards, and contain a wide variety of material, including pebbles and boulders brought by the Keewatin ice, some picked up from the Saskatchewan gravels, and those picked up locally. Sorting is mostly lacking, and because of the variety of sizes, the presence of weak material, and its general dirtiness, the quality of the gravel is usually poor. The main importance of these deposits is that they often occur in districts where no other gravel is present. A partial list of the locations of these deposits follows. Usually other small depsoits are present in the neighbourhood of these.

QUARTER	SECTION	TOWNSHIP	RANGE
NW	33	37	I9
SE	I7	37	I8
	3, 4, 5, 9, I0	33	25
NE	22	37	I7
NW	29	35	22
SW	8	35	24
SW	I4	35	22
NE	I6	35	22
NW	3	38	24
NE	4	38	24
NW	30	37	I6
NE	6	39	I5
NE	9	39	2I
SE	I9	34	28
SW	I9	34	25
SE	I7	34	25
NE	23	34	23
SE	I9	34	22.

It will be observed that gravel is in good supply over most of the map-area, with the northeastern districts having the smallest supplies. The Saskatchewan gravels are the best in quality, with reworked Saskatchewan gravels or gravels containing much material from the Saskatchewan gravels the next best. Luckily these gravels constitute the greater part of the gravel in the area. The gravel deposits directly connected with glaciation are often of poor quality.

Distance from its source greatly limits the use of gravel. It is seldom economical in this area to carry even the best gravel much farther than 25 miles by truck, and thus most of the gravel is used locally. At greater distances than this from gravel supplies alternatives may at times be used. It is often cheaper to collect boulders from the surface of the till and crush them than to transport gravel. This has been done successfully, and will probably be done increasingly. In a few places, mainly in the northeast, burnt shale, made by burning of coal seams, is used in place of gravel.

Sand.

Little sand is used at present in this area, and any required can usually be obtained locally. Large amounts of lake, wind and stream deposited types are present, and the gravel deposits also contain much sand. The chief deposits are in the old beds of glacial-lake Red Deer, glacial Buffalo Lake, and in the area southwest of Stettler. The wind deposited sand, probably the best for most purposes, is chiefly two and one-half miles south of the city of Red Deer, southeast of Blackfalds, and in Township 35, Range 28, southwest of Innisfail (see p. 29). The bedrock formations also contain much sand, and especially the Paskapoo which contains large quantities of good, uncemented and largely unweathered sand, both coarse and fine.

Clay.

Clay is present in some parts of the area, but as far as is known none of it has ever been used commercially. No examination was made into the quality of any of the clay or its possible uses.

Both the Edmonton and Paskapoo formations consist largely of clay and shale, and this clay is much more widespread and usually of more uniform quality than that of the Pleistocene and Recent deposits. However, it will not be discussed here.

The Pleistocene and later clays are in the old beds of the glacial-lakes previously described (pp. 27, 29). The main deposits are in Township 36, Range 27, as shown on the map; along the west side of the Red Deer River from where it enters the area to several miles north of the city of Red Deer; and the clay deposited in the valleys of Kneehills, Threehills and Ghostpine Creeks, when lakes were present in these valleys due to damming. Some varves are present in all these areas, but are most noticeable west of the Red Deer River and in Kneehills Creek. Small patches of clays, often varved, are present at other points, both in the knob and kettle moraine and in glacial-lake areas.

Large Boulders.

The boulders brought by the Keewatin ice and presently found scattered in the fields have, in a few instances, been used for building, mostly for barn foundations but also for houses. These boulders are usually suitable for the purpose, and the results are generally good-looking.

Chapter 8. Water Supply.

One of the chief purposes of the surveys of this map-area was to study the water supply. It has been mentioned (p; 2) how the information collected on water supply is being published, and only some general information on it will be given here.

The information on water supply was mostly collected from the well owners. While this method is probably the best that could be adopted, it has obvious limitations which are more important in some areas than in others. These limitations include the following. Often the well owners (mostly farmers) moved to their present locations since the well was made, and these newcomers seldom know much about the well except for its type and supply of water. The information they possess about the well itself is largely gained from cleaning it, or was supplied by neighbours. The amount of knowledge possessed about their wells by the owners varies greatly from region to region. Some districts, especially the first settled and the best farming districts, have a stable population, whereas in others, especially the dryer and poorer farming areas, more than half the farms have changed hands in the past five years. In these latter districts information is difficult to obtain, particularly as they are often thinly settled and few wells are present, and it is in these districts that the information is most needed.

