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GLACIAL GEOLOGY
ALLIANCE - BROWNFIELD DISTRICT
ALBERTA

by
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

GLACIAL GEOLOGY
ALLIANCE-BROWNFIELD DISTRICT, ALBERTA

CHAPTER I

INTRODUCTION

General Statement

This report presents the preliminary results of mapping surficial deposits of the Alliance-Brownfield district of eastern Alberta. The distribution of glacial deposits in the Alliance-Brownfield district is shown on two maps, (1) 57-2A, Alliance district and (2) 57-2B, Brownfield district.

The eastern part of the Alliance-Brownfield district is made up of hummocky dead-ice moraine and the western part is a relatively flat till plain, the Torlea flats (Warren, 1937). Till covers most of the surface of the area, and other glacial and nonglacial deposits comprise only a small fraction of the total. The bedrock of the area is composed of Upper Cretaceous unconsolidated bentonitic shales and sandstones which have a gentle dip to the southwest.

Examination of the glacial land forms in the Alliance-Brownfield district suggests that they were deposited from stagnant ice. Consequently, the origin of glacial deposits and the glacial history is discussed in terms of large-scale downwasting and stagnation of the last glacier which covered the district.

Results of a shallow drilling program and a description of gravel deposits found in this district are given at the end of this report.

Location of District

The district mapped is located in east-central Alberta between $111^{\circ}00'$ and $112^{\circ}00'$ longitude and between $52^{\circ}15'$ and $52^{\circ}30'$ latitude (fig. 1). The total area comprises about 714 square miles. The district lies west of the Fourth Meridian and this interpretation is intended for all locations in the report unless otherwise specified.

Previous Work

Reconnaissance studies on the glacial geology of east-central Alberta have been made by Warren (1937, 1954), Rutherford (1941), Bretz (1943), and Bayrock (1955). The morainic belt which is found in the eastern portion of the Alliance-Brownfield district was first mapped and named the Viking moraine by Warren (1937). In the same report Warren named the area of flat ground moraine which lies to the west of the moraine, the Torlea flats.

More detailed reports on the glacial geology of adjacent districts have been made by Gravenor and Bayrock (1955), Gravenor (1956) and Gravenor and Ellwood (1957).

The soils of the region have been mapped by Wyatt, Newton, Bowser and Odynsky (1938), on a scale of 1 inch to 3 miles. J. A. Allan wrote an appendix to this report describing in general terms the bedrock

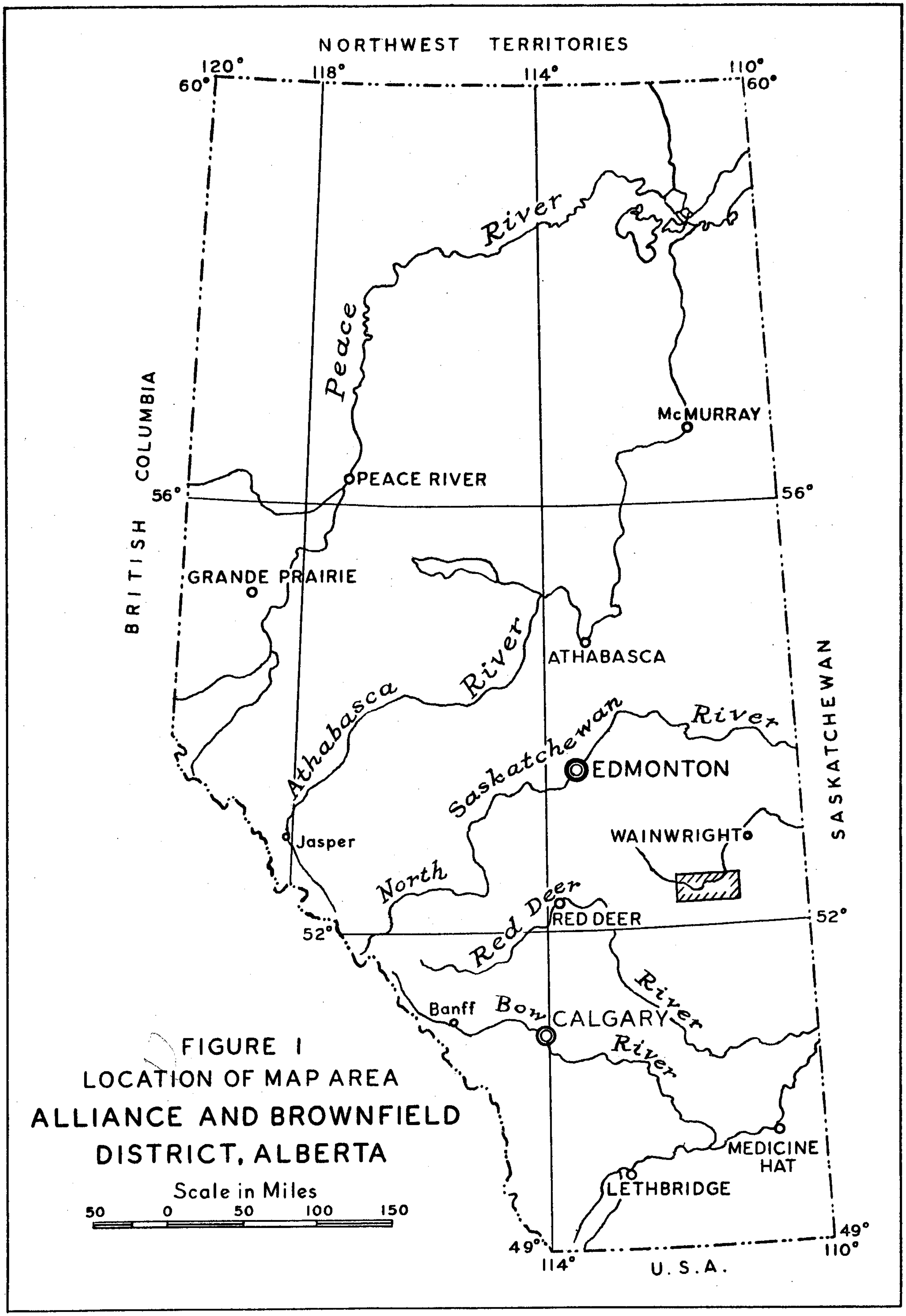

FIGURE I
LOCATION OF MAP AREA
ALLIANCE AND BROWNFIELD
DISTRICT, ALBERTA

geology, water supply and origin of surficial materials.

Field Work

The mapping was carried out during the summer of 1955 with the aid of aerial photographs from the Alberta Department of Lands and Forests. Field information was collected by shallow digging, hand-auger boring, and the examination of road cuts and river sections. Additional data was obtained by drilling with a 60-foot auger power drill.

Acknowledgements

The writer is indebted to R. F. Black, University of Wisconsin, who made many valuable suggestions on the deglaciation of the district.

