GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 306

SURFICIAL GEOLOGY OF THE RED DEER-STETTLER MAP-AREA, ALBERTA

A. MacS. Stalker

Price, $1.25

1960

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No. 2553
3,000—1959—1379

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By

A. MacS. Stalker

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THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1960

Price $1.25 Cat. No. M46-306

PREFACE

The Red Deer-Stettler area of central Alberta lies near the western limits of the region overrun by the great Laurentide ice-sheets of the Pleistocene epoch. These glaciers were thin during most of their occupation of the area and consequently their movements and effects were strongly influenced by the pre-existing topography. The mantle of various materials left by them has a marked effect on agriculture, water supply, and engineering.

This report deals with the surficial deposits laid down by the glacier, by meltwater from the ice, and by contemporaneous and subsequent action of streams, lakes and wind. It describes the origin and the physiographic forms of these deposits, and stresses the marked effects of ice stagnation. Particular attention is given to gravel deposits, which are listed and described in detail, to the ground-water capabilities of the various surficial materials, and to the fill of the preglacial Red Deer valley which crosses the area. The report also portrays the general regional history during the Pleistocene epoch and, with aid of sketches, details the sequence of events during the final, or Wisconsin, deglaciation of the map-area.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, August 15, 1958

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Illustration

SURFICIAL GEOLOGY OF THE RED DEER-STETTLER MAP-AREA, ALBERTA

A geological report by Allan and Sanderson (1945) on the south half of the area contains some discussion of Pleistocene and Recent geology. General regional reports that include the present area are those of Tyrrell (1887), Bretz (1943), Rutherford (1937, 1941), and Warren (1937, 1944, 1954). Rutherford (1939 a, b) mapped the bedrock geology; the Dominion and Provincial Departments of Agriculture mapped the soils. Soil survey information on the north half of the area is contained in the Peace Hills report (Bowser, *et al.*, 1947) and that on the south half in the Red Deer report (Bowser, *et al.*, 1951).

Field Methods

The surficial geology was mapped by making use of topography, types of materials, and features of deposition. Whereas stream-cuts, typically rather steep walled, provide excellent sections locally, the general character of the materials throughout the area was determined largely from road-cuts and ditches. The ditches are generally 3 to 4 feet deep and provide fairly continuous exposures. Road-cuts in the more rolling districts are commonly about 15 feet deep and hence supply valuable supplementary data. The excellent sections provided by the steep stream banks are apparent from Plates I A, II, III, IX, and X. Battle and Red Deer Rivers provide especially important sections. Gravel pits, strip coal mines, and foundation excavations provided data locally. Augering was resorted to only where other sources of information were lacking.

Records of several thousand water-well and oil-survey test hole logs were also collected and studied. Although most of these records are indefinite and incomplete, they did supply information on thickness of the surficial materials, extent of gravel deposits, and locations of buried valleys. These records were supplemented by information obtained directly from the well drillers.

Most of the area has air-photograph coverage on a scale of 4 inches to 1 mile. Study of these photographs was invaluable, particularly for tracing geological boundaries, outlining esker ridges and drumlins, and as an aid in deciphering the Pleistocene history. The topographic maps used are on a scale of 1 inch to 3 miles and have a 50-foot contour interval. Elevations given in this report are generally estimated from the maps; some were obtained from railway survey data, others were measured by aneroid barometer.

Terminology

The term 'Pleistocene and Recent' is used in this report to include the present nonglacial interval with the former glacial and interglacial stages that are commonly regarded as comprising the Pleistocene epoch. No sharp division is possible between the close of the last glacial stage in the area and the following nonglacial interval, sometimes referred to as 'Recent'.

The term 'glacial lake' is used for those lakes whose waters were actually ponded by the glacier ice and which, in the Red Deer-Stettler area, largely disappeared when the ice melted. The term is not used for lakes formed through damming by moraines, eskers, or other glacial deposits, or for kettle lakes. Most of the lakes formed in these last-mentioned ways are still in existence. The word 'kame' is used for deposits laid down by water within the margins of the glacier, and which remain today as a few irregular low mounds. 'Outwash' refers to all those deposits formed by streams flowing off the glacier, regardless of the form of the deposit. The terms 'stagnant ice' and 'dead ice' are used frequently to refer to large areas of the ice-sheet where plastic flow ceased and the ice became inactive and melted away in place. Within these areas local, minor movements do take place, but they are largely a result of slumping, local downhill movements, or folding and faulting of the stagnant ice caused by pressure of the active glacier adjoining the stagnant zone.

'Hummocky moraine' is the general name used to designate a hilly, rolling, knob-and-kettle topography formed in drift, and does not indicate a method of origin. This term is used in Sweden for similar topography (Hoppe, 1952, p. 3). Only a small part of the hummocky moraine of the area was formed as a marginal deposit of the glacier during a balance of movement and melting. The name 'moraine' is retained for this knob-and-kettle topography as it has already been described and mapped by various geologists as recessional, terminal, or end moraine. Where the method of deposition of the hummocky moraine is known, it is specifically referred to as 'dead-ice moraine' or as 'recessional moraine'; the former refers to hummocky moraine deposited under stagnant ice conditions, and the latter to that laid down in an ice-marginal position during a period of equilibrium between forward ice movement and marginal melting of the glacier.

The term 'buried valley' is used for any former stream valley which is now partly or completely filled by drift or other deposits.

The word 'esker' is used as an adjective in this report, as in esker stream, esker ridge, or esker gravel. It is so used as many of the esker ridges in the area were not formed in the normal manner; that is, as deposits by streams flowing in ice-bound tunnels or fissures, but apparently they were formed largely by till being squeezed up into these tunnels by weight of adjoining ice.

'Cordilleran' and 'Laurentide' designate the mountain ice-sheet in Western Canada and the great inland ice-sheet east of the Rocky Mountains, respectively. The former is the commonly used term. Laurentide is an old name which has been little used in late years, having generally been superseded by the term 'Keewatin'. It had been assumed that the last glacier on the plains had its source in the Keewatin district of the Northwest Territories, in what was commonly

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referred to as the 'Keewatin Ice Centre'. As the last glacier in the Red Deer-Stettler area apparently received little ice from this supposed centre, it seems preferable to use the term Laurentide for the continental ice there (Flint, 1943, pp. 326-329).

In the following account of the surficial geology of the Red Deer-Stettler area the glacial features refer to the whole Pleistocene epoch and not solely to the last glaciation, unless otherwise stated.

Acknowledgments

The well drillers and farmers of the area invariably gave most helpful and whole-hearted cooperation. The writer thanks P. S. Warren of the University of Alberta for the benefit of much discussion, his many suggestions, and particularly for the suggestion that the last glacier in the area advanced in a general southward direction. B. A. Latour, of the Geological Survey of Canada, mapped the district around Red Deer, Lacombe, and Innisfail during his ground-water surveys, and much of his work is embodied in the accompanying maps. Much beneficial discussion was had with R. T. D. Wickenden, the late J. S. Stewart, and Bruce G. Craig, all of the Geological Survey of Canada, and with W. H. A. Clow and D. E. Duff, both formerly with the Research Council of Alberta. In 1947 the writer was assisted by Norman Millar, in 1948 by Harold Van Camp, in 1951 by A. Aurey Carter, and in 1952 by J. W. M. Fraser.

Chapter II

PHYSICAL FEATURES AND BEDROCK GEOLOGY

Physical Features

The Red Deer-Stettler area is on the eastern flank of the Alberta geosyncline. The bedrock consists of late Cretaceous and early Tertiary sediments that dip west or southwest at about 15 feet to the mile, and locally more steeply. Differential erosion determines the principal topographic features. The area underlain by Tertiary rocks stands higher than that underlain by Cretaceous rocks.

The highest land is in the south-central part and particularly in a northward-trending belt, in ranges 25 and 26, between the southern edge of the area and a point east of Ponoka. In this district the Tertiary rock includes particularly resistant sandstone beds. Elsewhere the effects of the more resistant bedrock layers are confined to forming small, flat-topped hills or long, sinuous, cuesta-type ridges, and to controlling some of the drainage. Although the rivers of the area, particularly the preglacial Red Deer River, carved valleys that are important features of the topography, bedrock control undoubtedly was the chief factor in determining the locations of the valleys. For instance, the belt of high, resistant sandstone in ranges 25 and 26 marks the eastern edge of the former Red Deer valley, and was a major factor in determining the northward flow of the Red Deer River in the western part of the area.

The highest point in the area lies east of Red Deer and is about 3,500 feet above sea-level, whereas the lowest point, where Battle River crosses the eastern edge of the area, is at an altitude of about 2,150 feet. However, the general drop of the prairie level is from about 3,200 feet in the southwestern part of the area to about 2,250 feet in the northeastern part. This amounts to a northeastward gradient of about 8 feet to the mile.

The Pleistocene glaciers were responsible for the small topographic features that modified the larger effects imposed by the bedrock. The glaciers formed these smaller features by scouring the bedrock or other deposits, by moulding previous deposits, by direct deposition from the ice, through diversion of drainage channels, and by deposition and erosion by meltwater streams. Periglacial and permafrost conditions probably affected much of the area following retreat of the glaciers, but they have had little apparent influence on the topography. Settlement and ploughing of the land no doubt have destroyed most of the minor periglacial effects.

Erosion by the last glacier was weak in the west half of the area, partly because of the thinness of the ice. It was stronger in eastern districts, where the ice was thicker and the Cretaceous bedrock more easily eroded; such erosion was partly responsible for the fairly smooth surface of this region. In general, however, the effects of ice erosion are not apparent; they are partly covered by drift. Direct deposition from ice was more important in shaping the topography, and it formed the rounded hills and rolling plains that cover most of the area. It also buried many preglacial topographic features, or lessened their topographic expression. Moulding by ice, or the reshaping of earlier deposits by the pressure and movement of overriding ice, was important only locally. Between Innisfail and Morningside, and particularly west of Lacombe, the last ice advance elongated earlier drift hills parallel to the direction of ice movement. The overriding ice also produced some local folding and faulting in the bedrock. Erosion by meltwater streams and by rivers diverted from their earlier channels by glacier ice caused some of the most striking topographic features, one of which is the numerous deep, steep-walled valleys. Some of these valleys, such as that of the Red Deer River from Blackfalds downstream, are still occupied by streams.

Physiographic Divisions

General Statement

The Red Deer-Stettler area may conveniently be divided into physiographic units that reflect the results of long-continued uplift and erosion prior to glaciation, or it may be divided into glacial systems according to the type of glacial deposit that is prominent. The two methods of division are complementary, as the type of glacial deposit in any one area was largely determined by the pre-existing topography, and results in only minor differences of outline. The area is divided into three large and one small physiographic units, as shown in Figure 1.

Central Highland

The Central Highland includes all the topographically high ground in the central and south-central parts of the map-area; it thus includes the Delburne Highlands of Bretz (1943, p. 50). Its northern and western borders are roughly the southern and eastern edges of the former Red Deer valley, and its eastern boundary is near the contact of the Cretaceous and Tertiary rocks. This division includes the highest land in the Red Deer-Stettler area; adjoining areas are generally 200 to 300 feet lower in elevation. The resistant Tertiary sandstone beds that underlie most of the Central Highland are chiefly responsible for its prominence. Erosion of gently dipping beds of differing hardnesses has resulted in many long cuestas, high plateaux, and locally some incipient badland

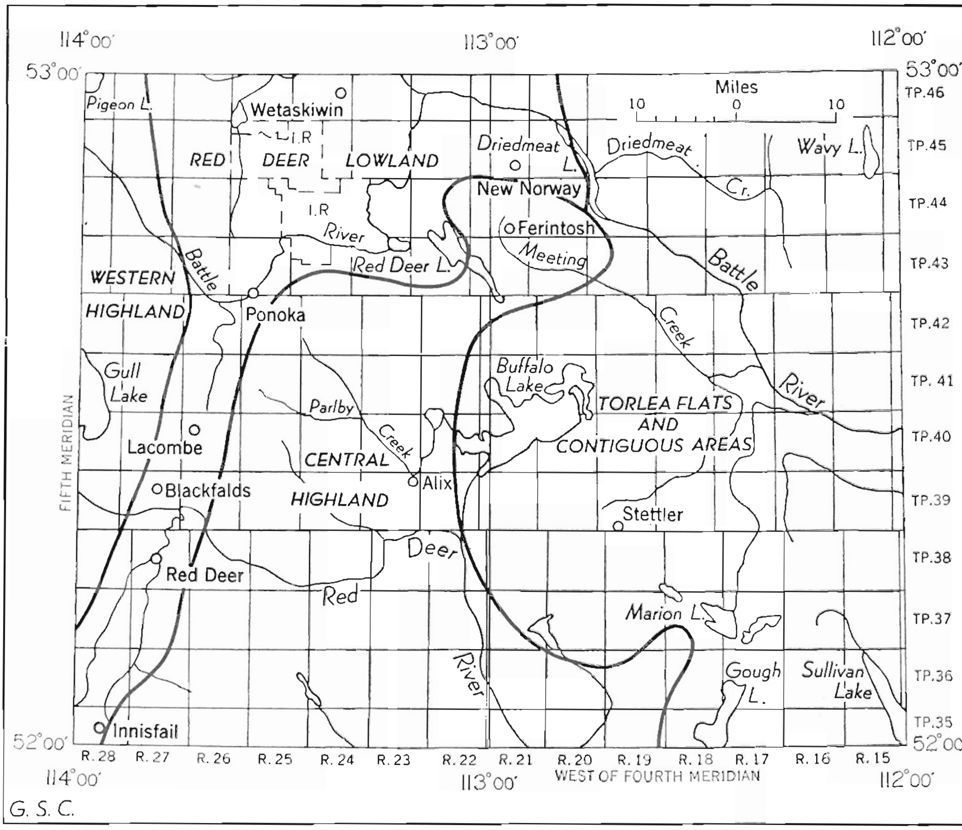

Figure 1. Physiographic divisions of Red Deer-Stettler area.

topography with its pointed and rounded hills. This uneven bedrock surface and a thicker-than-average layer of drift combine to form the roughest topography in the area. The Central Highland is thinly settled, and comprises much bush, and many lakes, ponds and swamps. Farming is not important there.

Red Deer Lowland

The Red Deer Lowland occupies the former Red Deer valley between Innisfail and New Norway, and also includes the flat region northwest of the old valley. It is a lowland chiefly because of long-continued erosion by the former Red Deer River. This river cut a wide valley through Tertiary rock that is only slightly less resistant than that underlying the Central Highland. It is marked by a string of dry lake basins and patches of gently rolling till plain. The glaciers smoothed this lowland by filling much of the former Red Deer valley and other low districts with drifts and it was further modified by glacial-lake deposits. This division contains most of the population of the area and is the most intensively farmed.

Torlea Flats Lowland

The Torlea flats were named by Warren (1937, p. 303). They occupy a broad area in south-central Alberta that includes the eastern part of the Red Deer-Stettler map-area. As used in this report, however, the Lowland includes certain districts contiguous to the 'flats' as originally outlined. It includes all the area lying east of the Central Highland, and also that east of the Red Deer Lowland in the northern part of the map-area. The Torlea flats are underlain by nearly flat-lying, soft, Upper Cretaceous rock; this is chiefly responsible for the characteristics of the division. It is a region of rolling plains, dry lake basins and small, scattered hills; it is a monotonous area of low relief (*see* Plates X, XI, XII, XIII). The lakes within the Torlea flats are shallow and commonly go dry in summer. The streams that rise locally are small and have poorly defined valleys. The other streams which flow across the flats in deep valleys have little influence on the adjoining land. The drift cover is thin and is composed chiefly of material from the underlying rock. The western parts of the division are moderately populated, but eastward the land is sparsely populated and farming is less intensive.

Western Highland

The Western Highland is the smallest of the physiographic divisions. It lies in the northwestern and west-central parts of the area. It is similar to the Central Highland in both geology and physiography, and is separated from it by the Red Deer Lowland. It is a district of broad, bedrock hills, ridges and deep old valleys, overlain by markedly rolling drift plains, scattered morainal hills, and small, dry, lake basins. The drift is thinner than in the Central Highland, and is not much thicker than in the Torlea Flats Lowland. The Western Highland is sparsely settled, and contains much bush and swamp.

Glacial Systems

Buffalo Lake Moraine System

The Buffalo Lake moraine system overlies the entire eastern part of the Central Highland physiographic division and extends beyond it to the north and east; its location was largely determined by presence of this Highland. It surrounds Buffalo Lake, near which the knob-and-kettle topography is strongly developed, and includes the broad surrounding area of more moderate knob-and-kettle topography, most of which is dead-ice moraine. This system thus includes most of the hummocky moraine of the area, as well as some true recessional moraine,

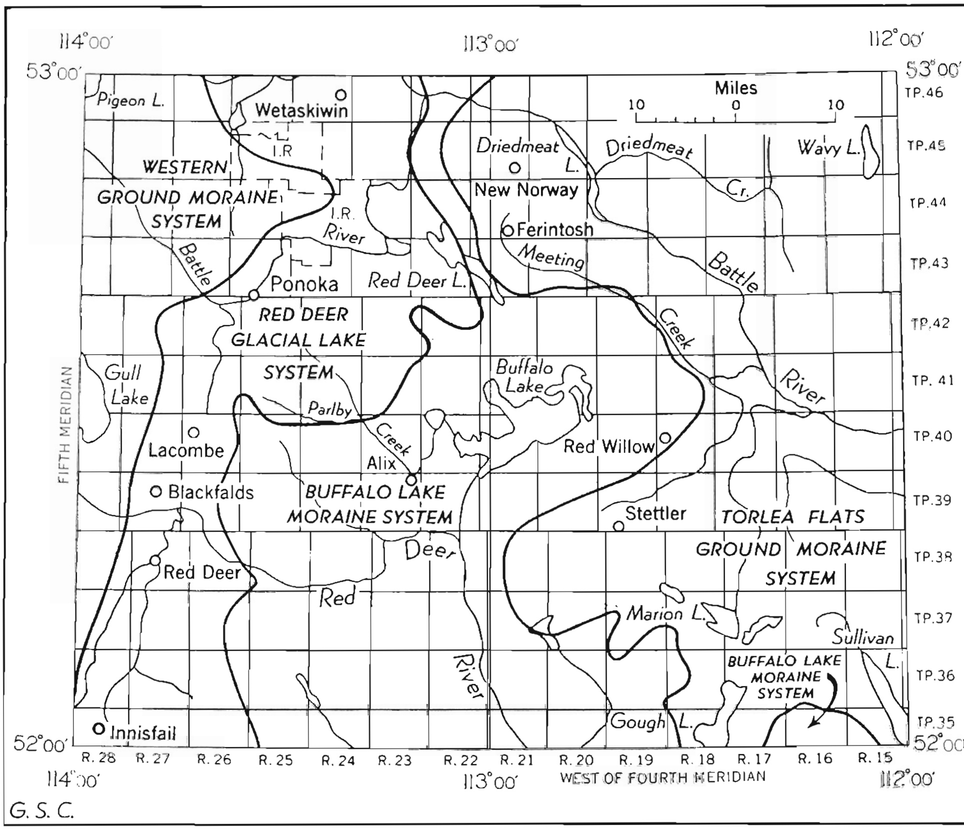

Figure 2. Major glacial systems of Red Deer-Stettler area.

moraine plateaux, ice-block depressions, outwash, and lake deposits. The average drift cover there is thicker than in the rest of the Red Deer-Stettler area. The area is but thinly populated, as it is unsuited to farming.

Red Deer Glacial-Lakes System

The Red Deer glacial-lakes system corresponds roughly to the Red Deer Lowland physiographic division. Lake deposits form most of its surface but this system also includes large amounts of outwash and much alluvial material (*see* Plates III, IV, VIII, IX).

Torlea Flats Ground Moraine System

The Torlea flats ground moraine system lies east of the Buffalo Lake moraine system and corresponds roughly to the Torlea flats physiographic division. Warren (1937, pp. 303, 304) originally used the name Torlea flats to refer to the region of thin drift lying between the Buffalo Lake and Viking recessional moraines. The Torlea flats ground moraine system as used here includes the Torlea flats proper, the associated ground moraine plains lying east of the Buffalo Lake moraine system, and minor areas of lake deposits and hummocky moraine. The system also includes some areas of thick drift, particularly in the abandoned former valleys of Red Deer River and in the lake basins bordering the Buffalo Lake moraine system.

Western Ground Moraine System

The Western ground moraine system corresponds roughly to the Western Highland physiographic division, but extends farther northeastward. It is an area of roughly rolling ground moraine that overlies bedrock hills and valleys. The system also includes scattered patches of hummocky moraine and small glacial-lake basins.

Bedrock Geology

Information on the bedrock geology of the area is contained in the report of Allan and Sanderson (1945) and on the maps of the Red Deer and Stettler areas by Rutherford (1939a, b). The general geological column for the Upper Cretaceous, Tertiary, and Quaternary periods is shown in Table I. The formations listed were laid down in the Alberta geosyncline, and they represent phases of advance and retreat of the sea, with consequent marine, brackish-water, fresh-water, and subaerial deposits as the land sank or rose relative to sea-level. They consist of shale, siltstone, and sandstone of marine, brackish-water and freshwater origin, with minor ironstone bands and coal seams. Much volcanic ash is present locally.

Some of the rock is poorly consolidated or even unconsolidated, and substantial thicknesses of loose sand or weak clay are common. The consolidated sandstone, ironstone bands, and coal seams are the resistant beds and these commonly form steep valley walls. The beds dip gently to the west or southwest and, as the land surface rises in these same directions, younger formations outcrop westward as far as the western flank of the Alberta geosyncline, beyond the Red Deer-Stettler area.

The Pale and Variegated beds, Bearpaw formation, and Edmonton formation, all of Upper Cretaceous age and the Paskapoo formation of early Tertiary age are the formations that outcrop or that directly underlie the surficial material. The other formations listed in Table I outcrop in adjoining districts, and some of their materials were incorporated in the drift that was deposited in the Red Deer-Stettler area. The high content of fine material and the small amount of consolidated material in the bedrock is reflected in the general fineness of material and the sparsity of large fragments of local bedrock in the drift of the area.

The formations that outcrop in the area are of freshwater or brackish-water deposition, with some interfingered thin marine beds that are present mostly in the Bearpaw formation. They represent the final phases and the withdrawal of the Cretaceous (Pierre) sea, and the increased outpouring of material from the rising mountains to the west.

Table I

Bedrock Formations of Red Deer-Stettler and Adjoining Areas

Era	Period	Epoch	Age	Formation
Cenozoic	Quaternary	Recent Pleistocene	Post-Glacial Glacial	
Cenozoic	Tertiary	Paleocene		Paskapoo
Mesozoic	Cretaceous	Upper Cretaceous		Edmonton Bearpaw Pale and Variegated beds Birch Lake Grizzly Bear Ribstone Creek Lea Park

Bedrock Formations

Pale and Variegated Beds

The Pale and Variegated beds directly underlie the drift in only about 4 square miles of the very northeastern part of the area; they do not outcrop. They consist largely of bentonitic, light grey sands and light or dark grey shales; but ironstone nodules, thin coal seams, and carbonaceous shales occur, and selenite crystals are abundant. This formation is nonmarine and is somewhat similar to the Edmonton formation, from which it is separated by the predominantly marine beds of the Bearpaw formation. The thickness of the Pale and Variegated beds in this area is not known, but it is known to be more than 1,000 feet east of the map-area.

Bearpaw Formation

The Bearpaw formation directly underlies the surficial material in about 90 square miles of the northeastern part of the area, just southwest of the Pale and Variegated beds. The Bearpaw deposits in the area are of shoreline origin and contain more freshwater and brackish-water beds than do typical Bearpaw rocks elsewhere, but marine beds are present. The local Bearpaw rock consists of bentonitic, green, brown, or black shale and minor sandstone. It is easily eroded and slumps quickly, and newly exposed outcrops quickly become obscured. There are, as a result, no outcrops in the flat region in the northeast of the area, but farther south both Battle River and Paintearth Creek have cut into the upper part of this formation and good exposures are present near the bottoms of their valleys. The Bearpaw formation elsewhere is 600 feet thick, but in the Red Deer-Stettler area its maximum thickness is only 150 feet. The upper part of this formation grades without noticeable unconformity into the basal beds of the overlying Edmonton formation.

Edmonton Formation

The Edmonton formation underlies the surficial material in 3,450 square miles, or two thirds of the area; outcrops are numerous. It underlies most of that part of the Torlea flats and contiguous areas southwest of the Bearpaw formation (*see* Plates X, XI, XIII), most of the Red Deer Lowland, and part of the Central Highland. The formation is largely of brackish-water and freshwater origin, and it consists of grey, green, and brown clay and shale; argillaceous silt; sandstone and sand; with some important coal seams and conspicuous ironstone bands. Some of the layers contain much bentonite, which gives them a white appearance when dry. When wet this bentonite is sticky and swells greatly in volume, helping to break down the beds containing it.

The Edmonton formation is about 1,000 feet thick. It apparently is separated from the overlying Paskapoo by an unconformity.

Paskapoo Formation

The Paskapoo formation of Tertiary age underlies the surficial material in the Western Highland, most of the Central Highland, and part of the Red Deer Lowland. It forms the bedrock in about one third of the area, and it consists mostly of freshwater deposits of clay, shale, silt, sand, and sandstone, with some coal seams. The beds are commonly massive, and generally greyish, brownish, or rust coloured. In general, the material is coarser than that of the Edmonton formation. Thick sections of the Paskapoo are exposed in the valleys of Red Deer (*see* Plate I A), Blindman, and Battle Rivers, and small outcrops are numerous in gullies, road-cuts, stream valleys, and on ridges and hills where drift is thin. The Paskapoo formation in this area reaches a thickness of more than 700 feet.

Erosion

The differential resistance to erosion of the various formations and of the different beds within each formation was most important in shaping the topography of the Red Deer-Stettler area. The Bearpaw is the weakest formation and it slumps and weathers quickly; its outcrops are practically unrecognizable after a few years. Thus, though streams cut into it easily and tend to carve deep valleys, recognizable outcrops are rare. The land above this formation tends to be flat. The Edmonton formation and the Pale and Variegated beds are more resistant than the Bearpaw formation, but much weaker than the Paskapoo. The ease with which streams cut into the Edmonton formation, along with the presence of some relatively resistant beds, tends to give good vertical exposures. The Paskapoo beds, though weak as compared with most rock types, are relatively strong and resistant in comparison with those of the other formations in the area. As one result the land surface commonly rises 50 to 150 feet from the Edmonton formation to the Paskapoo formation near their contact. In addition, rivers flowing towards the Edmonton formation increase their gradients near this contact, as is well shown in the valleys of both the preglacial and modern Red Deer Rivers.

The differential resistance to erosion of various beds within each formation is best shown in the Paskapoo formation. In it, thick sections of loose sand and other weak materials alternate with massive beds of consolidated sandstone. This hard sandstone forms bluffs on river valleys and the flat tops of many hills and ridges. The land surface above the Paskapoo beds is the roughest in the area.

Chapter III

GENERAL GEOLOGY

The surface exposures of the various surficial deposits and the thickness of this material are shown on the maps accompanying this report. As the surveys upon which this report is based were conducted largely in connection with ground-water study, the deposits that have an important effect on ground-water supply are emphasized. Thus in much of the Torlea flats where bedrock outcrops or is overlain by less than 5 feet of till, which amount is unimportant in ground-water supply, the region is mapped as bedrock rather than as ground moraine in order to emphasize the nearness of the bedrock to the surface. Similarly, where lake water has modified ground moraine or other material with only local deposition of thin lake deposits the original material, commonly with a note about the modification, is shown.

On the map the principal classification of deposits is based on the manner in which the surface material was deposited; that is, its origin. Secondary divisions are based on the lithology of the material present and on topographic form. The distinction between the three methods of classification is not always sharp as certain terms (e.g., drumlin, ground moraine) imply a combination of two or more of these classifications. In addition, the origin of some deposits is uncertain. For example, the silt and sand west of Buffalo Lake, which is mapped as outwash, could include much coarse lake material. The interpretation of the origin of this and other material has been strongly influenced by the surrounding geology.

The geological boundaries are shown as defined, approximate and assumed. Most of the defined boundaries are beside valleys, gullies, and around areas of wind deposits. The most common boundary is the approximate, which represents transitional or gradational contacts, or those where more definite information is lacking. Assumed boundaries mark those contacts where personal opinion can influence strongly the placing of the dividing line, or where the contact is a change in degree of phase rather than a sharp change in material or topography. Thus the strongly and moderately developed hummocky moraines are separated by an assumed contact, but the change is gradational. Assumed boundaries also outline the entire districts that include deposits of materials of possible economic importance, such as outwash gravels, although the whole district may not consist of such materials.

The legend shows the surficial deposits in a general, overall, order of decreasing age from bottom to top. Such an arrangement of these deposits is not, of course, valid for the whole region; for instance, the melting ice-sheet may have deposited hummocky moraine later than ground moraine in one district, yet this same hummocky moraine could be earlier than some of the ground moraine elsewhere; or again glacial-lake deposits may have been laid down in one region before the normally older hummocky moraine or ground moraine of another region. In addition, several of the classes of deposits are somewhat contemporaneous, such as the two divisions of ground moraine and the drumlins; or the two divisions of the hummocky moraine, which are also of the same age as some of the outwash and many of the stagnant ice deposits. Similarly, sand duning, stream erosion, and stream deposition have proceeded together since disappearance of the ice. The legend does, however, give a general impression of the relative ages of the various deposits.

The surficial material is generally thin (*see* Map 1081A), particularly so in comparison with that to the east in Saskatchewan. This is a result of the shorter period of occupation by glaciers in central Alberta, perhaps fewer major glaciations and thinner ice, with consequently less glacial erosion and deposition. The average thickness of the surficial material is about 25 feet. Of this material, approximately 5 per cent consists of gravel and sand deposited prior to the first glaciation. An undetermined but probably small proportion was deposited in interglacial or in post-glacial stages, and is also not of glacial origin.

The various Pleistocene deposits of the area have not been referred to the standard Pleistocene chronology. Any such correlation would be guesswork based on physiographic development and depth of weathering. Radiocarbon datings are necessary to supply the information required for such correlation.

Description of Deposits

Bedrock

General Statement

The various bedrock formations are described in Chapter II. About 345 square miles of the Red Deer-Stettler area are mapped as exposed or shallow bedrock, most of which is Edmonton formation. The thinly covered bedrock areas include much of the Torlea flats of Warren (1937, pp. 303, 304). They have a rather monotonous, flat to undulating, surface. These districts of little or no drift are subdivided into those that received little or no glacial deposition (*see* Plate XIII) and those from which the drift was removed by subsequent erosion (*see* Plate X). The districts of little deposition include most of the region between Gough and Sullivan Lakes (tp. 37, rge. 16, W. 4th mer.) and certain districts adjoining Paintearth Creek and Battle River valleys. The districts in which erosion of the drift has uncovered the bedrock include the valleys of Paintearth and Meeting Creeks, Battle River, most of the region around Lonepine and Marion Lakes, a region bordering Sullivan Lake, various small valleys, and some districts of badland topography. The cause of the thinness of drift in these districts is discussed in Chapter V under Red Deer-Stettler Area.

Geography

These districts of exposed or shallow bedrock require more precipitation than neighbouring regions to support the same amount of vegetation, and in dry years they are nearly barren. Little farming is now carried on as compared with earlier times. Even near the sloughs and lakes, bush is absent and short, sparse grass is the predominant vegetation. The water in the sloughs is commonly alkaline. There is little variation in plant growth between the districts with no drift cover and those with patches of thin drift, as the latter have a high content of the underlying bedrock.

Tertiary and Early Quaternary Alluvium

General Statement

The Tertiary and Early Quaternary alluvium in the map-area consists entirely of preglacial gravel and sand. McConnell (1885, p. 70) described gravels lying beneath the Laurentide drift and named them 'South Saskatchewan gravels'. Other early mention of such gravels was made by Dawson and McConnell (1895, p. 31), Tyrrell (1887, p. 139), and Coleman (1910, p. 7). With discovery of other deposits not connected with the South Saskatchewan River their name was changed to 'Saskatchewan gravels'. Rutherford (1937) described the gravels in detail and suggested use of the modified name 'Saskatchewan gravels and sands'. This name is more suitable because of the many beds and lenses of sand. However, none of these names is used in this report, as the age of the preglacial gravel and sand in the area is uncertain and as there is some doubt as to what the name 'Saskatchewan gravels and sands' includes. Preglacial gravel and sand is used here as a general term to include any Saskatchewan gravels and sands, and any other preglacial gravels and sands that may be present.

Distribution

The preglacial gravel and sand directly overlies the bedrock in some 500 square miles of the Red Deer-Stettler area, mostly in the preglacial valley of Red Deer River where it is fairly continuous. It commonly is only a foot or two feet thick, but locally is as much as 30 or more feet thick. It is exposed over a total of about 5 square miles. The largest exposures are as follows: on a plain in sec. 4, 5, 6, tp. 44, rge. 17, W. 4th mer.; beside a stream valley in sec. 15, 16, 17, 18, tp. 45, rge. 18, W. 4th mer.; as a capping on a hill in sec. 17, 18, tp. 45, rge. 19, W. 4th mer.; on a valley side in sec. 22, tp. 44, rge. 21, W. 4th mer.; as a capping on a hill in sec. 28, 29, tp. 44, rge. 21, W. 4th mer.; on a gently rolling plain in sec. 4, 5, 8, 9, tp. 41, rge. 27, W. 4th mer.; on the banks of a valley in sec. 11, 12, 13, tp. 43, rge. 15, W. 4th mer.

Many outcrops of this gravel and sand that are too small to be shown on the surficial geology map are shown on Figure 19 and are listed in Chapter VI. They are exposed mostly in vertical sections along stream banks. In certain other gravel outcrops the age could not be determined but it is thought to be preglacial. Buried gravel is reported in several hundred water well records and seismic well logs. None of this buried gravel was examined, but most of it is undoubtedly preglacial. Many of its reported locations are listed in Chapter VI; most of these are in the preglacial valley of Red Deer River.

The loose gravel on Driedmeat Hill, sec. 17, 18, tp. 45, rge. 19, W. 4th mer., is overlain by sandstone, which is better consolidated than much of the sandstone in the Paskapoo formation of Paleocene age. This suggests that some of the bedrock included with the Paskapoo formation may in reality be younger.

Composition

The preglacial gravel and sand can be separated from other types of gravel and sand in the area by its position beneath the drift and by absence of fragments of rock types found in the Precambrian Shield. These rock types, such as granite, gneiss, schist, gabbro, and diorite, are represented in both the Laurentide drift and other material deposited subsequent to the first Laurentide glaciation of the area. Except for fragments of local bedrock, the gravel consists of rock types found in the mountains to the west. These include hard sandstone, quartzite, chert, arkose, and limestone. The gravel was carried far enough to be composed mostly of the well-rounded or flattened, disc-shaped pieces that are characteristic of the river gravels of the region. The journey was also long enough to weed out the weak material, such as shale, siltstone, and much of the local bedrock. Limestone fragments are common in the western part of the area but they decrease greatly in amount eastward. The resulting gravel is well sorted, clean, of good quality, and consists mostly of hard sandstone and quartzite. The gravel includes boulders as large as 12 inches in greatest dimension; boulders up to 6 inches in diameter are common. Sand and silt lenses and beds are prominent in much of the deposit. Here and there the gravel and sand is cemented with lime, forming a strong conglomerate.