Also, when the owner knows the well's depth, he seldom can state how much lower this is than the aquifer supplying the water. However, most drillers in the area go from five to ten feet beyond the aquifer for a necessary reservoir, though in some cases the well stops at the aquifer while in others the reservoir is deeper. However, if the depth of the well is known, the depth of the aquifer can usually be roughly determined.

Often the person who knows most about the well is not available to give information, which could thus be only second-hand and general. Obviously the well-drillers should be able to supply a great deal of information, which they did. However, more than half the wells, and especially the older ones, were drilled by persons who no longer reside in the district, and while the drillers gave much information about newer wells, these are also the ones about which the owners knew most. One handicap is the fact that few of the drillers keep written records.

The elevations of the tops of the wells are taken by aneroid barometer and are generally within five feet of the true elevations, and are rarely more than ten feet out.

In spite of the above limitations, and although the information received is often general and scanty, the elevations of aquifers, as given in the water-supply papers, have a fair degree of accuracy.

Most of the wells in use, perhaps more than 80 per cent, were drilled, and the proportion of the water gained from such wells is even greater. The remainder are divided more or less equally amongst bored wells, dug wells and springs. In the drilled wells six inch casing is the most common, being used in all districts, and it is generally satisfactory. In the region west from the town of Stettler towards Buffalo Lake and the Red Deer River two inch casing is common, and it is generally used for both pipe and casing. Amongst the reasons for its frequent use in this and other areas is the fact that it is easier to drive through the quicksand, which is common in the local bedrock formations, than larger casing. Its cheapness, which stems not only from its smaller size but also from being used as both casing and pipe, is also important. As the water usually enters the wells from the aquifers quickly, the larger reservoir which would be given by the bigger casing is unnedessary. This smaller casing also has its disadvantages, such as the smaller collecting reservoir present if the aquifer is not strong, and the often greater difficulty of repair work on it.

Most of the casing in use is iron, and this is usually satisfactory, being strong and lasting well in most districts. Some of the aquifers in the Paskapoo formation supply a water which is extremely hard on the iron casing and shortens its life. This water usually has a high content of iron. Practically none of the water from Edmonton aquifers is hard on iron casing. The aluminium casing, which is coming into more frequent use, is seldom successful in wells drawing water from the Edmonton formation, as the high content of soda in the water rapidly eats it away. Galvanized casing has not had much success anywhere in the area, mostly because of its lack of strength. Generally, except for some small districts, iron casing is best in all this area.

Springs are especially common along the Red Deer River valley and other streams and valleys, but most districts have a few, though they are absent from some. Several of these springs have an excellent supply of water, and practically all of them supply water from the bedrock. It is interesting to note that the first settlements in many districts were beside the first springs.

Boring is used mostly when water is wanted from the drift. For this it has many advantages, as the slow seep of water through much of the drift necessitates the larger collecting surface and the bigger reservoir which it furnishes. Bored wells are found mostly in the recessional moraine areas, and they have been quite successful.

While hand dug wells are still fairly common, they are mostly old. They are sometimes used to obtain bedrock water where the drift is thin; to obtain water from the drift when only a small supply is wanted; or to draw upon the large supplies of water contained in glacial-lake sands or outwash gravels. These dug wells are perhaps most common in the knob and kettle recessional moraine districts.

Wells are not dug by hand as often now as formerly, and the persentage of drilled ones, which are generally more satisfactory, is increasing. But as some wells are still being hand dug, a few words should be said about the danger of gas in them. Poisonous gases are an ever-present danger in digging wells anywhere in this map-area, but especially in that region west of the Red Deer River in Townships 33 to 38, Ranges 22 to 24, inclusive, where they have caused a number of fatalities. If a well must be dug by hand precautions should be taken to ensure that it is free from such gases before it is entered, several persons should be around the top of the well while digging is in progress, and means of quick egress from the well should be available.

Generally the water supply is satisfactory for present needs nearly everywhere in the map-area. The few exceptions are mostly local areas such as near Gadsby, Halkirk, Botha, east of the Red River in ranges 2I and 22, southeast of Buffalo Lake where deep wells are necessary, and in the northeast of the area where the Bearpaw formation is near the surface and where precipitation is less. In this latter district the shortage of good water is the most serious.