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CHAPTER II

PHYSIOGRAPHY

General Statement

The west portion of the area is made up of relatively flat ground moraine which is occasionally interrupted by a kame or crevasse filling. To the east the topography of the ground moraine gradually becomes more irregular and finally is quite hummocky in the east half of the Brownfield sheet. For the purpose of this report the area is subdivided into three units, (1) flat till plain, (2) undulating ground moraine, and (3) hummocky dead-ice moraine. The district is crossed approximately from west to east by the Gwynne outlet (Gravenor and Bayrock, 1956), which at one time overflowed its banks and eroded parts of the adjacent upland. The hummocky dead-ice moraine has been modified considerably by the action of glacial meltwater which left a series of interconnected, debris-filled channels in the east part of the district.

Flat Till Plain

Flat ground moraine extends from the west boundary of the Alliance sheet to about Range 11. It is characterized by an even surface and is dotted with broad shallow kettles. Except for the dissection of the plain by the Gwynne outlet, generally the ground moraine increases in thickness in the Alliance district from the southwest to the northeast.

In the southwest corner of the Alliance map-area the till averages about 20 feet in thickness. In the northwest part of the same map-area the till thickens and in Tp. 40, R. 12 it is found to be 50 feet.

Undulating Ground Moraine

Moving from west to east the boundaries of the flat till plain, the undulating ground moraine, and the hummocky dead-ice moraine are generally gradational in character. Consequently, the boundary of the hummocky dead-ice moraine as shown on the Brownfield sheet is approximate. The relief on the undulating ground moraine ranges from 20 to 40 feet. Small and relatively deep kettles are very common. Most of the kettles are water-filled and the water level fluctuates in response to short climatic changes.

Till-filled meltwater channels - - stream-trenches - - are numerous in the northwest part of the Brownfield sheet and the northeast part of the Alliance sheet. In some places where the stream-trenches intersect or broaden, the topography becomes quite irregular and assumes a hummocky dead-ice morainal character.

The Battle River flows in a wide, deep valley, the Gwynne outlet, which originated as a glacial meltwater channel. This channel cuts through the undulating ground moraine in a northeasterly direction. The topography is much the same on either side of the channel with the exception that stream-trenches are more closely spaced on the north side.

Hummocky Dead-Ice Moraine

Hummocky dead-ice moraine which exists in the east portion of the Brownfield sheet is a part of the Viking moraine of Warren (1937), Rutherford (1941), and Bretz (1943), who interpreted it as a terminal or a lateral moraine. In Europe, moraine of similar appearance has been called dead-ice moraine [Toteismoräne, Woldstedt (1954)]. In the Beiseker area of Alberta Stalker (1956) called this type of moraine, knob and kettle moraine. In the Moose Mountain area of Saskatchewan, Christiansen (1956) used the term dead-ice moraine. Hoppe (1952) uses the term hummocky moraine terrain for such features. In this report the term hummocky dead-ice moraine is used.

The main features of hummocky dead-ice moraine are, (1) knobs and kettles, (2) ridges, (3) moraine plateaus, and (4) stream-trenches. In this area knobs and kettles are the most common of these features, stream-trenches are of secondary importance, and moraine plateaus and ridges are rare. Accordingly, the dead-ice moraine of the Brownfield district is called hummocky dead-ice moraine.

The relief on the hummocky dead-ice moraine ranges from 40 to 80 feet. In the east portion of the Brownfield sheet the moraine border is well defined. To the south and west the moraine border is gradational into the undulating ground moraine area. This gradational border is shown on the map of the Brownfield district by an indefinite geological boundary.

The hummocky dead-ice moraine has more undrained depressions than the undulating ground moraine, and a great number of the depressions are filled with water throughout the year. The morainal topography is so rough in places that the area is inaccessible by road and cannot be used for farming. In contrast, the undulating ground moraine is generally farmed.

On the basis of experience in adjacent districts stream-trenches probably occur throughout much of the hummocky dead-ice moraine, but due to the fact that they have been infilled with hummocky glacial debris their presence is difficult to detect.

Spillway

Although most of the glacial meltwater probably flowed away through stream-trenches, there is one major spillway in the moraine which is floored with well-sorted gravel. It is quite possible that this spillway formed at a later date than the stream-trenches as there is no till-capping over the gravel.

The Gwynne Outlet

The Gwynne outlet as defined by Gravenor and Ellwood (1957) is the outlet used to drain glacial Lake Edmonton. The outlet is now occupied, over much of its course, by the Battle River. The history of the Gwynne outlet is very complex and as yet its complete history has not been determined.

The Gwynne outlet enters the Alliance-Brownfield district in the northwest corner of the Alliance sheet and continues in an east-southeast direction. In the southeast corner of Tp. 39, R. 12 the outlet makes a sudden change in direction to the north-northeast. In the Brownfield district the outlet continues along a general northeasterly route and cuts through a topographic high.

About 40 miles northwest of the northwest corner of the Alliance sheet the Gwynne outlet splits into two channels. This split was created by an excess of water in the outlet which overflowed the channel and spilled through an outlet which is now occupied by Paintearth Creek. This additional overflow channel, the Paintearth Creek outlet, joins the main Gwynne outlet at Alliance, thus forming a loop in the Gwynne outlet.

A similar situation occurred at Alliance where the combined waters of the Gwynne and Paintearth Creek outlets overflowed the valley walls and flooded the surrounding countryside. This flooding was limited mainly to Tp. 39, R. 13 and Tp. 39, R. 12. The flood waters eroded away most of the surface till cover, and in some places cut deeply into the underlying bedrock.

The duration of the life of the Gwynne and Paintearth Creek outlets is difficult to evaluate. The fact that the Gwynne outlet abruptly changes direction in Tp. 39, R. 12 and then cuts through a topographic high in the Brownfield district, suggests that it originated as a melt-water channel cutting through stagnant ice, i.e. a stream-trench.

CHAPTER III

DESCRIPTION OF MATERIALS

Bedrock

The bedrock of the area is Upper Cretaceous in age. A representative section is given below, showing the strata recorded in Canadian Gulf N.J. Ellis No. 4 well, Lsd. 4, Sec. 10, Tp. 38, R. 20 in the Stettler area [after Lockwood & Erdman (1951)].

Formation	Thickness	Description
Recent and Pleistocene	70'	Glacial and Recent deposits.
Edmonton formation	646'	Shales, sands, silts, clay and coal, with silty shale predominating. Thin irregular siderite bands, scattered bentonite bands, tuff and thin calcite bands are also present.
Bearpaw formation	269'	Chiefly dark-grey to grey black, fissile, micro-micaceous shale, in part glauconitic and carbonaceous. A sandstone member, the Bulwark sandstone, is present in the area.
Belly River formation	875'	Predominantly shales and sandstones. Limestone, coal, siderite, and bentonite bands are common throughout the formation.

The formations in the map-area have a slight dip to the southwest. The Belly River formation outcrops along the Battle River in the Brownfield district. The Bearpaw formation underlies Pleistocene deposits over most of the district. The Edmonton formation attains a maximum thickness in the southwest corner of the map-area where 100 feet of the formation are present. All of the formations are unconsolidated and bentonitic.