Origin and Age

McConnell (1885, p. 70) suggested that some of the gravel was redeposited from Tertiary conglomerates and gravels such as are present on the Cypress, Hand, and Swan Hills, which are all outside the map-area. Dawson (1895, p. 31) and

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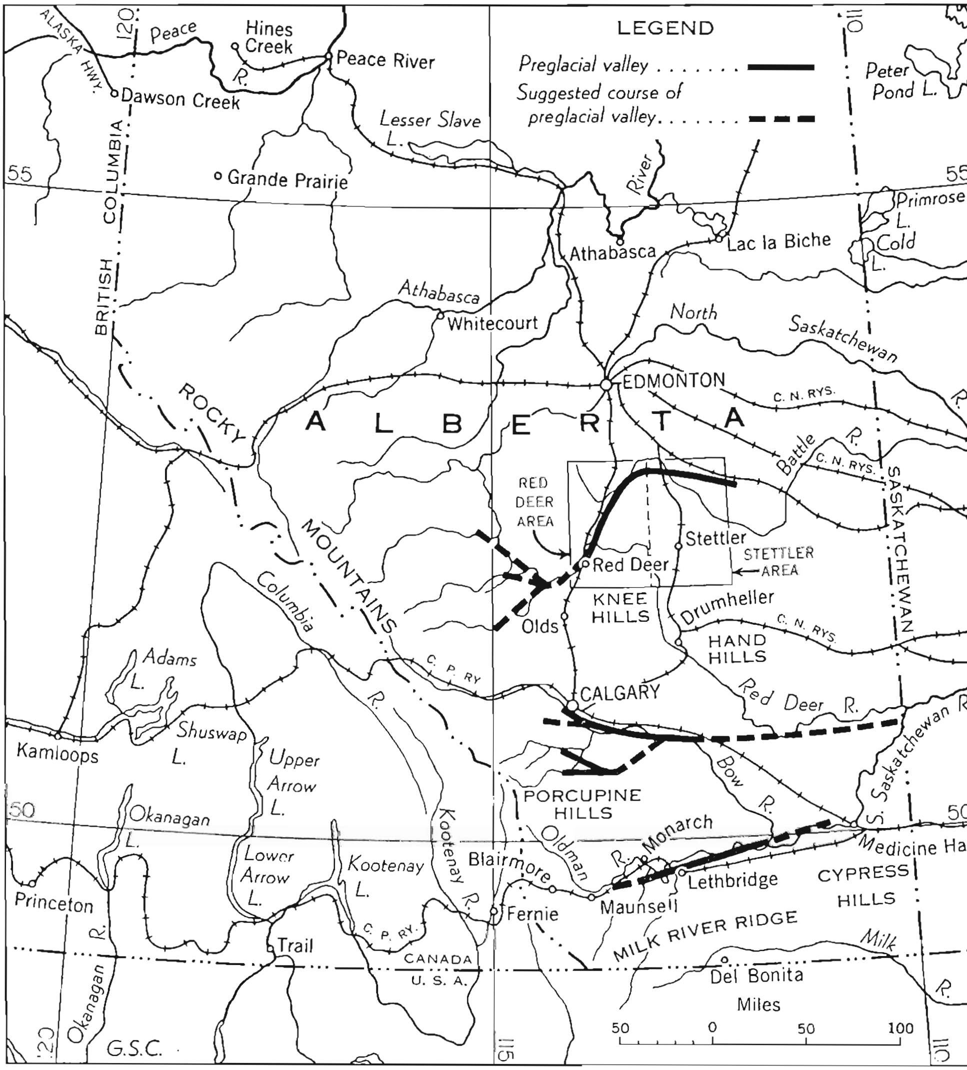

Figure 3. *Index map of southern and central Alberta showing Red Deer-Stettler map-area and major preglacial valleys.*

Coleman (1910, p. 7) suggested that it represented outwash from, or a reworking by water of, a 'pre-Laurentide' Cordilleran ice-sheet. Rutherford (1937, pp. 81, 82) gave detailed information on the origin and deposition of this gravel and sand.

All deposits in the Red Deer-Stettler area, except the one in sec. 4, 5, 8, 9, tp. 41, rge. 27, W. 4th mer., lie along or near the preglacial valley of Red Deer

River. The exception, though some distance from the known course of the old Red Deer River, was probably laid down by this river or one of its tributaries. Deposits of this gravel, not obviously connected with any present or past known drainage, do occur south of the area. For the deposits in the area, however, it is unnecessary to assume any other origin than direct deposition by the former Red Deer River and its tributaries, which brought the material from the west, mostly from the Rocky Mountains. At present Red Deer River is forming somewhat similar deposits about 20 miles west of the area, but it carries little gravel into the Red Deer-Stettler area.

The deposition of the preglacial gravel and sand, though intermittent, undoubtedly extended over a long time. The earliest deposits were laid down when the old Red Deer River was flowing some 325 feet above its final, preglacial, grade level. No fossils that date the gravel and sand have been found in the area. The only method of estimating its age is by comparing relative heights above present drainage of these gravel deposits and those of known age, such as those on Cypress Hills, and perhaps those of the Hand Hills (Chapter IV).

The preglacial gravel and sand was an important source of material for the overlying drift: it supplied about one half of the stones found in the till of the area and a large proportion of those in subsequent gravel deposits.

The outcrop area of this preglacial gravel and sand is too small to have much effect on settlement or farming. It is largely waste land or wooded.

Ground Moraine

Distribution

Ground moraine is the most extensive surface deposit of the Red Deer-Stettler map-area. It covers about 2,450 square miles, and in addition underlies most of the lake and wind deposits, and overlies much of the region mapped as shallow bedrock. The ground moraine is generally less than 20 feet thick, and its surface is typically rolling with broad, rounded hills rising 2 to 15 feet above the nearby depressions.

It is most prominent in districts of comparatively low elevation, though in the lowest land it is generally covered with shallow lake deposits. As a consequence the largest ground moraine plains are in the northeastern and northwestern parts of the area, with smaller ones in the east-central and west-central parts. The restriction of the ground moraine to low ground is most marked in the east half of the map-area, for in the west it extends over part of the Central Highland just to the east of the preglacial Red Deer valley.

The more rolling ground moraine is concentrated in the higher parts of the ground moraine plains, though some is present in the Torlea flats near Forestburg, Halkirk, and Botha. It is distinguished from the hummocky moraine by its weaker development of knob-and-kettle topography. The contact is gradational and some

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of the most rolling ground moraine could be included with the hummocky moraine, as it has been in some past mapping. The contact between gently rolling and strongly rolling ground moraine is, of course, gradational and their boundary therefore is somewhat arbitrarily chosen. The distinction between them is made because of the importance of the differing topography on road building, farming, water supply, run-off, and in retention of moisture throughout the year.

Composition: General Statement

The ground moraine is composed of till or boulder clay, the most common surficial material in the area. Till also composes most of the hummocky moraine and drumlins, and is exposed over about 3,600 square miles, or about three quarters of the map-area.

The till consists mostly of local bedrock and, particularly in the thin drift districts of the east, it is locally difficult to distinguish it from the disturbed, upper zone of the bedrock. It also contains material from bedrock in adjoining and distant regions and from preglacial river deposits. During deposition it was in part modified by removal of some fine material by meltwater. Material from the preglacial gravel and sand is found in greatest proportion in the western part of the map-area where most of the deposits of this material were, and over the former Red Deer valley. In contrast, the proportion of material derived from the Precambrian Shield is greatest in the northeastern part of the area, the part nearest the Shield, and decreases rapidly westward. Except for numerous pieces of coal and ironstone formation, material from the bedrock is inconspicuous amongst the pebbles and boulders. This is because much of the bedrock is poorly cemented or even unconsolidated and breaks up rapidly during transportation.

In general, the till above the Paskapoo formation contains much more sand than that above the Bearpaw or Edmonton formations, and commonly is reddish yellow or rust. In contrast, the till above the Bearpaw and Edmonton formations is normally white to grey-brown. Where the till is thick, whether above the Bearpaw, Edmonton, or Paskapoo formation, it is commonly light grey or blue, particularly if it is below the water-table and the zone of oxidation.

Several till size analyses have been made. These do not necessarily represent anything but the local till deposit from which they were taken, but they do indicate its general size composition. It is a good till, with significant amounts of all size components.

From place to place, the till also varies in hardness, density, permeability, porosity, jointing, and resistance to erosion. These features are largely dependent on its composition, but they also are affected by its age, the effects of loading and compression subsequent to deposition, the height of the water-table, and weathering.

Generally, the permeability is low, and seepage of water slow. The permeability increases somewhat in the more sandy till and where joints are common, but it is nowhere high. Little is known of the porosity. Most of the till is compact, dense, and very sticky if wet. This property is due largely to a high content of bentonite derived from the local bedrock.

Composition: Stone Content

All the till of the area contains rock fragments from the Precambrian Shield, brought into the area by three or more Laurentide ice-sheets. The till in the western part of the area contains many erratics of Cordilleran origin that were seemingly added by intermixing of mountain and Laurentide ice, but there is no evidence that any of them were brought in solely by Cordilleran ice. The proportion of larger fragments in the till varies greatly, but it is generally small. Stones with a diameter of more than one half inch rarely account for more than 2 per cent of the volume of the typical till, and generally for less than 1 per cent. Most of the stones were derived from the preglacial gravel, and more than 50 per cent of them had their source in the mountains to the west. Where studied, mostly in the northern part of the area, the proportion of the various rock types in the surface part of the till is about as follows:

	%
Hard sandstone and quartzite	40.8
Limestone	11.8
Dolomite	10.7
Local bedrock (includes all stones originating on the plains, such as ironstone, coal, weak sandstone, shale)	17.2
Igneous (mostly granite)	17.8
Metamorphic (mostly gneiss and schist)	1.7

Assuming that all the quartzites, hard sandstones, limestones and dolomites had their source in the mountains to the west, the origin of the stones is about as follows:

	%
Cordilleran types	63.3
Prairie types	17.2
Precambrian Shield types	19.5

However, it is possible that a few of the quartzites, hard sandstones, limestones, and dolomites originated in the Precambrian Shield. This would increase slightly the percentage of Precambrian Shield stones at the expense of the Cordilleran types.

Composition: Till Members

The till of the area can be divided into three members that represent three separate glaciations. For convenience it is thought best to name these tills, and it is hoped that this will aid in their correlation in various parts of the province, and quicken establishment of the sequence of glacial events. Until now, colour, composition, and position names, such as black, blue-black, brown, blue, grey, silt, basal, middle, lower, upper, have been used to describe these tills (Horberg, 1952; Collins, 1955, p. 16). The two tills older than the one generally found on the surface are present only locally, and mostly where preserved from later glacial erosion in valleys and other low ground. The lowest till is here called 'Labuma' from good exposures on Red Deer River near Red Deer, particularly west of the city at Labuma (appendix, section 1) (sec. 19, tp. 38, rge. 27, W. 4th mer.), but also within the city (appendix, section 9) and just upstream from it. The middle till is here called 'Maunsell' from its excellent exposures on the north bank of Oldman River, about 4 miles northeast of Maunsell, in the NW. ¼ sec. 18, tp. 7, rge. 28, W. 4th mer. (outside the Red Deer-Stettler area). The topmost till is here called 'Buffalo Lake' from the many good exposures of this till around Buffalo Lake in the Buffalo Lake hummocky moraine. These three tills are commonly separated by beds of gravel, sand, and silt.

Any difference in the material composing the three tills, or in its relative grain size, is generally smaller than lateral variations within each till. Thus in most districts there is no significant variation in the proportions of various types of stones in each of the three tills. The chief differences between the tills are mostly due to differences in compaction, age, oxidation, and effects of burial below the water-table.

Each of the three tills, below the zone of oxidation, can be distinguished by its joint system. Upon exposure and drying the Labuma till fractures in one horizontal and two vertical planes to give cubes 3 or 4 inches to a side. The jointing in the Maunsell till forms vertical, rectangular or prismatic blocks, generally 3 feet, but locally as much as 20 feet long, and 3 or 4 inches wide. If the fracture planes in these two tills are not horizontal or vertical it can be assumed that the till has slumped or has been contorted by overriding glaciers. On cliffs and river banks the jointing of the Maunsell till results in distinctive bluffs and columnar forms, as the till slumps or breaks along these fractures and tends to give vertical faces as much as 70 feet high. Dawson (1885, pp. 143c, 144c) described such features along the Oldman River, south of the Red Deer-Stettler area. Similar cliffs along Bow River, also south of this area, are formed by the Labuma and Maunsell tills. The jointing in the Buffalo Lake till is irregular and not very prominent. This till is weak and rarely forms vertical bluffs.

The Labuma till is dark blue or black, perhaps due to a large content of carbonaceous material derived from Cretaceous and Tertiary coal seams and carbonaceous shale, and to long burial below the water-table. However, it seems to retain this colour even when near the surface and above the water-table. The Maunsell till is light to dark blue, also due to its content of carbonaceous material and long burial under the water-table, though for a shorter time than the Labuma till. The Buffalo Lake till is more variable in colour, with varying browns, yellows, greys, and light blues where unoxidized. Upon drying the three tills become light in tint, to various shades of grey.

The Labuma is the most massive of the three tills, and it is extremely sticky if wet. The Maunsell till has similar properties, though to a lesser extent. Both these tills are rather impermeable, and seepage of water is mostly along joints or through included lenses of sand and silt. These tills have undergone compaction by weight of later glaciers and by longer emplacement, and are generally harder and more resistant to water erosion than the youngest till.

Only minor weathering is noticeable on the two older tills. It takes the forms of thin, oxidized or leached zones at their surfaces. Later glaciers apparently removed most of the weathered material at the surface. In addition, oxidized zones are common near water-carrying gravel or sand lenses in the tills, but their nature is self-evident.

The three tills have been described elsewhere, and apparently retain the same characteristics everywhere in the province. The Labuma till is the till described by Horberg (1952, pp. 310, 311) as the 'Basal Till'. It also corresponds to the lower of the tills at the Weed Creek exposure (appendix, section 16) NW. ¼ sec. 26, tp. 49, rge. 28, W. 4th mer., shown to the writer by T. W. Peters of the Dominion Soil Survey. It appears to correspond to the lowest of the three tills present in several of the strip coal mines near Morinville (particularly in sec. 24, tp. 55, rge. 25, W. 4th mer.) shown the writer by W. Clow, then of the Research Council of Alberta. The thickest section of this till known to the writer is that along Bow Valley between Carseland and Gleichen, where much of the fill of the former Bow Valley appears to be Labuma till.

The Maunsell till corresponds to the 'Lower Till' described by Horberg (1952, pp. 311-313), which is locally exposed along Oldman Valley between Castle and Bow Rivers, particularly near Fort MacLeod, Lethbridge and Taber. It is the second till in the Weed Creek section (appendix, section 16), apparently the upper till at the Labuma section (sec. 19, tp. 38, rge. 27, W. 4th mer.), and apparently is the lower till in sections 3, 5, and 11 in the appendix. In the Red Deer-Stettler area, Maunsell till is more common than Labuma till.

The Buffalo Lake till is the one normally described in the various geology and soil reports on the area.

Modified Ground Moraine

The modified ground moraine shown on the map includes those till plains that have undergone strong modification by river or lake water subsequent to deposition, but which remain basically ground moraine. Much of the fine material was eroded from the surface of the till, leaving behind a sandy mantle or even minor gravel and scattered boulders. More locally the modified ground moraine represents till on which a thin mantle of silt, sand, and gravel has been deposited. Where such materials were deposited in significant quantities they are mapped separately as lake or river deposits.

Most of the regions modified by river floodwater adjoin Battle River from Driedmeat Lake downstream, and are largely on the southwest side. The modification resulted from flooding by Battle River, mostly before its course was firmly established and its valley deeply cut. The flooded areas commonly have a marked southeast-trending surface lineation, approximately parallel to the river. This lineation is very conspicuous on aerial photographs. Northwest of Halkirk, floodwaters carved several short valleys parallel to Battle River. Elsewhere, particularly to the northeast of Stettler and north of Gadsby, other streams meandered upon the fairly level till plains, with seasonal flooding and many changes of channel. This covered the ground moraine with a thin mantle of silt and sand, which is readily mistaken for lake deposits.

The areas of ground moraine that were modified by the lake water generally adjoin areas of lake deposits, but occur at somewhat higher altitudes. These high-level lake stages apparently were short-lived, and the water was shallow and generally quiet. Local patches of gravel, sand, and clay, or scattered stones, commonly are all that mark the former ponding.

Origin and Age

Most of the ground moraine was deposited from the base of the ice with the addition, as the ice melted, of material from within and from the surface of the glacier. This moraine is the glacial deposit of flat regions, where there were few topographic obstructions to impede regular ice flow, and where there were no high areas against which the ice margin lay for any length of time during its retreat. The ice stagnated and melted fairly evenly across wide belts of these flat regions, and spread a consistent and even cover of till. Only a few kames and esker ridges break the monotony of the plains.

The strongly rolling ground moraine of the high land commonly overlies a rough bedrock topography. This rough sub-ice surface caused local variation in amount of material deposited, increased the number and size of kettles formed through melting of buried ice blocks in the swales, and aided the formation of small kames and short esker ridges through its effect on glacier flow. In lowland areas, near Forestburg, Halkirk, and Botha, some of the strongly rolling ground moraine may represent a thickening of drift such as marks minor halts in the ice retreat, or true recessional moraine. It does not, however, have the strong knob-and-kettle development of the hummocky moraine.

The ground moraine plains of the area were not all formed at the same time; those in the southern part were completed while those in the northeastern part were still being formed. As the hummocky moraine is generally on high ground, and as the ice largely disappeared by lowering of its surface, the hummocky moraine of the area was largely deposited before most of the ground moraine plains were completed. In any local district the ground moraine was the earlier, however.

The thinness of the drift (*see* Plate XIII), mostly ground moraine, in the Torlea flats system has often been emphasized (Warren, 1937, p. 304), and in places it is less than 5 feet thick. Actually, however, it has an average thickness of between 5 and 10 feet, or only about 5 feet less than on other ground moraine plains of the map-area. For instance the till of the ground moraine plains west of Red Deer, Lacombe, Ponoka, and Hobbema, and between the western edge of the Buffalo Lake moraine system and the eastern edge of the former Red Deer valley, is commonly less than 5 feet thick, and has an average thickness of between 10 and 12 feet. However, on the Torlea flats, the ice was thicker and lasted longer than that farther west, and the ground moraine might be expected to be thicker there.

Several factors give an impression that the ground moraine above the Edmonton formation, on which the Torlea flats lie, is much thinner than that overlying the Paskapoo formation. Thus the brown, sandy till above the Paskapoo appears more like normal, weathered till than does the tight, greyish white, clayey and silty, nearly stoneless till so common above the Edmonton formation and so similar in appearance to much of this formation. Also the greater precipitation in the western part of the area, combined with the greater absorption of water by the till overlying the Paskapoo rock, promotes much stronger plant growth there than is found over the Torlea flats. The vegetation on the till of Torlea flats is sparse and similar to that on the driftless bedrock 'burns' of the region; this also tends to emphasize the thinness of the drift. As a result of weathering and slumping, bedrock exposures are fewer and less noticeable in districts of Paskapoo rock than on the dry Torlea flats.

That the general thinness of the drift on the Torlea flats is not due to post-glacial erosion is evident from the following facts: the region is relatively flat and poorly drained; the clayey drift is not susceptible to wind erosion; present stream erosion is small; there are few residual stones; the precipitation is low, evaporation high; the numerous small hills show little effect of erosion; and undrained depressions, swamps, and sloughs are common. Post-glacial erosion was important only locally, particularly near Lonepine, Marion, Shooting, and Sullivan Lakes; and near Battle River and Paintearth Creek. This erosion was done largely by ice-front streams during glacier retreat.

The general thinness of the drift cover on the Torlea flats results chiefly from an original lack of deposition of till from the ice-sheet. There the last glacier retained movement and eroded strongly until it had nearly disappeared. This is indicated by recessional moraines, thinness of drift, the many shallow basins eroded in the bedrock by the glacier, the ice-flow markings that are evident on both ground moraine and bedrock, and the general freshness and lack of weathering of the bedrock beneath the drift, as if the surface of the bedrock had been removed by ice. The eroded material, along with materials from other areas, was carried to regions where less erosion was taking place, and particularly to the Buffalo Lake moraine system. Upon stagnation and melting of the ice the only drift deposited was the small amount contained in the overlying ice; commonly too little to obscure the ice-flow markings. This material, carried near the base of the ice, was derived mostly from local bedrock. A minor cause of the thinness of drift was that the Torlea flats, unlike the western part of Red Deer-Stettler area, did not receive any of the material that was added to the Laurentide ice-sheet by Cordilleran glaciers.

Geography

Though the ground moraine plains are not farmed as intensively as certain of the lake basins, their large expanse makes them the chief farmland of the area. The ground moraine has a good soil, and it is rarely rolling enough to have strong soil erosion. The shallow depressions are important for their retention of water through times of little precipitation and for their support of shrubs and trees in otherwise treeless regions. Some of the more rolling ground moraine is used only for cattle grazing, hay raising, or bushland. In general, except in the more arid districts, the till plains are well populated.

The ground moraine that has undergone modification by water is largely in the dry parts of the area, and thus is less important than it would be if it occurred elsewhere. The remnant boulders and gravel, if common, impede farming. Where the modification consists of fine lake deposits the effect on farming is the same as that of the thicker deposits of the major glacial lakes. The surface modification of the ground moraine has no effect on water supply.

Drumlins and Ice-flow Markings

Many drumlins and other ice-flow markings which reflect direction of ice-movement are found in the area. Most are on till plains, but some occur in outwash and lake deposits that have been overrun by late ice advance (*see* Plate

IV). Some of those on thin lake deposits are reflections of forms occurring on underlying ground moraine. Ice-flow markings are most common in the former Red Deer valley in the western part of the area. The drumlins and related ridges are generally composed of material similar to that forming the nearby surface deposits. Thus on a till plain they are composed of till, in outwash districts of silt, sand, and gravel, and in lake deposits of clay, silt, and sand.

Only three drumlins are large enough to be shown in colour on the geological map of the area; the others and the rest of the large ice-flow forms are shown by symbol only. Each of the three large drumlins (one in sec. 27, tp. 43, rge. 26, and two in sec. 4 and 10, tp. 36, rge. 28) is more than a mile long and an eighth of a mile wide, and each of the first two has a height of more than 100 feet. All are till drumlins, but the second and third have a covering of lake deposits. That all three are elongated in the same direction (to the south) is fortuitous, as many of the smaller drumlins have other directions of elongation. The other drumlins and drumlinoidal ridges range in size down to those 100 feet long and 5 feet high. Most of the drumlinoidal ridges are long and straight, lower than true drumlins, and commonly wider towards their lee ends.

Most of the drumlins and related ridges apparently were formed by swiftly readvancing ice that moulded the material it overran. This moulding was most effective on outwash hills, kames, and hummocky moraine, and few large drumlins were formed where the surface was flat or gently rolling, with no obstructing hills. Drumlins are absent in most of the hummocky moraine as much of it lies on high land that was not overrun by late ice advance. A few of the ice-flow forms were built to the lee of bedrock hills.

Most of the other ice-flow markings were formed during a late rejuvenation of the glacier. A few remain from an earlier ice advance, probably the main Wisconsin. These last are chiefly in the eastern part of the area.

Hummocky Moraine

General Statement

The hummocky moraine is typically found in districts of high elevation, and particularly in the Central Highland. These are the districts of high bedrock hills and plateaux. Where the bedrock surface becomes lower the hummocky moraine generally ends; this is particularly noticeable on the eastern edge of the Central Highland. Minor patches of knob-and-kettle topography, separate from the main mass of the hummocky moraine, are present on the low till plains of the Torlea flats system and on the high land east of Lacombe. Morainal hills also occur in the outwash ridge between Innisfail and Morningside, but these are included with the outwash on the map. Altogether hummocky moraine covers about 1,100 square miles of the Red Deer-Stettler area. The drift composing it is mostly 20 to 50 feet thick, although here and there it is much thicker.

On the map the hummocky moraine is divided into districts with strong and moderate knob-and-kettle development. The former (*see* Plates I B, V, VI) covers 520 and the latter (*see* Plate VII) 575 square miles. They are thus divided as there are large differences in the heights and sizes of knobs and depths of kettles. The heights of the knobs vary in different districts from as little as 15 feet to as much as 150 feet above the floors of the neighbouring kettles. Combination of the two divisions on the map would give a misleading impression of a large mass of hummocky moraine with a general southward trend, whereas the twofold division brings out the complexity of the moraine in detail and indicates the more correct eastward trend in various parts of the moraine. A single moraine division also gives a misleading impression of the size and intensity of the moraine, and is of less value in indicating the suitability of the land for cultivation, pasture, and other uses. No set degree of development of the moraine is used as a dividing line for the whole area. The twofold division is somewhat arbitrary and is based on factors such as shape and form of the knobs, their concentration, and the character of the surrounding topography and underlying bedrock surface. In the districts of moderate hummocky moraine, the sectional roads are fairly straight, fields are fenced and grazed, hay is gathered, and much of the bush cleared. In the strongly developed moraine, the few roads wind continually, bush is common, and little attempt is made to farm.

Composition and Description

Most of moraine is composed of till similar to that of the ground moraine, although commonly coarser because of removal of much fine material as outwash during deposition. In addition the hummocky moraine includes numerous pockets and hills of gravel and sand.

Most of the knobs in the hummocky moraine are gently rounded, equidimensional hills, but hills and ridges of all shapes are present. Typical examples of the round knobs occur north of Lousana. Many have a small depression in the centre, probably caused by melting of a remnant ice block buried in the hill. Another type is shaped somewhat like a barchan dune, and in the map-area the high end and convex side are generally to the south. In the more strongly developed moraine the knobs generally have slopes of between 12 and 20 degrees, rarely as much as 25 degrees, and in the moderate hummocky moraine, of between 8 and 15 degrees.

Modified Hummocky Moraine

Some of the hummocky moraine was modified by "minor lake erosion or deposition". This modified moraine is most common on the eastern edge of the Buffalo Lake moraine system, where water was ponded between the higher parts of the moraine and ice that blocked the natural drainage to the east or northeast. This drowning of the low margins of the moraine was short-lived, as the water soon found outlets parallel to the ice-front and the ice barrier melted and lowered. The deposits of this ponded water are generally thin and patchy. Elsewhere fine material was removed from upper parts of the moraine, leaving concentrations of boulders and gravel. In general, the modification was minor, and the modified hummocky moraine retains its knob-and-kettle characteristics, though they are somewhat subdued.

Origin and Age

Some of the hummocky moraine was laid down near the ice-margin during a temporary halt or slight readvance of the retreating glacier, and is true recessional moraine. Such recessional moraine is largely confined to the lower parts of the hummocky moraine, and is found principally north of Red Deer Lake, near Lowden Lake, west of Gough Lake, and north and east of Stettler. Some also is found along the eastern and northeastern edges of the Buffalo Lake moraine system between Red Deer Lake and Gough Lake, and some of the southwest-trending belts of hummocky moraine southwest of Red Deer Lake may also be true recessional moraine.

The origin of the rest of the hummocky moraine is in doubt. Hoppe (1952) reviewed the possible origins of such moraine. The origin of the hummocky moraine of the area appears to be associated with relatively slow movement of the glacier over the rough, high land of the area as compared to adjacent low land, resulting in less erosion and more deposition on the high ground. Also, as the ice-sheet decreased in thickness during its retreat, ice stagnation and formation of hummocky moraine started on the highest parts of the area and spread downwards as the glacier thinned. The hummocky moraine evidently took a long time to form, and during all this time active ice carried material mostly from the west, north, and east to near the contact of active and stagnant ice. These factors increased the thickness of the drift in the hummocky moraine areas at the expense of its thickness in nearby areas.

The hummocky moraine generally does not have the ridges, or the alignments of knobs and kettles, parallel to former ice-fronts that are commonly characteristic of recessional moraine. Also the remnant ice blocks in the stagnant ice produced rounded kettles or depressions, rather than elongated ones. The lack of lineation suggests that much of this moraine was deposited within the stagnant ice itself, rather than at the edge of the ice-sheet or at the active-stagnant ice contact. Vertical movement of basal till, pressed up into any available cavity or fissure in the dead ice by weight of nearby ice, appears to have been important in formation of the hummocky moraine. Thus, if the saturated till beneath the ice were unfrozen and plastic, it would flow into any cavity in the base of the ice and rise to a height determined by supply of till, thickness of the ice, and relative densities of the till and ice. The cavities need not have reached the surface of the ice. Faulting and folding in the otherwise stagnant ice may also have had a part in giving the rough, unaligned, knob-and-kettle topography.

Evidence of ice stagnation during deposition of the hummocky moraine is provided by the associated short esker ridges, kames, wind gaps, and dead ice plateaux, all of which typically form when ice movement has practically ceased. Also some knobs in the southern part of the hummocky moraine are capped by undisturbed, horizontally bedded sediments that were laid down in water while the nearby ice was melting. As these sediments are undisturbed, the surrounding ice could not have been active.

A downward-melting glacier surface would clear land largely in order of altitude. Thus high ground far from the ice margin would be cleared of ice early in the deglaciation. Active ice would then tend to build moraines, somewhat similar to those built at the main margin of the ice-sheet, around this high ground. The large moraines of the prairies, such as the Buffalo Lake moraine system, do not necessarily represent successive halts in the retreat of the glacier margin, with each successive moraine to the northeast being younger than the next one to the southwest, and with the surface drift southwest of each moraine being older than that to the northeast. They may, however, represent halts in the lowering of the ice surface. Thus these moraines in any region should be correlated chiefly by elevation, rather than by location. Three or four such moraines could form simultaneously; thus much of the Buffalo Lake moraine system formed before either the Duffield moraine to the west or the Viking moraine to the east (both outside the map-area), but the highest parts of the Duffield moraine at altitudes of 2,700 to 3,000 feet formed at about the same time as those parts of the Buffalo Lake moraine system lying at altitudes between 2,800 and 3,100 feet.

There are few run-off channels and outwash deposits associated with these moraines, as the meltwater had to escape over or under belts of ice to reach the main glacier margin. This has been a puzzling feature of many hummocky moraines of the southwestern plains (Johnston and Wickenden, 1931, p. 40).

The Buffalo Lake moraine system and similar systems formed while they were completely or largely surrounded by active ice and are not typical terminal or recessional moraines. They are more nearly medial, or interlobate moraines, but perhaps the best name is 'island moraine'.

Geography

In general, the areas of hummocky moraine are sparsely populated and little cultivated. They contain some pasture land, and the kettles commonly furnish satisfactory water supplies for stock. There are few roads and few towns. Thicks bush covers much of the hummocky moraine in northern parts of the map-area.

Stagnant Ice Deposits

General Statement

The deposits described here include those of the 'moraine plateaux', 'ice-block depressions', and kames. Altogether they cover about 50 square miles of the area, mostly within the confines of the Buffalo Lake moraine system. These deposits are grouped on the map, as they all require stagnant ice in contact with water and holes in the ice-sheet for their formation.

Moraine Plateaux

The term moraine plateaux, which is partly descriptive and partly genetic, is used by Hoppe (1952, p. 5) for certain plateaux within hummocky moraine, similar to those in the Red Deer-Stettler area. These plateaux formed during conditions of practically 'dead ice', and mostly within the borders of hummocky moraine. They are relatively flat-topped in comparison with the nearby hummocky moraine knobs and typical ground moraine, commonly have flat-lying sediments as their surface, and are higher than most of the neighbouring country.

Moraine plateaux are the most common, the most important, and generally the largest of the stagnant ice forms (*see* Plate V). A similar type of mound, probably related to the moraine plateaux in method of formation, occurs typically on ground moraine plains. These are common in much of the province but are rare in the map-area. They are about 5 to 15 feet high and 100 to 500 feet in diameter. The moraine plateaux form a chain that trends from a point north of Pine Lake northeastward across Red Deer River and almost encircles Buffalo Lake, from whence it trends southward from near Nevis to a point west of Big Valley. The largest and best examples are those west of Big Valley and northeast, east, and southeast of Buffalo Lake (*see* Figure 4).

The moraine plateaux vary greatly in composition and structure. They generally overlie till hills similar to those in the adjoining hummocky moraine. These till hills may be completely buried by the plateau deposits, may reach the surface locally, or may form most of the surface of the plateau. The plateau material overlying the till hills includes water-deposited beds of gravel, sand, silt, and clay, with here and there a bed or lens of till amongst the stratified

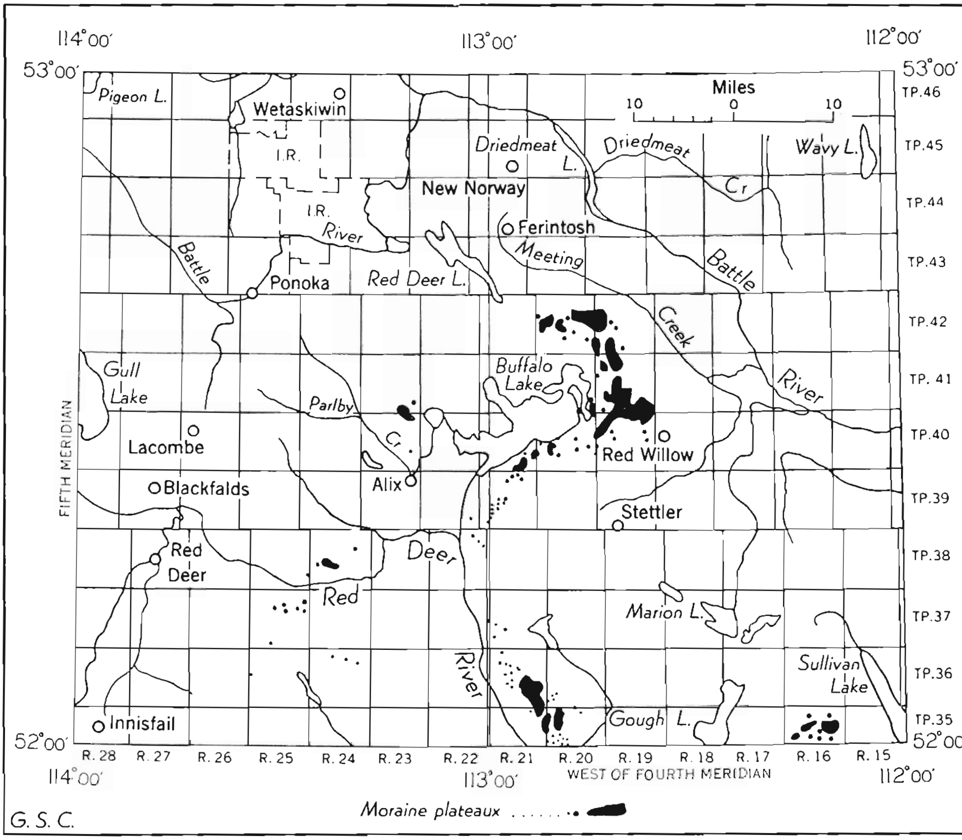

Figure 4. *Locations of moraine plateaux in Red Deer-Stettler area.*

material. Not all of these materials need be present in any individual plateau, and there may be several beds of one or more of them, but they are not in any set sequence. Here and there the silt and clay are varved. Clay is the most common material on the surface of the plateaux; gravel is less common than the other stratified materials, and sand is less common than silt or clay. Rafted stones are rare in the silt and clay, and the beds inside the margins of the plateaux are little deformed. In general, the deposits appear to have been laid down in quiet water.