The top of the Bearpaw formation seems to form the practical lower limit of good water supply, for not only is little water available in that formation, but that little is apt to be salty. It is risky to go below the

Edmonton formation in seeking water here.

The bottom 300 or so feet of the Edmonton formation also often seems to lack large quantities of water, and this is the reason for the shortage around Halkirk and Gadsby. If possible, it is best to avoid trying to obtain water from the lower 300 feet of the Edmonton formation.

The remainder of the Edmonton formation seems everywhere to be well supplied with aquifers containing fairly large supplies of water. These aquifers are only local and cannot be traced far, as they are generally lenses of sand present in the largely clay formation. In places the aquifers are connected with coal seams, and these can be traced for longer distances. Though the aquifers are mostly lens-like, they are numerous, and sufficient supplies of water can be obtained at less than I50 feet depth into the Edmonton formation practically everywhere except near its base, the main exception to this being the area of deep wells southeast of Buffalo Lake.

Water, if taken from more than a short distance of the surface of this formation, is soft, usually extremely soft. This is due to a high content of soda which was taken by the water from the bentonite in the formation, and which replaces the lime. The sodium is the chief mineral constituent of the water, and largely determines its quality. In about half of these wells into the Edmonton a noticeable, though never large, amount of iron is present.

The Paskapoo formation, which covers the largest part of the area, also has large supplies of water practically everywhere, the main exception being the area of Paskapoo formation lying east of the Red Deer River in Ranges 2I and 22. This formation, containing as it does more coarse sand than the Edmonton, yields its water faster, and often contains more of it. Once again, sufficient water can usually be had within 150 feet from the top of the formation. In the only large area where this is not true, that area of Paskapoo east of the Red Deer River in Ranges 21 and 22, the formation seems to contain no water whatsoever, and wells have to pass right through it and into the Edmonton formation below in order to obtain water. This often adds 100 or 200 feet, or even more, to the depth of wells in this district. The chief reason for this lack of water is probably the ease with which water can drain through the formation into the nearby Red Deer River.

Water from the Paskapoo formation has more variation in quality than that supplied by the Edmonton formation, and ranges from soft to very hard, the latter being too hard for any kind of washing, for which rainwater is often collected. Medium hard to hard waters are the commonest. Noticeable iron is present in much of the water, and in the hardest of it large amounts of iron are generally present, enough to prevent its use in some instances.

Except for the salty water of the Bearpaw formation, and the water from the Paskapoo with a high iron content, the water everywhere in the area seems suitable for ordinary usage. In places the soda content of water from the Edmonton formation is higher than what is supposed to be the maximum for human consumption.

No trouble has yet developed anywhere in the area through overpumping, and the bedrock should be able to supply the amounts presently being drawn from it indefinitely. It is true that the height to which the water rises in the wells has fallen slightly, perhaps about five feet in much of the area, but this is to be more or less expected with any pumping and does little harm. Greater quantities of water can yet be withdrawn practically anywhere, with no harm but a slight further drop in the height to which the water rises in the wells. There need be no worry about overpumping as long as the water is wanted only for ordinary farm and town use, and not for irrigation or industry.

The total amount of water available should be greatest in the western half of the map-area, due to the slightly greater precipitation there, the smaller run-off, the lower rate of evaporation, and the greater ability of the Paskapoo formation to soak up and retain water.

By far the greatest amount of water used in this region is derived from bedrock, but secondary amounts are taken from the unconsolidated deposits. The water supply in the surface deposits was the original reason for mapping the glacial geology of the area, but it was soon apparent that the unconsolidated deposits played only a minor role in water supply here. In general, the ground moraine has no available water, due to its thinness and to the clayey nature of the till composing it. The recessional knob and kettle moraine in places furnishes a fair supply, mostly from wells near the kettles. The glacial-lake sands, outwash gravels and dune sands usually have available good, and in some places excellent, supplies of water. The water from the drift is practically always hard to very hard, and is never soft.

The water supply of the unconsolidated deposits is important in only a few areas:- in areas of glacial-lake sands, mainly in the area southwest of Stettler; in parts of the bed of glacial-lake Red Deer; and in areas having little bedrock water the small amounts in the drift are utilized. The water table in the lake sands is usually near the surface. If it is deep it is usually better to try for a bedrock well, which is apt to have better water and a more reliable supply. The water supply of several of the sand districts is mentioned in the descriptions of these areas.