Till

There is apparently little variation in the composition of the till over most of the map-area. The till, aside from the boulder and pebble fraction, is made up of about equal parts of sand, silt and clay. An average of mechanical analyses of 42 till samples taken throughout central Alberta shows the following results: sand 40.1%, silt 31.9%, and clay 28%. Mechanical analyses of three till samples from the Alliance-Brownfield district are given in appendix C. The predominant clay mineral in the clay fraction of the till (Bayrock, 1955) is montmorillonite which imparts to the till a "gumbo"-like appearance. The presence of this clay mineral makes the till relatively impervious and closed depressions on the surface generally contain water.

The till is oxidized to a depth of 20 feet (average of 28 drill holes). At the surface the till is brown, yellowish-brown, light-brown to dark-brown in color. Below the oxidized zone it may pass gradually or abruptly into a till of grey to dark-grey color. When samples of the grey till are exposed to air or oxygenated water for a period of time, they become brown in color and hence the grey till is believed to represent the unoxidized portion of the brown till. This process of oxidation can be noticed in fresh road cuts which show a distinct color difference between the oxidized and the unoxidized portions, but if left exposed the color difference disappears.

Field observation in areas underlain by till showed that the abundance of boulders at the surface is quite variable. It was thought that the relative abundance of surface boulders might give some information on glacial transport, and hence a brief study was undertaken to see if the boulder concentration had any significance. The results, which are given in figure 2, show that there is no obvious pattern to areas of equal boulder concentration, but that there is indeed wide variability in the boulder content of till over short distances.

It is quite common to find lenses of sand and gravel within the till and from a limited number of observations these sand and gravel lenses are apparently more abundant in areas of hummocky dead-ice moraine, than in ground moraine. The composition of till in areas of hummocky dead-ice moraine is much the same as the adjacent ground moraine.

Crevasse Filling and Kame

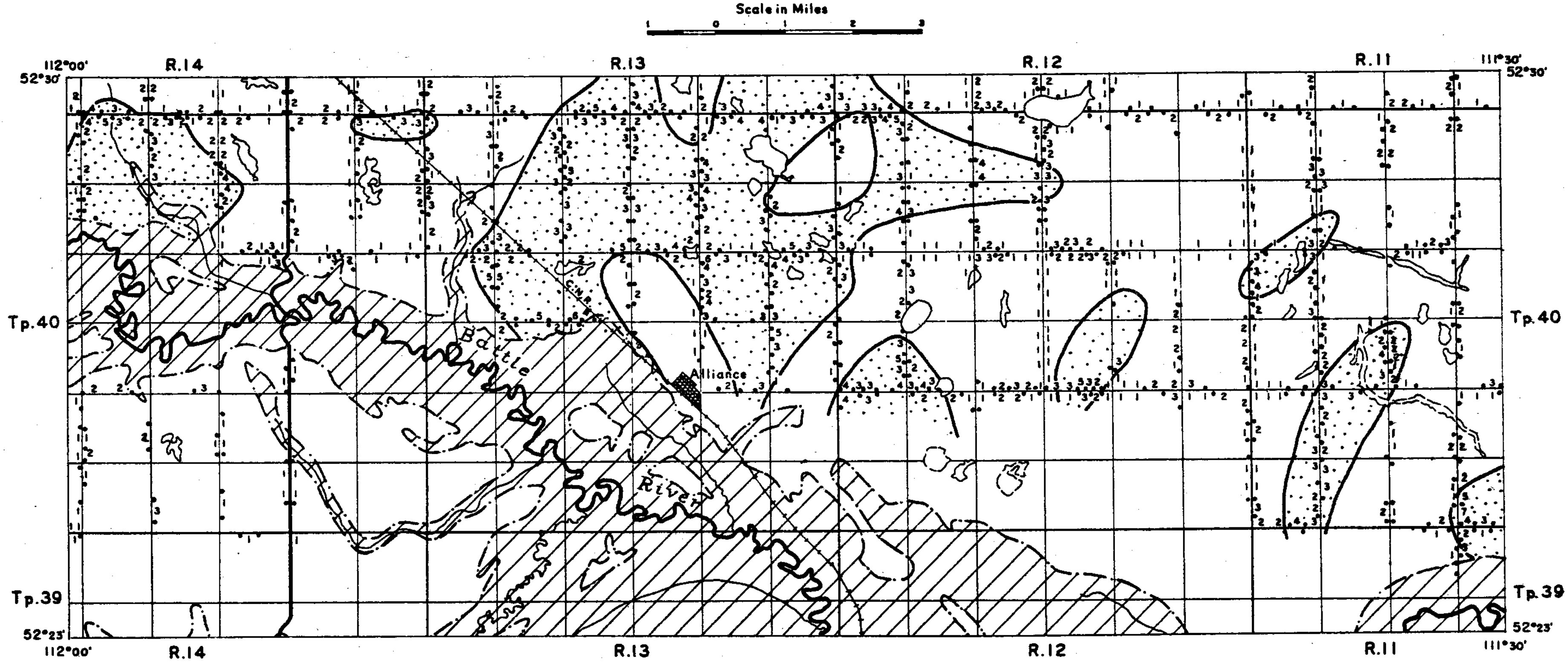
During the course of mapping, it became necessary to set limits of composition and morphology for kames and crevasse fillings. Holmes (1947) defines a kame as " .... a mound composed chiefly of

FIGURE 2-RELATIVE ABUNDANCE OF SURFACE BOULDERS ON TILL

ALBERTA

WEST OF FOURTH MERIDIAN

Scale in Miles



Cartography taken from Department of Lands and Forests, Alberta, Aerial Survey Sheet No. 73 D/3

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Published in 1957

LEGEND

Numbers indicate increase in abundance of boulders from few to many.............1 to 7

Boulders relatively low in concentration.............

Boulders relatively high in concentration.............

Erosion.............

gravel or sand, whose form has resulted from original deposition modified by any slumping incident to later melting of glacial ice against or upon which the deposit accumulated." Flint (1957) classifies a crevasse filling as a special type of kame "having the shape of a short ridge". Flint's definition has been modified slightly by Charlesworth (1957) who has set up size limits: length about 400 m. or less, and usually 3.5 to 4 m. high. Charlesworth prefers to use the term crevasse infilling to crevasse filling. All the above definitions stress the fact that kames and crevasse fillings are composed essentially of glacio-fluvial material and a crevasse filling is only a special type of a kame. Crevasse fillings made up essentially of till are reported by many authors [e.g. Hoppe (1952) and Kupsch (1956)].

The crevasse fillings in the map-area are reasonably short and fall within the size limits set up by Charlesworth (1957). They differ markedly in composition, however, as most of them are made up essentially of till with occasional pockets of sand and gravel. Kames, on the other hand, have a predominance of well-sorted material. Accordingly, linear ridges which are composed primarily of till are called crevasse fillings, and mounds or elliptical hills composed of more than 50 per cent washed material are called kames. In the field it is sometimes difficult if not impossible to determine the composition of some hillocks because of the lack of adequate cuts. The kames found in Tp. 40, R. 13 have some linearity and there are probably all gradations between kames and crevasse fillings. Although most of the kames in the map-area are composed of sand a few contain gravel and are discussed in Appendix A.