The typical plateau has a flat surface with lake-plain characteristics, if the surface material is sand, silt, or clay. If the surface is formed of till it is commonly gently rolling or undulating. Kettles formed by melting of remnant ice blocks buried in the till or lake deposits are found in many of the plateaux, and some of these kettles contain ponds. These kettles are shallow, particularly in comparison to those in the nearby hummocky moraine. The typical plateau is as high as, or slightly higher than, the highest knobs in the neighbouring hummocky moraine.[1] In subdued hummocky moraine, level patches in the otherwise gently rolling plain commonly are the only topographic features that indicate the presence of the moraine plateaux (e.g., those east of Pine Lake). The plateaux range in height from a few feet to 150 feet. The highest, Boss Hill, in sec. 2, tp. 41, rge. 20, is in the strongly developed hummocky moraine east of Buffalo Lake. Most of the plateaux are between 30 and 70 feet high.

Rim ridges border about one quarter of the perimeters of the moraine plateaux. They are composed of the ordinary clay-till of the area. They rise 2 to 20 feet above the plateaux surfaces, towards which they dip with a slope of a few degrees, and pass under the sediments that generally form the surfaces at about the same slope. The ridges are rounded on top, and dip steeply (at about the angle of repose for the material forming them) into the kettles of the hummocky moraine surrounding them. The drop from the top of the ridge away from the plateaux is generally several times as great as the drop towards their centre. In certain places where no rim ridges rise above the surface, road-cuts reveal one and, in rare examples, two parallel till margins which do not rise to the tops of the sediments. These appear to be incipient rim ridges that did not reach full development before their formation ceased.

The origin of the moraine plateaux and their rim ridges is a puzzling phenomenon. Hoppe (1952, particularly pp. 5-9, 54, 55) gave a complete description of them, discussed the various theories of origin and reached certain conclusions. The writer is essentially in agreement with these conclusions. The following features of the moraine plateaux have an important bearing on their origin:

> They form a fairly continuous belt through the hummocky moraine (*see* Figure 4).
>
> They are mostly confined to districts of hummocky moraine, and are particularly numerous where this moraine is strongly developed and rough, and near outwash that is associated with this moraine.
>
> The plateaux generally overlie till knobs of the hummocky moraine, which here and there reach the surface of the plateaux.
>
> Most of the plateaux are as high as or higher than the hills of the adjoining hummocky moraine.
>
> The surfaces of the plateaux are generally flat or gently rolling, and shallow kettles are present.

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[1] The moraine plateau in sec. 35 and 36, tp. 40, rge. 23, is a special one, as it lies on a sloping surface. The eastern part of the plateau rises above the hummocky moraine knobs but, since its surface is nearly level, the western part of the plateau is lower than the moraine hills and has more the appearance of an ice-block depression or a large kettle.

67898-7—4

The surfaces of the plateaux commonly are composed of quiet-water sediment such as silt and clay, which is commonly varved, and ice-rafted stones are rare.

Ridges, composed of ordinary compact, clayey, basal-type till, and without structure or bedding, rim the whole or part of many of the plateaux. (*see* Plate V).

The till of the plateaux areas is of a plastic, clayey type.

The central parts of the plateaux are undisturbed by ice pressure.

The formation of the plateaux has three separate problems. The first is the method of formation of the depressions or holes in the ice in which the plateaux necessarily formed; the second is the cause of the rim ridges (Hoppe, 1952, pp. 5, 7); and the third is the origin of the plateaux themselves. Holes do occur in many present-day glaciers. They are most likely to occur in thin stagnant ice, as active ice would tend to fill them, and the climate needs to be warm enough over the greater part of the year to keep meltwater from freezing and partly filling the holes with new ice. Such conditions were present during the final retreat of the last glacier from the Red Deer-Stettler area. Hence numerous holes could form and harbour the ponded waters in which stratified deposits would be laid down. The water apparently drained subglacially or englacially through crevasses or tunnels, and the ponded water was maintained at a fairly constant level by topographic barriers in the outlets or by the altitude of the plastic ice during the slow retreat of the glacier. It is difficult, however, to explain how the largest holes, those now occupied by plateaux with lengths up to several miles, were formed.

The till composing the rim ridges could have come from the top of, within, or from beneath the surrounding ice. If the wet material slumped or otherwise worked its way down the surrounding ice surface, it should have resulted in the development of some structure in the till, and this is not apparent. If water removed fine material, such slumping would result in a loose, coarse till with more sorting and structure. Such slumping or carrying of the ridge material also would necessitate holes with gently sloping sides, in order to collect drift from an extensive area of the ice-sheet. Such sloping sides would tend to spread the material over a wide belt rather than into a ridge, as the ice slowly melted. In addition, an ice-sheet commonly carries only a small amount of material within its upper zones, probably not sufficient to form the larger ridges.[1] Running water would be required to bring material from any great distance, and the material brought in this manner would be sorted.

[1] The maximum distance slumping would carry material to the ridge would be determined by the horizontal distance in which a slope, starting at a height equivalent to the top of the present ridge and just steep enough to allow till to slump towards the depression, would reach the surface of the ice-sheet. This distance would probably be about a half mile.

The material in the ridges apparently was squeezed from beneath the adjoining ice into the margins of the holes by weight of the ice itself. Such an origin would explain the plastic, basal-type, structureless, till that composes the rim ridges, and give an adequate source of materials. Removal of material from beneath the adjoining ice would also tend to accentuate the heights of the ridges and depths of the adjoining kettles upon melting of the ice. This method of formation requires steep-walled holes. The maximum possible height of such a ridge is largely determined by the thickness of the adjoining ice and the relative densities of the ice and saturated till. Thus, disregarding friction and any other minor factors, dead ice 200 feet thick and with density of 0.8 could build a ridge some 80 feet high, using till that had a density of about 2.0. A few of the rim ridges in the Red Deer-Stettler area are about 70 feet high, which indicates that the ice during their formation was about 200 feet thick, or about the maximum thickness that the ice could have without plastic flow taking place. Such a great height is rare as a number of other factors, such as supply of plastic till, ice-thinning, and glacier retreat from the pond area are also involved. In several places the ice-margin around a hole appears to have retreated a short distance following formation of the rim ridge. This occasionally resulted in formation of a second ridge, generally smaller than the first.

Similar till ridges not associated with moraine plateaux, but believed to have originated through the same squeezing process in crevasses that reached the base of the ice, are also present in the area. Many of the till ridges shown on the surficial geology map are believed to have formed in this manner.

The sediments of the moraine plateaux were apparently deposited while the rim ridges were being formed. Here and there, however, the rim ridges were shoved up under the edge of the sediments, raising the margin of the beds but not otherwise disturbing them. Most of the basin material was brought in from some distance by streams, but some came from the adjoining ice. The gravel beds represent either local deltas of the streams carrying the material in, or a quickening of melting in the nearby ice. Slumping from the surface of the adjoining ice apparently formed most of the till beds. Melting of grounded icebergs may have formed local lenses of till but the rarity of ice-rafted stones in the fine sediment indicates that calving of icebergs into the water of the depressions was not common. Much of the sediment is of a quiet-water type and apparently was deposited slowly, a natural outcome of slow melting of the ice near these holes. Generally these holes were well within the ice-sheet, far from the rapid melting of the marginal belt, and any meltwater was produced under fairly cool conditions.

The moraine plateaux are a striking contrast to the surrounding hummocky moraine. They are oases of farmland in an otherwise unsettled and rough country. The soil is generally good and commonly free of stones; bush is present only near the shallow kettle depressions.

67898-7—4½

Ice-Block Depressions

The ice-block depressions cover only a few square miles. They are mostly in the subdued hummocky moraine northeast of Pine Lake, but a few occur on ground moraine plains. They are flat areas of till, or of clay, silt, and sand, mostly less than a square mile in extent, that are enclosed by long and narrow, generally nearly circular, ridges of till, gravel, sand, and silt. In contrast to the moraine plateaux they are generally the lowest parts of a district. They are distinguished from the regular kettles of hummocky moraine by their rim ridges, flat floors, and generally larger size. The ice-block depressions also contain more water-deposited sediments than do the ordinary kettles.

The origin of the ice-block depressions differs markedly from that of both moraine plateaux and morainal kettles. These depressions formed by melting of exposed and isolated ice blocks, rather than of buried ones, as was commonly true of the kettles of the hummocky moraine. They were also formed late during the retreat of the glacier, when there was little other ice nearby. Material was carried off these ice blocks by both slumping and meltwater; thereby they were rimmed with debris. Also some material may have been squeezed up into the debris rims from beneath the ice blocks themselves. The rim ridges are up to 30 feet in height, and in hummocky moraine areas the tops of the ridges are generally 10 to 30 feet lower than the tops of the nearby knobs. On ground moraine plains the ice-block depressions are conspicuous chiefly by these circular ridges.

The ice-block depressions were the last features formed directly from the ice itself during the retreat of the glacier. Advantage is taken of their flat surfaces for agricultural purposes.

Kames

The word kame is here restricted to mound-shaped deposits laid down by running water in a moulin or other hole in the ice-sheet. Kames are the least important of the stagnant ice deposits in the map-area. Several small hills north of Nevis are mapped as kames, though they may be small moraine plateaux; few of these have been examined on the ground. Other small kames may be present in the hummocky moraine or the till plains, but they are not readily distinguished by shape from regular morainal hills. A few small kames occur in the hummocky moraine east of Byemoor, but these are too small to map individually. Their location is indicated on the map of gravel deposits. The kames, as far as is known, are composed of roughly stratified gravel, sand, silt, with minor till.

Outwash

Distribution

The main deposits of outwash are around Buffalo Lake, south of Alix, north of Pine Lake, west of Innisfail, north of Red Deer, and between Blackfalds and a point west of Morningside. These and many small deposits are shown on the surficial geology map. Smaller areas of outwash are not mapped separately but are included with hummocky moraine or lake basins.

The outwash covers about 175 square miles of the Red Deer-Stettler area. The average thickness of drift in the outwash areas is surpassed only by the thickness of drift that fills the former Red Deer valley. The drift in the outwash area northwest of Innisfail is as much as 150 feet thick, and most of it is outwash. The outwash southwest of Lacombe and east of Buffalo Lake is nearly as thick, but elsewhere the deposits are thinner.

The boundaries of the outwash are generally gradational, as at Lacombe where the outwash surface slopes gently eastward down into the glacial-lake sand and silt beds of glacial Lake Red Deer. There the boundary is drawn at the approximate bottom of this slope. A similar condition exists west of Buffalo Lake, where lake deposits and outwash also grade into each other.

Most of the outwash is an integral part of the hummocky moraine. This is so in those extensive areas near Buffalo Lake, south of Alix, and north of Pine Lake. The Innisfail-Morningside outwash belt represents a former ice-front and includes or overlies many moraine hills of till, particularly west of Morningside and northwest of Innisfail. These till hills are included in the main mass of the outwash on the surficial geology map.

Subdivisions

On the map the outwash is subdivided into pitted plains that retain obvious correspondence of summits; plains that are so strongly pitted as to retain practically no correspondence of heights; and outwash material that was deposited directly and rapidly at the ice-margins without any semblance of plaining. A fourth subdivision, which includes parts of the other three subdivisions, is made for economic reasons to indicate the more gravelly outwash.

Pitted plains form the major outwash deposits, and contain most of the fine outwash material. Good correspondence of summits is found west of Lacombe, west and northwest of Innisfail, and some indication of correspondence exists in the outwash south of Alix. The outwash near Buffalo Lake is so strongly pitted as to show little or no resemblance to a former plain. The smaller outwash deposits, except for a pitted plain in sec. 16, tp. 37, rge. 26, are ice-marginal types without plain surfaces. These consist of coarser material; gravel is prominent, and material finer than sand is generally of little importance. The topography over these small outwash deposits is generally rough and hilly, as a result of their rapid deposition.

Composition and Description

The outwash in general consists of gravel, sand, silt, and clay, and commonly surrounds or covers morainal till hills. Till also occurs locally in lenses or bands in the outwash sediments themselves. Sand is the most common constituent. Gravel, though not a major constituent proportionately, is locally present in large pockets and any one of the outwash areas probably contains deposits of economic importance. In general, the surface of the outwash becomes rougher as the constituent material becomes coarser.

The plain or pitted plain outwash consists of well-bedded and crossbedded sand and silt, with minor amounts of clay. Gravel is important only locally, but where present forms high hills that rise above the rest of the plain. The clay and silt are locally varved. The silt beds are mostly 1 inch to 12 inches thick, and contain lenses of sand. They are nearly horizontal except where disturbed by late deformation. The sand and gravel beds generally dip more steeply and are less continuous. Ice-rafted and stream-carried stones are scattered throughout the outwash in varying concentrations.

Good sections of pitted-plain type outwash northwest of Innisfail show nearly horizontal silt bands 8 to 10 inches thick, lenses of till and sand, and in the higher hills nearby, more steeply dipping gravel and sand beds. Farther east in this area clay deposited in later glacial lakes covers the outwash. The silt beds are little disturbed or deformed, except for minor slumping which has increased the dips. Farther north in this same outwash belt and a few miles west of Lacombe, the outwash contains deformed beds of sand, silt, gravel, and till. Pressure of the nearby glacier, combined with melting of adjoining ice and resultant slumping, was responsible for this contortion. The beds are now folded, some of the folds being overturned, faulted, and the beds intermingled. Overrunning of the Innisfail-Morningside outwash by ice has caused much deformation, particularly by stretching the outwash hills into drumlins and ridges (*see* Plate IV).

The pits or kettles in the outwash are characteristically deep, steep-sided, and commonly contain ponds. They vary greatly in size. Most are only a few hundred yards in diameter, but others are 2 or 3 miles long; the largest of all are the depressions now occupied by the main body of Buffalo Lake. The depths of the kettles and the slopes of their walls are generally greater than in the kettles of the hummocky moraine. The surface of the original outwash plains, before melting of the ice blocks, was flat to undulating, being flattest where the outwash material was finest. The flat tops and the correspondence of tops of many of the present hills reflect the original flat surface. The margins of the outwash plains may be gentle slopes towards lake beds, as at Lacombe; or a sudden drop, such as marks the western edge of both the outwash west of Lacombe and the outwash east of Penhold; or a series of terraces, such as form the western edge of the outwash northwest of Innisfail near Red Deer River.

The non-plain type of outwash, except for its gravel and sand composition, commonly resembles hummocky moraine. The pits or kettles tend to be deep, and the material on their sides lies at about its angle of repose. Many of the hills rise to peaks, rather than to the flat tops common in the plain-type outwash. The individual patches of such deposits are generally small, rough-surfaced, and have abrupt margins. The deposits were strongly affected by slumping as the ice-margin withdrew and the buried remnant ice blocks melted.

Origin and Age

The outwash consists of material that was carried out of the ice-sheet by streams and rivers. Some of it was dropped rapidly near the ice-margin, particularly where this margin was steep, when the meltwater streams lost their rapid velocity and were unable to transport the coarse material any farther. This coarse material forms the small patches of non-plain type outwash. The finer material was carried farther, either to be laid down as lake deposits, or to be deposited as outwash where there was no standing water. This latter material was spread fairly evenly for some distance from the ice-margin, and forms the extensive areas of non-plain type outwash. In a few places this outwash was spread over the margin of the ice itself.

The conditions during deposition were different for each of the large outwash deposits. The Innisfail-Morningside outwash appears to have been deposited in a re-entrant in the ice, probably with water carrying in material from the ice on both sides. Glacial Lake Red Deer to the south tended to prevent material being carried away from the outwash in that direction, and was partly responsible for determining the surface elevation of the outwash plain. Deposition of the outwash in a re-entrant in the ice-sheet, along with control of part of its margins by lake water, resulted in an outwash belt, narrow relative to its length and height, and in complex mixture of pitted-plain outwash, ridges and hills, with important amounts of coarse material and many morainal features, such as till hills.

Dips of the gravel and other beds, and stone orientation studies, indicate that most of the material in this outwash belt was deposited from the west, northwest, north, and northeast and very little from the south. It appears that a large number of small meltwater streams deposited the outwash. A single stream would have had to flow from the north, and if subglacial would have had to raise coarse material 400 feet between Lacombe and Innisfail to deposit it in the southern part of the outwash. It is possible, though unlikely, that a superglacial stream could have deposited the material as a series of deltas in the re-entrant as the ice-sheet retreated. Much of the evidence as to the manner of formation of the outwash was destroyed by subsequent ice advance, and the presence of Red Deer River has further complicated the situation. This river may have added some material to the outwash, but most of its load was dropped farther west, and much of the material it brought into the area was carried down the outlet channels southeast of Innisfail towards glacial Lake Drumheller, to the south of the Red Deer-Stettler area.

The outwash near Buffalo Lake was deposited in an area of high relief and rough topography that was nearly or totally surrounded by stagnant ice, and probably overlies hummocky moraine. The surface of the ice roughly determined the altitude of the top of the outwash plain. The thickest and most strongly pitted outwash is in the eastern and southern parts of the deposit. The western part of the outwash was laid over the margin of the ice itself, and westward grades into lake deposits. This outwash contains more material than could have been supplied by local ice, which indicates that much of it was transported by water a long distance into this area.

The deposition of the outwash near Pine Lake and south of Alix took place under conditions very similar to those controlling deposition of the Buffalo Lake outwash. The thickest and coarsest of the Pine Lake outwash is in the northern part of the deposit. Southward the outwash grades into lake deposits. Drainage was southward, along much the same route as present drainage from Pine Lake.

Geography

The outwash areas are characteristically poor farmland, as they are commonly rolling or hilly and as the soil is generally light and sandy. As a result they are only thinly to moderately well settled. Hay is raised, cattle are grazed, and important quantities of gravel are extracted. The capacity of the outwash to absorb precipitation allows bush to grow well and gives it importance in ground-water supply.

Pleistocene Alluvium

General Statement

The Pleistocene alluvium consists of sand, silt, and clay, with minor gravel, that were deposited chiefly by rivers and streams draining glacial lakes. It also includes some material that was deposited by rivers flowing directly from the ice, some deposited by non-meltwater streams in Pleistocene time, and small amounts of outwash. Where large amounts of good quality gravel occur such gravel is separated, because of its economic importance, from the other alluvium and is mapped as coarse alluvium. The areas mapped as Pleistocene alluvium include material slumped from valley walls and bedrock exposures that are too small to map separately. This division thus includes a large variety of deposits that it is unnecessary, and practically impossible, to separate. These deposits owe their origin to strong erosion and deposition by short-lived streams, and they include much material carried from the melting ice.

Fine Alluvium

Fine Pleistocene alluvium covers about 110 square miles of the map-area. It is important in that it indicates the position of many now dry or practically dry valleys trenched by meltwater. Other such channels are shown on the map by some of the bedrock exposures, and by the modern alluvium where streams still occupy the valleys.

Coarse Alluvium

The coarse Pleistocene alluvium includes small but important deposits of gravel that cover about 33 square miles of the area. These include deltas and river-bars or terraces formed during the carving of meltwater channels or glacial-lake outlets.

Individual gravel deposits are described in Chapter VI. Preglacial gravel deposits were the main source of material for the alluvial gravel which, as a result, is basically Rocky Mountain type material with but a small admixture of Shield or locally derived stones. It thus consists of sandstone, limestone, quartzite, chert, with a few granite, gneiss, and schist fragments. The gravel is commonly clean, well sorted with most of the weak material weeded out, and with prominent bedding and crossbedding. Sand lenses are common. The deposits vary greatly in thickness and areal extent. The gravel is more than 80 feet thick in tp. 45, rge. 20; it is 50 feet thick in the deposits near Ferintosh, southwest of Ponoka, near Blackfalds, at Bashaw, and along the diversion channel in tp. 38, rge. 22. Elsewhere, as near sec. 29, tp. 43, rge. 26, the gravel is but a few feet thick.

Delta Deposits

The delta deposits include those in sec. 15, tp. 39, rge. 27, where Blindman River flowed into glacial Lake Red Deer; in sec. 26 and 35, tp. 42, rge. 26, where Battle River entered a later stage of this same lake; in sec. 29, tp. 43, rge. 26, where a glacial spillway joined Battle River; in sec. 5 and 18, tp. 41, rge. 24, and in sec. 6, tp. 41, rge. 23, where small glacial meltwater channels flowed into other streams or small lakes; and in the vicinity of sec. 28, tp. 41, rge. 21, where a spillway flowed into a high-level stage of Buffalo Lake near Bashaw. Most of the deltas are flat-topped or undulating, but aerial photographs generally show a complex pattern of former stream courses. A few of the deltas, with steeply sloping edges, rise above the surrounding land. An example of such is the delta formed where Battle River entered glacial Lake Red Deer. The surfaces of the other deltas are level with or slightly lower than the surrounding country, and these deltas lie in estuaries. An example of this type is at the point where Blindman River entered glacial Lake Red Deer.

Bar and Terrace Deposits

The best example of the river-bar type of deposit is in Big Valley southwest of Fenn (sec. 12, 13, 14, 23, 27, 28, 32, 33, tp. 36, rge. 20). The deposit at sec. 29, tp. 40, rge. 23, is partly a river bar, and is probably more extensive than indicated. Other important Pleistocene bar and terrace deposits include: a deposit near Ferintosh in tp. 44, rge. 21, which was formed by an outlet from glacial Lake New Norway; a deposit bordering Battle River in tp. 45, rge. 20, where this river crosses the former valley of Red Deer River and has redeposited much of its gravel; and deposits in two former temporary diversion channels of Red Deer River in the northwestern part of tp. 38, rge. 22. Other deposits occur along a similar old diversion channel of Red Deer River at sec. 18, tp. 38, rge. 23, and in a valley in sec. 19, tp. 43, rge. 14. The deposits may lie either in the centre of a valley or along its edge, and they are typically long, narrow, steep-sided, and flat-topped. In composition, they are similar to the deltas. As most of these deposits lie in valleys, their surfaces are below the level of the surrounding country.

The Pleistocene alluvium is either waste land or lightly farmed, depending on the type of material. Much of it is used for pasture or for raising hay. The porosity of the coarser alluvium enables precipitation to seep in and the gravel commonly supports good bush and holds large supplies of hard water. The Pleistocene alluvial gravel is second only to the preglacial gravel in quantity, and owing to its general accessibility and nearness to places where required and to its good quality, has been used in greater quantity than any other type of gravel.

Lake Deposits

Distribution

Lake deposits cover 1,015 square miles and are third in extent among all the deposits. Small patches not shown on the surficial geology map are common, and these represent former small lakes or local deposits from short-lived, high stages of large lakes. The large lakes include several lake deposits in the former valley of Red Deer River, formed when normal drainage to the east or northeast was blocked by ice. Other deposits are associated with the Buffalo Lake moraine system, and formed between the moraine and the ice or in large kettles in the moraine itself. The former Red Deer valley contained three large glacial lakes with their various stages. These are here called glacial Lakes Red Deer (*see* Figures 8, 9, 10, 11), Malmo (*see* Figures 13, 14, 15, 16), and New Norway (*see* Figure 17). Their deposits stretch along the former valley, with a few breaks, from Innisfail to east of New Norway and form the largest and the thickest mass of lake deposits in the area. The lake basins of the Buffalo Lake moraine system include the deposits west of Buffalo Lake (*see* Figure 15) and scattered patches in the hummocky moraine near Delburne. The lakes southwest of Stettler and near Gough Lake were ponded between the ice-front and the hummocky moraine (*see* Figures 13, 14). The large expanse of thin lake deposits to the east of Red Willow (*see* Figure 17) represents flooding by the early Battle River, when it was just starting to carve its present valley.

The total area covered at various times by glacial-lake water is much larger than the extent of lake deposits shown on the map of surficial geology. Some of this former lake area is included with the water-modified ground and hummocky moraine, as earlier described. This represents land that was flooded by short-lived, shallow ponds. Water action modified the surface by deposition of small patches of lake material and by local erosion. Much of the modified moraine is near Gough and Marion Lakes and represents high stages of these lakes where they formed one large lake (*see* Figure 15).

Composition and Description

The lake deposits are divided into coarse types, covering 810 square miles, and fine types, covering about 205 square miles. The contact between them is normally gradational. Deposits of different grain size have a thin covering of common surface material, which is worn away by only slight erosion; lenses of different size materials are common in the deposits. Thus the lake deposits can change greatly within a short distance. However, the division into coarse and fine lake deposits does indicate the general grain size in any district, and separates the areas of clay and silt of quiet-water deposition from the areas of silty sand and sand. On the map, the gradational areas have generally been included with the coarser material.

The coarse deposits are further divided to separate lake beds of sand and silt from those of gravel and sand. The coarsest material is found only in tp. 45, rge. 20, just west of Driedmeat Lake, where it interlenses with regular lake beds of finer material. The early Battle River flowed into glacial Lake New Norway in this area before its valley to the southeast was opened, and it deposited coarse material within a mile or two miles of its present valley but carried the fine material farther westward. The margins of this coarse material are also gradational with the other lake material.

Sand and silt, with smaller amounts of clay and gravel, compose the lake deposits. Ice-rafted stones appear to be rare, but this may be a result of the upper beds of the lake deposits being most often examined. The lower beds, which were laid down when the ice was near, may contain many such stones.

Beaches

A characteristic of all the glacial-lake basins is the absence of wave-cut cliffs, wave-built ridges[1] or other definite limits to the lake deposits. The boundaries of the lake deposits are gradational, with patches of lake deposits overlying other drift near the edge of the lake basin, and becoming thicker and more continuous inward. Near the centres of the basins all other drift is covered.

The chief factors that prevented formation of beaches were the small expanse of any lake at any stage, the continual change in lake level, and the short life of any single lake due to opening of low-level outlets. Each lake consisted of a narrow belt of water ponded between the margin of the retreating glacier and high land. As the glacier margin retreated the lake would spread into the newly cleared land, but generally a new outlet would lower the lake level, and the lake continued to consist of a narrow belt marginal to the ice. There was thus never any wide expanse of water over which large waves could build up. The weak character of the bedrock and the high gradients of the outlet channels allowed quick deepening of the outlets and a steady lowering of the water level. Thus just as the waves were starting to build a beach at one elevation the water level would drop, the incipient beach would be abandoned, and another strand line started at the new water level. In addition, floating ice and seasonal freezing tended to prevent formation of the large waves necessary to build beaches. Post-glacial destruction of beaches by slumping, stream erosion, and by wind erosion and duning apparently was not important, as it appears that few beaches had originally formed.

Lake Basins

Glacial Lake Red Deer (*see* Figures 8, 9, 10, 11) was the earliest of the lakes in the former Red Deer valley. It was fed partly by Red Deer River, partly by other streams, and partly by meltwater from the ice to the north. Its deposits consist chiefly of sand and silt, but clay was deposited in some of the more quiet bays. Near the centre of the basin the deposits are more than 50 feet thick but elsewhere, particularly in the high parts of the basin where the lake was short-lived, they are much thinner. Westward the deposits grade into outwash, and near the present Red Deer River they grade into alluvium. Preglacial alluvium also underlies the lake deposits near the channel of the former Red Deer River. Varving is common below the surface beds. The coarse deposits of the lake supplied sand for the dunes in the basin.

[1] Remnants of what appears to be a wave-cut cliff are present east of Innisfail, a few miles east of the shore of glacial Lake Red Deer. This cliff may represent the shoreline of a glacial lake that existed in the region prior to the final readvance of the last glacier during its general retreat from the district.

The deposits of glacial Lake Malmo (*see* Figures 13, 14, 15, 16; Plate IX), the second lake in the former Red Deer valley, are mostly finer and more representative of quiet-water deposition than are the deposits of glacial Lake Red Deer. The lake was fed from the north, northwest, and southwest, and thus the deposits in the northern and western parts of the basin are coarser than those elsewhere, and consist mostly of sand and silt. These parts of the glacial lake were shallow and the deposits are 5 to 15 feet thick. Many sand dunes are now found in these areas of coarse lake deposits. Southeast of Wetaskiwin, the lake deposits are 15 to 30 feet thick, and include much silt and clay; varves are present. The thickest deposits are near Samson Lake, where Battle River continues to build its silt and clay delta into a remnant of the glacial lake.

The deposits of glacial Lake New Norway (*see* Figure 17), the third lake of the series in the former valley of Red Deer River, are more varied than in the other lake basins. This lake was fed largely from the northeast by meltwater and by the ice-marginal river—the early stage of the modern Battle River—that drained glacial lakes ponded farther north near Edmonton. As a result, the coarsest lake material, including outwash, is in the northeastern part of the basin bordering Battle Valley. Sand beds are found in the northern part of the basin near the Battle Valley. The lake material becomes finer westward, and silt and clay are present in the western part of the basin near the hummocky moraine. The lake water drained southward past Ferintosh, carrying away much fine material, and in the southern part of the basin, silt and sand are the typical deposits. The average thickness of the lake deposits is about 15 feet, but the thickness varies from 5 to 10 feet in the western part and from 20 to 25 feet in the eastern part of the basin.

Glacial Buffalo Lake (*see* Figures 14, 15, 16) covered the present Buffalo Lake basin and contiguous districts. Its deposits are mostly coarse to fine sand, with some silt, but, in the southern part of the basin, fine material is present and there are silt and clay varves. The deposits are rarely more than 20 feet thick and, especially in the western and southern parts of the basin, are generally much thinner. The thick sand east of the glacial-lake deposits is largely outwash deposited by the meltwater that was feeding the lake. In its late stages the lake was fed largely by glacial Lakes Red Deer and Malmo from the north and northwest. West of Buffalo Lake the glacial-lake sand overlies hummocky moraine, and a subdued knob-and-kettle topography is preserved.

The glacial lake northeast of Red Willow (*see* Figure 17) was formed by water from Battle River and Paintearth Creek, which temporarily flooded this district before the valleys of these streams were well established. The lake was fed from the north, and deposits range from coarse sand in the north to silt in the south. The deposits are patchy, perhaps due to the former presence of numerous blocks of remnant ice, but locally they are more than 20 feet thick.

The glacial lake that lay south of Erskine (*see* Figures 13, 14, 15), (tp. 38, rge. 20 and 21) was fed by meltwater from the north and east. The deposits are thus thickest and coarsest in the northern and eastern parts of the basin. They are mostly sand and more than 40 feet thick near Erskine and Ross Lakes.

The glacial lake that lay in the vicinity of present Gough and Shooting Lakes (*see* Figures 13, 14) was fed by meltwater from the north, and the deposits are some 30 feet thick north of Gough Lake. Farther south, where the lake water was calm, the deposits are finer and thinner than in the northern parts of the basin. The type of deposit present varies with depth.

Ice-damming and local stream diversion caused minor ponding in valleys of the Western Highland (*see* Figure 10). The resulting lake deposits are mostly sand and rarely are more than 10 feet thick. Elsewhere in the map-area the glacier or remnant ice blocks temporarily blocked valleys in the hummocky moraine and formed small lakes. Similar lakes formed between belts of moraine, especially near Delburne. Their deposits are mostly sand and rarely are more than 10 feet thick. Many small lake basins occur in the till plains of the northeastern part of the area. The lake deposits in them are generally less than 5 feet thick, and range from silt and clay in the centres of the basins to sand on the edges. The sand is commonly residual, left behind when finer material was washed into the centres of the lakes.

Age

Most of the lake deposits were laid down during the retreat of the glacier, close to the ice-front. Deposition is still going on around shrinking remnants of some of the glacial lakes.

Geography

The districts of coarse and fine lake deposits differ strongly in topography, crops raised, bush cover, settlement, and amount of precipitation needed for farming. The clay regions are flat to undulating, typically are poorly drained, and require much precipitation. Most of the clay area is farmed, bush is rare and trees tend to be small. The areas of coarse material are varied in topography. The silt districts are flat to undulating, with swamp common in low-lying areas. Parts of the silty lake basins in the west half are the most intensively farmed regions in the map-area. The sand areas are rolling, and less intensively farmed than the silt areas, but they generally support heavy bush and contain good aquifers of hard water. In any area of thin lake material the underlying topography is reflected at the surface.

Wind Deposits

General Statement

The wind deposits consist entirely of sand and coarse silt; loess does not occur. On the surficial geology map the boundaries of the dunal areas are drawn on the outside edges of the large dunes, and the districts mapped as wind deposits thus include the intervening blowouts. These districts cover about 110 square miles. The chief dunal districts are in the basins of glacial Lakes Red Deer (*see* Figures 9, 10, 11) and Malmo (*see* Figures 13, 14, 15; Plate VIII). Small patches of dunes also occur in minor lake basins in the northwestern part of the area, to the south of Erskine Lake, and in outwash near Buffalo Lake. Other patches of dunes consist of only a few low, small dunes or one or two large ones, and are too small to be shown on the surficial geology map. For unknown reasons, large regions of coarse lake deposits that appear favourable for dune formation do not have any.

Some of the interdunal areas (or blowouts) have been swept clear of sand and silt, exposing the underlying clay or ground moraine, and leaving behind a scattering of stones. Where the sand is not completely removed, stones are concentrated near its surface. Most of the dunes, especially the large ones, are composed of well-sorted, clean, medium to coarse sand. Some of the dunes contain finer sand and those of the Peace Hills west of Wetaskiwin contain much silt. Many of the dunes have carbonaceous bands which represent former sod lines that developed in stable periods between movements of the sand. Such sod lines are well developed in the dunes that are found a few miles south of Red Deer.

Some of the dunes to the east of Menaik and in the Peace Hills are 80 feet high and several miles long; the average height is 25 feet, but many of the longer ones are only 10 to 15 feet high. Most of the dunes, and especially the large ones, are of the parabolic type but transverse dunes are common. Many of the parabolic dunes are arranged *en échelon*. Barchan dunes are rare. The crests of certain large dunes are outlined on the map; these crests indicate that, in general, the dunes have a marked parallel lineation. Crest lines of many hundreds of small dunes are not shown, and the orientation of some large ones is too confused to be shown. Generally the slopes from the crest on either side are of about equal steepness. The predominance of the parabolic type results in the bedding having generally low dips, commonly of 5 to 10 degrees. This is most marked in the dunes that are composed of fine material, and in those of the Peace Hills much of the bedding is nearly horizontal. In the dunes of certain districts, and particularly in those found a few miles south of Red Deer, dips are much greater.

Origin and Age.

The dunes are post-glacial; their formation and movement have continued intermittently since the disappearance of the glacier. Farther southeast the country is drier and minor movement of sand still takes place. In the cooler and more humid regions to the north and west a large climatic change would be necessary before much sand drifting could take place. The intermediate position of this area is indicated by the fact that the southern limit of trees crosses the area. The northern and northeastern sides of the dunes are covered with trees and bush, whereas the southern sides are grassed or have local patches of exposed sand.