Though the well information did not identify any major aquifers in the area, it did indicate for each district the general depth at which adequate supplies of water could be obtained, and the districts in which the water table is deep, those in which the supply is small, those in which water is missing or expensive to tap, the districts from which it is best to stay away if large amounts are wanted for cattle, irrigation from local wells, or any other usage, and those districts in which the quality of the water is poor for certain purposes, such as irrigation.

The above is a very general statement of water and well conditions in the map-area, and further information on these conditions may be found in the water-supply papers, previously mentioned (p. 2), that have been published on this area.

Besides the information on water supply, the wells also gave much information on the bedrock and unconsolidated deposits. The figures for thicknesses of drift given in this thesis are largely determined from the wells, as is also much information about its composition, which areas contain two tills, and where gravel is present under the till. Indeed, without the information gained from wells the mapping of the glacial geology would have been much more difficult.

Chapter 9.
Multiple Glaciations and Conclusions.

Multiple Glaciations- Introduction. A number of sections given on previous pages (pp. 87, 89, 99, 100) show two tills. One of these tills was, in each section, a buff, brown or some other light colour, whereas the other was always from light-blue to nearly black. All the localities yet mentioned where the darker till is present are in the valley of the Red Deer River, and in every instance the bluish till lies below that which is light-coloured.

A few details should be mentioned here. The upper of the tills is usually little affected by weathering. Carbonates and unweathered rock fragments often occur nearly or right to the surface, while erosion has, in places, removed any weathered material which might have been formed. The small amount of weathering is due to several causes. Not only has the length of time during which the till has been exposed been short, but the climate is also not conducive to quick weathering (p. 7), the annual precipitation being small and a large proportion of it coming in only a few falls. Also the clayey character of much of the drift increases run-off, and tends to prevent the water from soaking in. Most important is the fact that, for a large part of the year, the temperature is low and the surface of the ground frozen. For these reasons little weathering can be expected in the modern drift. There is little reason to believe that many of these factors were greatly different during any inter-glacial period, and little weathering would be expected on any older drift unless a vastly longer interval of time had passed for it than that duration of time since the last glaciation.

<u>Occurrences of the Lower Till.</u> The lower, dark till has been mentioned as being present in sections at the following points:

SW quarter of section 19, Township 38, Range 27.
W half of section 7, Township 39, Range 26.
SE quarter of section I7, Township 38, Range 27.
Section 32, Township 38, Range 23.
NW quarter of section 35, Township 38, Range 23.

All the sections at the above points are from the banks of the Red Deer River, where are present the best exposures in the map-area. The dark-blue till is also exposed in the following places.

NE quarter of section 8, Township 38, Range 27.
SW quarter of section 28, Township 37, Range 24.
NE quarter of section 20, Township 37, Range 24.
SW quarter of section 20, Township 39, Range 26.
SE quarter of section 20, Township 37, Range 22.

The above are the more important exposures of the dark-blue till in this map-area. However, this till is present in other districts, such as west of Edmonton and further south in the province. In one instance, in the southeast quarter of section 18, Township 3I, Range 26, a thickness of eight feet of the dark-blue till is covered by twelve feet of a yellow till, which in turn is covered by about two feet of soil.

In the first of the above-mentioned occurrences, that of the southwest of section I9, Township 38, Range 27, the dark-blue till stretches a long distance (probably more than one mile) along the north bank of the Red Deer River with fairly uniform thickness. In the second occurrence, that in section 7, Township 39, Range 26, the outcrop is also long and the till quite thick. The dark-blue till is also present at other points along the river between these two exposures.

The exposure in the gravel pit in section I7, Township 38, Range 28, is of much interest, although only a little of the dark-blue till is present. Just a little to the east only the buff till is present, and in this pit it cuts indiscriminantly across the layers of Saskatchewan gravels and the blue till, bevelling them off at an angle from the bottom until it rests on top of the six inches of the dark-blue till. This pit gives perhaps the best evidence that the two tills are distinct types.

The exposure in section 32, Township 38, Range 23, is best seen from across the river. Here dark-blue till, with an average thickness of about I5 feet, lies more or less horizontally over the Saskatchewan gravels. The top of the dark-blue till, which is covered by the buff till, is uneven and rolling. The darker till can be traced for more than a mile on the outside of the river bend.