Esker

Only two very small eskers are present in the map-area, one in Secs. 12 and 13, Tp. 40, R. 13, and the other in Sec. 16, Tp. 40, R. 10. Both of these eskers are composed mainly of fine to medium grained glacial sand. Although elsewhere eskers are usually composed of gravel, sandy and even silty eskers are frequently found in central Alberta. The first of the two eskers mentioned above has a well developed onionskin structure.

Spillway Deposit

Spillway deposits are composed of stratified gravel and sand found in glacial meltwater channels. The life of a spillway is usually cyclic in nature, with alternating periods of active downcutting and aggradation. In any one cycle the initial stage is usually one of high meltwater discharge, and hence downcutting, followed by a lessening in the amount of meltwater and aggradation of the channel. During the final stages in the life of a spillway, short-term weather fluctuations probably had a strong effect on the amount of meltwater discharge and hence on the coarseness of the material deposited.

The spillway located in Secs. 11 and 12, Tp. 38, R. 12 is composed mainly of sand with minor amounts of gravel. Another spillway which is located in Tp. 40, Rs. 8 and 9, and Tp. 39, R. 8, is composed mainly of well sorted gravel overlain by a thin cap of sand and Recent bottomland deposits. This spillway was probably formed during the final stages of glaciation and the ice must have been melting quite rapidly to account for the active downcutting and subsequent gravel fill.

At the point where the Paintearth Creek and Gwynne outlets join in the Alliance district, the accumulated waters spilled over the banks of the main channel. The overflow waters removed a large portion of the surface till in Tp. 39, Rs. 12 and 13 and left a series of high-level bedrock channels, some of which are floored with a thin veneer of sand and gravel from 2 to 5 feet thick. A small spillway which has similar characteristics to the overflow area of the Gwynne outlet, is located in Tps. 38 and 39, R. 11. This spillway drained a small glacial lake which was located at the south end of the spillway.

Outwash Deposit

Glacial outwash deposits are distinguished from spillway deposits on the basis that spillway deposits are found in channels, whereas outwash deposits are unconfined. Three types of outwash deposits are present in the area: (1) those composed mainly of gravel, (2) those composed mainly of sand, and (3) those which are composed of sand and gravel, or sand, but are relatively thin, averaging from 2 to 5 feet in thickness. Outwash deposits largely composed of gravel are relatively rare, and form only a small part of the total outwash deposits present in the district. Descriptions of these deposits are found at the end of this report in appendix A. The gravel found in them is usually well sorted but often has associated sand lenses, a characteristic of river deposited material.

The sandy outwash is composed mainly of medium to fine grained sand which is similar in composition to the underlying bedrock. The surface of some of the sandy outwash deposits has been partially worked by wind as is shown by small dune development and these are mapped as aeolian sand overlying outwash sand.

Areas of thin sand and gravel outwash overlying till or bedrock are quite common in the district, especially in the area inundated by the overflow from the Gwynne outlet. Considerable variation in the size of material is encountered in this type of outwash deposit, and it is usually unsuitable for economic development.

Glacio-lacustrine Deposit

Glacio-lacustrine deposits are composed mainly of clay and silty clay. Local sand beds are found within the clay and probably represent old shorelines or deltaic deposits from incoming glacial meltwater. The lake in Tp. 38, R. 8 was produced by the damming of the valley east of the district after most of the ice had melted from the map-area. The lake in Tp. 38, R. 4 was a proglacial lake which has continued to receive sediment up to the present time. This lake was drained by a small spillway, tributary to the Gwynne outlet. Other lakes in the area are generally quite small and contain only a small volume of sediments. In many cases the glacio-lacustrine materials have a capping of Recent sediment and in such cases it is rather difficult to differentiate glacial from non-glacial deposits.

Recent Deposits

Aeolian Sand The surface portion of some outwash sands has been modified by wind action and small dunes have been produced. In most cases the sand was not driven far beyond the area of deposition of the outwash sand. At the present time there is apparently little danger of further migration of the sand due to removal of vegetation by farming practices, because the surface of the aeolian sand now contains an appreciable percentage of clay which acts as a binding medium. Longitudinal dunes in the district show a wind direction from about north 50 degrees west, which is the same as in the Sedgewick district [Gravenor and Ellwood (1957)].

Bottomland Deposit Recent bottomland deposits are found along drainage courses, around lake shores, and in depressions where ponds had formerly existed. Recent alluvial deposits are found along the floodplains of the Battle River, Paintearth Creek, and some sections and tributaries of Castor Creek. The deposits are composed of sand, silt, and clay with a high montmorillonite content. Very little organic matter is associated with the flood-plain deposits.

Recent lacustrine deposits are made up primarily of silt and clay, mixed with a large amount of partly decomposed organic matter. A high salt concentration is often encountered in some lake waters and their deposits, especially in the Brownfield district. No extensive peat developments were recognized in the district.

<u>Alluvial Fan</u> Alluvial fans of recent origin are closely associated with badland type erosion, especially in the southwest corner of the Alliance sheet. The alluvial fans are quite small except for one which occupies a depression in Tp. 38, R. 14. In most cases recent alluvial fans have been derived from the erosion of bedrock, and where the alluvial fan material is well bedded it can be easily confused with undisturbed bedrock.

<u>Colluvium, Slump and Landslide</u> Steep slopes are almost always covered with a thin veneer of colluvium, regardless of the nature of the underlying material. Usually the composition of the colluvium is heterogeneous and may appear similar to the sandy phases of the till in the district. The thickness of the colluvium veneer is variable, but is usually from 1 to 2 feet. As a result of the colluvial cover, bedrock outcrops are difficult to find along spillways and stream valleys.

Slumping is the major process of valley modification in the area underlain by the Bearpaw formation. In some places in the Alliance-Brownfield district the valley of the Battle River has been widened as much as one mile by slumping. The individual slump blocks contain relatively undisturbed material, but the overlapping of the blocks produces repetition of strata, e.g. quite often till is found underlying bedrock.

Landslide deposits are found in Sec. 24, Tp. 39, R. 12. Landslides may be quite common along the banks of the Battle River, but the scarcity of exposed sections makes it impossible to recognize them.

CHAPTER IV

GLACIAL AND RECENT HISTORY

Preglacial Topography

The reconstruction and interpretation of the preglacial topography is complicated by three factors, (1) the preglacial surface has been eroded and contorted by glacial action, (2) glacial and possibly interglacial drainage channels have modified the bedrock surface, and (3) little is known about the preglacial climate and hence it is difficult to set up hypothetical landforms.

In spite of the above difficulties a very general picture of the bedrock topography can be presented on the basis of field observations, borehole data, and topographic maps. In general the preglacial surface of the land was level. Two gently rising "topographic highs" are present in the area: the first is located near the southwest corner of the Alliance map-area and has gentle slopes, and the second is located in the Brownfield area. The latter "high" has a whale-back shape and is oriented on east-southeast direction. Both of these "topographic highs" have a relief of about 250 feet and have slopes on the order of 20 feet per mile. Two small mesas are found in the district; one, in the southeast corner of the Alliance map-area, is called Bell's Hill, and the other is found in the southeast corner of the Brownfield sheet. The latter, judging by its morphology, is made up of glaciallycontorted Upper Cretaceous sediments. Both of these bedrock mesas have a thin cover of till. No buried valleys or preglacial gravels were found in the area.