Sand drifting was probably strong immediately after retreat of the last glacier and before vegetation had secured a strong hold. Another period of strong duning probably was connected with the post-glacial 'climatic optimum'. The location and basic forms of the dunes were probably decided during these periods of strong drifting, but whenever the climate became drier or warmer, as in the 1930's, some minor drifting occurred.

Many dunes were formed by winds from various directions, but the orientation of the large dunes indicates that they were formed by approximately northwest winds (*see* Plate VIII). This is now the most common direction of wind, though various easterly and southeasterly winds are nearly as common. In some districts, as near Red Deer, topography had large control of the winds that formed the dunes. Also, the growth of vegetation on the north side, which is stronger than on the south side, may have had an important part in shaping some of the dunes and giving them a northwesterly lineation.

The longitudinal dunes formed typically in districts where supply of sand was small, and they occur in the small, outlying dune fields formed in small lake basins. Transverse dunes formed where supply of sand was plentiful, and they are found in the large lake basins. The parabolic dunes are secondary features, formed out of transverse dunes apparently due to vegetation having anchored segments of these dunes while the intervening sections were blown leeward into parabolas. Stronger winds may also have played a role in their formation. The arms of some of the parabolic dunes are so lengthened that these dunes are nearly of the longitudinal type.

Geography

The dunal districts commonly support good bush, particularly on the northern and northeastern sides of the dunes, and the chief spruce woods are in dune areas. Good sand is present in large amounts, and many of the wind deposits contain large supplies of hard water. As the soil is light and sandy, the topography rolling, and many of the interdunal areas swampy, farming and grazing are not important.

Recent Alluvium or Eroded Areas

General Statement

These areas include modern stream valleys in which substantial post-glacial deposition has taken place or in which the valley has been carved into surficial deposits with little exposure of bedrock. Those districts in which bedrock is extensively exposed are mapped as bedrock. This map division indicates the amount of Recent valley formation, and separates such valleys from glacial spillways, which are now mostly dry.

The alluvium consists of clay, silt, sand, pockets of gravel, and some slump; most of the erosion has been into till. The eroded areas near Red Deer River, as far as its eastward swing in tp. 39, rge. 26, are on lake silt, sand, and preglacial gravel. The valley of Battle River between Ponoka and tp. 46, rge. 22, is carved in lake sand and silt (*see* Plates VIII, IX). Farther downstream where its gradient lessens, the river has deposited much silt at the northern end of Driedmeat Lake. The Blindman valley is floored either by the lake sand and silt it has cut through or by alluvial silt, sand, and gravel. Most of the small streams meandering across the Torlea flats cut into till but are as yet little entrenched. Locally they are depositing sand and silt. The valley system north of Gadsby is the only one of these valleys large enough to map separately.

Geography

The Recent alluvium and eroded areas are of little economic value; here and there they are grazed or support good bush. Most of the sand and gravel is of poor quality and the gravel pockets are small. Some alluvial gravel is extracted from the Red Deer valley, particularly from a point west of Penhold where the deposits contain much material from the preglacial gravel.

Esker Ridges

Description and Composition

The Red Deer-Stettler area contains many esker ridges, mostly in its western and northeastern parts. A few of the esker ridges are as high as 80 feet but most are 5 to 30 feet, and about 75 to 300 feet wide. They vary in shape, but most are long ridges with even tops; some are a series of hills. Gaps or breaks are present in the longer ridges, and these gaps are commonly marked by a small channel that connects the segments of the ridge. Many of the 'wind gaps' described below cross ridges that lie between these segments. Branching of the ridges or joining of branches is not common. Most of the ridges are between a half mile and four miles long. The longest single segment of esker ridge (east of Sylvan Lake) is about 7 miles long, but if several other segments farther north, which belong to the

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same esker stream system, are included the total length is about 15 miles. The most remarkable esker system is that in tp. 35, rge. 25, which continues southward out of the area. It consists of several segments of esker ridge connected by channels, in one case a channel along the side of a broad valley, and intervening gaps where the esker stream ran across ice.

The direction of flow of most of the esker streams is indicated on the map of the surficial geology: generally it was roughly parallel to the direction of glacier movement, but sometimes it was very different. The direction of flow of the esker streams was occasionally found through ground study of bedding, dips, and other features of the ridges, but it was generally determined from external features such as slope of land surface, locations of esker deltas, and by position of the ridges in relation to glacial lakes and moraines; in several places it could not be determined.

A few of the esker ridges are composed of silt, sand, and gravel. Such normal esker ridges are largely confined to the western part of the area, particularly west of the former Red Deer valley. The best and largest example of such a normal esker ridge lies south of Bearhills Lake. In general the largest of these ridges contain the coarsest material, and the rest are composed of sand and silt, along with small pockets of gravel and till. A few of these ridges are covered with till. Most of the stratified materials are poorly sorted, and large boulders are scattered through the ridges. The large amount of fine material present appears to be the result of low gradients. Most of the ridges, however, and particularly those in the northeastern part of the area, are composed of till—generally a basal type—with small pockets of sand and gravel. These ridges resemble the other esker ridges in every way except in their till composition.

A crevasse filling, composed of silt, sand, gravel, and till, in sec. 3 and 10, tp. 46, rge. 22, is included with the esker ridges. Other crevasse fillings also may be included.

Origin

The esker ridges composed of silt, sand, and gravel very probably formed in the normal manner: that is, through deposition of sediment in the beds of streams flowing in tunnels near the base of the ice, or in open air crevasses, or as a series of small stream deltas formed at the retreating ice-margin. The large-scale ice stagnation that accompanied the retreat of the glacier in the map-area gave ample opportunity for the formation of the necessary crevasses and tunnels. The manner of formation of the esker ridges composed entirely of till constitutes more of a problem.

The best examples of the till ridges are in the northeastern part of the area, about 5 to 10 miles north of Battle River between Rosalind and Kelsey. There these ridges are the most prominent features of a gently rolling ground moraine plain. Streams commonly flow along one side or both, and may change from one side to the other by flowing through gaps in the ridges. Many of the ridges have a parallel depression along both sides. A notable feature is that several miles to the south large gullies enter the Battle valley along strike of these ridges, and these gullies evidently were started by the same streams responsible for the ridges. These gullies, the numerous pockets of sand and gravel, and tributary ridges, all indicate that running water was present during formation of the ridges. In general the ridges are nearly parallel to the indicated direction of movement of the last glacier.

Till ridges could originate by till slumping down the sides of crevasses. This slumping also would decrease the amount of material in the adjoining ice and cause the bordering depressions upon melting of the ice; meltwater streams flowing into the crevasses would then form the pockets of sand and gravel. However, till deposited in similar manner would most likely be a loose, partly sorted type rather than the basal type actually found and it is doubtful if enough drift would exist near the surface of the nearby ice to form some of the large ridges. The main argument against such an origin is, however, the arrangement of the ridges. The surface pattern bears no resemblance to any crevasse pattern known on present-day stagnant or moving glaciers. A crevasse pattern is not likely to have long, sinuous, meandering, branching and joining crevasses.

The till composition of the ridges, and the string of connected hills that form many of them, might suggest that they were formed as a type of moraine. Meltwater streams flowing off the ice-margin could have deposited the pockets of sand and gravel, and the combined movement and melting of ice that is common in moraine formation could have supplied sufficient other material. Removal of material from the adjoining ice to the ridge could have caused the bordering depression on the iceward side of the ridge, and erosion by a meltwater stream could have caused the depression on the other side. An origin as end, washboard, push, or shove moraines is unlikely, as all these types of ridges are formed perpendicular to glacier movement. If the ridges are morainal they most likely are lateral or medial moraines, formed probably at the contact of stagnant and active ice. The pattern of the ridges does not fit any normal system of morainal ridge formation, however, particularly any that would be formed in a flat area. Also, it should be possible to trace such morainal ridges or corresponding morainal features for much longer distances, though perhaps with gaps, rather than their being restricted to this broad but short district.

The similarity between the ground pattern of the normal sand and gravel esker ridges and that of the till esker ridges strongly suggests that the latter also originated through stream action in tunnels or crevasses in the ice. The till ridges are common in the region north of Battle River, largely because a belt of stagnant ice 5 to 10 miles wide lasted there for a relatively long time. These ridges appear to have

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formed in a manner somewhat similar to the formation of the moraine plateaux rim ridges described earlier (p. 33). Once the ice-sheet was too thin to retain plastic-flow near its base, a network of streams flowed through basal tunnels towards its margin. The ground beneath the ice appears not to have been frozen at that time, and it consisted of a plastic, clayey, basal type of till. This till was squeezed into the tunnels from beneath the adjoining ice, and formed ridges. These ridges rose as long as the supply of plastic till was adequate, and until they either reached the roofs of the tunnels and filled them completely or until the weight of the till was almost sufficient to counterbalance the weight of the ice forcing it up. As earlier mentioned (p. 35), assuming till of density 2.0, and ice of density 0.8, a thickness of 200 feet of ice could create a ridge about 80 feet high. The maximum height of any of the till ridges is about 75 feet, and probably few tunnels existed at the base of ice thicker than 200 feet. The loss of till from below the adjoining ice would cause the troughs that now border these till ridges.

It appears that during the squeezing of the till into the ice-confined stream channels there was little stream action along the channels, for the ridges show little indication of stream erosion. The stream deposits present consist of pockets of silt, sand, and locally fine gravel: the streams thus apparently were small and slow-flowing.

Wind Gaps

The wind gaps of the Red Deer-Stettler area are dry, stream-cut gaps or valleys crossing narrow ridges. They have been dry since the disappearance of the last ice-sheet and are now much slumped, but they are typically short and V-shaped in cross-section. These gaps are confined to the Central and Western Highlands, and mostly to the highest parts of the Central Highland. They all are in regions underlain by the most resistant beds of the Paskapoo formation, with its ridges and small cuestas. Most of the ridges they cross are narrow and sinuous, and are 100 to 200 feet high. Commonly two or more of these gaps, with occasionally a short segment of esker ridge, are aligned and apparently were formed by the same stream. Most of the gaps cut straight across the ridges and are short, but a few cross at a low angle or cross wide ridges and are correspondingly longer. The longest and most remarkable wind gap strikes from sec. 5, tp. 36, rge. 25 to the southern edge of the area in sec. 14, tp. 35, rge. 25, and the course of the stream that carved it can be traced farther southward as a large esker ridge. This gap strikes nearly parallel to the bedrock ridge it crosses.

The cutting of the wind gaps started when the stagnant ice in the Central Highland had melted below the tops of the highest ridges of the district. A network of streams carried the meltwater out of the district, but had to cross exposed bedrock ridges to do so. In addition, as the ice surface lowered many other ridges were uncovered and the streams superimposed across them. Thus meltwater streams cut these gaps, which were abandoned upon disappearance of the glacier and the meltwater streams.

Most of the streams apparently flowed on the ice surface between the ridges and have left few traces. Subglacial streams forced over the ridges by hydraulic pressure evidently carved the gaps that have esker ridges on one end or both ends, but lower than the base of the gap. In this latter type the section of the stream through the gap could also have been subglacial, though this is unlikely.

Ridges

The ridge symbol on the map is used for ridges of undetermined origin which are found mostly in hummocky moraine. Most of them are composed of till with pockets of silt, sand, and gravel, but in some the proportion of sand and gravel is large. Some of the ridges are as much as 75 feet high, 500 feet wide, and 2 miles long. Some of them may have been formed by material being squeezed up or slumped down between ice blocks, or in crevasses or tunnels in the ice-sheet, in the manner described above for some of the esker ridges; a few may be normal esker ridges; and some are probably small end moraines.

Buried Valleys

On the map the valley symbol outlines valleys from which the stream has been diverted and which now are completely filled with drift, stream deposits, and lake deposits, or which are only partly filled and are marked by a chain of lakes. Little is known about many of these old valleys and the boundaries shown on the surficial geology map are only approximate or assumed. Additional buried valleys, particularly tributaries of the former Red Deer River, undoubtedly exist but have so far escaped notice.

Some of these valleys, such as that of the former Red Deer River, are preglacial. Others, such as the buried valley that strikes through Mikwan and Goosequill Lakes, are interglacial or interstadial. The former Red Deer is the largest of the buried valleys, and it controlled formation of the rest. The Mikwan-Goosequill valley is as much as 300 feet deep and 3 miles wide, but the other buried valleys are less than 150 feet deep and a mile wide.

These buried valleys contain large amounts of hard water and much good gravel and sand. Generally the gravel is somewhat inaccessible, and it is rarely used.

Chapter IV

DRAINAGE

Preglacial Drainage

Much of the following section is based on study of surficial deposits outside the map-area in southwestern and central Alberta. Repeated regional uplifts in preglacial time generally prevented the rivers from reaching a stage of old age. These rivers, however, through several cycles of erosion carved broad, deep valleys across the plains and large passes in the Foothills and Rocky Mountains, and their courses remained fairly stable for long periods of time. The better known preglacial valleys in southern and central Alberta include those of Red Deer, Bow, Elbow, Oldman, and Highwood Rivers. These valleys trend in much the same direction, or perhaps slightly more northerly, than their present-day successors. The preglacial drainage, like that of today, was therefore in general at an angle of about 45 degrees to both the regional slope of the land surface and the bedrock strike. The reason for the drainage being eastward, rather than northeastward, is not known. Suggested courses for these preglacial rivers in southwestern and central Alberta are shown in Figure 3. Warren (1944) also discussed preglacial drainage in Alberta.

Just prior to the coming of the first glacier, typical river valleys in southwestern and central Alberta, such as the valleys of Red Deer, Bow, and Oldman Rivers, were 5 to 20 miles wide, 200 to 350 feet deep, and had gently sloping sides. Most of these valleys were carved below the level of the corresponding present-day valleys, and represented a long period of river cutting. The rivers apparently flowed in the valley bottoms with shallow channels and with gradually shifting courses, and slowly deepened and widened the valleys. Over a long period of time, the rivers changed their courses considerably, and with the general lowering of the prairie surface the former valleys commonly became high areas. Remnant patches of gravel mark former positions of these valleys and, being more resistant than most of the bedrock material, formed protective cappings during formation of many of the hills and benches in southern and central Alberta. Over a long period of time a valley would swing as much as 25 miles to the north or south, as indicated by these remnant patches of gravel. Thus, coarse river gravel, which evidently was laid down by Bow River, is found on terraces of hills 15 miles south of the present river some 30 miles to the east of Calgary. It, therefore, appears that this river, while lowering its channel about 600 feet, shifted its course about 15 miles northward. These gravel deposits afford a means of estimating the general rate of lowering of the prairie surface in preglacial time. If the time of their deposition is known, then the time that elapsed between their deposition and the coming of the first glacier, divided by the difference in elevation of the deposit and the valley bottom of the corresponding preglacial river at a point the same distance from the Rocky Mountains, gives the average rate of surface lowering. The best deposit to use for the comparison is the early Oligocene gravel and conglomerate on top of the Cypress Hills, which is at an altitude of about 4,750 feet. The bottom of the nearby South Saskatchewan River valley at an equivalent distance from the Rocky Mountains is just under 2,100 feet, or about 2,650 feet lower. The South Saskatchewan River there is near its preglacial grade. Using these figures, the prairie surface in this region has been worn away at a rate of about a foot every 8,000 to 12,000 years. Similarly, a comparison of the less-well-dated Miocene or early Pliocene gravels at 3,550 feet altitude on the Hand Hills (Craig, 1956, p. 40) with the bottoms of the preglacial Red Deer and Bow Valleys to the north and south, respectively, at equivalent distances from the Rocky Mountains, gives a figure of one foot lowering every 7,500 to 11,000 years. This erosion was not at a steady rate, and was interrupted by regional uplifts separated by intervals of decreasing erosion. It is thought, however, that the figures determined above do give an approximate rate that can be used to estimate roughly the age of other preglacial gravel and sand deposits in south-western and central Alberta. Thus the gravel deposit on Driedmeat Hill, which is 190 feet above the bottom of the nearby former Red Deer valley would, with adding of an estimated 1,000,000 years for time elapsed since diversion of the Red Deer River from this former valley, be between 2,500,000 and 3,300,000 years old.

Former Red Deer River

General Statement

The valley of the former Red Deer River within the Red Deer-Stettler area is a typical preglacial valley. This was the major valley within this map-area, and it drained a much greater area in western Alberta than does the modern stream (*see* Figure 3). The Clearwater River, other present tributaries to the North Saskatchewan River farther north, and even the headwaters of the North Saskatchewan itself, may have been tributary to the preglacial Red Deer. The greater drainage basin of the former Red Deer River partly accounts for the large size of the boulders carried by that river and deposited in the map-area as compared with the present river.

The course of the preglacial Red Deer River in the map-area is shown on the map of surficial geology. The valley was traced through study of logs of holes drilled for water or in connection with oil exploration, from information given by water-well drillers, from exposures in modern stream valleys and road-cuts, and from a study of topography. Information on thickness of surface deposits, depth to bedrock, and the presence of river gravel and sand resting on the bedrock was obtained. This information indicated that the coarse gravel (which was readily recognized by the drillers) was fairly continuous and widespread. Information was obtained at the same time on occurrences of old tills and inter-till sediments. Reported occurrences of all these materials are shown on Figure 19 (in pocket). The section through the valley fill eastward as far as Driedmeat Lake, from information obtained from these sources, is similar to the section exposed by the modern river where it cuts across the old valley near Red Deer. Between Red Deer and Ponoka the old valley is also indicated by a topographic depression. Beyond Ponoka, flat lake beds or rolling ground moraine covers the valley, which is indicated by drill data, and topography only serves to limit its possible course. Occurrences of bedrock outcrops or of thinly covered bedrock at relatively high altitude also commonly give extreme limits to the old valley. Thus in the eastern part of the area the bedrock walls of the Battle valley and strip coal mines near Forestburg give an extreme southern limit to the old valley.

Description of Valley

The valley of the former Red Deer River is a complex system of abandoned channels and surrounded remnant hills. Driedmeat Hill, past which the river flowed first on one side and then on the other, is a good example of the latter. The old valley, as outlined on the map, includes the total area in which the land dropped rapidly below the general prairie level towards the final, entrenched preglacial river channel, and hence includes all the valley carved by the river over a long period of preglacial time. The total length of this old valley in the area is about 120 miles, which includes 25 miles south of Blackfalds where the modern river still flows.

The altitude of the bottom of the old valley falls from about 2,800 feet at Red Deer to about 2,100 feet at the eastern edge of the area, which is some 100 miles distant. Thus the present gradient of this former valley, excluding possible meanders, is about 7 feet per mile. However, most sections of the old valley apparently had a gradient of about 5 feet to a mile, or about the same as that of the modern river in the old valley above Blackfalds ($4\frac{1}{2}$ feet per mile). The main cause of the high overall gradient of the former valley was a large drop in altitude upon crossing the Cretaceous-Tertiary contact between Morningside and Ponoka. In addition, the elevations used in determining the gradient of the old valley are somewhat uncertain and Pleistocene or Recent differential uplift or depression may have changed the gradient.

The old valley is easily traced above Blackfalds, where the modern Red Deer River cuts through the valley fill in a topographic depression. Between Blackfalds and Ponoka, and particularly between Morningside and Ponoka, the former valley is narrower and deeper than elsewhere in the area. The river there crossed from the Paskapoo formation to the less-resistant Edmonton formation with swift current and high gradient. This northward course of the river represents the shortest route across the Paskapoo formation to the weak Edmonton beds. The valley fill there forms the thickest surface deposits in the Red Deer-Stettler area. It consists of a confused section of gravel, old tills, modern till, and lake deposits.

The old river gradually turned northeastward from Ponoka to flow towards New Norway. The valley gradually widens and becomes shallower as it crosses the weak Edmonton beds; it is widest near New Norway. This, with the decreased gradient, resulted in deposition of large amounts of gravel, much of it coarse, in this part of the valley. This section of the old valley was traced mostly by drillers' reports of gravel and old tills. Despite the width of the valley and the decreased gradient in the Ponoka-New Norway district, the old river was able at times to transport boulders up to 10 inches in diameter as far east as Driedmeat Lake.[1]

Near New Norway the old valley gradually swings to strike east-south-eastward to the eastern edge of the map-area. The size of the gravel decreases steadily, possibly due to a lower gradient, but coarse gravel continues eastward to Kelsey, and stones up to 2 inches in diameter are found to the eastern edge of the area. The proportion of sand and fine gravel increases greatly. The buried valley is difficult to trace in the east half of the area, owing to the small amount of gravel and lack of topographic expression. Bordering areas of shallow bedrock and a few reports of gravel deposits, however, roughly delineate its course to the eastern side of the map-area. The valley gradually narrows for a short distance down valley from New Norway, but farther east it maintains a constant width.

The former Red Deer valley was not carved at a constant rate, but its erosion was interrupted by several regional uplifts that caused rejuvenation of the river, with increased erosion and valley deepening. As its erosion once again decreased and as the river neared grade, gravel and sand commonly were deposited in its valley. This gravel, which was more resistant than the bedrock, was commonly left during subsequent erosion and now caps many of the high hills near the

[1] The district between 5 miles east and 7 miles west of New Norway and Duhamel is a good area for intensive study of the Pleistocene section in this part of Alberta. Besides the preglacial gravel and sand and two or more tills, inter-till beds are common. These are commonly reported to contain plant and animal remains. Good sections rarely are exposed, however, and drilling equipment capable of handling coarse gravel would be necessary for proper investigation. The area around Lacombe would also be worthy of similar investigations.

former valley. These gravel deposits mark earlier positions and altitudes of the former river. Such gravel cappings occur on a hill southwest of New Norway (sec. 27, tp. 44, rge. 21) at an altitude of 2,650 feet, or 325 feet above the bottom of the former valley as seen in the Battle River valley just north of Duhamel; on top of Driedmeat Hill at an altitude of 2,470 feet, or 190 feet above the base of the preglacial gravel in the buried valley nearby; and 3 miles north of Ferintosh at about 2,550 feet, or 225 feet above the bottom of the old valley to the north. Thus the former Red Deer River flowed through this district at least long enough to degrade its valley a minimum of 325 feet.

Most of the preglacial drainage of the area developed in conjunction with, and was controlled by, Red Deer River. No tributaries of this river have been traced in the area, but preglacial gravel northwest of Lacombe and a thick section of sand and silt lying directly on the bedrock southwest of Forestburg may represent such tributaries. Topography gives little information about possible tributaries, but most of them probably entered the river from the west or northwest. The southeastern part of the area drained south or southeastward as at present.

Pleistocene and Recent Drainage Development

Red Deer River

The diversion of Red Deer River from its former course, north of the city of Red Deer, is the most important single effect of the Pleistocene glaciation in the area. The river abandoned its former north-northeast-trending valley downstream from Blackfalds and turned more than 90 degrees to flow eastward across high land, through which it has carved a valley as much as 700 feet deep (*see* Plates I A, II). The time of this diversion and consequent valley erosion can be judged through a study either of the deposits in the old, abandoned valley, or of erosional features in the new valley. Both methods of study indicate that the river was diverted early in the glacial age.

Red Deer River was diverted by the glacier that deposited the till covering the preglacial gravel in its former valley, and it probably never again occupied the old valley downstream from Blackfalds. This part of the valley remained an area of deposition, and drift deposited in it was largely protected from subsequent glacial erosion. Much preglacial gravel and sand, much old till, and many interglacial deposits, were preserved in it. Only two tills have been noted in the old valley between Blackfalds and the eastern edge of the area, but good exposures are rare, and the Labuma and Maunsell tills are difficult to distinguish in well logs, which supply most of the information about the section. The lowest till exposed is considered to be the Maunsell, but it is possible and indeed probable that the Labuma till is represented. For the present, however, it can only be stated that the river was diverted prior to deposition of the Maunsell till.

Certain deposits along the new valley of the Red Deer downstream from Blackfalds also indicate that the river was diverted before the last glaciation. These deposits include river gravel lying beneath one till near Drumheller (NW.¼ sec. 7, tp. 29, rge. 20, W. 4th mer., south of the Red Deer-Stettler area) and under two tills, locally separated by gravel and sand, near Heatburg and Ardley (appendix, section 3), the lower till apparently being Maunsell. Also near the last-mentioned places old till directly overlies bedrock along much of the valley bank. The till evidently was protected from later glacial erosion by its being in a valley. Thus the valley near Ardley and Heatburg apparently is older than the Maunsell glaciation.

That Red Deer River was diverted prior to the last glaciation is also indicated by another factor. To cut the modern valley across the high land east of the city of Red Deer (*see* Plates I A, II) either the river was superimposed on the high area from ice or else an ice-dam farther north forced the river water to spill eastward across this high land. During the last glaciation, however, water followed various routes around the high land, to the southeast of Innisfail and to the north by Parlby Creek and Buffalo Lake. These routes and the lower valley through the high land could not both have formed during the last glacier retreat. It thus appears that, if the river was superimposed across the high land, this took place prior to the last glaciation and that this channel was blocked by ice during much of the last deglaciation. Similarly, if the channel was formed as a spillway of a lake ponded in the old Red Deer valley, it was cut before the last glaciation, as during this glaciation the various outlets past Innisfail and down Parlby Creek kept the lake water at a maximum height of 150 feet under that necessary to cause it to spill eastward across the high land. In addition, the drainage channels to the north and southeast were carved and abandoned during the last glaciation, and the glacial ponding in the Red Deer valley was ended before water flowed eastward through this spillway across the high land. Apparently this channel was cut prior to the last glaciation but was blocked by ice until the district was largely deglaciated. The river crosses one of the highest parts of this high land east of Red Deer, and its location may have been decided by presence there of an old tributary valley of the former Red Deer River. Another possibility is that when this high area was surrounded, but not covered, by the glacier, a section of a supraglacier river crossed this area, which may have been somewhat lower than the nearby ice surface. Indirect evidence for early diversion of the river is the fact that any glacier advancing from the northwest, north, or northeast would dam the northeastward stretch of the old river and force it to find a new channel to the east or south.

The glacier that deposited the Labuma till probably also diverted the river, as Maunsell till is found on the upper levels of the modern valley near Ardley, and the Labuma glacier is the only older one known. However, the valley from Nevis downstream is more youthful-looking than the Blackfalds-Nevis stretch, and only the Buffalo Lake till is found in it. The river may have occupied this section of the valley later than the Blackfalds-Nevis section, and perhaps following upon the Maunsell glacier.

Minor Streams

Threehills, Kneehills, and Ghostpine valleys, and the partly buried valley that strikes through Goosequill Lake, have the broad, gently sloping valley walls produced by long erosion. The streams in them are underfit. The Goosequill Lake valley apparently was a temporary channel of the Red Deer River and is interglacial in age. The others may be either interglacial or preglacial.

A steep-sided, dry valley, half a mile wide and 50 to 100 feet deep, trends northward from a point just west of Ponoka to Bearhills Lake. This valley drops about 115 feet in this 13 miles, for a gradient of 9 feet to a mile. Another valley of similar size, and also youthful in appearance, strikes north-northwestward from Red Deer Lake. In 7 miles it drops 150 feet to the small lake in sec. 18, tp. 45, rge. 22, for a gradient of 20 feet to a mile. These two valleys were cut by northward-flowing streams, and their youthful appearance indicates that they were formed late in the glacial age. As the glacier blocked the low land to the north during its last advance and retreat and generally diverted drainage southward, these valleys apparently were cut before the final disappearance of the ice. The valley northwest of Ponoka, which is a former channel of Battle River, may have formed during the retreat just prior to the Innisfail rejuvenation (described in Chapter V). A large mass of remnant ice in the low land near Ponoka, perhaps the same ice that formed the Innisfail-Morningside outwash, may have diverted the river northward. Similarly, remnant ice occupying the low land northwest of Red Deer Lake at about the same time may have caused Battle River to cut the now-dry valley north of Red Deer Lake.

Present Drainage

The retreat of the last glacier left the drainage of the area in a disordered state. Sections of old valleys, such as those of Red Deer River, Threehills, Kneehills, and Ghostpine Creeks, and younger meltwater channels and short spillways were all available, but they were largely unconnected. Most of the meltwater and spillway channels were abandoned quickly, and the various streams took new courses across lowland areas. They have since retained these new courses, and the chief subsequent changes include continued deepening of their valleys, smoothing of their gradients, and lowering or draining of the remnant lakes. Development of the drainage system varies greatly from place to place. Some areas are well drained, but others have practically no surface drainage system.

Rivers

Red Deer River

The Red Deer, a tributary of North Saskatchewan River, is the largest river in the map-area and drains the northern and western parts. It rises in the Rocky Mountains to the southwest of the map-area and thus has a large volume of water the year round. It carries much sediment on leaving the mountains, but drops most of this upon losing its high velocity in the flat country just west of the map-area. Before the Pleistocene glaciers disrupted its gradient, and before it lost some of its volume to the present North Saskatchewan drainage system, Red Deer River carried much mountain material into the present map-area.

The river now flows in its preglacial valley between Innisfail and Blackfalds with an average gradient of $4\frac{1}{2}$ feet to a mile. It resumed flow in this section following retreat of the last glacier, and is now cutting a narrow, steep-walled channel 50 to 150 feet deep into the beds of glacial Lake Red Deer and also, in most places, into the underlying bedrock. In the eastward stretch of the river, between Blackfalds and Nevis, the river has a gradient of 9 feet per mile. This high gradient may be in part due to the youth of this section of the valley, but it probably is mostly a result of the river crossing from the resistant Paskapoo beds to the weaker Edmonton beds. The valley in this section is steep-walled, a half to a mile wide, and 100 to 300 feet deep. The land on either side of the valley has little or no slope towards the valley. The many small, dry valleys near the present river, but at higher levels, mostly represent former diversions of the river by local ice damming during retreat of the last ice-sheet.

The river between Nevis and the southern edge of the area is entirely in the easily eroded beds of the Edmonton formation. The gradient is only 4 feet in a mile, despite the youthful aspect of the valley. The valley is a mile to $1\frac{1}{2}$ miles wide, 200 to 600 feet deep, steep-walled, with badland topography developing within it. In this section the river has cut its valley indiscriminately across low valleys and high ridges in complete disregard of pre-existing topography, and there is no slope towards the valley in adjoining areas. This disregard for earlier topography may indicate that sections of the river were superimposed on the land surface from the ice-sheet, and that the river cut through any ridges it encountered before general cutting of its bed into the bedrock. The southeast-trending sections of the valley are parallel to the bedrock strike, and may have been captured from earlier, southeast-flowing streams.

Blindman River

Blindman River flows in a steep-walled valley, a mile wide and 250 feet deep, with a gradient of about 10 feet in a mile. It enters Red Deer River near Blackfalds. The section of valley in the Red Deer-Stettler area was first used during retreat of the last glacier by an ice-front or ice-marginal river. As Blindman River rises on the prairies, most of its flow is in spring.

Battle River

One hundred and thirty miles of the length of Battle River is in the Red Deer-Stettler area. This river rises on the prairies and often floods in spring, but it is nearly dry during most of the summer. The river, both in the area and elsewhere, consists of a complex system of short sections of ice-marginal meltwater channels (*see* Plate X) connected by sections of smaller, recent valleys (*see* Plates VIII, IX). Its average gradient in the area is 5 feet to the mile, but for much of its course the gradient is only 3 feet to the mile. The high average gradient is a result of a 13-foot-per-mile gradient between Samson Lake and a point east of Gwynne, where the youthful valley drops sharply into a former ice-marginal valley near Gwynne.

Other Streams

Other streams in the area include Big Valley, Paintearth, Parlby, Tail, and Meeting Creeks, which flow in former meltwater channels, and Ghostpine, Kneehills, and Threehills Creeks, which flow in preglacial or interglacial valleys. All these streams are underfit and, though they have a fair flow in spring, their flow is small during most of the year.

Trend of the Drainage

Much of the drainage of the area has a strong southeastward trend. This trend is evident in Threehills Creek, Ghostpine Creek, the valley through Goosequill Lake, most of Big Valley Creek, most of Red Deer River from Nevis downstream, much of Parlby Creek, and the valley in which lies the village of Nevis. Meeting Creek, much of Battle River, and many small valleys have nearly the same trend. The southeast trend is nearly parallel to both the general contour of the land and the general bedrock strike, and is also found south of the western part of the map-area.

Several of the southeast-trending valleys, including sections of Battle River and Meeting Creek, were formed along the southeast-trending ice-margin that followed the general contour of the land. The southeast trend of much of Big Valley was controlled by the southeast strike of the nearby Cretaceous-Tertiary contact. The cause of the southeast trend of the other valleys is not known. Allan and Sanderson (1945, pp. 12-17) give evidence for bedrock structural control of valleys such as those of Ghostpine, Kneehills, and Threehills Creeks. Warren (1944, pp. 12, 13) suggested that the southeasterly "pattern of flow of smaller streams must be attributed to glacial control rather than to rock structures beneath the glacial drift". The retreat of the last glacier by downmelting with resulting irregular glacier margins, rather than by a general northeasterly retreat of the ice-margin, indicates that this glacier could not have controlled formation of these valleys. Earlier glaciers may have retreated in a different manner, however, and these valleys apparently were formed prior to the last glaciation. The trends of Ghostpine, Threehills, Kneehills, Goosequill Lake valleys and sections of the Red Deer valley, are approximately parallel to the bedrock strike. However, the bedrock beds thicken and thin rapidly and vary greatly in hardness within a short distance, and it is difficult to conceive of such beds controlling trends of valleys for the necessary 20 or 30 miles. The cause of the southeast trend of these valleys still remains an open question.

Lakes, Ponds, and Swamps

In wet years, the water of lakes and large sloughs covers about 250 square miles of the map-area; in dry years, it covers only half that area. The large lakes in the west half of the area, such as Gull and Pigeon Lakes, remain fairly constant in size, but those in the east, particularly in the Torlea flats, practically disappear in dry years.

Undrained depressions are common through the area (*see* Plate XII), and the rarity of lakes and ponds in places is generally due to low precipitation, high evaporation, or very permeable surface material, rather than to a lack of the necessary depressions. Marion, Shooting, Lonepine, and other lakes in the thin drift of the Torlea flats were formed through glacial erosion of bedrock. Buffalo Lake and others in the hummocky moraine were formed by melting of remnant ice blocks; and others, such as Samson, Red Deer, Foxall, and Goosequill Lakes, were formed through morainal blocking of valleys or (e.g., Pine Lake) by combinations of these methods.

The basins have, at best, but poorly developed outlets. The water escapes from them mainly by evaporation or seepage rather than by overflow, and as a result many of the ponds in the east half of the map-area are alkaline. Outlets are best developed on ground moraine plains, where clayey till deters seepage, the depressions are shallow and overflow readily takes place.

Chapter V

HISTORICAL GEOLOGY

Southwestern and Central Alberta

The early reports of Dawson (1885, 1890, 1891, 1895) and Tyrrell (1887) contain much information on the Pleistocene historical geology and the topography of southwestern and central Alberta. Bretz (1943) and Horberg (1954) published similar information about an area near the United States border, and Alden (1932) described events in parts of the United States adjacent to southern Alberta. These reports give fairly detailed accounts of Pleistocene events, and the following description of the regional glacial history is a summary made to give a regional setting for the events described for the Pleistocene and Recent history of the Red Deer-Stettler area. It is based upon the author's field work done in adjoining regions, and an intensive study of aerial photographs. No attempt is made to describe the regional events in detail, as is done in the description of the Red Deer-Stettler area, but only the major events and features as they appear to the writer. Locations mentioned are shown on Figure 3.