The dark-blue till in the northwest quarter of section 35, Township 38, Range 23, is best seen in the strip coal-mine there present. Here the dark-blue till lies directly on bedrock, and it is covered by gravel, which appears to separate it from the buff till.

At the exposure in section 8, Township 38, Range 27, which is in or near the city of Red Deer, three or four feet of the dark-blue till overlies Saskatchewan sands and gravels. No buff or yellow till is here present, and lake clay and silt forms a covering over the surrounding region.

A dug well in the southwest quarter of section 28, Township 37, Range 24, gives evidence that the dark-blue till is here present under the surface at a depth of several feet. This till is visible towards the bottom of the well at a depth of perhaps six to eight feet.

The exposures in the northeast of section 20, Township 37, Range 24, were in cuts made for a newly graded road. They have now been largely destroyed by slump. The following section was present above the road grade.

6 feet	Sandy-clay till, light-grey, containing pebbles brought by Keewatin ice.
I/2 foot to 6 feet.	Clay till with bands of generally dark-buff sand which is sometimes of an iron-rust colour.
I I/2 feet	Dark-grey till, of a clay composition, containing pebbles brought by Keewatin ice.
	Road surface.
9 to I3 I/2 feet.	Total exposed thickness.

The middle deposits, where thickest, consist mostly of dark-buff sands with a few pebbles. Intermingled with these sands are layers of clay, sandy-clay and silt. Some of the sands are oxidized to an iron-rust colour, and this weathered zone is well below the modern zone of weathering. Five feet below the surface of these sands fossil shells of gasteropods, mostly of a spiral type but including some plani-spiral ones, are present. These could only be found in such a position if they were deposited in an interglacial period, probably around some small pond or lake. Rather similar gasteropods are present around many of the existing ponds and lakes in the area.

The exposure in section 20, Township 39, Range 26, was in a stream gully half a mile south of Blackfalds Lake. It has now been largely destroyed by road building. The section here was as follows.

20 feet	Sandy, light coloured till, containing pebbles brought by the Keewatin ice.
12 feet +-	Blue-black, clayey till containing pebbles brought by the Keewatin ice.
3 feet	Fine sand, fragments of sandstone, lime concretions, with underlying sand containing gasteropod shells and fragments.
35 feet	Total thickness.

The blue till in section 8, Township 38, Range 27, is reported only from a drilled well. It is mentioned here for the reason that it indicates that the blue till is more common and widespread than the other exposures would indicate.

Besides the above outcrops of the blue till, a large piece of it, about 8 feet in diameter, is seen in a new cut on the north side of the Stettler highway east of Nevis. Later ice than that responsible for its formation picked up this piece of blue till, and it is now contained in the buff till.

Another exposure of the blue till, present in a road cut in the northwest quarter of section 36, Township 38, Range 22, has not yet been examined.

It will be seen from the above-mentioned occurrences that the blue till is fairly widespread. Several features in connection with these occurrences are outstanding. Of the eleven mentioned occurrences of the blue till in place in this area all, save for two in road cuts and two in wells, are near rivers or stream gullies. This is to be expected, as the blue till is almost everywhere so deeply covered by the buff till that few road cuts go low enough to reach it, and since it is seldom recognized in wells as a till. Streams remain as the only normal source of cuts deep enough to expose it. Thus local patches of the till are probably more common than is indicated by the blue tills outcrops.

This till would, of course, be better protected from later glacial erosion in the old valleys, and this may partly explain the large proportion of its outcrops that are along the Red Deer River.

Another feature about these occurrences is that they are all in the western half of the map-area. This is probably due largely to later glacial erosion having been more active in the east.

Comparison of the Two Tills. Wherever the 'lower till' was seen it showed little variation in its characteristics, the most striking of which is the colour. It is always dark, generally a dark blue and in places almost black, while less commonly it is dark grey, or dark greyish-blue. Its colour is always a marked contrast with that of the upper till, which is invariably light, usually yellow, buff, brown or white.

The bluish till is generally of a clayey composition and is very seldom sandy, whereas the upper till is more varied in composition and is often sandy or bouldery.