Glacial Advance

As yet no evidence of multiple glaciation has been found in the Alliance-Brownfield or adjacent districts. Nevertheless, since multiple glaciation is known to occur in other parts of Alberta, it is assumed that the district was covered more than once by continental glaciers. Judging by the fresh topography and shallow soil profiles, it is quite likely that the last glacier to cover the district was of Wisconsin age.

One radiocarbon date (Gravenor and Ellwood, 1956) made on a log found in till from the Smoky Lake district of central Alberta gave an age of 21,600 $\pm$ 900 years. If this log represents a tree, which was overrun by the last glacier and deposited shortly afterwards, the time of onset of glaciation in the Alliance-Brownfield district is probably of the same order of magnitude.

The maximum thickness of the ice attained in the map-area is very difficult to ascertain. It is known that the major trend of ice-movement in the district was from the north-northeast (Gravenor and Bayrock, 1955), and consequently the glacier was advancing upslope to the Rocky Mountains. The altitude of the Alliance-Brownfield district is about 2,500 feet above sea-level, and the maximum altitude of the junction of the Keewatin and Rocky Mountain glaciers is about 4,000 feet at a point about 250 miles west of the map-area. If there was about 1,000 feet of ice at the junction of the two glaciers and if another 1,000 feet is added for the slope of the surface of the glacier, there would be approximately 3,500 feet of ice in the Alliance-Brownfield district. The above figure of 3,500 feet is very approximate and was deduced from rather questionable assumptions but indicates the order of magnitude of the thickness of the ice.

Deglaciation

Most glacial features of the district were produced by stagnant ice, as already described in preceding chapters of this report. The stagnation of the ice was not limited to the map-area but probably encompassed a large part of central Alberta (Gravenor and Bayrock, 1956; Gravenor and Ellwood, 1957). Such extensive stagnation of the ice can be explained only by large scale climatic change or possibly even a climatic catastrophe. The evidence for a world-wide climatic catastrophe, which probably took place about 11,000 years B.P., has been summarized by Broecker (1957).

It is believed that the ice advanced into Alberta as a "cold-ice" glacier and during a warming period which may have taken place about 11,000 years ago, the ice warmed up rather abruptly. Applying this hypothesis to the origin of stream-trenches, it is believed that the position of the trenches was partly controlled by fractures which developed in the cold ice. The ice then started to warm up at the surface, and meltwaters which flowed along fractures cut through the lower cold ice and into the underlying bedrock. As the warming trend continued the glacier finally became warm to its base and started to flow. This flowage closed the meltwater channels and distributed till in the base of the channels.

An earlier publication (Gravenor and Bayrock, 1956) suggested that the stream-trenches were infilled by ice and debris slumping into the meltwater channels. It has been found, however, that some of the stream-trenches are well over a mile in width and in some cases the flow of ice into the trenches would appear to be a more satisfactory explanation of infilling than slump. A similar suggestion has been made by Woldstedt (1954) who believes that Rinnentäler (stream-trenches) were formed in ice channels open to the sky which were later infilled by a slight readvance of the ice.

In most cases the morphology of the till surface in the base of the stream-trenches is similar to the till surface outside the stream-trenches; for example, in areas of hummocky dead-ice moraine the stream-trenches have a cover of hummocky till, small moraine plateaus and till ridges. This similarity of surface cover is explained more satisfactorily by a minor readvance of the ice walls into the meltwater channels.

After most of the ice had melted the present day drainage system was established. In many cases rivers utilized the existing stream-trench and spillway valleys as drainage courses.

Recent Modifications

Recent erosion is very localized. In some places the Gwynne outlet has been undercut, to a minor degree, by the Battle River. Mass wasting is limited to steep slopes, and although slumping of the Battle River valley in the map-area is impressive in places, it is quite localized. Badland type of erosion is limited to a relatively small area in the south-west corner of the Alliance sheet. Colluvium covers most of the steep slopes in the area, but it does not modify or obscure the topography. Generally very little modification of the surface has taken place after glaciation of the district.

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APPENDIX A

GRAVEL DEPOSITS

All the gravel deposits located in the district are of glacial origin. Spillway type of gravels are reasonably well sorted, large in volume and thickness. Outwash gravels are medium well sorted, but of limited extent. They tend to be bouldery and sometimes their economic development requires considerable crushing. Kames are of secondary importance because of wide variations in mechanical composition over short distances. The reader is advised to use the following descriptions with the maps included in this report, in order to obtain the areal extent of the deposits. All descriptions have been given purely on field observations conducted during the field season of 1955. Descriptions of gravel deposits of no apparent economic use have been omitted.

ALLIANCE DISTRICT

Location	Extent of Gravel	Description of Deposit
Secs. 19, 20, 21, 28, 29, Tp. 40, R. 13	Limited extent, economically.	This area encompasses a large field of kames; the major ones are shown on the map. A number of these kames contain good-grade gravel pockets, several of which have been mined. Further development will need extensive test pitting. Two active gravel pits are present.
Lsd. 8, Sec. 10, Tp. 40, R. 13	Very limited extent.	The kame is quite small, and sandy, with only small

Location	Extent of Gravel	Description of Deposit
		pockets of gravel. The gravel pit at this location has been abandoned.
Lsd. 14, Sec. 3, Tp. 40, R. 13	Very limited extent.	Kame of same quality and size as the preceding one. Some gravel pockets have been exploited in the past.
Lsds. 3, 4, Sec. 5, Tp. 40, R. 13	Very limited extent.	Two small kames (as shown on the map) are very sandy but small economic gravel pockets should be found.
Sec. 3, Tp. 40, R. 13	Limited extent.	The esker (as shown on the map) is quite small. It is composed of fine to medium grained sand. No gravel. No economic value.
Lsd. 16, Sec. 8, Tp. 40, R. 13	Fairly extensive, at present just about mined out.	Spillway type of gravel, varying in thickness from 10 to 20 feet. Sorting variable, poor to good. At present the deposit is about exhausted.
Lsds. 12, 13, Sec. 9, Tp. 40, R. 13	Fairly extensive.	Eastern extension of the preceding deposit. Mostly thin to very thin. Poorly sorted. Not economic.
Sec. 5, Tp. 40, R. 13	Very limited extent.	Kame in centre of section, probably composed mostly of impure sand. Not economic.
Lsd. 1, Sec. 9, Tp. 40, R. 12	Very limited extent.	Kame composed of fine to medium grained sand. Not economic.
Lsds. 12, 15, Sec. 2, Tp. 40, R. 12	Very limited extent.	Kames composed predominantly of fine to medium grained sand. Not economic.
Lsds. 15, 16, Sec. 8, Tp. 40, R. 11	Areal coverage about 30 acres, average depth about 10 feet.	Spillway type of deposit. Probably predominantly poorly to well sorted gravel. Economic exploitation expected.