Preglacial Time

Topography

Prior to Pleistocene glaciation, southwestern and central Alberta had undergone long-continued erosion. Changing climate, and uplift or gradation of the plains, increased or decreased the rate of erosion and gave several cycles of erosion. Local deposition of material also occurred at times, particularly when the western mountains were rising, and during these times the preglacial gravel and sand of the region was deposited. The long period of preglacial erosion resulted in bedrock control of river courses and a topography that reflected the different hardnesses of the various bedrock formations and beds. Thus the flat-lying, resistant bedrock layers underlie the many flat-topped hills and benches. The largest of these are the Porcupine Hills, which rise 1,000 to 2,000 feet, and the Milk River Ridge, which rises 500 to 800 feet, above the general prairie level. Other such hills include the Kneehills just south of the Red Deer-Stettler area and some of the high hills a few miles east of Red Deer. If the hard beds had a greater dip, large ridges and small cuestas formed. Such ridges are particularly common in the Foothills of the southwestern part of Alberta, but small hogsbacks and cuestas are present in the Central Highland of the Red Deer-Stettler area. In addition, along their contact within the map-area, the surface commonly rises 50 to 200 feet from the Edmonton beds to the harder beds of the Paskapoo formation. Areas of weak beds are commonly reflected in the locations of the broad, preglacial river valleys.

The principal topographic features of the region were present before the Pleistocene glaciations, and they were more extreme with more relief than they have today. The glaciers modified and subdued these large features through filling of some of the large valleys, by strong local erosion on some of the highlands, and commonly by deposition of thicker drift on the lowlands than on the high areas. Also, the general level of the large rivers was raised. The small topographic features, on the other hand, were less varied and less important than now. They included only those features developed by long-continued erosion. Glacial features such as esker ridges, morainal hills, and drumlins, which now are so conspicuous, were absent.

Climate

The climate of southwestern and central Alberta prior to glaciation is not directly known, but certain aspects of it can be inferred from topography. Thus the forms of many bedrock hills in the high land, east of Red Deer, suggest a preglacial 'badlands' topography. Thick bush now covers this area and the badlands topography is being destroyed. The climate must therefore, have been drier or warmer than now, and bush was probably absent. Also, the preglacial gravels do not contain any logs or branches of trees, of either local or Rocky Mountain derivation, as do the present river gravels. A more arid climate must, therefore, have prevailed over a wide region.

Other fossils from the preglacial gravel and sand are rare and mostly of aquatic types; they have not provided any information on the preglacial climate. As much of the preglacial gravel in southern and central Alberta is as coarse as or coarser than the gravels of the present rivers, and assuming the preglacial river gradients were not greater than those of today, it appears that the volume of water in the preglacial rivers was not less and perhaps greater than now. Thus regional precipitation at the time of deposition of the preglacial gravel was probably at least as great as at present; hence the apparent aridity was probably due to higher temperature.

The climate in recent historical times appears, however, to have been wetter and cooler than during most of post-glacial times. The average climate for all of post-glacial time has probably been much like the average climate for some time prior to glaciation. Thus at present, sloughs that have no incised outlets commonly overflow. The resulting erosion, if it had occurred during all of post-glacial time, would have incised good outlet channels. Also stream erosion and

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Table II

Suggested Major Quaternary Events

Epoch	Stage	Substage	Central and southwestern Alberta	Red Deer-Stettler area
Recent			Ice free; river deposition and erosion	*See* Table III. Ice free
Pleistocene	Wisconsin	(Valders) Mankato	Ice free? River deposition and erosion	*See* Table III. Ice free?
		Cary	Rejuvenation and readvance of glacier?	Innisfail rejuvenation? Other fluctuations in glacier margins and ice thickness. *See* Table III
		Tazewell Iowan	Glaciation and deposition of youngest drift. Southward movement of ice, followed by retreat of the glacier from much of the region	Glaciation, followed by thinning and retreat of the ice-sheet from much of the area. Deposition of youngest drift
	Sangamon		Interglacial river deposition and erosion	Interglacial river deposition and erosion
	Illinois		Possible glaciation with later removal of drift, or deposition of Maunsell drift at this time rather than during Kansan stage	Unknown. Possible glaciation with later removal of drift, or deposition of Maunsell drift at this time rather than during Kansan stage
	Yarmouth		Interglacial river deposition and erosion	Interglacial river deposition and erosion. Cutting of Goosequill valley?
	Kansan		Glaciation with deposition of Maunsell drift? Southwestward movement of glacier?	Glaciation with deposition of Maunsell drift?
	Aftonian		Interglacial river deposition and erosion	Interglacial river deposition and erosion. Red Deer River assumed its present course. Cutting of Ghostpine, Threehills, and Kneehills valleys?
	Nebraskan		Glaciation and deposition of Labuma drift? Southwestward movement of glacier? Diversion of preglacial drainage	Glaciation and deposition of Labuma drift? Diversion of Red Deer River from former valley
	Preglacial		Deposition of youngest preglacial gravel and sand	Deposition of youngest preglacial gravel and sand in former Red Deer valley

development of drainage systems are now proceeding rapidly in areas, such as the Torlea flats, that have not developed good drainage systems since retreat of the last glacier. Forests also appear to be spreading, but this may be due as much to control of prairie fires as to a changing climate.

The amount of precipitation in the region is controlled largely by its being shielded from westerly storms by the mountains to the west, and this factor is not likely to have changed much since immediate preglacial time. If the area was more arid in preglacial time, and for much of post-glacial time, than it is now, a warmer climate rather than less precipitation was probably the reason. This is also indicated by the above comparison of present and past gravel deposits.

Glaciation

General Statement

It is generally assumed that there were in North America four glacial stages during the Pleistocene epoch. Each glacial stage may have included several major glacier advances and retreats; the last glacial stage, the Wisconsin, has been subdivided into four or five such substages. The sequence generally recognized for North America is shown in Table II, along with a general summary of the major events during these stages as assumed by the writer for central and southwestern Alberta and the Red Deer-Stettler area. The glacial stages appear to have coincided in the Cordillera and the rest of the continent, though there is less evidence that the substages were contemporaneous. Pleistocene glaciers covered all of southwestern and central Alberta except some of the Rocky Mountains and Foothills, a small area of high land in the very south of the province near Del Bonita, and the highest parts of the Cypress Hills.

Multiple Glaciation

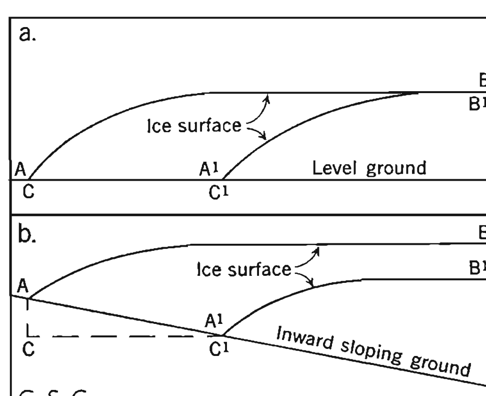
The evidence for multiple glaciation in the region includes: changes in drainage that required more than one glaciation to explain, particularly where the same section of a river has been diverted more than once and the earlier channels filled with drift; the presence of valleys that are neither pre- nor post-glacial; and the presence of two or more tills in single exposures through the drift, in a few instances separated by inter-till gravel, sand, silt, and clay. A few of the occurrences of two or more tills are listed in the appendix, sections 1, 3 to 7, and 9 to 16. These are mostly in drift-filled, preglacial valleys. Three tills of different ages are mentioned in Chapter III. Earlier observers who described two or more tills, commonly with inter-till beds, include Dawson (1885, particularly pp. 143C, 144C); Dawson and McConnell (1895, pp. 65, 66); Tyrrell (1887, pp. 139E-147E); Alden (1932, pp. 71-74); Johnston and Wickenden (1931, pp. 30-35); Horberg (1952, pp. 301-305, 311, 312, 316); Bretz (1943, pp. 33, 34); Jones (1941). Most of these observers discussed the age of these tills, and Horberg (1952, pp. 304, 305) summarized their conclusions. There is complete disagreement in the conclusions of the various observers, not only as to the glacial substage represented, but also as to which glacial stages are represented in the Alberta drift. Estimates of the age of the lowest (Labuma) drift alone range from Nebraskan to Wisconsin.

The only evidence that has been available to determine the age of the tills was appearance of topography, such as degree of erosion and drainage development, glacier-caused changes in drainage, soil development, depth of leaching, and the position of the large 'terminal' moraines and glacial drainage channels on the prairies. There has not been direct correlation with type sections in the United States. Obviously none of these methods is reliable, each being based upon unknown factors, such as past climate and precipitation, absolute and relative durations of the glacial ages and stages, and directions of ice advance and retreat.

The early determinations of the ages of the tills, particularly those using the large moraines of the prairies, commonly assumed that the various substages of the Wisconsin stage represented large-scale advances and withdrawals of the glacier on the prairies, and that this glacier advanced from and retreated to the northeast. In central and southwestern Alberta the ice-sheets were bounded by the high land of the Foothills and Rocky Mountains on the west and southwest and by the high land of the Milk River Ridge on the south. The ice therefore thickened rapidly inward from its margin without necessarily any great rise in its surface. Thus a glacier thinning of 1,000 feet or so might have caused a marginal withdrawal of only a few miles, whereas in flat regions elsewhere the same amount of thinning might result in a retreat of several hundred miles. This is illustrated in Figure 5, a and b.

The area of land cleared or overriden by ice during each substage was probably minor in this region, the important factor being the stage as a whole. Also, as the ice apparently advanced southward, rather than southwestward as

Figure 5. Comparison of retreat of the margin of an ice-sheet on level and inward sloping surfaces. AB is the original ice surface, A^1B^1 is the final ice surface, CC^1 is the horizontal distance of retreat of the margin, and is equal in both cases, BB^1 is the vertical lowering of the ice surface inside the glacier's marginal zone. a. On level ground only negligible lowering of the ice surface (BB^1) is needed to allow retreat CC^1. b. On inward sloping ground considerable lowering of the ice surface (BB^1) is needed to allow retreat CC^1.



assumed by most observers, the large moraines of the prairies, such as the Buffalo Lake, Viking, and Coteau or Altamont, do not necessarily represent glacier limits of Wisconsin substages. If the Wisconsin substadial withdrawals and readvances were small in southern and central Alberta, then the Wisconsin glacier would in general be represented by only one till. Thus the three tills described in Chapter III apparently represent glacial stages rather than the various Wisconsin substages. If this is so, then the inter-till deposits are interglacial rather than interstadial.

The best evidence available, the youthful appearance of the topography, drainage, soils, and the small amount of leaching of the top drift, indicates that Wisconsin ice covered the region. If so, the youngest (Buffalo Lake) till is of Wisconsin age. The even more youthful aspect of the topography northeast of this region indicates later Wisconsin substages there and glaciation of the present region prior to late Wisconsin time. The well-developed ice-marginal drainage systems in southwestern Alberta indicate that the glacier lay near its point of maximum advance for a long time. The writer believes that the last glaciation of the region was early Wisconsin, and probably the Iowan and Tazewell substages combined. Cary ice may have affected the northeastern part of the region.

Some black spruce wood collected in 1953 from the banks of Oldman River, 10 miles west of Lethbridge and 5 miles southeast of Monarch, has been radiocarbon dated. The wood was taken from the limonitic sand at the top of the lower till in section 6 of Horberg (Horberg, 1952, appendix, p. 325) and is iron stained. Black spruce does not now grow in this region and is rare or absent in the Foothills to the west. The wood came from a tree that was washed into place by the river. It consists of sections of branches that lie in much the position in which they were deposited and which have been flattened by weight of both overlying material and later glaciers. The wood underlies about 100 feet of till and inter-till silt and sand. The same inter-till stratified unit is found locally to a point north of Edmonton, and especially in strip coal mines near Morinville. This is a distance of some 300 miles and an elevation difference of some 700 feet. The glacier retreat responsible for this inter-till break apparently was not a local marginal fluctuation, but a large or even major retreat.

Horberg (1952) assigned the bed containing the wood to just above or in the top of his lower (the present Maunsell) till, and older than his upper (the present Buffalo Lake) till. The writer agrees with this position. The radiocarbon date of the wood (Lamont 221C) is "greater than" 26,000 years. The date gives a minimum age to the underlying (Maunsell) till, and indicates that deposits below the bed containing the wood, including the basal and lower tills of Horberg (Labuma and Maunsell tills of this report), are pre-Wisconsin. These inter-till deposits therefore are of Sangamon age, or, if Illinois glaciers did not reach this region, of Yarmouth, Illinois, and Sangamon ages combined. The problem of their age might be solved by intensive study of temperature conditions that prevailed during their deposition.

The lowest (Labuma) till is found chiefly in drift-filled preglacial valleys and commonly forms a large part of this valley fill. This is the lowest till, except for local deposits of old Cordilleran till, and it directly overlies either bedrock or preglacial gravel and sand. It is the lowest bed that contains stones from the Precambrian Shield. This till also represents the glacier that caused the major changes in the preglacial drainage and diverted the large rivers from their preglacial valleys. The underlying gravels, which are found in each of the large filled valleys and represent a long period of deposition, rarely contain striated or angular stones of glacial origin and do not show effects of any earlier glaciers. The Labuma till thus represents the first major Pleistocene Laurentide glaciation of the region. There is no reason to assume that Nebraskan ice did not reach the region, and it appears best to assign a tentative Nebraskan age to the Labuma till.

The Maunsell till, the middle till of the three recognized in the region, is apparently of either Kansan or Illinois age, if the other two tills are Nebraskan and Wisconsin and if, as thought, it represents a glacial stage. Thus, drift of one of the glacial stages, probably Kansan or Illinois, has not yet been recognized in the region. The break between the Labuma and Maunsell tills is widespread, and has as great an elevation range as that mentioned above between the Maunsell and Buffalo Lake tills. If the tills below and above are of Nebraskan and Kansan ages respectively this interval represents the Aftonian interglacial stage; if the Maunsell till is of Illinois age then this interval includes the Aftonian, Kansan and Yarmouth stages.

Altitudes Reached by the Glaciers

Direct evidence of the maximum height of Laurentide glaciation includes the maximum altitudes at which stones from the Precambrian Shield are found in the Rocky Mountains and Foothills of Alberta, the altitudes of hills that were overrun by the glaciers, and the minimum altitudes of unglaciated areas. Other evidence, available only for the last glacier and rather unreliable, includes the amount of control that topography had on the glacier's flow (which apparently decreases as ice thickness increases), and the amount of glacial erosion.

Dawson (1885, p. 148C) reported stones from the Precambrian Shield in the Foothills of the Rocky Mountains, 20 miles north of the 49th Parallel, at an altitude of 5,280 feet. Nichols (1931, sections opposite p. 52) reported such stones northwest of Calgary at altitudes of 4,500 or 4,600 feet. Douglas (1950, pp. 6, 7) described similar erratics west of the 5th meridian in the Porcupine Hills at altitudes between 4,200 and 5,000 feet. The writer found stones from the Precambrian Shield in the Porcupine Hills to the southwest of Claresholm (sec. 12, tp. 11, rge. 1, W. 5th mer.) at altitudes as high as 5,420 feet and northwest of Calgary at about 4,500 feet. Directly west of the Red Deer-Stettler area the writer found such erratics at 4,000 feet and others probably occur at higher altitudes.

The glaciers covered the highest hills in the Red Deer-Stettler area, which rise to about 3,500 feet above sea-level. Farther south a glacier apparently carried material to the leeward side of the Porcupine Hills where their crests rise to 5,400 feet. In order to carry this material to the top of these crests, the ice surface must have reached a present-day altitude of about 5,700 feet in the Porcupine Hills, and a similar altitude to within 20 miles of the United States-Canada boundary.

The best known of the unglaciated hills are the Cypress Hills in the southeastern part of Alberta. These rise to an altitude of about 4,800 feet and were surrounded one or more times by ice-sheets. The Del Bonita area in southern Alberta, at an altitude of about 4,300 feet, also appears not to have been glaciated. Evidence from different sources as regards the height to which the ice-sheet rose is contradictory and requires explanation.

The ice-sheets in southwestern Alberta were enclosed on the west, southwest, and south by the high land of the Foothills, the Rocky Mountains, and the Milk River Ridge. The ice pushed into the area from the north, and perhaps also from the northeast and northwest, and thus the surface of the ice, if there were no counteracting factors, would have risen in these same directions. Owing to the enclosing high land, however, any ice-sheet in the area when at its maximum thickness would tend to have a level surface rather than one sloping downwards towards its margin, as glacier surfaces normally do. In addition the glacier received considerable ice from valley glaciers to the west and northwest which here may even have tended to raise the ice surface slightly towards the west. Thus the surface of the ice at its maximum height was approximately level in much of southwestern and central Alberta, and this surface at the maximum of the strongest glacier was at an altitude of around 5,700 feet. Farther east, in southern Alberta, the ice could escape southward or southeastward around the eastern end of the Milk River Ridge into lower land in the United States. The ice in southeastern Alberta could thus expand southward at the expense of its thickness, and tend to have a lower surface there than farther northwest. This may explain the lack of glaciation of the tops of the Cypress Hills and the southern part of the Milk River Ridge.

The elevations given in the foregoing refer to the most severe glaciation of the region; the one represented by either the Labuma or Maunsell till. The last glacier in the region was not as strong and did not advance as far into the Foothills and Milk River Ridge as did one or both of the others (Horberg, 1952, pp. 305, 306).

Soils are commonly thicker and leaching deeper above 4,500 feet, and the Wisconsin Laurentide glacier did not rise much above this altitude. That it was not thick in the Red Deer-Stettler area is indicated also by the strong control that topography had upon its movement and by the variation in its erosion on high and low land. An erratic train in southwestern Alberta also indicates that the Wisconsin ice did not rise to as high altitudes as did previous glaciers (Stalker, 1956, pp. 17, 18).

Direction of Ice Movement

The direction of glacier flow in southwestern and central Alberta is indicated by drumlins, elongated ridges (*see* Plate IV), and flutings, by stone orientation in the youngest till, and by the source area of some erratics. The evidence from ice-flow markings and stone orientations indicates that the ice moved southward or south-southeastward in southwestern Alberta. This was first suggested by Tyrrell (1890, p. 401), who, in discussing ice flow in Manitoba stated: "...... the direction of flow was southward or southeastward...... and parallel to the main axis of the Rocky Mountains. This direction was in all probability sustained by the glacier all the way across the Canadian Plains." The local direction of movement varies as much as 70 degrees to the east or west of the general movement. This variation is due mostly to local topographic control, with the swiftest ice flow in lowland areas and along broad valleys. It may also be due in part to an increased eastward component of movement in the late stages of the glacier, caused by rapid ice wastage in low land to the southeast, largely in the United States.

The ice-flow markings and stone orientations give evidence only about movement of the last glacier. Certain erratics, mostly granites, gneisses, and schists from the Precambrian Shield, indicate southwestward or south-southwestward movement. These apparently were brought into the region by one or both of the earlier glaciers, which apparently moved in a more westerly direction than did the last one. The last glacier in southwestern and central Alberta did not add much Precambrian Shield material to that already present near the southwestern limit of drift, but rather diluted the concentration of Shield-type stones already there, up to altitude of 4,500 feet, with quantities of Cordilleran-type stones. This is indicated by the fact that in southwestern Alberta the proportion of Shield-type stones apparently increases somewhat above this altitude.

Relation of Laurentide and Cordilleran Glaciers

The Laurentide glaciers in southwestern and central Alberta apparently had no direct contact with the main Cordilleran ice mass, but they had local contacts with valley and piedmont glaciers that formed on the eastern slopes of the Rocky Mountains (Douglas, 1950, pp. 6-9). Generally moraines did not develop along these contacts. In the western part of the region, as in the former Bow Valley at Calgary, Cordilleran drift here and there underlies the lowest Laurentide drift. During Wisconsin time, contact with valley glaciers south of Calgary was minor. Farther north contact appears to have been greater and much Cordilleran ice was added to the western part of the Laurentide ice-sheet. This may have been one of the factors that induced southward or south-southeastward flow in the combined mountain and Laurentide ice, and that diluted the concentration of Precambrian Shield stones in the drift of the western part of the region. The valley glaciers on the eastern slopes of the Rocky Mountains appear to have waned before the Laurentide glacier did, probably as a result of starvation caused by moisture being precipitated farther west over the main large, cold mass of the Cordilleran glacier. Thus, when the Laurentide ice-sheet was melting from the region, the drainage basins of the Bow, Red Deer, and other large rivers appear to have been largely ice-free and there is little glacial material in their deposits.

Valley glaciers from the west did not reach the Red Deer-Stettler area, and no pure Cordilleran drift exists. However, the drift in the western part of this area is a mixture of Cordilleran and Laurentide drift, with the Cordilleran proportion increasing westward. Thus in the eastern part of the Red Deer-Stettler area 20 to 35 per cent of the stones and in the western part 10 to 15 per cent are from the Precambrian Shield. About 15 miles farther westward the proportion is about one per cent, and the percentage generally decreases rapidly westward until such stones are absent.

Isostatic Adjustment

Various observers (Dawson, 1885, 1895; Rutherford, 1941, pp. 115-118) have used isostasy to explain peculiarities in altitudes to which Laurentide drift is found on the eastern slopes of the Rocky Mountains and Foothills, and various changes in drainage. These features, which mostly result from the last glaciation, can also be explained in other ways. The ice of the strongest glacier in southwestern Alberta was nowhere much more than 3,000 feet thick and generally much less, and it thinned rapidly westward. It is doubtful if this thickness of ice could have produced any large-scale depression or subsequent elevation of the land surface. The last ice-sheet in particular appears to have averaged only about 1,000 feet in thickness over most of the region at its maximum thickness.

Glacier Retreat

The last glacier, and probably the earlier ones, retreated from the region chiefly through downmelting. Northward or eastward retreat of the ice-margin through wastage near the glacier's edge was generally not of major importance, for the retreating margins uncovered continually lower land and had to wait until the general glacier surface had lowered before further retreat could take place (Figure 5, a and b). Movement of ice from the region to low land farther southeast where melting was quicker, particularly into the United States, also helped dissipate the ice from the region. The limiting of ice on the west and south by rising land, rather than by downward slope of the ice surface, was chiefly responsible for the large amount of ice stagnation during retreat of the last glacier from the region.

The disappearance of the ice-sheet chiefly through downmelting was largely responsible for forming island moraines on high land long distances back from the ice-margin. It also left ice, mostly stagnant, in lowlands and valleys long after it had disappeared from the high areas. The glacier margin was thus irregular and complex and at no time was it a simple, single glacier edge.

The remnant ice lying in lowland areas forced meltwater across ridges and other high land, where it rapidly carved run-off channels. These channels form both the small 'wind gaps' and the many deep, steep-walled valleys from a mile to 40 miles long, which are found throughout southwestern and central Alberta. These latter represent sections of the marginal drainage system.

Red Deer-Stettler Area

Except for local deposits of old drift and inter-till material, the changes in drainage, and the presence of a few valleys formed in interglacial stages, the effects of pre-Wisconsin glaciers in the Red Deer-Stettler area have been destroyed. Only events during the last stages of the final glacier in the area are known in detail. This glacier advanced in a more or less southerly direction and undoubtedly ponded lakes at its margin and diverted rivers, but no trace remains of most of these early effects. The advancing glacier first affected the low areas, particularly the Torlea flats and the valley of the former Red Deer River, and was diverted around the Central Highland. Higher areas were overrun as the ice-sheet grew thicker, but the swiftest movement and thickest ice continued to be in the lowland.

It has been estimated that the last (Wisconsin) glacier rose to an altitude of 4,500 feet in southwestern and central Alberta. The Red Deer-Stettler area lies between 2,300 and 3,500 feet, and thus at its maximum the last glacier was some 2,000 feet thick in the Torlea flats region and 1,300 feet or so thick in the Central Highland. The relative difference in thickness was even greater during most of the glaciation when the ice was thinner. The thick ice and its long period of movement in the low land gave strong glacial erosion, but in the high land such erosion was negligible and deposition from the ice was more conspicuous.

Ice flow continued, though at a decreasing rate, as the ice-sheet thinned. Most of the ground moraine was deposited during this period of thinning ice, but few other topographic features were formed during the early stages of deglaciation. The general sequence of major events during the further thinning and retreat of the last glacier in the Red Deer-Stettler area are listed in Table III. For convenience, the deglaciation in the Central Highland, the Red Deer Lowland, and the Torlea Flats Lowland are described separately.

Deglaciation

Central Highland

The first effects of deglaciation were in the high parts of the Central Highland. The ice stagnated there early in its retreat, and the stagnation spread northward and eastward as the ice-sheet thinned. Moving ice in adjoining areas continued to carry in drift, which was deposited near the margins of the stagnant ice, but at continually decreasing altitudes. Meltwater streams also carried much material into the district, commonly from long distances, and this material composes much of the outwash and moraine plateaux. These additions of material increased the thickness of drift in the Central Highland at the expense of drift thicknesses elsewhere.

Periods of relative stability or even of slight increase in thickness with renewed glacier movement interrupted the ice thinning. This lengthened the time during which material was added to the Central Highland, and the increased movement was particularly important in bringing material into the northern part of this district. These rejuvenations and renewed movements formed the various ice-flow markings, and the moraines crossing meltwater channels, in the northern part of the Central Highland. None of the rejuvenations was large enough to end ice stagnation in the highest parts of the district. The largest rejuvenation may correspond to one of the late substages of the Wisconsin (Cary substage ?).

The hills east of Red Deer and Innisfail were the first points cleared of ice. The ice-sheet was now stagnant over much of the southern part of the Central Highland, and the patches of bare ground enlarged and became interconnected until they covered most of this Highland (*see* Figures 7 to 10). Large blocks of ice lasted long after most of the district was ice-free, and as this ice occupied the basins and valleys it had a great effect on drainage. One or two such blocks formed the basin now occupied by Buffalo Lake. In addition such remnant ice kept the Red Deer River from reoccupying its valley through the Central Highland until late stages of the deglaciation. This enabled lake water to be ponded in the former Red Deer valley north of the city of Red Deer and forced it to find outlet routes, such as the Parlby Creek spillway, farther north (*see* Figures 10-12).