The lower (blue) till is generally more compact, more solid, and harder than the upper. It is practically impermeable to water, except through cracks and joints, of which there are many, they being more common here than in the upper till. The lower till is resilient, and the hammer will often bounce bach from it without making much impression. A pick will also rebound to some extent, and the till is hard digging when dry. When wet it is exceedingly sticky, and clings tenaciously to a shovel.

The dark blue till has generally the property of breaking into square or rectangular blocks, usually about equal in two dimensions, and much longer in the third and vertical dimension. Such jointing is usually observed in the outcrops.

It will be noticed that both the tills contain igneous and metamorphic pebbles and boulders brought by the Keewatin ice, pieces of quartzite of western mountain origin and pieces of local bedrock. Little difference is apparent either in the number of boulders contained in the two tills or in the relative proportion of types. In places the lower till may contain slightly fewer boulders, but this could be largely due to some slight weathering subsequent to deposition, or in places to concentration of larger stones in the upper till by removal of finer material by erosion.

Neither till shows much sign of weathering. In the lower, pieces of granite are sometimes crumbly and reduced to the individual grains. The biotite schists have often suffered the most weathering. Sometimes a rusty spot is all that remains of boulders.Sometimes the cement in pieces of sandstone has been removed, but the quartzites in both tills are almost completely unaffected. The upper till generally has fewer rotted boulders than the lower. However, weathered rock fragments are present only occasionally, and the presence of lime carbonates practically everywhere in both tills indicates that little leaching has occurred.

In almost every instance in which it was observed the contact between the two tills was definite and sharp. The surface of the lower till has a smooth and shiny polished appearance where it lies against the upper. This is especially noticeable in that occurrence in section 20, Township 39, Range 26. The two tills are easily separated along this polished surface, leaving the shine exposed. Only where sand and gravel separated them, as in the northeast of section 20, Township 37, Range 24; the northwest of section 35, Township 38, Range 23, and at places in the southwest of section 19, Township 38, Range 27, was there not a sharp contact between the tills.

Significance of the Two Tills. The problem naturally arises as to the significance of these two tills, and no other explanation seems possible, when certain features of the exposures are taken into account, but that they are the products of two separate glaciations. Amongst these features are the following:- the sharp contacts; the sand and gravel that separates them in places; their position in regard to the Saskatchewan gravels and bedrock; the instance mentioned where the upper till has bevelled diagonally across both the Saskatchewan gravels and the lower till; the presence of the blue till chiefly in lower areas where it was protected from the last glaciation; its absence in areas where the last glaciation seems to have eroded very actively; the presence of an independent piece of the lower till in the upper; the widely scattered appearances of the blue till in the province with similar characteristics everywhere; and, finally, the differences in compactness, method of breaking, appearance and composition of the two tills.

Evidence given by rivers and streams is probably of even greater significance in pointing to more than one glaciation. The diverting of the Red Deer River from its old course by glacial action has been mentioned (pp. 25, 75). But recessional moraine crosses this river farther southeast, and is present in the valley at other points, thus indicating that the diversion of the river occurred prior to the last glaciation. Some difficulty exists even in explaining the present course, turns and valley of this river without recourse to a theory of three glaciations. Some of the other streams mentioned, if their southeast courses have been determined by glaciation rather than by bedrock peculiarities, as seems most likely in many cases, are proof of more than one glaciation, because their fairly wide valleys are now covered with moraine, and two glaciations is the only method by which this could be done.

As both the blue till and the upper, lighter-coloured one contain pebbles brought from the east, both the glaciations they represent seem to have been Keewatin, coming from the north and east, and not of Cordilleran origin and coming from the west or northwest. It is possible, though not likely, that the later of the glaciations picked up its large content of Keewatin type pebbles from the earlier drift, but other evidence also points to this ice having come from the east. As stated earlier (p. 8), no evidence is present to show that the Cordilleran glaciers ever reached this far east. It is nevertheless possible that ice of such origin spread over all or part of this area. If so, this glaciation was probably earlier than the others, and it may have been responsible for the diversion of the Red Deer River. Such an hypothesis would explain the presence of Saskatchewan gravels in the newer portion of the Red Deer valley, and would supply the three glaciations that would best explain the course of the Red Deer River.

If, as seems certain, the area has suffered more than one glaciation, the small amount of drift commonly present becomes even more peculiar. The amount present is small for one glaciation, and very small for two or three.