Location	Extent of Gravel	Description of Deposit
Lsds. 4, 5, Sec. 10, Tp. 40, R. 11	Areal extent about 50 acres. Depth from 10 to 20 feet.	Poorly to medium sorted spillway type of gravel. Sand lenses common. Abandoned gravel pit quite small. Good economic possibility, extensive test pitting required.
Lsds. 5, 11, 12, Sec. 10, Tp. 40, R. 11	Areal extent about 70 acres. Average depth about 10 feet.	Spillway type of gravel deposit, probably of same grade as two preceding ones. Good economic possibility, extensive test pitting required.
Lsd. 7, Sec. 22, Tp. 39, R. 11	Areal extent about 30 acres. Depth very shallow, averaging 2 to 3 feet.	Spillway type of gravel, very thin and poorly sorted. No economic value.
Lsds. 3, 4, 5, 6, Sec. 7, Tp. 39, R. 13, and Lsds. 8, 9, Sec. 12, Tp. 39, R. 14	Extensive, about 120 acres. Depth variable, average 7 feet.	Glacial outwash gravel, poorly sorted, sand lenses common. In places the gravel could be too bouldery for economic use, otherwise there exists a good possibility for economic exploitation of this deposit.
Lsd. 16, Sec. 11, Lsds. 11, 12, 13, 14, 15, Sec. 12, Lsds. 2, 3, 4, 5, Sec. 13, Lsds. 1, 2, 6, 7, 8, 10, 11, Sec. 14, Tp. 40, R. 13	Very extensive deposit covering about 250 acres. Average depth 10 feet.	Spillway type of gravel, showing good bedding, some ironstone and coal. Sorting good over short distances. Sand layers extensive in places. Three active gravel pits present. A large kame located in the southeast part of the deposit is composed predominantly of fine to medium well washed glacial sand.
Lsds. 11, 12, 13, Sec. 14, Lsds. 9, 10, 11, 16, Sec. 15, Tp. 40, R. 14	Very shallow deposit, averaging 2 feet in thickness, covering an area of about 150 acres.	This is the western extension of the previous deposit. The gravel is very shallow and very poorly sorted. Not economic as a whole, but some small pockets may be found of better sorting and greater depth.

Location	Extent of Gravel	Description of Deposit
Lsd. 4, Sec. 27, Lsd. 1, Sec. 28, Tp. 40, R. 14	Areal extent about 5 acres, depth about 5 feet.	Outwash gravel, very poorly sorted, quite shallow and impure. Many large boulders present. Not economical as a whole.
Lsds. 8, 9, 15, 16, Sec. 1, Tp. 40, R. 14	Limited economic extent.	This deposit is comprised of a large number of small kames which in places contain good quality gravel. Theoretically the steeper the slopes on the kames, the better gravel they should contain. Many sand and till lenses are to be expected. Economic development will require extensive test pitting.
Lsds. 1, 2, 9, 10, Sec. 12, Tp. 40, R. 14	Limited extent.	These kames are the northward extension of the kame field from section 1. They are generally smaller and probably quite sandy. Economic development not expected.
Lsds. 4, 5, 6, 7, Sec. 15, Lsd. 8, Sec. 16, Tp. 39, R. 13	Extensive deposit covering about 200 acres.	Outwash gravel producing a low relief ridge. Poorly sorted, in places very sandy. Economic possibilities will have to be ascertained by test pitting.
Lsd. 16, Sec. 15, Lsd. 1, Sec. 22, Tp. 39, R. 13	Fairly extensive deposit covering about 40 acres. Depth varying from 5 to 10 feet.	Glacial outwash gravel, poorly sorted. A small gravel pit shows many sand lenses. Possible economic development.
Lsds. 13, 14, Sec. 13, Lsds. 15, 16, Sec. 14, Lsds. 1, 2, Sec. 23, Lsds. 4, 5, Sec. 24, Tp. 39, R. 13	Fairly extensive, covering about 150 acres, depth varying between 5 and 15 feet.	Glacial outwash gravel, poorly to medium well sorted, sandy. Test pitting could reveal good economic gravel.

Location	Extent of Gravel	Description of Deposit
Lsds. 4, 5, Sec. 13, Lsds. 1, 7, 8, Sec. 14, Tp. 39, R. 13.	Fairly extensive, covering about 150 acres.	Poorly sorted outwash gravel of same grade as the two preceding deposits. Test pitting required. A small gravel pit has been abandoned. Possibility of good grade gravel exists.
Lsds. 5, 6, 10, 11, Sec. 34, Lsds. 8, 9, Sec. 33, Tp. 38, R. 13	Fairly extensive, covering about 200 acres. Average depth about 15 feet.	Spillway type of deposit, usually sandy, but in places well sorted good gravel present. A small gravel pit present. Better development foreseen.
Lsds. 8, 9, 15, Sec. 7, Lsds. 5, 6, Sec. 8, Lsds. 2, 7, 9, 10, 11, 12, Sec. 18, Tp. 38, R. 11	Very extensive, covering about 400 acres. Depth varying between 0 and 40 feet.	A complex kame composed predominantly of well sorted material. Sand pockets very common. Very favorable development foreseen. A few small operating gravel pits were coming into production.

BROWNFIELD DISTRICT

Location	Extent of Gravel	Description of Deposit
Lsds. 9, 16, Sec. 19, Lsds. 12, 13, Sec. 20, Tp. 40, R. 10	Limited extent, areal coverage 30 acres, average depth about 15 feet.	Glacial outwash, gravel, poorly to medium well sorted, containing large boulders. Gravel pit partly active.
Lsds. 15, 16, Sec. 16, Tp. 40, R. 10	Limited extent.	Very small esker containing poorly sorted sand and gravel. Economic use doubtful.
Lsds. 7, 8, 9, Sec. 14, Tp. 40, R. 9.	Limited extent.	Complex of small crevasse fillings which are partly composed of gravel. Economic use doubtful.
Secs. 12, 13, 23, 26, 35, 36, Tp. 40, R. 9; Secs. 1, 2, Tp. 41, R. 9; Secs. 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, Tp. 40, R. 8, Secs. 27, 28, 32, 33, Tp. 39, R. 8; Secs. 6, 7, Tp. 40, R. 7.	Extremely large areal extent, about 7 square miles. Depth varying from 0 to 40 feet, average about 20 feet.	This is a large spillway (see map) in the Viking moraine. For most of the course, this spillway is filled with gravel. The gravel is expected to be reasonably well washed and sorted. Sand lenses and layers are to be encountered. In Tps. 39, 40, R. 8 and Tp. 40, R. 7, the bottom of the spillway is poorly drained. One large gravel pit is located in Lsd. 7, Sec. 26, Tp. 40, R. 9. Reserves of gravel in this deposit are very large. Economic development on a large scale foreseen.
Lsds. 6, 11, Sec. 33, Tp. 39, R. 10.	Limited extent, about 20 acres, average depth 15 feet.	Spillway type of gravel, medium well sorted. The existing gravel pit exhausted about half of the deposit.
Lsds. 6, 7, 11, 12, Sec. 27, Lsds. 6, 8, 9, Sec. 28, Tp. 38, R. 9.	Fairly large extent, depth varying.	Very poorly sorted glacial outwash gravel. No immediate economic use foreseen.
Lsd. 9, Sec. 33, Lsds. 12, 13, Sec. 34, Tp. 38, R. 8	Limited extent, average depth about 30 feet.	Glacial outwash gravel, poorly sorted. Economic use of some better sorted parts possible.