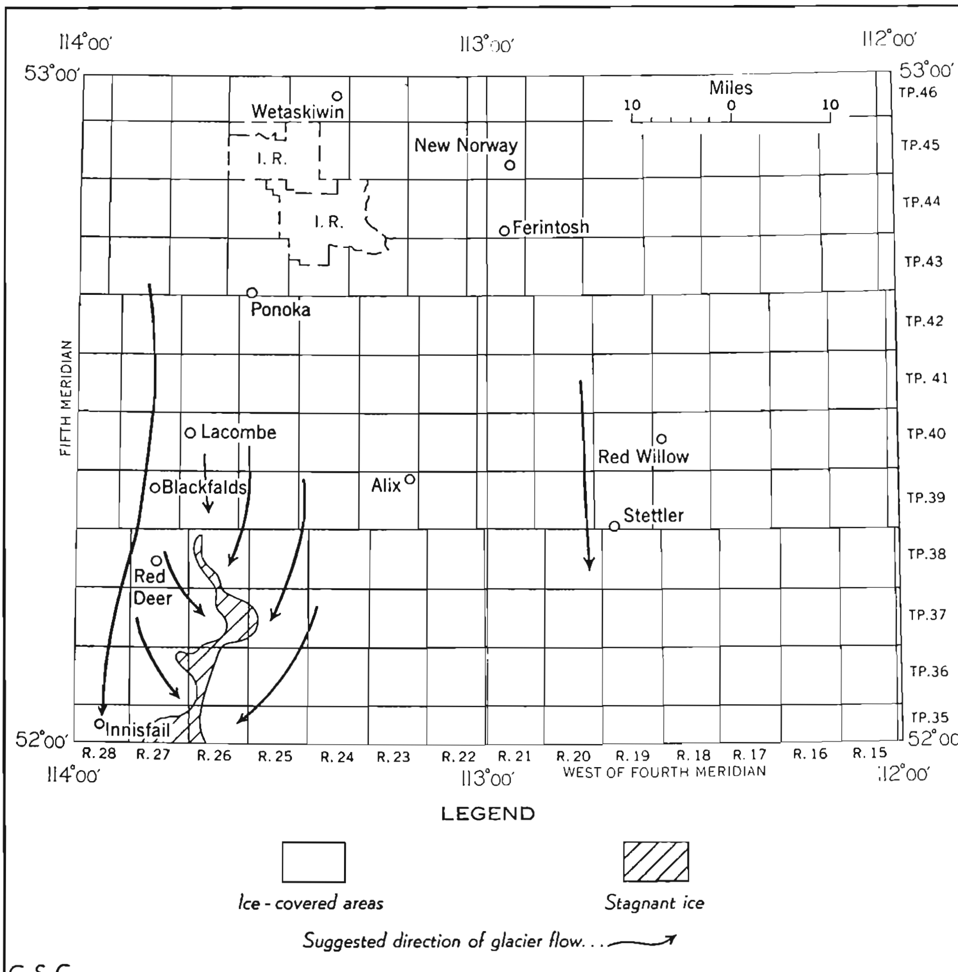


Figure 6. **Deglaciation of Red Deer-Stettler area (number 1).**

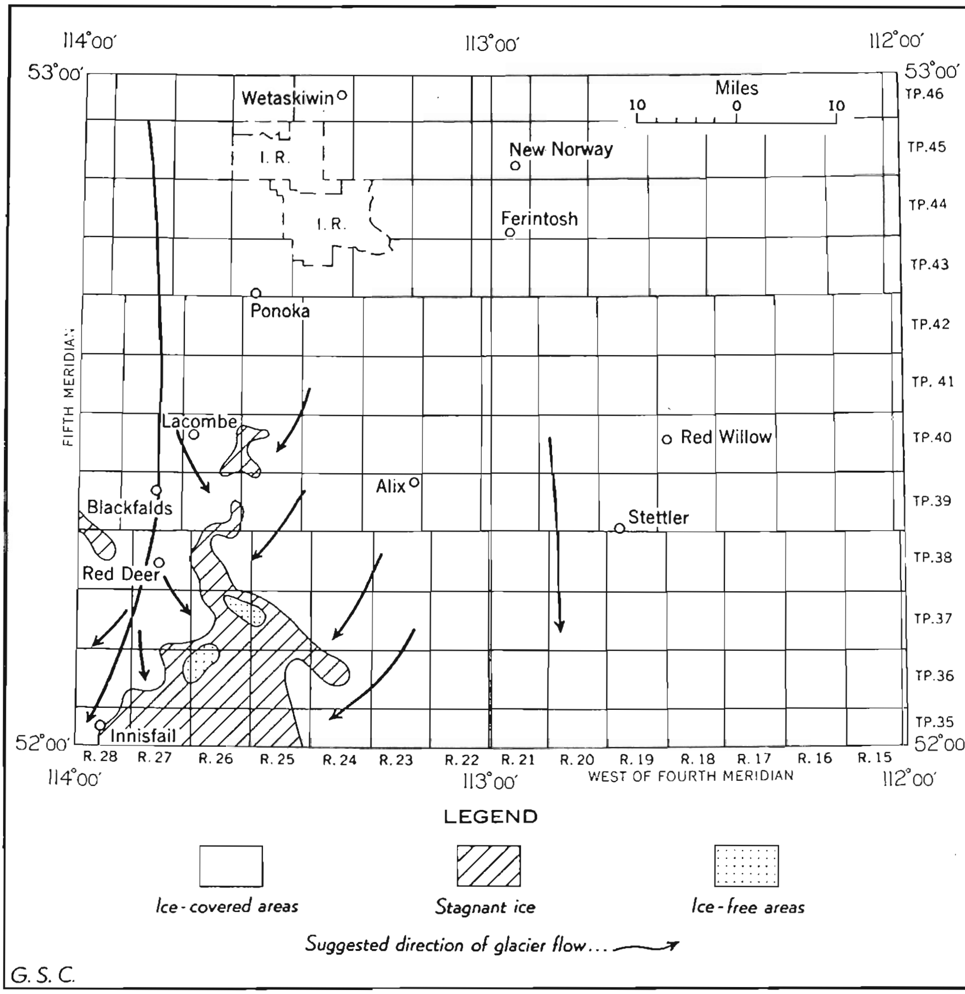


Figure 7. **Deglaciation of Red Deer-Stettler area (number 2).**

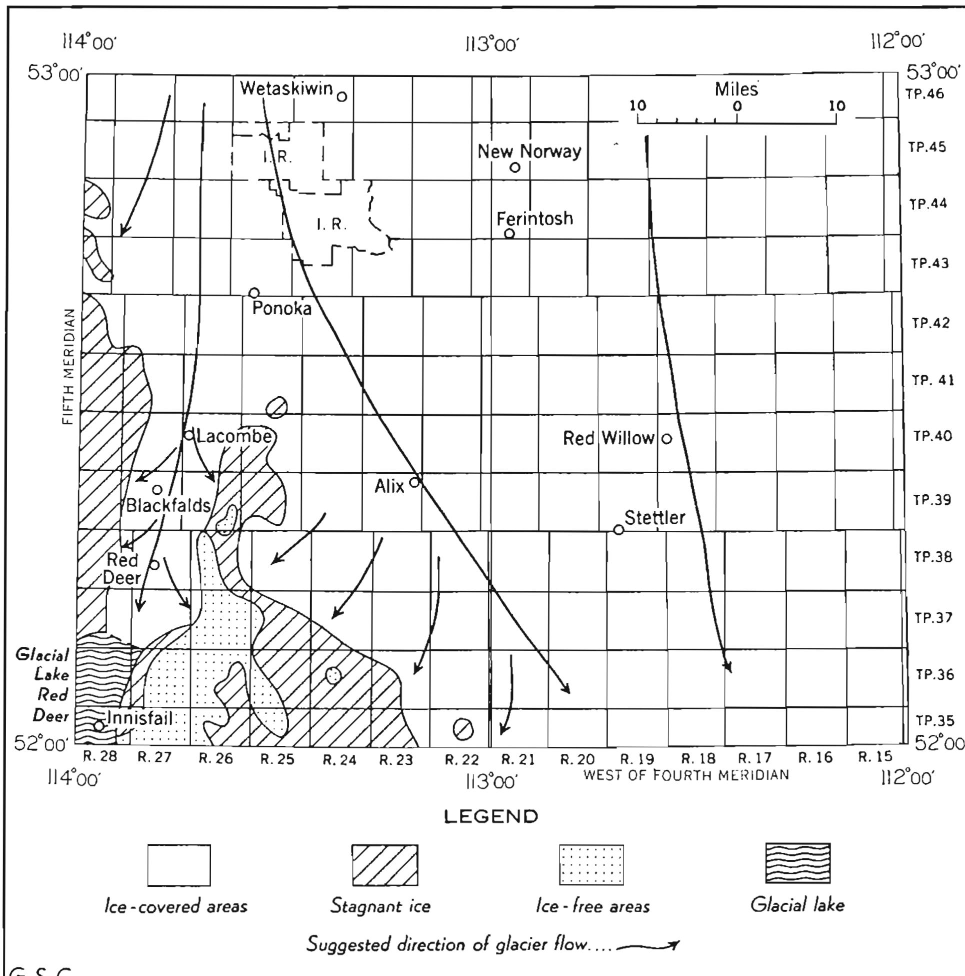


Figure 8. *Deglaciation of Red Deer-Stettler area (number 3).*

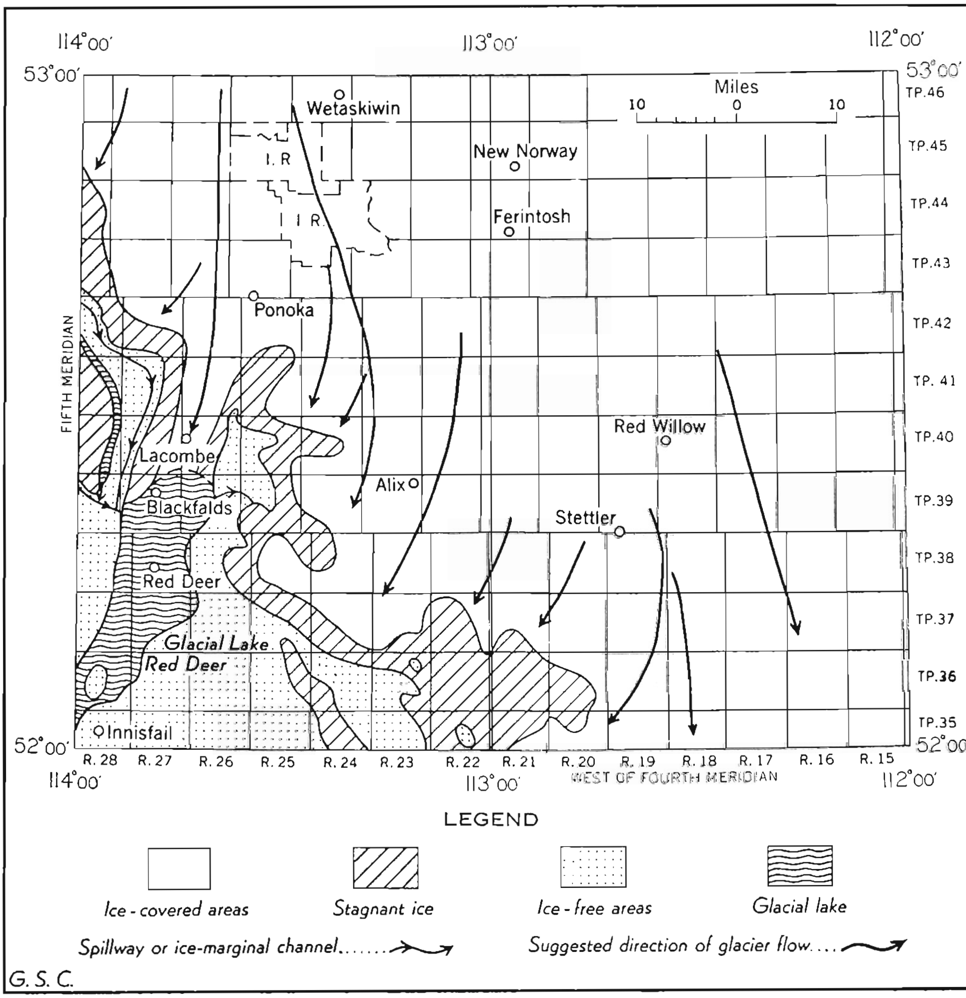


Figure 9. **Deglaciation of Red Deer-Stettler area (number 4).**

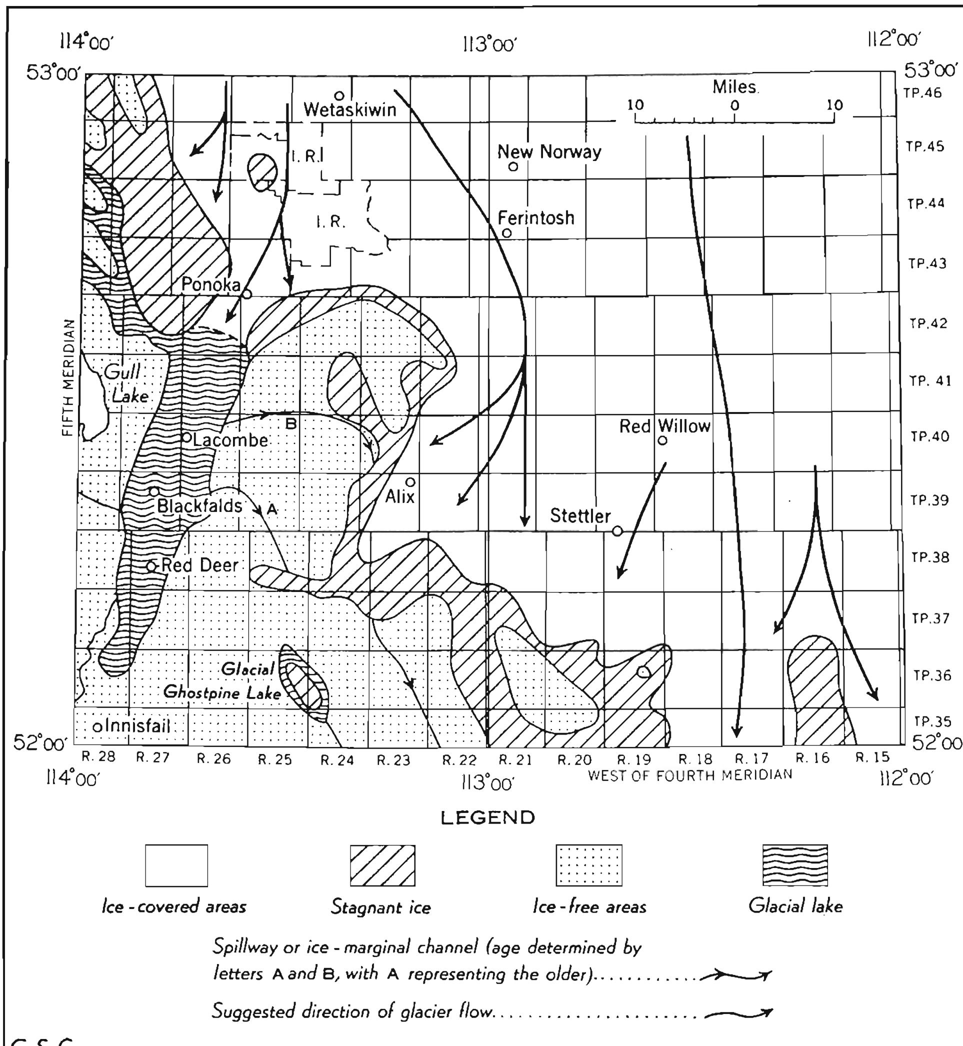


Figure 10. **Deglaciation of Red Deer-Stettler area (number 5).**

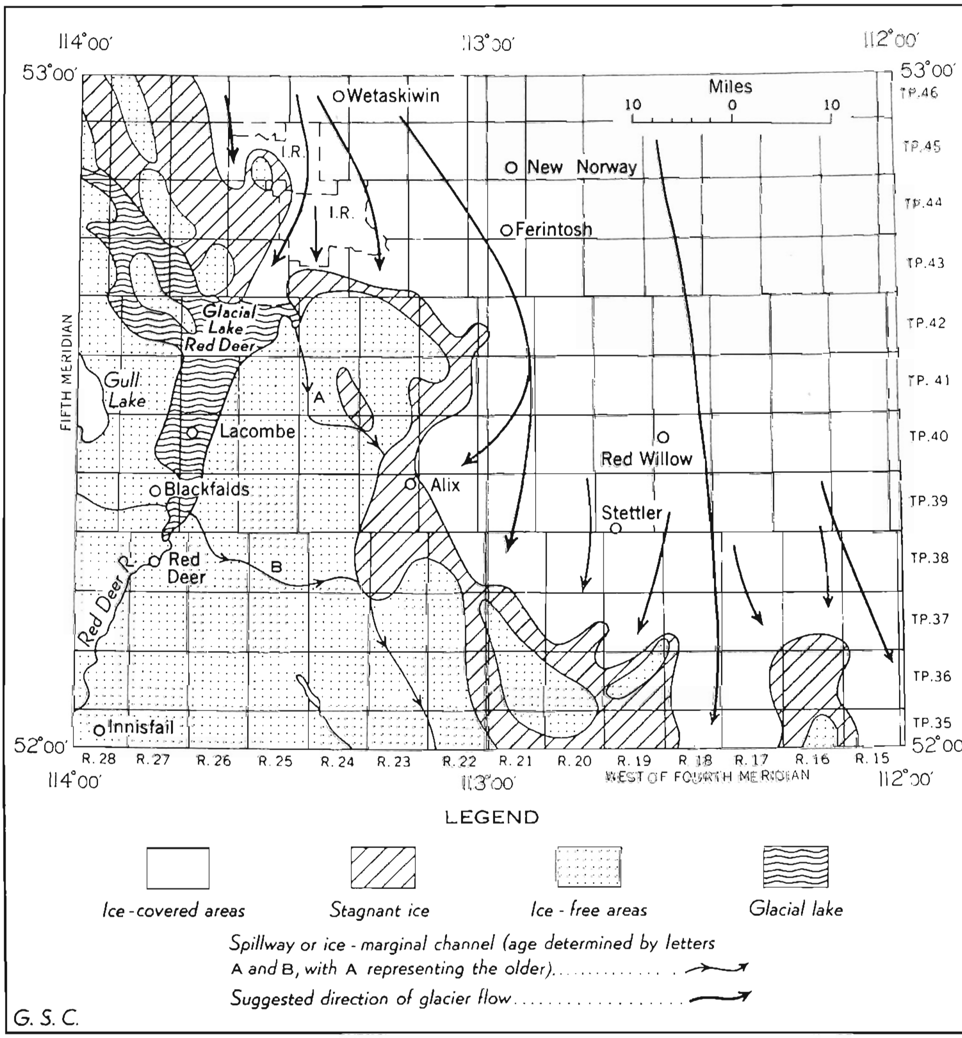


Figure 11. Deglaciation of Red Deer-Stettler area (number 6).

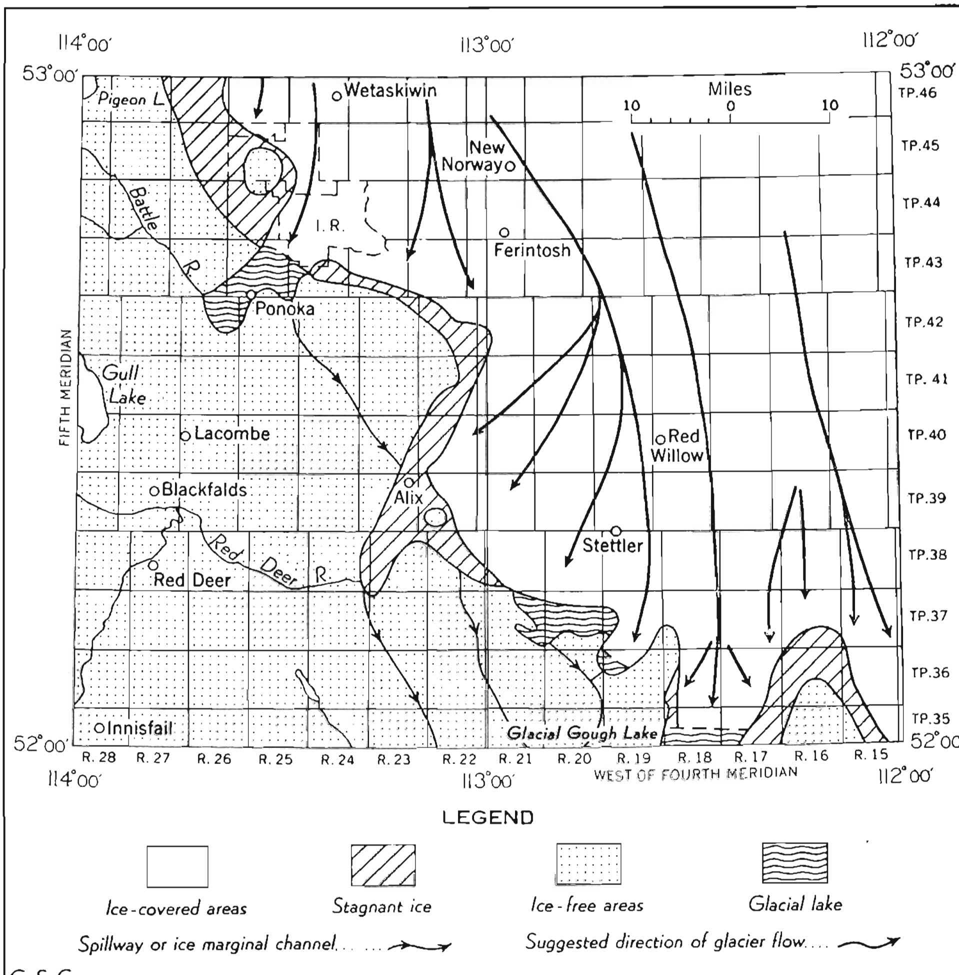


Figure 12. Deglaciation of Red Deer-Stettler area (number 7).

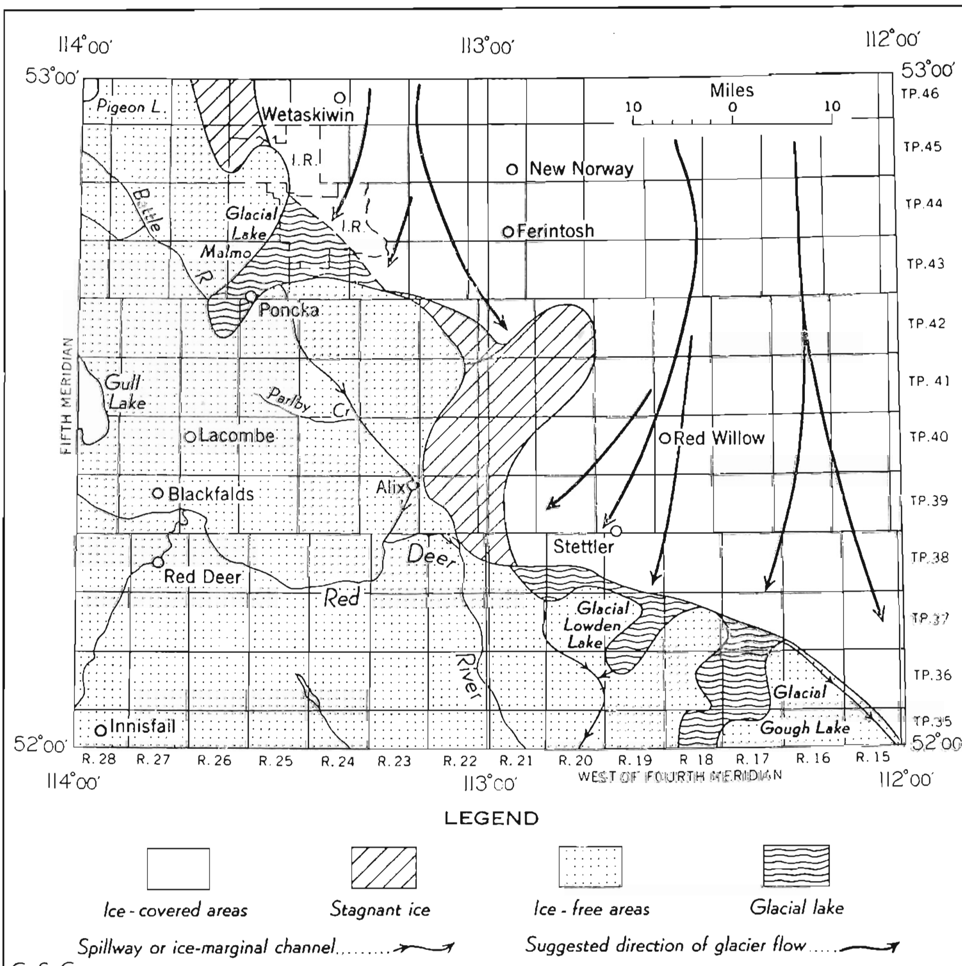


Figure 13. Deglaciation of Red Deer-Stettler area (number 8).

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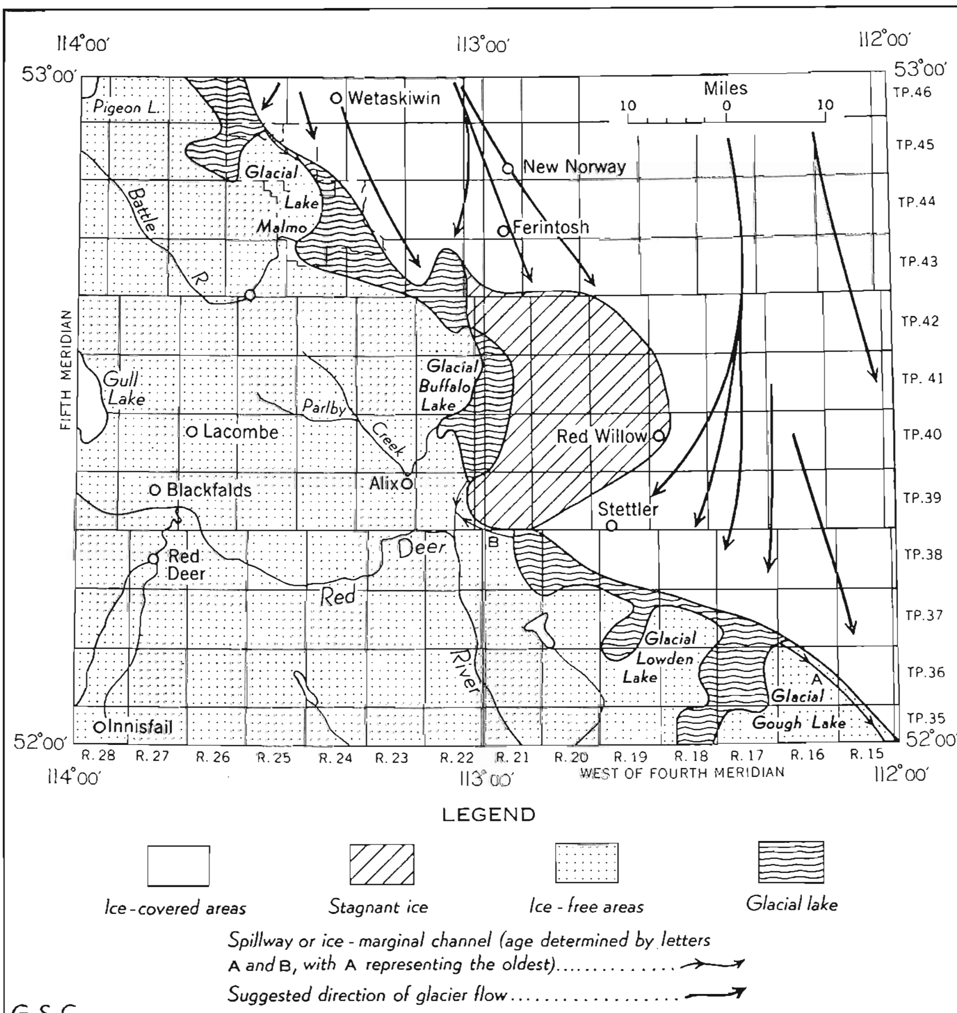

Figure 14. Deglaciation of Red Deer-Stettler area (number 9).

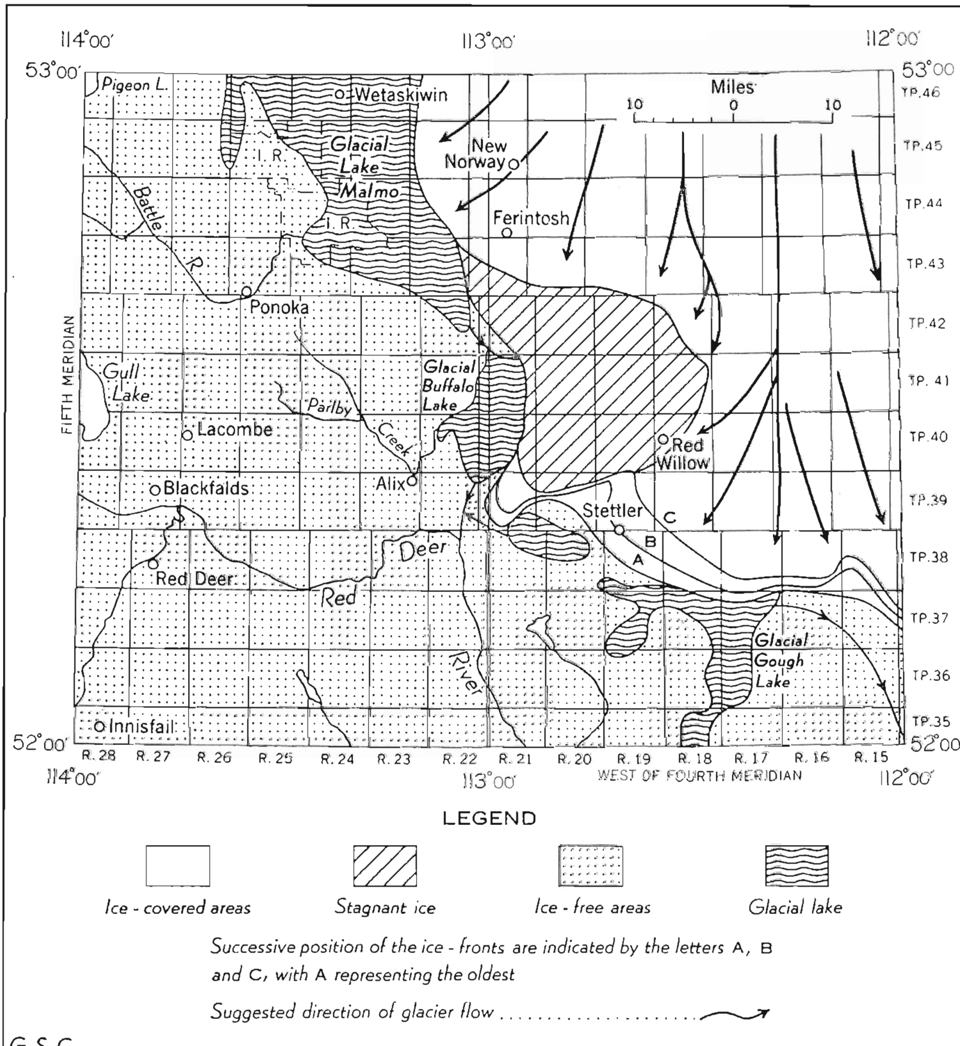

Figure 15. **Deglaciation of Red Deer-Stettler area (number 10).**

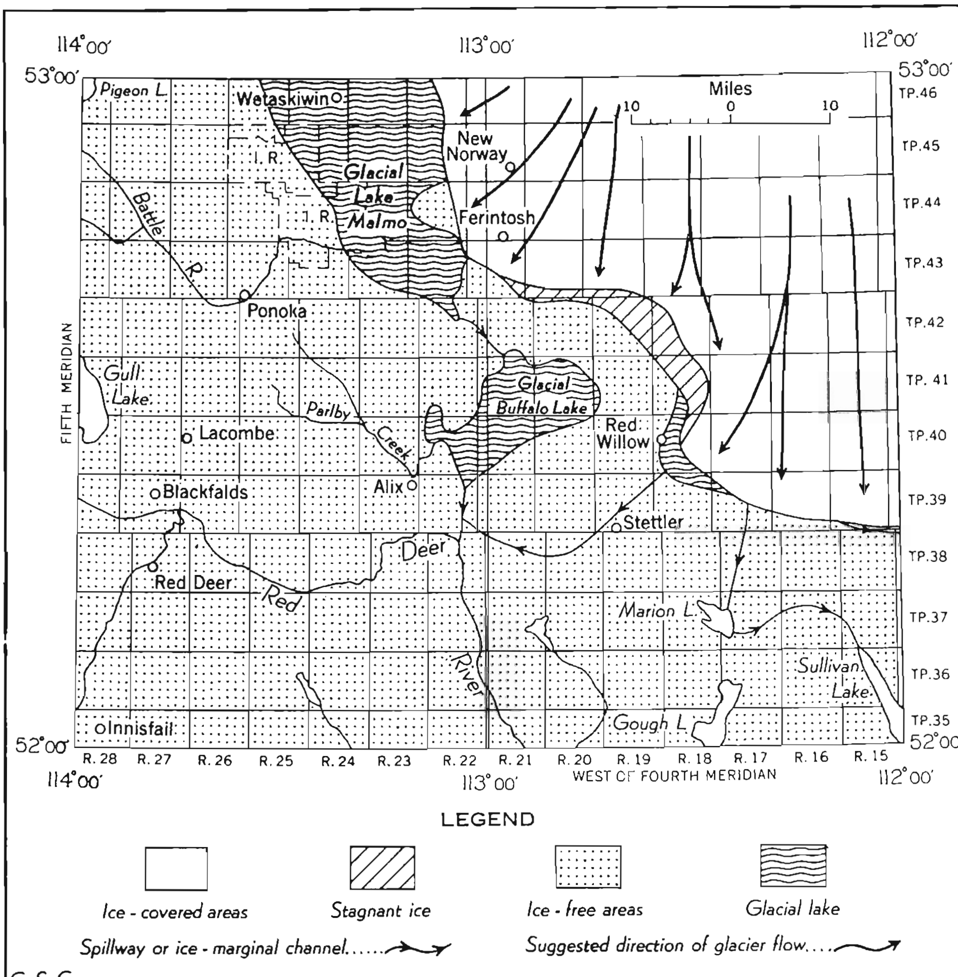

Figure 16. *Deglaciation of Red Deer-Stettler area (number 11).*

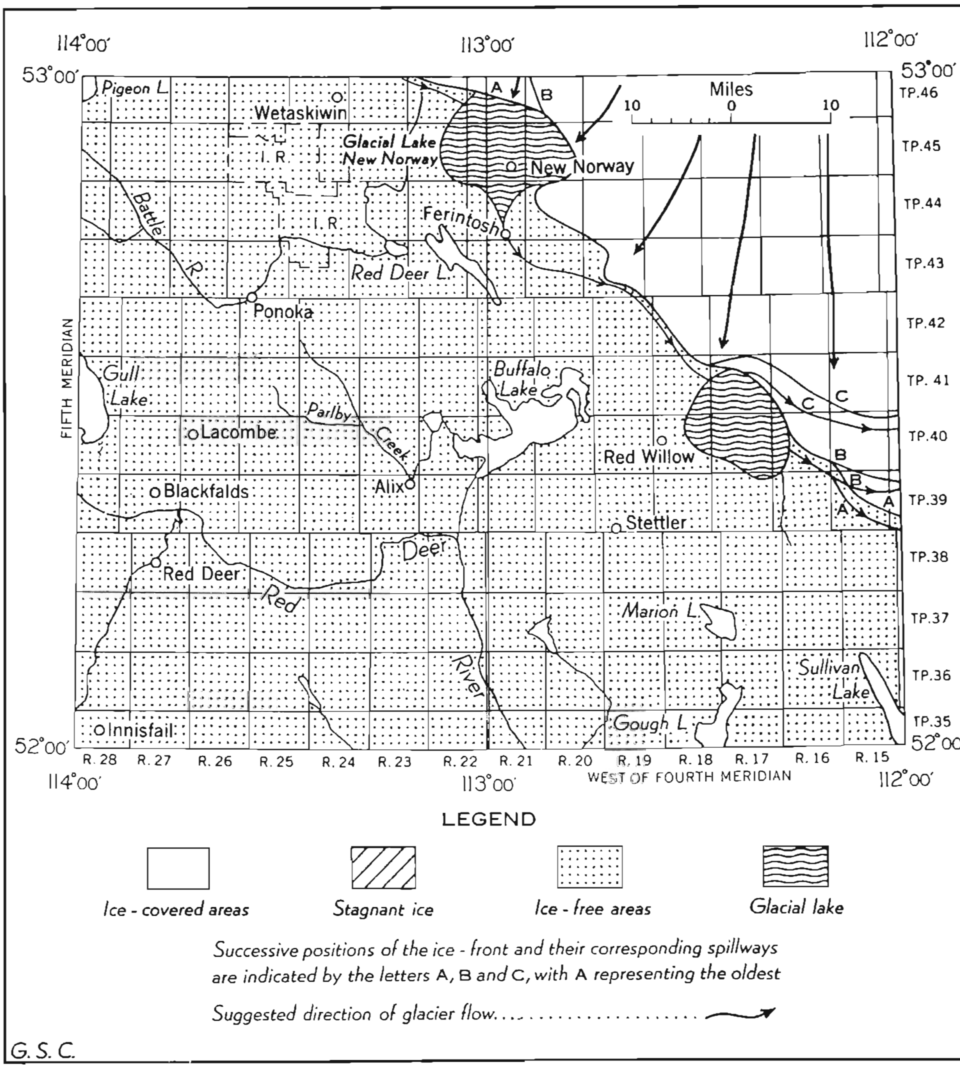

Figure 17. **Deglaciation of Red Deer-Stettler area (number 12).**

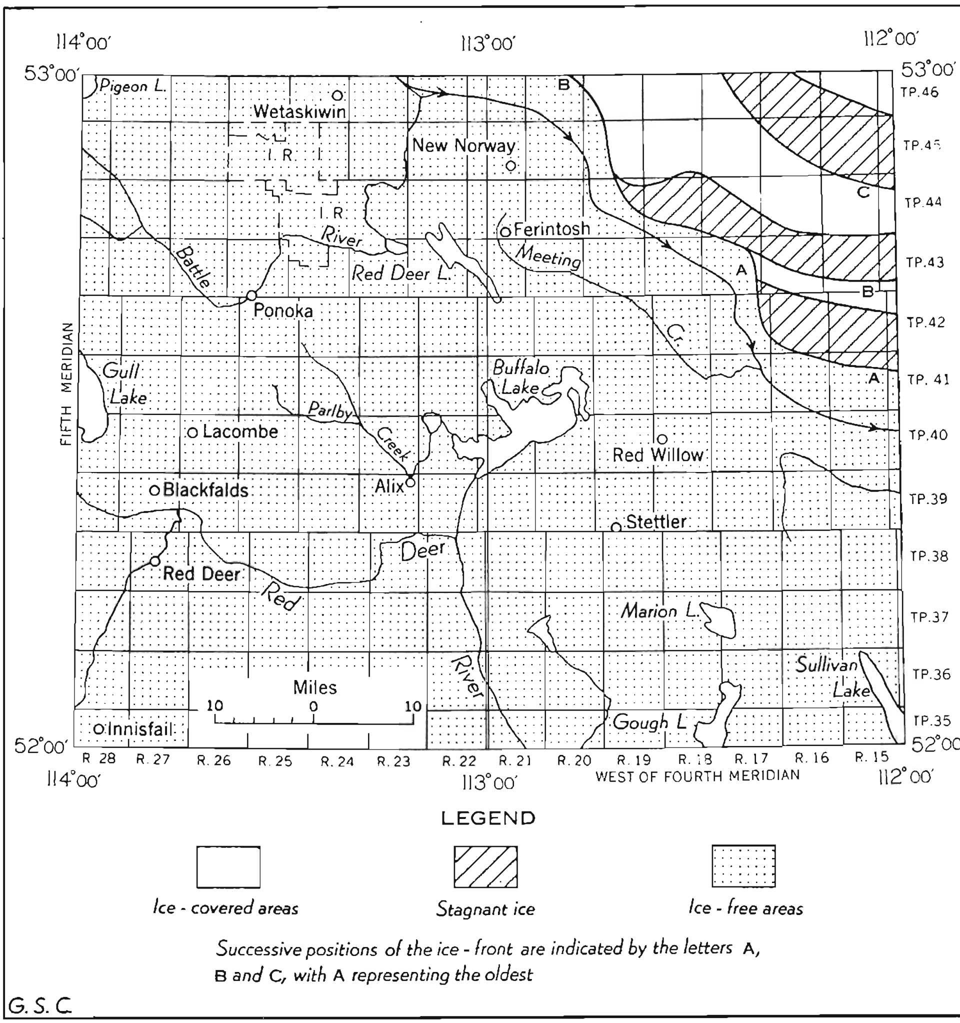

Figure 18. Deglaciation of Red Deer-Stettler area (number 13).

The topographic features formed in the Central Highland are those of deposition from stagnant ice. The largest feature, the Buffalo Lake moraine system, is largely a dead ice moraine, and the extensive pitted outwash, moraine plateaux, kames, ice-block ridges, esker ridges, and wind gaps owe their origins largely to the ice stagnation. Ice-flow markings are rare, partly because of lack of ice movement but also as they are buried by hummocky moraine and outwash that was deposited during the stagnation.

Meltwater from the Central Highland drained southward, partly through small valleys but mostly under or over the ice. No trace remains of the sub- or superglacial streams. In the final stages of the glacier in this district the drainage was largely southward through Big Valley and Red Deer valley (*see* Figures 12-15).

Red Deer Lowland

The glacier had retreated from much of the Central Highland before thinning of the ice had much effect in the Red Deer Lowland. Ice movement continued there long after it had ceased in the Highland, and it may even have quickened for a time as ice wastage increased to the south and west and as the ice that earlier would have moved over the Central Highland and over high land to the west was channelled through the Red Deer Lowland.

The first part of this district affected by the thinning of the glacier was the southern area near Innisfail, at altitudes of 3,100 and 3,200 feet (*see* Figure 8). The ice slowly stagnated, ending southward flow through the Red Deer Lowland, and southward-flowing ice from north of the area was diverted to the east of the Central Highland. Movement in the Red Deer Lowland then was sufficient only to compensate for local marginal wastage. Apparently the glacier thinned sufficiently to expose an area east of Innisfail and the ice-margin may have retreated much farther northward (*see* Figures 9 and 10). The Innisfail-Morningside outwash was deposited at about this time. A lake then was ponded between the ice-margin and high land to the south, and Red Deer River, which was draining largely ice-free land to the west, may have flowed into this lake. The lake spilled southward through the western of two deeply incised channels southeast of Innisfail, outside the Red Deer-Stettler area.

A rejuvenation of the glacier with rapid thickening now caused it to advance southward in this district. This advance overran the Innisfail-Morningside outwash and moraine (*see* Plate IV) and the northern part of the Central Highland. Any glacial lakes east of Innisfail were destroyed, the outlet channel southeast of Innisfail was blocked, and all of the Red Deer Lowland was covered by ice (*see* Figure 7). Only an increase in ice thickness of between 300 and 500 feet was needed to produce all the observed effects.

Following the rejuvenation, thinning of the ice-sheet again took place, the ice again stagnated in the southern part of the Red Deer Lowland (*see* Figure 7), and the stagnation slowly spread northward. The esker ridges in this district were formed at about this time. The thinning glacier again retreated from the southern part of the Lowland, east of Innisfail, and a lake was ponded at an altitude of about 3,250 feet, between the ice-margin and the high land to the south (*see* Figure 8). The lake water, along with the water of Red Deer River, again drained southward but the former channel southeast of Innisfail apparently was blocked by ice. A new and larger spillway was incised to the east of the earlier one. With continued thinning of the glacier, stagnation spread northward and the ice-free area in the south expanded (*see* Figure 9). Lake water occupied the newly cleared land, but at first the expanse of the lake did not change much as its outlet was being incised more deeply and the lake slowly drained from the high ground to the south. However, when the outlet channel had been incised to an altitude of just under 3,100 feet, its final altitude before being abandoned, it was near grade and the lake level remained fairly constant. The lake now expanded as the ice-margin moved northward.