The inter-glacial interval would seem to include a vastly longer duration of time than that which has passed since the ice last melted from this area. Comparatively little erosional work has been accomplished since the disappearance of the ice, and the post-glacial valleys are immature. Those valleys that are probably inter-glacial, however, are fairly broad, have more gently-sloping valley walls, lesser gradients, and are generally much larger. A comparatively long time would be necessary to develope these. Since the last glaciation there has not even been enough time to remove much of the moraine from these valleys.

Direction of Ice Movement. The direction of ice movement in any of the glaciations in this area is difficult to determine. The presence of pieces of rock of Keewatin origin does, of course, give an impression of general movement from the northeast. It is not necessary, however, that all the ice-sheets moved in the same direction, and either only one or more of them may have brought boulders from the northeast. Indeed, it seems probable that the directions of movement of the various ice-sheets was not, in all cases, the same.

Due to the weak nature of the bedrock formations no striae or grooves are present. No drumlins were noticed. The tracing of pieces of local bedrock contained in the drift to their source is difficult, because so large a part of the bedrock is covered with drift, because much the same varieties of rock are widespread in the formations, and because the local bedrock is weak and loses its characteristics rapidly.

The evidence available gives information mostly about the ice-front during retreat of the last glaciation. This evidence is contained in recessional moraines, lakes and streams: from the ridges in the moraine, from the trends of valleys, and from the elevation of glacial-lake deposits in various parts of old lake beds. None of this evidence is entirely satisfactory. The morainal ridges are sinuous and give varying directions due to lobes and irregularities in the ice, while some of the ridges may also be due to crevice filling or other origin. The boundaries of former lakes are often difficult to determine, and the deposits have frequently suffered reworking by wind or water. Valley trends may be controlled by many factors.

From evidence seen on the ground, from maps and from study of aerial photographs of the area, the ice, during the melting of the last ice-sheet seems to have been moving from a direction between the east and northeast, the exact direction varying with local topography, with the stage of development of the glacier, and with different districts and with the thickness of the ice.

Effect of Isostasy. For the development of this thesis present-day elevations of the various districts in the map-area have been used. These, however, are not necessarily- indeed are quite unlikely to be- the same as they were during the Glacial Age.

From this arises the problem of what part isostasy has played in influencing the glaciation, lakes, rivers and streams in this area. Only the relative elevations of different districts in the map-area affect this thesis, and changes in elevation over broad regions of the prairies would have little effect on the thesis material. Glacial-lake Red Deer and its outlets, and the new course of the Red Deer River would be the chief features of the area affected by isostasy. It is difficult to see how isostasy could have produced sufficient relative difference in elevation over the short distances concerned to have affected any of the thesis material. (Usually 100 or more feet of relative change in elevation would be required over distances of 10 or 20 miles to have any great effect on drainage here.) Isostasy may have had a part in causing lakes in Kneehills, Threehills and Ghostpine Creeks, however, and the shores of these old lakes may have the best evidence of isostasy in the area. No evidence of relative change in elevation was noticed elsewhere.

<u>Age of the Upper Drift.</u> No opinion can be offered here as to whether the upper drift in the area is of Wisconsin or of earlier age. As previously mentioned (p. II3), weathering can give little information. The amount of weathering of the drift varies from district to district. The drainage developed on the drift is also of little help. In some of the knob and kettle moraine regions a good start has been made towards drainage of the kettles, whereas in other regions not even a beginning of a drainage system for the kettles is noticeable. In the ground moraine, bedrock and lake-sands areas the drainage also varies from district to district in matureness. The writer has seen no evidence in the area favouring the view that the upper drift is or is not of Wisconsin time. The upper drift appears, however, from the newness of the drainage on it and the small amount of erosion and weathering on it, to have been deposited late in the Glacial Age, rather than early.

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Little has been written upon glacial geology in Alberta. The southern districts have been the most studied; in the early days by G. M. Dawson, R. G. McConnell and others, and more lately by W. A. Johnston and R. T. D. Wickenden, amongst others. Several general papers have been written on glacial geology, erosion and drainage in Alberta, but little has been written directly on the area covered in this thesis. Most of the following references have only slight connection with this area, and little relation to the subjects covered in this thesis. They mostly deal with one or two topics, such as drainage or erosion, and are not confined to any one part of Alberta. Soil surveys have been made of the Red Deer map-area by the University of Alberta and the Dominion Department of Agriculture, but no report has yet been published.

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