Location	Extent of Gravel	Description of Deposit
Lsds. 1, 2, 3, 8, Sec. 35, Lsds. 5, 6, 7, 8, 9, 10, 11, 15, 16, Sec. 36, Tp. 38, R. 8; Lsds. 12, 13, Sec. 31, Tp. 38, R. 7	Limited extent of gravel.	Esker type of kame surrounded by lake clays and silts. The kame is composed of medium to coarse sand. Gravel lenses are rare but it is expected that economic gravel pockets will be found in this kame.

APPENDIX B

DRILL HOLES

Drill Hole No.	Location	Depth feet	Description of Material
1	Lsd. 16, Sec. 15, Tp. 40, R. 13	0 - 25	Brown clayey till, stones common
		25 - 30	Grey clayey till, stones common
		30 -	Water table
		30 - 50	Grey sandy till, stones rare
		50 - 60	Bedrock; Bearpaw formation; dense bluish-grey shale
2	Lsd. 16, Sec. 32, Tp. 40, R. 13	0 - 13	Brown clayey till with gypsum and stones
		13 - 18	Bedrock; brown to yellowish-brown, fine grained, bentonitic sandstone
3	Lsd. 16, Sec. 26, Tp. 40, R. 14	0 - 22	Brown clayey till with gypsum crystals
		22 - 23	Dark grey till with gypsum crystals
4	Lsd. 16, Sec. 26, Tp. 40, R. 14	0 - 23	Brown clayey till
		23 - 25	Grey clayey till
		25 -	Water table
		25 - 30	Grey sandy till
		30 - 45	Bedrock; blue-grey clay and sandy clay
5	Lsd. 1, Sec. 2, Tp. 41, R. 14	0 - 25	Brown clayey till
		25 - 26	Grey clay till
		26 - 47	Grey sandy till
		28 -	Water table
		47 - 50	Bedrock; dry, blue-grey bentonitic shale
6	Lsd. 13, Sec. 32, Tp. 40, R. 14	0 - 5	Brown silty till
		5 - 6	Light-brown, fine grained glacial sand
		6 - 22	Light-brown silty till
		22 - 26	Grey clayey till
		26 -	Water table
		26 - 30	Grey, coarse grained glacial sand
		30 - 35	Bedrock; sky-blue sandy clay
7	Lsd. 1, Sec. 3, Tp. 41, R. 13	0 - 16	Brown clay till, stones common
		16 - 25	Grey clayey till
		25 - 28	Bedrock; dark-green sandy clay to clay; dark-grey clay

Drill Hole No.	Location	Depth feet	Description of Material
8	Lsd. 13, Sec. 32, Tp. 40, R. 12	0 - 25	Brown clayey till
		25 - 77	Light-brown to light-grey, clean, fine to medium grained glacial sand
9	Lsd. 4, Sec. 6, Tp. 41, R. 12 (middle of buried valley)	0 - 1	Muck and organic matter
		1 - 3	Brown, clayey, fine grained, glacial sand
		3 - 12	Brown clayey till
		12 -	Water table
		12 - 44	Grey, medium grained, glacial sand with coal fragments
10	Lsd. 15, Sec. 31, Tp. 40, R. 12	0 - 27	Brown clayey till
		27 - 60	Grey, medium grained, glacial sand
		33 -	Water table
11	Lsd. 14, Sec. 33, Tp. 40, R. 12	0 - 20	Brown clayey till
		20 - 25	Bedrock; brown oxidized sandy shale; iron concretions; dark-grey shale
12	Lsd. 13, Sec. 31, Tp. 40, R. 11	0 - 2	Yellow-brown, fine grained, glacial sand
		2 - 12	Brown sandy till
		12 - 14	Brown, medium grained glacial sand
		14 - 20	Brown clayey till
		20 - 60	Grey sandy to clay till
		45 -	Water table
13	Lsd. 13, Sec. 34, Tp. 40, R. 11	0 - 25	Brown clayey till
		25 - 60	Grey clayey till
		40 -	Water table
14	Lsd. 13, Sec. 10, Tp. 40, R. 11	0 - 14	Brown clayey till
		14 - 18	Brown, coarse grained, pure glacial sand
		18 -	Water table
		18 - 60	Grey, coarse grained glacial sand
15	Lsd. 16, Sec. 12, Tp. 40, R. 12	0 - 12	Brown clayey till with occasional sand lenses
		12 - 20	Brown, medium to fine grained glacial sand
		20 - 30	Brown, medium grained glacial sand
		30 -	Water table
		30 - 60	Grey, medium grained glacial sand

Drill Hole No.	Location	Depth feet	Description of Material
16	Lsd. 1, Sec. 18, Tp. 40, R. 12	0 - 15	Brown clayey till
		15 - 35	Grey clayey till
		35 - 40	Bedrock; dark-grey bentonitic shale
17	Lsd. 4, Sec. 15, Tp. 40, R. 12	0 - 15	Brown clayey till
		15 - 20	Grey clayey till
		20 -	Water table
		20 - 30	Grey sandy till
		30 - 40	Bedrock; yellowish-brown bentonitic sandstone
18	Lsd. 4, Sec. 3, Tp. 40, R. 12	0 - 12	Brown clayey till
		12 - 20	Bedrock; yellowish-brown clay to sandy clay; iron concretions; large gypsum crystals
19	Lsd. 13, Sec. 22, Tp. 39, R. 12	0 - 3	Brown sandy till
		3 - 10	Bedrock; yellowish-brown clayey sandstone; iron concretions; greyish-brown clay
20	Lsd. 14, Sec. 28, Tp. 39, R. 12	0 - 2	Brown clayey till
		2 - 8	Bedrock; yellowish-brown sandstone; iron concretions (at 8')
21	Lsd. 6, Sec. 29, Tp. 39, R. 12	0 - 2	Brown to reddish-brown sandy till
		2 - 4	Bedrock; yellowish to yellow-red fine grained sandstone with iron stainings
22	Lsd. 16, Sec. 31, Tp. 39, R. 12	0 - 3	Brown to reddish-brown, fine to medium grained glacial sand (partly eolian)
		3 - 11	Brown clayey to sandy till
		11 - 15	Bedrock; yellow to brownish-yellow sandstone; iron concretions
23	Lsd. 4, Sec. 19, Tp. 40, R. 12	0 - 5	Brown clayey till
		5 - 8	Bedrock; light-brown to yellow sandstone
24	Lsd. 1, Sec. 25, Tp. 40, R. 13	0 - 11	Brown clayey till
		11 - 14	Bedrock; light-yellowish brown sandstone with iron stainings