The Innisfail spillway was used until the ice-margin had retreated northward to Blackfalds. Minor outlets to the east of Blackfalds were then available (*see* Figure 10), or possibly, though not likely, the lake water spilled eastward down the present Red Deer valley. These outlets lowered the lake level to 3,000 or 3,050 feet, and the lake drained from the southern part of its basin. The ice-marginal Blindman River now started to flow down the western side of the former Red Deer valley (*see* Figure 9). It incised its valley rapidly and cut indiscriminately across esker and drumlinoid ridges, as if superimposed from the glacier. This river added much sediment to the lake, and some of the thickest deposits of glacial Lake Red Deer were laid down at this time.

Much of the Western Highland north of Gull Lake and west of Ponoka was now exposed (*see* Figure 10), and ice lying to the east ponded small lakes in the eastward-trending valleys of this district. The drainage was southeastward into glacial Lake Red Deer along the margin or front of the ice, approximately parallel to but southwest of, the present Battle River. Glacial Lake Red Deer was still spreading northward in front of the retreating ice-margin, and its level in the vicinity of Ponoka was just under 3,000 feet. At this stage the small glacial lakes north of Gull Lake drained and the drainage from this district into glacial Lake Red Deer was concentrated at the position of the present Battle River west of Ponoka.[1] This glacial spillway is still used by Battle River to a point 2 miles west of Ponoka. At this point the spillway strikes northward to Bearhills Lake, whereas modern Battle River flows eastward to low land near Ponoka.

[1] Certain morainal ridges and small meltwater channels lie parallel to the present Battle Valley, but a few miles to the north. These represent the glacier margin during the early stages of Battle River, and they indicate that this river was originally ice marginal.

Further slight retreat of the glacier opened an outlet from glacial Lake Red Deer down Parlby Creek valley to the southeast of Ponoka (*see* Figure 11). This outlet immediately lowered glacial Lake Red Deer by 150 feet, and before being abandoned by a total of 300 feet to an altitude of about 2,700 feet. The Parlby Creek drainage at first used the channel that trends southward on the western side of tp. 41, rge. 24, as the ice still covered the lower land to the east. When this ice melted the lower and larger channel that strikes southeastward across this township was cut (*see* Figure 12). The initial lowering of the lake by 150 feet drained the whole region south of Red Deer. Until this time Red Deer River had flowed into this lake, and was perhaps its largest source of water, but the river channel east of Blackfalds now opened and the river flowed eastward and away from the remaining part of glacial Lake Red Deer. Blindman River now entered Red Deer River rather than glacial Lake Red Deer, and the lake was fed by Battle River and by meltwater. With the final lowering of the lake by 300 feet, through deepening of the Parlby spillway, glacial Lake Red Deer receded to north of Morningside and was of only minor importance (*see* Figure 12). The Red Deer stage of ponding in the former Red Deer valley was now ended.

The remaining ice in the western part of the Red Deer Lowland was now stagnant, and most of the esker ridges in the northern part of this district formed at this time (*see* Figure 12). With further northward retreat of the glacier margin, water was ponded between the ice and high land to the south (east of Ponoka). The Parlby outlet controlled the level of this lake (glacial Lake Malmo), which was at about 2,700 feet altitude. Glacial Lake Malmo expanded in front of the retreating ice-margin (*see* Figure 13) until new outlets opened into Buffalo Lake near Bashaw (*see* Figure 14). The Parlby outlet was abandoned, the lake level fell to about 2,600 feet altitude, and the lake drained from the western part of its basin near Ponoka. Glacial Lake Malmo became (*see* Figure 15) a shallow body of water extending northward out of the Red Deer-Stettler area, and was bounded on the east by ice lying near the present position of the hummocky moraine north of Red Deer Lake. It was fed largely by meltwater, spillways from glacial lakes to the north, and by rivers from the west. The ice melted from the rest of the Red Deer Lowland and glacial Lake Malmo drained, mostly through the hummocky moraine to the east via the present course of Battle River (*see* Figure 17). A few small remnants of the lake, e.g., Sampson Lake, have continually decreased in size as their outlets deepened and sediment was deposited in them. Battle River then took its present course across the basin of glacial Lake Malmo, and cut a small valley which has since developed very little. East of Wetaskiwin the river appropriated large, eastward-trending channels that had been carved and later abandoned by ice-marginal streams and spillways of glacial lakes farther north. These channels emptied into glacial Lake New Norway. The only large change in the features of the Red Deer Lowland since the retreat of the glacier has been the formation of numerous sand dunes.

Torlea Flats Lowland

The surface of the glacier over the Torlea Flats Lowland was about 300 feet lower than in the Red Deer Lowland, and about 700 feet lower than in the Central Highland, before similar effects of the deglaciation were felt. By then most of the Central Highland was bare of ice, and much of the retreat in the Red Deer Lowland had taken place (*see* Figure 10). Ice flow may even have increased for a short time as western routes were blocked and the movement was concentrated to the east of the Central Highland.

Ice stagnation in the relatively high ground southwest of Sullivan Lake (*see* Figure 10), with formation of hummocky moraine, was the first effect of the thinning of the glacier. The glacier evidently retreated far enough to expose land near Gough Lake and perhaps to pond water between the ice-margin and high ground to the south (*see* Figure 12). This lake drained southward from Gough Lake, and this spillway may have held the glacial lake to a small size. A rejuvenation now interrupted the glacier retreat. If this rejuvenation was the same one that caused the strong readvance in the Red Deer Lowland, which appears probable, the glacier had retreated farther northward in this lowland than indicated above and had cleared from land as low as 2,700 feet altitude and northward as far as Ponoka. If this rejuvenation was not the same one, the rejuvenation in the Red Deer Lowland was the earlier and had little effect in the Torlea Flats Lowland.

Following the rejuvenation, the glacier covered the entire Torlea Flats Lowland (*see* Figure 7) and probably overran the northern edge of glacial Lake Drumheller, about 20 miles south of the Red Deer-Stettler area. Glacier thinning and retreat followed, hummocky moraine was deposited, and moraine plateaux were built on the high ground southwest of Sullivan Lake (*see* Figures 10 and 11). Active ice carried material to this moraine from the northwest, north, and east. Various ice-flow markings near Gough Lake, which were formed at this time, indicate that ice movement was southward.

Ice stagnation was important only locally in the Torlea Flats Lowland. The glacier was active nearly to its margin during most of the retreat, and wastage at the margin was important. Glacial erosion was strong, and the eroded material was carried nearly to the ice-margin before being deposited. As the margin stood for a fairly long time near the high ground to the south and west, much of this material was added to the hummocky moraine there (*see* Figures 10 to 15).

When the glacier withdrew from the high ground to the south, water was ponded locally along its margin between Leo and Nevis (*see* Figure 12). The largest lakes were those near the present Gough, Lowden, Foxall, and Ewing

Lakes (*see* Figure 13). The newly formed 'Big Valley' channel drained the western of these lakes. The Gough Lake region probably drained southward for a short time by meandering through or seeping under hummocky moraine that blocked the earlier spillway. Before a large channel could be incised, however, retreat of the glacier opened lower drainage. This was northeastward to Sullivan Lake around the northern end of the high land that lies southwest of Sullivan Lake. The lakes now expanded northward in front of the retreating glacier, and their level remained fairly stable for some time (*see* Figure 14).

Minor halts in the retreat of the glacier margin, north of Marion and Lonepine Lakes, formed a series of ice-frontal channels and small end moraines. Ice-flow markings indicate that ice movement was at right angles to these channels and moraines. All the glacial lakes then joined (*see* Figure 14); they drained through Sullivan Lake, earlier spillways were abandoned, and the water level lowered by some 30 feet to an altitude of about 2,700 feet. Gough Lake was then at about its present size.

The minor moraines near Botha, the moraine southwest of Stettler, and the moraine striking through Stettler itself (*see* Figure 15), formed in short periods of stability during further slight retreat of the glacier. These are true 'recessional moraines' formed by equilibrium between ice advance and wastage at the ice-margin. Further northward retreat of the ice-margin permitted ponding east of Red Willow (*see* Figure 16), between the ice and rising ground to the south. This lake originally drained southeastward to Sullivan Lake, then eastward through Paintearth Creek (*see* Figure 17), and finally down the present Battle Valley.

Until that time the glacier was adding material, gathered by erosion in the Torlea Flats Lowland, to the eastern and northeastern parts of the Buffalo Lake moraine system, including the hummocky moraine west of Ferintosh and New Norway. The glacier withdrew from the eastern edge of the Buffalo Lake moraine system in the Red Deer-Stettler area, and glacial Lake New Norway was ponded between the hummocky moraine and the ice-margin (*see* Figure 17). The lake was fed by meltwater from nearby ice and from ice to the north of Wetaskiwin; by spillways from glacial lakes farther north in the Edmonton district; and perhaps by the North Saskatchewan River. Much of this water flowed through the Battle valley east of Gwynne, and entered the lake near the present Driedmeat Lake. This large volume of water flowed southward out of glacial Lake New Norway past Ferintosh to Meeting Creek, and thence into the shallow glacial lake east of Red Willow (*see* Figure 17). The current was strong enough to cut the large valleys at Ferintosh and Meeting Creek, and the rapid deepening of the Ferintosh outlet lowered glacial Lake New Norway from about the 2,600-foot to the 2,450-foot altitude.

With further glacier retreat, marginal drainage started cutting Battle valley between Edberg and the eastern edge of the area (*see* Plate X; Figure 18), and glacial Lake New Norway quickly drained. This valley also ended the glacial lake east of Red Willow, if Paintearth Creek drainage had not already done so.

Continued glacier thinning and retreat featured the remaining glacial history of the district. Ice stagnation was important in the northern part of the district (*see* Figure 18), and esker ridges, ice-block ridges, and isolated blocks of hummocky moraine were formed. Local ponding was common but there were no large glacial lakes.

Final disappearance of the glacier left the part of the district north of Battle valley much as it is at present, poorly drained, with many sloughs and swamps. Dunes have since formed in the glacial-lake beds, particularly in those of glacial Lake New Norway, and in the glacial-lake basins east of Red Willow, near Lowden, east of Gough Lake at Leo, and south of Stettler.

Table III

Assumed Events of Wisconsin Deglaciation in the Red Deer-Stettler Area, Alberta

Figure	Red Deer Lowland and Western Highland	Central Highland	Torlea Flats and Contiguous Areas
—	Thinning of glacier and continued movement	Thinning of glacier and continued movement	Thinning of glacier and continued movement
6	Thinning of glacier and continued movement	Thinning of glacier; ice stagnates on highest hills	Thinning of glacier and continued movement
7	Thinning of glacier and continued movement	First hills exposed; ice stagnation spreads to lower land; material brought in from east, north, and west; deposition of hummocky moraine starts	Thinning of glacier and continued movement
8	Ice-sheet stagnant over much of Western Highland; first land cleared of ice in south of Lowland is covered by lake water which drains southeastward	Ice-free land expands; ice stagnation spreads northward and eastward; continued deposition of hummocky moraine	Thinning of glacier and continued movement
—	Further glacier retreat, with perhaps deposition of much of Innisfail-Morningside outwash; lake spreads northward but lowers as outlet deepens; outlet also carries water of Red Deer River	Ice-free land expands, much of Central Highland now exposed; continued deposition of hummocky moraine, esker ridges, kames, and outwash; some small glacial lakes present; meltwater drains southward	Glacier motion slows and ice stagnates in south; extent of glacier retreat unknown but some high land may be exposed and water ponded in the south

Table III—*Cont.*

Figure	Red Deer Lowland and Western Highland	Central Highland	Torlea Flats and Contiguous Areas
7?	Rejuvenation and readvance, with district covered by moving ice; ice-flow markings formed on Innisfail-Morningside outwash and elsewhere	Rejuvenation and readvance of glacier leaves only the highest hills ice-free; ice-flow markings formed in northern part of district	Rejuvenation and readvance of glacier covers district with moving ice
7?	Glacier thickening stops and thinning starts; continued movement	Glacier thickening stops and thinning starts; ice stagnates on high areas	Glacier thickening stops and thinning starts; continued movement
7?	Thinning of glacier and continued movement	Ice stagnation spreads to lower land, material brought in from east, north, and west; deposition of hummocky moraine	Thinning of glacier and continued movement
8	Ice stagnant over much of Western Highland; first ice-free land in south is flooded with lake water (glacial Lake Red Deer) which drains southeastward	Areas of ice-free land and stagnant ice expand; continued deposition of hummocky moraine	Thinning of glacier and continued movement
9	Glacial Lake Red Deer expands northward in front of retreating ice-margin, but level lowers as outlet deepens, new, small outlets open east of Blackfalds Lake; ice-frontal Blindman River forms, ice stagnation increases in Western Highland allowing esker ridges to form, and local ponding occurs there	Areas of ice-free land and stagnant ice expand; continued deposition of hummocky moraine	Thinning of glacier and continued movement
10	Glacial Lake Red Deer spreads northward in front of retreating ice-margin, but level lowers when outlet near Chigwell opens and the lake drains from southern part of Red Deer Lowland; spillway southeast of Innisfail abandoned; ice stagnation spreads northward	Most of district now ice-free but stagnant ice still blocks Red Deer valley and covers eastern and northern areas; continued deposition of hummocky moraine in these latter areas	Glacier stagnates over high land in south of district; chief ice-flow deflected east of district
11	Glacial Lake Red Deer spreads northward in front of retreating ice-margin, but level lowers as Parlby Creek spillway opens and lake drains from the district south of the city of Red Deer; Red Deer valley east of Red Deer may open at this time	Some stagnant ice remains in eastern and northern parts of the district, with continued deposition of hummocky moraine	High hills in south are ice-free; area of stagnant ice expands; deposition of hummocky moraine starts in south

Table III—*Cont.*

Figure	Red Deer Lowland and Western Highland	Central Highland	Torlea Flats and Contiguous Areas
12	Ice-free area expands northward; glacial Lake Red Deer drains as Parlby outlet deepens; glacial Lake Malmo starts; western segment of Battle valley in use	Some stagnant ice remains in northeastern part of district, with continued deposition of hummocky moraine there; western segment of Red Deer valley in use	Areas of ice-free land and stagnant ice expand; ponding starts in south, drains southward; deposition of hummocky moraine continues
13	Ice-free land spreads northeastward; glacial Lake Malmo expands, but continues to use Parlby Creek outlet	Some stagnant ice remains in northeastern part of district, with continued deposition of hummocky moraine there; all of Red Deer valley in use	Ponding spreads northward in front of retreating ice-margin; the western lakes drain southward down Big Valley and glacial Gough Lake drains eastward towards Sullivan Lake; active ice-movement continues in most of district
14	Glacial Lake Malmo expands northeastward, but level lowers and lake drains from southwestern part of its basin as Parlby Creek outlet is abandoned and new outlet opens past Bashaw to Buffalo Lake	All but northern part of district is ice-free; glacial Buffalo Lake drains southward to Red Deer River by Tail Creek	Southern part of district is ice-free, large areas of ice stagnate east of Buffalo Lake; much ponding along western and southern margins of the ice-sheet, glacial Lakes Gough and Lowdon drain eastward to Sullivan Lake and Big Valley outlet is abandoned
15	Glacial Lake Malmo, now at greatest size, drains southeastward to Buffalo Lake	All but northern part of district ice-free	Area of stagnant ice east of Buffalo Lake spreads northeastward, with formation of hummocky moraine and associated outwash; minor halts in northward retreat of the ice-margin with formation of minor recessional moraines; the glacial lakes in the south become lower and separate; the western lakes drain past Nevis to Tail Creek, the eastern lakes to Sullivan Lake
16	Glacial Lake Malmo lowers slightly as outlet deepens; hummocky moraine forms west of New Norway	All but northern part of district ice-free	Glacial lakes in south drained; new ponding starts northeast of Red Willow

Table III—*Conc.*

Figure	Red Deer Lowland and Western Highland	Central Highland	Torlea Flats and Contiguous Areas
17	District ice-free; glacial ponding ended; Battle River assumes modern course	District ice-free; modern drainage assumed	Glacial Lake New Norway forms, and drains southward past Ferintosh to Meeting Creek and down eastern segment of ice-frontal Battle valley; ponding northeast of Red Willow at maximum; ice-frontal valleys form during minor halts of glacier retreat
18	Modern drainage in use	Modern drainage in use	Glacial Lake New Norway drains as more of ice-frontal Battle valley in use; broad belts of ice stagnate near glacier margin in northeast of district and allow esker ridges to form
—	Modern condition; sand duning in former lake basins	Modern conditions	District ice-free; modern drainage assumed; some sand duning in former lake basins

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Chapter VI

ECONOMIC GEOLOGY

Water Supply

The ground-water supply in most of the townships of the area is described in detail in ground-water supply papers[1] of the Geological Survey of Canada. In this chapter the ground-water supply of the various types of surficial deposits is described in general. More than 80 per cent of the wells in the area draw from bedrock aquifers, and these wells supply more than 90 per cent of the water used. Bedrock water is generally preferred to water from the surficial deposits, as it is mostly softer and in more dependable supply. Use of water from surficial deposits will steadily decrease.

Aquifers in the surficial deposits are used where springs are present, or where bedrock aquifers are inadequate, chiefly in those districts underlain by Bearpaw formation or by the bottom 400 feet of the Edmonton formation. These districts are largely in the northeastern part of the area, however, where water is also difficult to obtain in the surficial material. Most of the wells in the surficial material are old, in poor repair, and are gradually being replaced by bedrock wells. The water in surficial deposits is hard, due to a high content of calcium carbonate picked up from the drift. The highest aquifers in the bedrock also commonly contain hard or medium-hard water, which has seeped into them from the overlying drift.

Aquifers in the Surficial Materials

Till

The till supplies water to wells either directly or from enclosed pockets of sand and gravel. Water will seep through most of the till, though slowly, and small amounts of water can be drawn from it. However, the till with a high

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[1] Number 274:	Townships	43 to 46,	Ranges	13 to 16.
Number 286:	"	35 " 38,	"	25 " 28.
Number 291:	"	39 " 42,	"	25 " 28.
Number 292:	"	39 " 42,	"	21 " 24.
Number 294:	"	39 " 42,	"	13 " 16.
Number 295:	"	35 " 38,	"	13 " 16.
Number 296:	"	39 " 42,	"	17 " 20.
Number 303:	"	35 " 38,	"	17 " 20.
Number 304:	"	35 " 38,	"	21 " 24.

The ground-water supply in tp. 43 to 46, rge. 17 to 28, is not yet described.

content of bentonite, which is mostly in the ground moraine of the Torlea flats, is practically impermeable. Much of the till of the hummocky moraine is coarser than that of the ground moraine, and seepage through it is quicker. The water supply in wells drawing from aquifers in till can be increased only by increasing the amount of till cut through. This can be done by deepening the well, increasing its diameter, or by digging other wells nearby. Owing to their large contact faces between the till and the gravel or sand, the pockets of sand and gravel enclosed in the till commonly collect seepage from a large amount of till, and water can be withdrawn rapidly from wells penetrating such pockets. The locations of these pockets rarely can be predicted before a well is dug, but they are more common in the hummocky moraine than in the ground moraine.

Wells in the till of the hummocky moraine, though generally not very satisfactory, are more successful than those in the till of the ground moraine. This is due to both the greater average thickness of, and the more rapid seepage through, the somewhat coarser till of the hummocky moraine.

Stagnant Ice Deposits

The moraine plateaux are the only stagnant ice deposits extensive enough to affect water supply. The till or till and clay plateaux have the same ground-water potentialities as the ordinary till described above. Of the other plateaux, water drains quickly from the small ones into nearby low land and the ground-water supply in the large ones has characteristics similar to those of the coarse lake deposits.

Outwash

The coarse outwash commonly contains much water. A little of this is used where bedrock aquifers are deep, particularly near Buffalo and Pine Lakes, but in all outwash areas most wells draw from bedrock aquifers. The extensive outwash between Innisfail and Morningside is not likely to contain much water, as it is higher than most of the surrounding areas and the coarseness of the outwash allows water to drain away easily.

Alluvium

The alluvium, particularly the delta gravel, contains much water where it is not readily drained to lower areas. This water, however, is rarely used in any quantity as nearby streams usually are satisfactory for watering stock.

Lake Deposits

The lake clays do not yield any ground water, except where they enclose beds of sand and silt. The lake sand and silt yield water, and their value as aquifers depends upon their thickness and the height of the water table. Where coarse lake

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deposits overlie rolling ground moraine the depressions and kettles on the moraine surface form good collecting basins for seepage. The lake deposits, particularly if more than 10 feet thick, are an important, but not the major, source of water between 5 and 15 miles southwest of Stettler, near Gough Lake, a few miles east of Red Willow (where bedrock water is difficult to obtain), just west of Buffalo Lake, and near Shooting Lake. The thick deposits in the centre of the glacial Lake Red Deer basin contain much water but it is little used as water is readily obtained from the bedrock there. Scattered patches of lake sand in the hummocky moraine constitute good local aquifers but the supply is limited and commonly decreases in dry years. In general, aquifers in the lake deposits are not important as sources of water.

The typical well in the lake deposits is hand dug, is old and in poor repair, and is difficult to keep free from sand and silt.

Wind Deposits

The dune sand is potentially a good source of water for local use, but it is difficult to keep the sand out of the wells. Although a little water is drawn from the sand, its use as a source of water will probably decrease as good bedrock aquifers exist in the dune areas.

Aquifers in Buried Valleys

Former Red Deer Valley

Little is known about the potential water supply of the preglacial and interglacial buried deposits of the former Red Deer valley. Water supply papers numbers 274, 286, and 291 cover part of the area of the valley, but they do not recognize the valley's presence. These papers do report buried deposits of gravel and sand, which at that time were not thought to be continuous, though some were thought to represent buried valleys (Rutherford, 1937, p. 90; Warren, *et al.*, 1947, p. 13).

The buried Red Deer valley does contain aquifers capable of furnishing large supplies of hard water. This water is mainly in the coarse, preglacial gravel and sand, with lesser amounts in the inter-till gravel and sand. These aquifers yield water rapidly and without much lowering of the water table during normal pumping. They are commonly perched above till sheets in the valley fill or above the bedrock itself. Many wells pass through several aquifers in the valley fill in order to obtain soft water from the bedrock, and the water in the valley fill is little used.

The water in the buried valley comes from downward seepage of local precipitation and from bedrock aquifers that were cut by the former Red Deer

River. There is apparently no flow directly from the present Red Deer River into the old valley, nor is there much seepage into the modern valley from the fill of the old valley. Buried tributaries of the former river may contribute some water. The flow through the gravel should increase downstream, provided the buried gravel and sand are not interrupted by crosscutting till sheets. Gravel and sand are absent locally in shallow parts of the valley, but the degree of continuity of the preglacial gravel and sand in the deepest part of the old valley, where it was well protected from glacial erosion, is unknown. Three overriding glaciers did not destroy or greatly disturb the bedding in the preglacial gravel exposed by modern streams near the city of Red Deer or elsewhere. This gravel probably was removed by glaciers in many places, however, and the flow down valley is not likely to be large. The buried gravel and sand serve mainly as good reservoirs for collecting local seepage.

The inter-till deposits are finer, thinner, and less widespread than the preglacial gravel deposits. As they occur at higher elevations than do the older gravels they are commonly cut, and partly drained, by modern gullies and valleys. Wells in these deposits are shallow, and the difficulty of drilling through gravel to reach the preglacial gravel, which is commonly necessary, is avoided.

The buried valley drains the highest aquifers in the nearby bedrock, and it is thus more difficult to obtain bedrock water in areas contiguous to this buried valley.

Other Buried Valleys

The surficial geology map shows a few buried valleys of interglacial or interstadial age; others undoubtedly exist. Local deposits of gravel and sand near the bottom of some of these valleys may contain large supplies of hard water.

Gravel

The largest gravel deposits are shown on the surficial geology map. The indicated boundaries of these deposits generally include all of the area in which gravel occurs, and so commonly outline areas that contain only scattered gravel deposits. Small gravel deposits, including buried ones, are indicated by symbol on Figure 19. Many other deposits of buried gravel undoubtedly are present. The known gravel pits, both abandoned and in use, are also shown. Most of the undeveloped surface deposits of gravel are small and unimportant. A few deposits such as the gravel on the north bank of the Battle valley north of New Norway, are large but are not developed as more economic supplies are available nearby.

For convenience the gravel is divided by age and method of deposition into seven types. These roughly classify the gravel by quality. The surface deposits of the various gravel types, other than those shown on the surficial geology map, are listed in Tables IV to XI, and the estimated reserves of each type are listed in Table XII.

The preglacial gravel deposits and material from these deposits contained in the younger gravel deposits, probably comprise about 98 per cent of the total volume of gravel in the area. As the preglacial gravel is best for most purposes, the quality of the other gravel types depends largely upon their percentage of preglacial gravel. Local bedrock fragments form the second largest component of the gravels, but these are mostly weak and are undesirable. The rest of the gravel consists of boulders and pebbles brought in by glaciers, chiefly from the Precambrian Shield. Much of this material consists of weak fragments, such as weathered pieces of schist and granite, but it commonly forms good gravel, particularly if it has been carried far enough by water to weed out weak stones.

Preglacial Gravel

The preglacial gravel is the best in quality of the various types of gravels, and is present in the greatest amount. Its use has been restricted as it generally is deeply buried and only rarely exposed, and as many of the deposits have a high

Table IV

Exposed Preglacial Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
SW	14	45	19	4	1 gravel pit
NW	14	45	19	4	1 gravel pit
SW	17	45	19	4	1 gravel pit
SW	23	45	19	4	2 gravel pits
NW	27	45	20	4	1 gravel pit
NE	28	45	20	4	1 gravel pit
NE	32	45	20	4	1 gravel pit
SE	33	45	20	4	1 gravel pit
NW	33	45	20	4	1 gravel pit
NE	22	44	21	4	2 gravel pits
SW	7	46	21	4	Undeveloped
SE	7	46	21	4	Undeveloped
SW	9	46	21	4	Undeveloped
SE	9	46	21	4	Undeveloped
SW	10	46	21	4	Undeveloped
SE	10	46	21	4	1 gravel pit
NW	10	46	21	4	Undeveloped
NE	10	46	21	4	Undeveloped
SE	17	38	27	4	1 gravel pit
NW	4	41	27	4	1 gravel pit

water table. In addition, more easily developed deposits of satisfactory gravel of other types are generally available. Preglacial gravel will be used more extensively as its good qualities are recognized and as some deposits of other types of gravel are exhausted. This gravel is described in Chapter III. Most of it is coarse and requires crushing before being used for purposes other than road foundations and railway ballast.

The surface deposits of preglacial gravel are listed in Table IV. Most of the buried deposits of gravel listed in Table XI are also of this type. This gravel is extracted from: a small pit in the city of Red Deer, the lowest beds of the large Canadian National Railways' pit northeast of Viewpoint, the lowest beds of several pits beside the Battle valley to the west of Driedmeat Hill, two small pits to the south of Rosalind, a pit on Driedmeat Hill, various pits in Driedmeat Creek, a small pit 3 miles west of Battle, a pit 4 miles east of Gull Lake, and from small pits found a few miles north of Ferintosh. It is used chiefly for roads and, from the pit northeast of Viewpoint, for railway ballast, and is quite satisfactory. The deposits in Battle River and Driedmeat Creek valleys are connected with the main body of gravel in the former Red Deer valley and have large reserves. Most of the other pits are in deposits near the edge of this valley, where the gravel is thin and intermittent. The reserves of these individual pits are not known, but if one deposit is exhausted another similar one can generally be found nearby.

The amount of preglacial gravel present is difficult to estimate, as most of it is buried. It is associated with the former Red Deer valley, 120 miles of which lies in the map-area. The upper 12-mile stretch of this valley apparently does not contain much gravel, and in the eastern part of the area sand replaces much of the gravel. The average width of the remaining section of the valley is about 8 miles. Assuming that gravel occurs in only one quarter of the area of this section, and that it has an average thickness of 10 feet, the valley contains some 2 billion cubic yards of this gravel, and the amount may be much larger. Most of this gravel is buried too deeply or lies too far beneath the water table to be economically useful for some time to come.

Glacial Gravels

Kame Gravel

Kame gravel deposits include both surface deposits and small pockets enclosed in till. None of the latter is used. This gravel is of poor quality but it is readily available and is used locally. In much of the Torlea flats it is the only gravel economically obtainable. It will be used less as the small supply is exhausted and as better gravel from large, efficiently operated pits becomes more generally available.

Table V

Glacial Kame Gravel Deposits Exposed or Near the Surface

Quarter Section	Section	Township	Range	Meridian	Remarks
SW	6	44	14	4	1 gravel pit
SE	6	44	14	4	1 gravel pit
NE	6	39	15	4	1 gravel pit
NE	22	37	17	4	1 gravel pit
SE	17	37	18	4	Undeveloped
NE	9	39	21	4	1 gravel pit
SE	16	39	21	4	1 gravel pit
SW	23	41	22	4	1 gravel pit
NE	34	38	26	4	1 gravel pit
NW	35	28	26	4	1 gravel pit
SW	30	45	26	4	Undeveloped
SE	16	41	27	4	1 gravel pit
SE	27	41	27	4	1 gravel pit
NE	27	41	27	4	1 gravel pit
NW	11	43	27	4	Undeveloped
NE	11	43	27	4	Undeveloped
SE	12	43	27	4	Undeveloped
NE	12	43	27	4	Undeveloped
NE	8	45	27	4	Undeveloped
SW	16	45	27	4	Undeveloped
SE	17	45	27	4	Undeveloped
SE	25	45	27	4	Undeveloped
NW	12	41	28	4	1 gravel pit

This gravel is poorly sorted, contains many lenses of sand, much weathered and weak material, and has a wide size range with some boulders greater than a foot in diameter. Much of its material came from local bedrock and the Precambrian Shield. The contact with the adjoining till is commonly gradational and the division between gravel and other drift depends largely on the purpose for which the gravel is required.

Table V lists all known deposits of this gravel but many others undoubtedly are present. Most of the deposits contain 1,000 to 10,000 cubic yards, and altogether there should be about a million cubic yards of this gravel. The gravel as it occurs in most of the deposits is useless for other than road foundation purposes. With crushing of large boulders, screening and removal of weak stones its quality improves, but is never good.

Esker Gravel

The esker ridges are described in Chapter III. Most are composed of till, silt, and sand, but there are some short gravel esker ridges and many others contain isolated pockets of poorly sorted gravel containing much weak material.

The deposits of this gravel are listed in Table VI. Patches of good gravel commonly are scattered among the poorer gravel. The northern part of the esker ridge south of Bearhills Lake and some of the ridges between Gull and Cygnet Lakes and in the hummocky moraine contain very good gravel. The small number and

Table VI

Exposed Glacial Esker Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
SE	8	44	17	4	1 gravel pit
NE	32	37	26	4	1 gravel pit
NW	33	37	26	4	1 gravel pit
NW	33	39	26	4	1 gravel pit
NE	25	45	26	4	1 gravel pit
SE	36	45	26	4	2 gravel pits
NE	10	38	27	4	1 gravel pit
SW	23	38	27	4	1 gravel pit
NE	21	38	28	4	1 gravel pit
NW	27	39	28	4	2 gravel pits
NW	2	40	28	4	1 gravel pit
NE	8	40	28	4	1 gravel pit
SE	17	40	28	4	1 gravel pit

size of pits in these ridges, however, may indicate that the better gravel is present only locally. Most of the esker ridges are in the Red Deer Lowland, where other types of gravel are in good supply. Where other types of gravel are scarce, as in the Torlea Flats Lowland, esker ridges also are rare.

The esker ridges contain more than 2 million cubic yards and perhaps as much as 4 million cubic yards of gravel, most of which is readily obtainable. Good gravel composes only a small part of this amount. This gravel probably will be used at much the present rate for a considerable number of years.

Outwash Gravel

The deposits of outwash gravel are listed in Table VII. Small pockets of fine gravel also occur in the sand and silt outwash that is shown on the surficial geology map. The areas mapped as outwash gravel are not necessarily wholly covered with gravel, but they do contain at least scattered deposits.

The coarse outwash gravel was not transported far by water; it is poorly sorted, dirty, and contains much weak material. It is similar to much of the kame gravel. The fine gravel was generally carried farther; it is better sorted, cleaner, and contains little weak material but many sand lenses. The outwash gravel consists basically of preglacial gravel with additions, commonly large, of local bedrock and Shield material.

The outwash gravel is not used as much as its geographical and surface locations would suggest. It is used mostly where other gravel is not readily available such as south of Nevis and northwest of Innisfail. Its use undoubtedly will increase. The largest amount is in the Innisfail-Morningside outwash, particularly to the northwest of Innisfail. The quantity in the map-area is difficult to estimate as the thickness of many of the deposits is not known. It covers some 10 square miles, and there should be between 20 and 100 million cubic yards, depending on the general thickness. The amount is probably closer to the latter figure.

Table VII

Exposed Glacial Outwash Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
NW	21	38	21	4	1 gravel pit
NE	21	38	21	4	1 gravel pit
NW	22	38	21	4	1 gravel pit
NE	35	41	21	4	1 gravel pit
SE	17	38	22	4	1 gravel pit
NE	16	37	26	4	1 gravel pit
NW	2	40	27	4	1 gravel pit
NW	11	40	27	4	1 gravel pit
SE	30	35	28	4	1 gravel pit
SE	5	36	28	4	1 gravel pit
NW	5	36	28	4	1 gravel pit
SW	17	36	28	4	1 gravel pit
SE	20	36	28	4	1 gravel pit
SW	28	36	28	4	1 gravel pit
NW	28	36	28	4	Undeveloped

Alluvial and Deltaic Gravel

This is at present the chief source of gravel in the area, and it is second in quality only to the preglacial gravel. It is found where rivers emptied into glacial lakes, such as near Blackfalds and to the southwest of Ponoka, or in former stream valleys as bar and channel deposits, such as along the former diversion channels of the Red Deer River to the northeast of Ardley. The gravel was carried far enough by water to be well sorted: it is composed of resistant stones, mainly hard sandstone and quartzite, gathered from the preglacial gravel. This is most noticeable in the deposits to the south of Blackfalds and southwest of Ponoka. Stones from the Precambrian Shield are common in the deposit along Parlby Creek and in a few others.

Most of the stones are an inch to 5 inches in diameter, but boulders 10 inches in diameter are present. Sand lenses are common. The deposits are easily developed, as they are at the surface and many even rise above surrounding areas; many of the deposits listed in Table VIII are in the more thickly settled parts of the area. Large deposits other than those shown on the surficial geology map are not likely to be present. The total quantity of this gravel is more than 100 million cubic yards, all the deposits are developed, and about 2 million cubic yards have been used. It will continue to be the major source of gravel for some years. The Blackfalds deposit alone covers 6 square miles, including the gravel buried by dune sand, and although its thickness is difficult to determine, an average of only 6 feet would mean that between 30 and 40 million cubic yards are present. The gravel to the southwest of Ponoka covers more than half a square mile and contains some 2 million cubic yards. The former diversion channels of the Red Deer River 6 miles northeast of Ardley contain some 10 to 15 million cubic yards, and the deposits along Parlby Creek probably contain several million cubic yards. The amount of gravel in the large deposits alongside Driedmeat Lake is not known. The amount present in the thin deposit 6 miles northwest of Ponoka is small, and this gravel is of poor quality. The gravel to the south of Bashaw

Table VIII

Exposed Glacial Alluvial and Deltaic Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
SE	18	45	18	4	1 gravel pit
NE	36	43	19	4	2 gravel pits
SW	14	45	19	4	1 gravel pit
NW	14	45	19	4	1 gravel pit
SW	23	45	19	4	2 gravel pits
SW	13	36	20	4	2 gravel pits
SE	23	36	20	4	1 gravel pit
SE	25	44	20	4	1 gravel pit
NE	23	45	20	4	1 gravel pit
SE	26	45	20	4	2 gravel pits
NW	27	45	20	4	1 gravel pit
NE	28	45	20	4	1 gravel pit
NE	32	45	20	4	1 gravel pit
SE	33	45	20	4	1 gravel pit
NW	33	45	20	4	1 gravel pit
SW	28	41	21	4	1 gravel pit
SW	4	42	21	4	1 gravel pit
SE	4	42	21	4	1 gravel pit

Table VIII—*Conc.*

Quarter Section	Section	Township	Range	Meridian	Remarks
NW	33	43	21	4	1 gravel pit
NE	34	43	21	4	2 gravel pits
SE	3	44	21	4	1 gravel pit
NE	22	44	21	4	1 gravel pit
NE	35	44	21	4	1 gravel pit
NW	29	35	22	4	2 gravel pits
SW	28	38	22	4	1 gravel pit
NW	28	38	22	4	2 gravel pits
SE	17	38	23	4	Undeveloped
NW	32	38	23	4	Undeveloped
NW	35	38	23	4	1 gravel pit
NW	15	40	23	4	1 gravel pit
SW	28	40	23	4	1 gravel pit
SW	6	41	23	4	1 gravel pit
SE	6	41	23	4	1 gravel pit
SE	27	46	23	4	2 gravel pits
NE	27	46	23	4	1 gravel pit
NE	32	40	24	4	1 gravel pit
NW	36	40	24	4	1 gravel pit
SE	18	41	24	4	1 gravel pit
NE	18	41	24	4	1 gravel pit
SW	3	38	25	4	1 gravel pit
SE	15	41	25	4	1 gravel pit
NE	15	41	25	4	1 gravel pit
NE	2	43	25	4	Undeveloped
SE	26	42	26	4	1 gravel pit
SE	34	42	26	4	1 gravel pit
SW	35	42	26	4	1 gravel pit
NW	14	39	27	4	1 gravel pit
SE	21	39	27	4	1 gravel pit
NE	21	39	27	4	1 gravel pit
SE	22	39	27	4	1 gravel pit
SW	23	39	27	4	1 gravel pit
NW	23	39	27	4	1 gravel pit

covers about 2 square miles and contains more than 5 million cubic yards, but much of the gravel in the southern part of this deposit is fine. The deposit in Big Valley, to the southeast of Ewing Lake, contains some 5 million cubic yards of gravel. The thin delta gravel 4 miles northeast of Wetaskiwin is fine grained, and requires screening before use. The quantity of gravel there, though large, is not comparable with the amount in most of the other deposits mentioned above.

Residual Gravel

The residual gravel consists of several small deposits of poor gravel, a few of which are listed in Table IX. These were formed in places where stream and lake action removed fine material from till or other drift and left behind a thin concentration of stones. Most of this gravel is found in the network of ice-front meltwater channels near Marion and Shooting Lakes and along Battle River to the northeast of Red Willow. This is the poorest type of gravel, and is important only because it is found in districts that lack other gravel. Some of it is used, particularly near Shooting Lake, but reserves amount only to several tens of thousands of cubic yards.

Table IX

Residual Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
NW....................	25	40	16	4	1 gravel pit
SE....................	16	37	17	4	Undeveloped
NE....................	16	37	17	4	Undeveloped
NW....................	33	37	19	4	1 gravel pit
SW....................	3	38	19	4	Undeveloped
NW....................	3	38	19	4	Undeveloped
SW....................	10	38	19	4	Undeveloped

Post-Glacial Alluvial Gravel

Large amounts of post-glacial alluvial gravel are found along the Red Deer valley between Innisfail and Nevis, and scattered pockets of it also occur in other types of alluvium in the Battle valley above Ponoka and along the Blindman valley. The deposits are listed in Table X. Much gravel has been taken from the Red Deer valley, chiefly to the west of Penhold, northwest of Innisfail (sec. 6, tp. 36, rge. 28, W. 4th mer.), and near the city of Red Deer.

Table X

Post-Glacial Alluvial Gravel Deposits

Quarter Section	Section	Township	Range	Meridian	Remarks
NE....................	4	43	25	4	1 gravel pit
NE....................	23	43	25	4	Undeveloped
SE....................	34	43	25	4	1 gravel pit
NW....................	35	43	25	4	1 gravel pit
SE....................	1	44	25	4	1 gravel pit
SW....................	2	44	25	4	1 gravel pit
NW....................	20	36	28	4	1 gravel pit
SW....................	5	36	28	4	1 gravel pit
SE....................	5	37	28	4	1 gravel pit

Table XI

Some Deposits of Buried Gravel

Approximate Location					Source of Information	Approximate Depth of Gravel (in feet)		Remarks
Quarter Section	Section	Township	Range	Meridian		From	To	
SW......	23	43	15	4	Water-well Driller	40	45	
	8	44	17	4	Water-well Driller	8	22	
	17	44	17	4	Water-well Driller	30	31	At Rosalind
NW......	13	44	18	4	Water-well Log	20	80	
SE.......	4	45	18	4	Water-well Driller	35	90	At Kelsey
	14	45	19	4	Water-well Driller	35	50	
SE.......	30	45	19	4	Water-well Log	70	91	
SE.......	31	45	19	4	Water-well Log	70	90	
NW......	7	45	20	4	Water-well Driller	50	110	2 miles east of New Norway
NE......	15	45	20	4	Water-well Driller	20	35	At Viewpoint
SE.......	25	45	20	4	Water-well Log	90	110	
NW......	11	45	21	4	Water-well Driller	87	102	At New Norway
NW......	12	45	21	4	Water-well Driller	60	90	
NE......	15	45	21	4	Water-well Log	30	80	
SE.......	22	45	21	4	Water-well Log	60	90	
NW......	27	45	21	4	Water-well Driller	60	90	
SE.......	34	45	21	4	Water-well Driller	60	80	At Duhamel
	15	46	21	4	Water-well Driller	40	80	Extends over general area
NE......	16	46	21	4	Water-well Driller	60	80	
NE......	15	44	22	4	Water-well Log	80	100	
NW......	22	44	22	4	Water-well Log	80	100	
NW......	25	44	22	4	Water-well Log	80	100	
SE.......	35	44	22	4	Water-well Log	80	100	
SW......	2	45	22	4	Water-well Log	80	100	
	6	45	22	4	Water-well Driller	50	60	Extends over general area
	11	45	22	4	Water-well Driller	80	100	Extends over general area
SW......	16	45	22	4	Water-well Driller	70	110	
SW......	17	45	22	4	Water-well Driller	70	70	Thin gravel bed
NW......	22	45	22	4	Water-well Driller	60	100	Extends over general area
NW......	36	45	22	4	Water-well Driller	60	80	Extends over general area
NW......	3	46	22	4	Water-well Driller	45	75	Extends over general area
	11	46	22	4	Water-well Driller	30	70	
	19	44	23	4	Water-well Driller	6	26	Extends over general area
	19	44	23	4	Water-well Driller	90	110	Extends over general area
NW......	12	45	24	4	Water-well Driller	5	25	
	31	42	25	4	Water-well Driller	83	95	Extends over general area
	4	43	25	4	Water-well Driller	85	110	Also higher gravel beds
NE......	9	43	25	4	Water-well Log	80	100	
	16	43	25	4	Water-well Driller	......	......	Several thin beds of gravel
SW......	20	43	25	4	Water-well Driller	80	95	Extends over general area

Table XII

Estimated Quantities of Gravel in Red Deer-Stettler Area

Type of Gravel	Estimated Quantity (cubic yards)	
	Minimum Estimate	Maximum Estimate
Preglacial	1,000,000,000	3,000,000,000
Glacial kame	500,000	1,500,000
Glacial esker	2,000,000	4,000,000
Glacial outwash	20,000,000	100,000,000
Glacial alluvial and deltaic	50,000,000	150,000,000
Residual	10,000	50,000
Post-glacial alluvial	1,000,000	10,000,000
Total	1,073,510,000	3,265,550,000

The alluvial gravel was formed by streams cutting through earlier material and concentrating the stones contained therein, and depositing them, along with small amounts of outside material, a short distance downstream. The gravel in the best deposits is generally coarse and for most purposes requires crushing. The river transportation removed some of the weak material so that much of the gravel is of good quality.

Miscellaneous Deposits

Sand

Sand is common in the area, and there is no difficulty in finding any amount required within a practicable distance. However, the quality or type of sand may not always be that desired. The bedrock, particularly the Paskapoo formation, contains much unconsolidated or weakly consolidated sand of good quality, though this is not being used. Sand is present in most of the gravel deposits, in most of the stream valleys, and in many of the former glacial-lake basins. The wind deposits in the west half of the area contain much sand, which is of high quality except where carbonaceous material from former sod lines is present. Only a small amount of sand is used, mostly for fill and building purposes.

Good sand is less common in the east than in the west half of the area. Glacial-lake deposits are the chief source of sand in the Torlea Flats Lowland.

Clay

There is little demand for clay in the area, although much is present. The properties of the clay deposits have not been studied. The deposits were laid down in glacial lakes, particularly in the southern part of glacial Lake Malmo (*see* Figure 15). The deposits are included with the fine lake deposits on the surficial geology map.

Boulders

The large boulders scattered over the ground and hummocky moraine have had a limited use in barn and house foundations, but such use now is rare. Locally, where gravel is scarce, such boulders are crushed and used for road gravel. There are large quantities of such boulders, but they rarely are concentrated enough to make their use economic.

Salts

Salts, mostly sodium carbonate or bicarbonate, are collected by water from the drift and carried into many of the sloughs. In exceptionally dry years, when the sloughs dry up, the salts are deposited over the floors of the sloughs to a maximum thickness of about an inch. They are most common in the east half of the area. They are not used, and apparently do not exist in sufficient quantity to be of economic interest.

Gold

Gold, along with several other heavy metals, is found in the alluvium of Red Deer River. At the time of writing (1953) some placer mining development is being done near Ardley. Rutherford (1937, pp. 81, 91-93) discussed the gold, suggested that it is associated with the 'Saskatchewan gravels and sands', and discussed other suggested origins. The writer believes that erosion of the upper beds of the Edmonton formation with resultant concentration of their gold content, prior to deposition of the Paskapoo beds, is a strong possibility. This was earlier suggested by Tyrrell (1915, pp. 78-81).

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APPENDIX

SECTIONS THROUGH THE SURFICIAL DEPOSITS[1]

Section 1. Bank of Red Deer River, near Labuma; SW.¼ sec. 19, tp. 38, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Silt and clay: varved, light to dark grey, rafted stones rare....................	5	5
Till (Maunsell): blue-grey, clayey; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal..	20	25
Sand and fine gravel: limonitic in places, mostly brown, (deposits only local)..	0.7	25.7
Till (Labuma): dark blue to black, clayey and silty, compact; contains scattered stones from the Cordillera, Precambrian Shield and local bedrock, including many fragments of coal; flat bottom and top, no sign of erosion of the surface, some indication of weathering of the surface............................	18	43.7
Gravel: minor sand beds particularly in the top 5 feet, mostly grey, locally limonitic; largely composed of quartzite, hard sandstone, limestone; no stones from the Precambrian Shield..................................	20	63.7
Bedrock (Paskapoo formation): dark grey shale, brown sandstone; continues below river level..	30	93.7

[1] All sections read from the highest beds downward. The various materials have been described more fully in Chapter III.

Section 2. Bank of Blindman River south of Burbank; NE.¼ sec. 13, tp. 39, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Sand: light grey; originally deposited in glacial Lake Red Deer, but upper layers have been redeposited by wind..	30	30
Gravel: minor sand beds particularly towards the top, mostly grey, locally limonitic; largely composed of quartzite, hard sandstone, limestone; no stones from the Precambrian Shield; the stones are well rounded and range up to 10 inches in diameter..	25	55
Bedrock (Paskapoo formation): dark grey shale, siltstone, brown sandstone, minor coal, continues below river level................................	25	80

Section 3. North bank of Red Deer River west of Heatburg; NW.¼ sec. 32, tp. 38, rge. 23, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): brown, clayey; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal...	5–15	5–15
Till (Maunsell?): light to dark blue, compact, clayey; contains scattered stones from the Cordillera, Precambrian Shield and local bedrock, including many fragments of coal; rolling surface....	10–20	25
Gravel, minor sand lenses: mostly coarse with stones up to 8 inches in diameter; stones from Precambrian Shield present; even top....	20	45
Bedrock (Edmonton formation): light grey sandstone and shale, coal seam at top, continues below river level....	60	105

Section 4. North bank of Red Deer River south of Burbank; W.½ sec. 7, tp. 39, rge. 26, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Silt and clay: varved, light to dark grey, rafted stones rare....	10	10
Till (Buffalo Lake): buff, clayey; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal..	25	35
Till (Labuma?): black, clayey, compact; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal....	20	55
Gravel and sand: mostly grey; largely composed of pieces of quartzite, hard sandstone, limestone, local bedrock, no stones from the Precambrian Shield	25	80
Bedrock (Paskapoo formation): sandstone, siltstone, clay; continues below river level....	30	110

Section 5. Strip coal mine on south bank of Red Deer River northeast of Ardley; NW.$\frac{1}{4}$ sec. 35, tp. 38, rge. 23, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): yellowish brown, silty; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock	2	2
Gravel: minor sand lenses, stones up to 4 inches in diameter, well sorted; contains stones from the Precambrian Shield	10	12
Till (Maunsell?): blue-black, very hard, rubbery, compact; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock	20	32
Coal: with shale partings	15	47
Bedrock (Edmonton formation): continues to below river level	?	

Section 6. Gully south of Blackfalds Lake, near margin of former Red Deer valley; SW.$\frac{1}{4}$ sec. 20, tp. 39, rge. 26, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): buff to yellowish brown, clayey; contains scattered stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal	20	20
Till (Labuma?): dark blue to black, clayey, compact, hard; contains stones from the Cordillera, Precambrian Shield, and local bedrock, including many fragments of coal; sharp upper contact	12	32
Gravel and sand: commonly in lenses, light brown; contains both angular and rounded fragments of siltstone, concretions, and sandstone and concretionary lime layers; no stones from the Precambrian Shield; sharp upper contact	3	35
Sand: fine, minor gravel lenses; light brown, no stones from the Precambrian Shield; contains scattered fragments of gastropod shells; continues to bottom of gully	?	

Section 7. General section in road-cut, west of Delburne at northern end of valley that contains Goosequill Lake; NE.¼ sec. 20, tp. 37, rge. 24, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): brown; silty; contains rock fragments from Precambrian Shield........	6	6
Till: lenses of sand, clay, and silt; the till is dark brown to blue, silty; the sand is rusty brown, the clay and silt are buff; the clay, silt, and sand contain gastropod shells........	6	12
Till: dark grey, clayey, compact; contains rock fragments from the Precambrian Shield; continues below road level........	2	14

Section 8. Section in road-cut through upper part of fill in valley that contains Goosequill Lake; southeast of Lousana; NW.¼ sec. 29, tp. 35, rge. 22, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): brown, silty and clayey........	12	12
Gravel: minor sand lenses; stones up to 6 inches in diameter; contains stones from the Cordillera, Precambrian Shield and local bedrock; stones well rounded, gravel clean, well bedded and crossbedded, dipping to southwest; bedding truncated by overlying till, gravel continues below road level.....	15+	27+

Section 9. Road-cut on bluff in southern part of the city of Red Deer; same sequence can be seen on banks of Waskasoo Creek a few hundred yards to the east; SE.¼ sec. 17, tp. 38, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Silt: bedded lake silt, light grey, rafted stones rare; elsewhere overlain by varved silt and clay, or sand	5	5
Till (Buffalo Lake): grey to brown, clayey; contains stones from the Precambrian Shield; uneven top	5	10
Till (Labuma): dark blue to black, clayey, compact, hard; uneven top	6	16
Sand: light brown, a few scattered stones; elsewhere this sand contains gastropod shells; even top	4	20
Gravel: grey; stones up to 6 inches in diameter, mostly quartzite, hard sandstone, and limestone, no stones from the Precambrian Shield, gravel continues below bottom of the cut	8	28

Section 10. Gravel pit in city of Red Deer, west of Canadian Pacific Railway tracks; SE.¼ sec. 17, tp. 38, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Sand: grey, final deposit in glacial Lake Red Deer	5	5
Silt: minor clay; locally varved, light to dark grey, rafted stones rare; deposit in glacial Lake Red Deer	15	20
Till (Buffalo Lake): brown, clayey or silty; contains scattered stones from the Precambrian Shield	10	30
Till (Labuma?): black, clayey, compact, hard, massive; contains scattered stones from the Precambrian Shield	7	37
Gravel: minor sand; grey; stones up to 8 inches in diameter, mostly quartzite, hard sandstone, limestone, and local bedrock fragments, no stones present from the Precambrian Shield; continues to base of face	10	47

Section 11. Strip coal mine on north bank of Battle River, southwest of Forestburg; SE.$\frac{1}{4}$ sec. 2, tp. 41, rge. 16, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till: (modern) brown, clayey or silty; contains stones from Precambrian Shield; even base	7	7
Sand: fine to coarse, grey, much contorted and deformed, commonly cut and enveloped by underlying till	5	12
Till: dark blue to black, compact, clayey; contains stones from the Precambrian Shield; much contorted and deformed, probably by subsequent glaciers, and pressed upward into and mixed with overlying sand	6	18
Bedrock (Edmonton formation): shale and sandstone; even top	5	23
Bedrock (Edmonton formation): coal, continues to bottom of face	7	30

Section 12. General section taken from water-well information, west of New Norway; vicinity of NW.$\frac{1}{4}$ sec. 22, tp. 38, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till (Buffalo Lake): clayey or silty, brown; contains Precambrian stones	35	35
Sand: minor gravel	5	40
Till: blue	20	60
Gravel and sand: varying thickness	30	90
Bedrock (Edmonton formation): shale and sandstone; continues below bottom of wells		

Section 13. General section taken from water-well information near New Norway; vicinity of NW.¼ sec. 11, tp. 38, rge. 27, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Sand and silt: lake deposit	15	15
Till: brown	15	30
Sand: minor gravel	10	40
Till: blue	30	70
Gravel: minor sand	30	100
Bedrock (Edmonton formation): shale and sandstone; continues below bottom of wells		

Section 14. General section taken from water-well information near Duhamel; vicinity of NE.¼ sec. 27, tp. 45, rge. 21, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Sand and silt: lake deposit	5	5
Till: brown	15	20
Till: blue or black	40	60
Gravel: minor sand	30	90
Bedrock (Edmonton formation): shale and sandstone, continues below bottom of wells		

Section 15. General section taken from water-well information southeast of New Norway; vicinity of S.½ sec. 4, tp. 45, rge. 20, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Till: brown; scattered stones, including many from Precambrian Shield	15	15
Till: blue	75	90
Sand and gravel	5	95
Bedrock (Edmonton formation); shale and sandstone; continues below bottom of wells		

Section 16. Cut along Weed Creek, west of Calmar; NW.¼ sec. 26, tp. 49, rge. 28, W. 4th mer.

Deposits	Thickness (feet)	Depth (feet)
Silt and clay: grey, varved, grading into pure clay towards top; elsewhere modern till overlies this silt and clay	3	3
Till (Maunsell?): blue; pronounced columnar structure; contains Precambrian Shield stones	8	11
Sand: grey to light brown; many fragments of coal	5	16
Till (Labuma): black, compact, hard, massive; contains Precambrian Shield stones; largely covered with slump; continues below bottom of cut	10	26

Stalker 7-3-1952

Plate I. *A. New valley of Red Deer River through high land east of Red Deer. The valley is more than 600 feet deep. Looking north from sec. 20, tp. 38, rge. 26, W. 4th mer.*

Plate I. *B. Morainal hills in Buffalo Lake hummocky moraine 4 miles west of Big Valley; moraine plateau in background. Looking north from sec. 30, tp. 35, rge. 20, W. 4th mer.*

Stalker 1-2-1952

RCAF A7652-24

Plate II. New valley of Red Deer River through high land east of Red Deer. The valley is about 600 feet deep, and thin ground moraine covers the adjoining areas. About sec. 32, tp. 38, rge. 26, W. 4th mer.

RCAF A7651-120

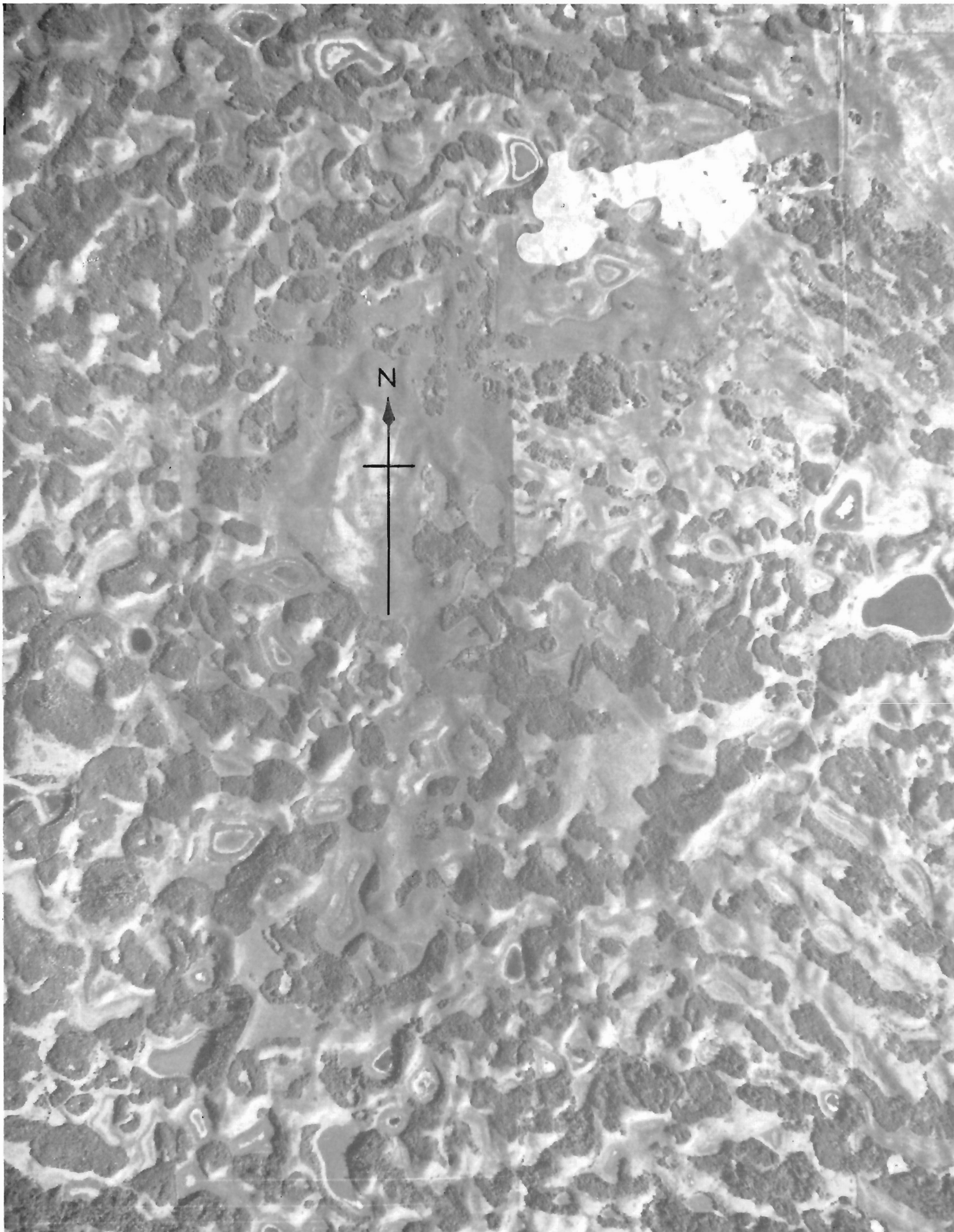
Plate III. *Incised meanders of Red Deer River a mile south of Burbank. The valley, about 150 feet deep, is cutting through coarse lake deposits, old tills and preglacial gravels into the bedrock. About sec. 12, tp. 39, rge. 27, W. 4th mer.*

RCAF A7648-15

Plate IV. *Ice-flow markings 2 miles northwest of Blackfalds. Outwash and other drift overriden by glacier advance and strung out into long ridges 15 to 40 feet high. About sec. 33, tp. 39, rge. 27, W. 4th mer.*

RCAF A7637-88

Plate V. *Large moraine plateau, bordered on northeastern edge by rim ridge rising 15 feet above plateau surface. Plateau surface is mostly clay. The strongly developed hummocky moraine lying to the east contains hills up to 70 feet high. About sec. 29, tp. 35, rge. 20, W. 4th mer.*

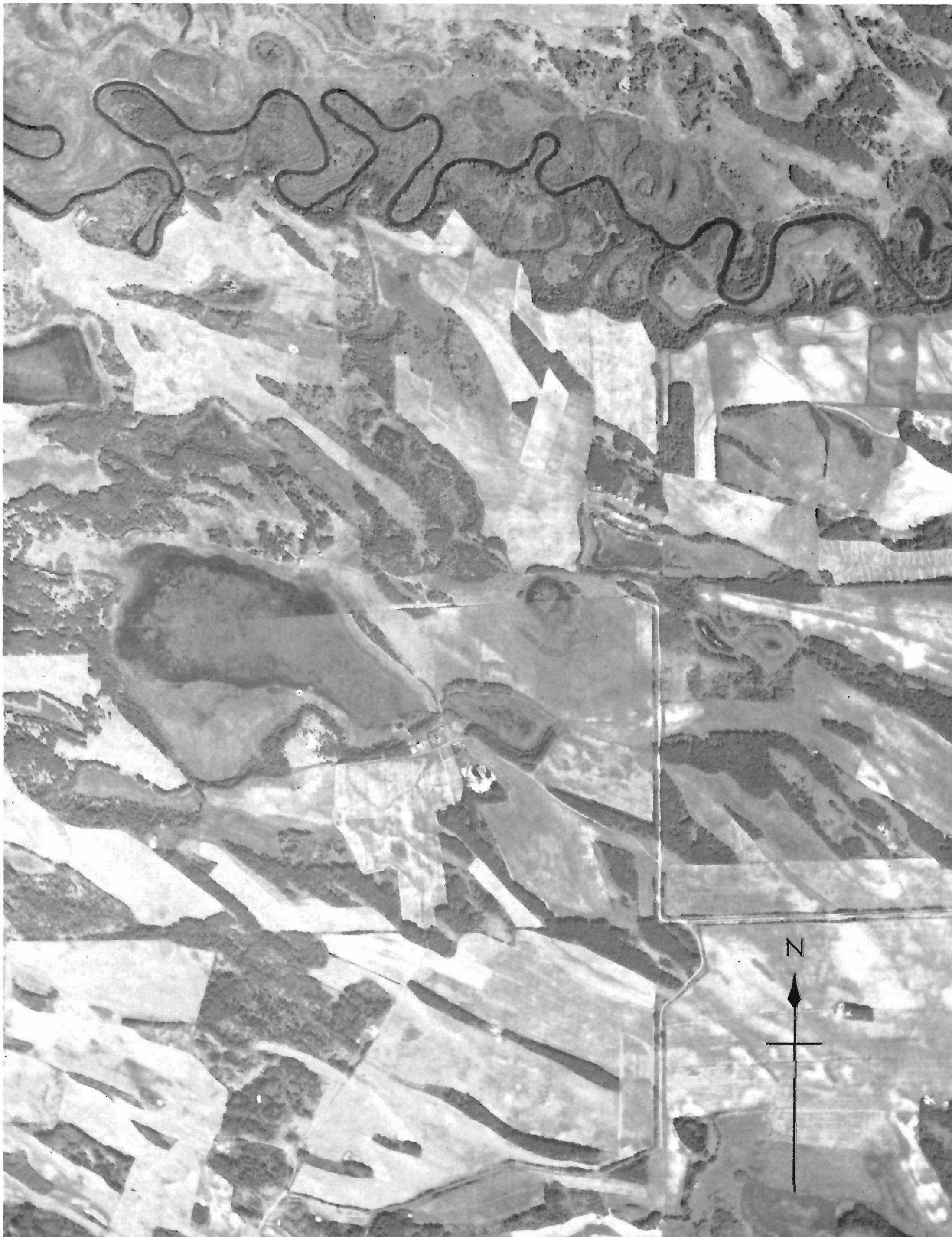


RCAF A9100-100

Plate VI. *Strongly developed hummocky moraine to the west of Foxall Lake. Hills are between 20 and 60 feet high and bush is confined largely to the northern sides of the hills. About sec. 30, tp. 37, rge. 21, W. 4th mer.*

RCAF A9099-13

Plate VII. *Lakes in buried valley about 5 miles southeast of Pine Lake. Movement of water between lakes is largely underground, and subdued hummocky moraine borders both sides of the valley. About sec. 36, tp. 35, rge. 24, W. 4th mer.*



RCAF A11694-85

Plate VIII. *Strongly developed sand dunes 5 miles west of Samson Lake. The dunes trend approximately northwest and bush is confined largely to their northeast sides. The Battle River meanders through the dunes in a shallow valley. About sec. 26, tp. 43, rge. 24, W. 4th mer.*

RCAF A11695-85

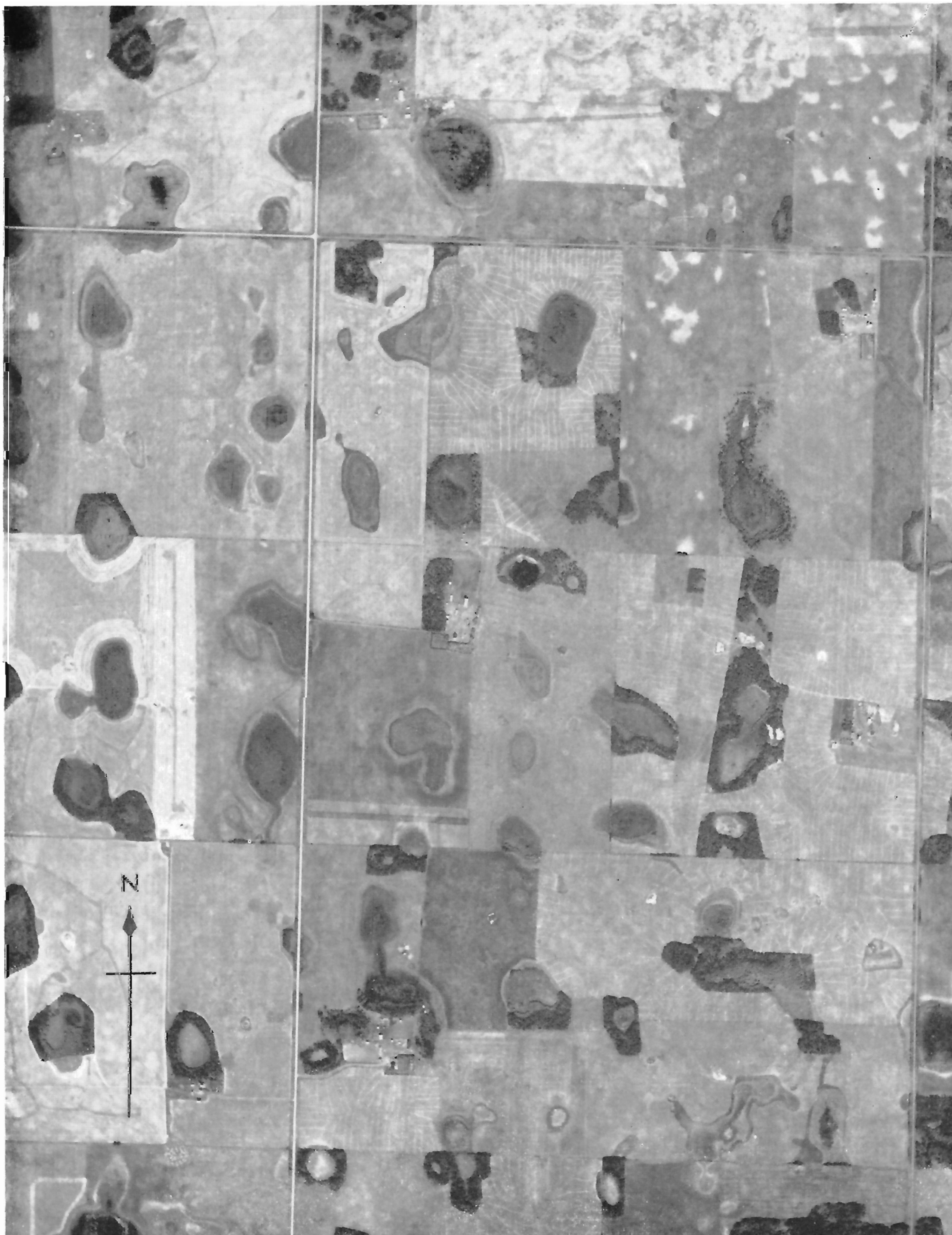
Plate IX. *Battle River crossing fine lake deposits of glacial Lake Malmo, 3 miles west of Malmo. Surface undulating to rolling. About sec. 21, tp. 44, rge. 23, W. 4th mer.*

RCAF A11694-232

Plate X. *Ice-frontal valley on Battle River 5 miles to the east of Edberg. The valley there is about 200 feet deep. The adjoining areas are poorly drained right to the valley edge. Bush is confined to the north-facing valley wall. About sec. 11, tp. 44, rge. 19, W. 4th mer.*

RCAF A11693-70

Plate XI. *Typical gullying near Battle Valley in thin drift areas of Torlea flats, 7 miles to the west of Heisler. The valley there is about 150 feet deep. About sec. 4, tp. 43, rge. 17, W. 4th mer.*



RCAF A11694-215

Plate XII. *Poorly drained ground moraine in Torlea flats, 6 miles to the south of Daysland. Gently rolling country. About sec. 10, tp. 44, rge. 16, W. 4th mer.*

RCAF A7647-91

Plate XIII. *An area of thinly covered or exposed bedrock in Torlea flats, 7 miles southwest of Halkirk. Dry, gentle rolling country with sparse vegetation. About sec. 21, tp. 37, rge. 16, W. 4th mer.*

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