Drill Hole No.	Location	Depth feet	Description of Material
25	Lsd. 1, Sec. 20,	0 - 7	Brown clayey till
	Tp. 40, R. 12	7 - 9	Bedrock; brown to yellowish-brown sandstone with iron concretions
		9 - 14	Bedrock; dark-grey shale to sandy shale
26	Lsd. 4, Sec. 33,	0 - 16	Brown clayey till
	Tp. 40, R. 12	16 - 17	Light brown, medium grained, impure glacial sand
		17 - 20	Brown clayey till
		20 - 40	Brown, medium grained impure glacial sand
27	Lsd. 13, Sec. 30,	0 - 11	Brown clayey till
	Tp. 39, R. 11	11 - 34	Bedrock; brown to yellow, fine to medium grained sandstone, coal lenses
28	Lsd. 4, Sec. 9,	0 - 14	Brown clayey till
	Tp. 40, R. 11	14 - 35	Yellowish-brown, fine grained sand
30	Lsd. 1, Sec. 15,	0 - 11	Brown clayey to sandy till
	Tp. 40, R. 14	11 - 12	Brown medium grained glacial sand
		12 - 14	Greyish-brown clayey till
		14 -	Water table
		14 - 29	Grey, medium to coarse grained sand
		29 - 30	Bedrock; dark-grey shale
31	Lsd. 13, Sec. 10,	0 - 10	Brown sandy till
	Tp. 40, R. 14	10 - 16	Grey clayey till
		16 -	Water table
		16 - 18	Grey, coarse grained glacial sand
		18 - 30	Bedrock; grey, bluish-grey, and green shale
32	Lsd. 1, Sec. 3,	0 - 16	Brown clayey till
	Tp. 40, R. 14	14 -	Water table
		16 - 20	Bedrock; dark-brown to grey-brown shale
33	Lsd. 1, Sec. 33,	0 - 16	Brown clayey till
	Tp. 39, R. 14	16 - 22	Bedrock; brown clay with gypsum crystals

Drill Hole No.	Location	Depth feet	Description of Material
34	Lsd. 9, Sec. 1, Tp. 40, R. 14	0 - 6	Brown sandy to clayey till
		6 - 16	Brown, fine grained, glacial sand
		16 - 22	Brown clayey till
		22 - 40	Grey clayey till
		40 - 43	Bedrock; blue, clayey sandstone
35	Lsd. 8, Sec. 12, Tp. 40, R. 14	0 - 1	Brown sandy till
		1 - 8	Brown, coarse grained glacial sand
		8 - 10	Brown clayey till
		10 - 12	Glacial sand and gravel
		12 - 14	Bedrock; dark-grey shale
36	Lsd. 13, Sec. 30, Tp. 39, R. 13	0 - 8	Brown clayey till
		8 - 9	Brown coarse grained glacial sand
		9 - 10	Glacial gravel
		10 - 12	Bedrock; fine grained bentonitic sandstone
37	Lsd. 5, Sec. 5, Tp. 40, R. 13	0 - 6	Brown clayey till
		6 - 8	Bedrock; yellow clayey sandstone
38	Lsd. 5, Sec. 26, Tp. 39, R. 14	0 - 3	Brown sandy till
		3 - 26	Brown clayey till
		26 - 27	Coarse grained glacial sand and gravel
		26 -	Water table
		27 - 29	Bedrock; grey to dark-grey bentonitic shale
39	Lsd. 1, Sec. 10, Tp. 39, R. 13	0 - 10	Brown clayey till
		10 - 15	Bedrock; yellow medium grained sandstone
40	Lsd. 4, Sec. 13, Tp. 39, R. 14	0 - 8	Brown clayey till
		8 - 14	Bedrock; yellow fine to medium grained sandstone
41	Lsd. 13, Sec. 33, Tp. 38, R. 14	0 - 25	Brown clayey till
		25 - 42	Grey clayey till
		40 -	Water table; water came up to 25 feet
		42 - 45	Bedrock; dark-brownish grey clay
42	Lsd. 13, Sec. 21, Tp. 38, R. 14	0 - 15	Brown clayey till
		15 - 20	Yellowish-brown, fine-grained, impure glacial sand
		20 - 25	Brown clayey till
		25 - 33	Bedrock; subbituminous coal, pure
		33 - 40	Bedrock; grey shale

Drill Hole No.	Location	Depth feet	Description of Material
43	Lsd. 16, Sec. 15,	0 - 5	Brown clayey till
	Tp. 38, R. 14	5 - 8	Bedrock; grey shale
44	Lsd. 13, Sec. 35,	0 - 12	Brown clayey till
	Tp. 38, R. 14	12 - 13	Bedrock; yellowish-brown, medium grained sandstone
45	Lsd. 16, Sec. 36,	0 - 12	Brown clayey till
	Tp. 38, R. 14	11 -	Water table
		12 - 16	Bedrock; grey shale
46	Lsd. 16, Sec. 13,	0 - 8	Brown clayey till
	Tp. 38, R. 14	8 - 12	Bedrock; brown, oxidized shale, iron concentrations
47	Lsd. 13, Sec. 9,	0 - 15	Brown clayey till
	Tp. 38, R. 13	15 - 17	Bedrock; grey shale
48	Lsd. 4, Sec. 28,	0 - 7	Brown clayey till
	Tp. 38, R. 13	7 - 9	Bedrock; brown shale with iron stainings
49	Lsd. 4, Sec. 27,	0 - 3	Brown clayey till
	Tp. 38, R. 13	3 - 5	Brown, medium grained, impure, glacial sand
		5 - 7	Brown clayey till
		7 - 10	Bedrock; brown, oxidized, shale with iron stainings
50	Lsd. 1, Sec. 4,	0 - 6	Brown clayey till
	Tp. 39, R. 13	6 - 7	Brown sandy till
		7 - 12	Brown clayey till
		12 - 13	Brown, fine grained, glacial sand
		13 - 22	Brown clayey till
		22 - 23	Glacial gravel
		23 -	Water table
		23 - 26	Brown, medium grained, impure glacial sand
		26 - 32	Grey clayey till
		32 - 37	Bedrock; grey to dark-grey shale
51	Lsd. 13, Sec. 2,	0 - 1	Brown clayey till
	Tp. 39, R. 13	1 - 3	Bedrock; light-yellow sandstone with iron stainings

Drill Hole No.	Location	Depth feet	Description of Material
52	Lsd. 13, Sec. 35, Tp. 38, R. 13	0 - 2	Brown, fine to medium grained, glacial sand
		2 - 18	Brown clayey till
		18 - 32	Grey clayey till
		32 - 36	Bedrock; grey shale; blue clayey sandstone
53	Lsd. 13, Sec. 36, Tp. 38, R. 13	0 - 18	Brown clayey till
		18 - 25	Grey clayey till
		25 - 28	Bedrock; grey bentonitic shale
55	Lsd. 13, Sec. 6, Tp. 39, R. 12	0 - 16	Brown clayey till
		16 - 32	Grey clayey till
		24 -	Water table
		32 - 37	Bedrock; grey shale
56	Lsd. 13, Sec. 4, Tp. 39, R. 12	0 - 7	Brown clayey till
		7 - 12	Bedrock; grey shale
57	Lsd. 4, Sec. 25, Tp. 38, R. 13	0 - 3	Light-brown, soft, lacustrine, clay
		3 - 10	Light-brown, fine grained, impure glacial sand
		10 - 16	Light-brown, soft, lacustrine, clay
		16 - 32	Brown clayey till
		28 -	Water table
		32 - 35	Grey clayey till
		35 - 39	Bedrock; grey shale
58	Lsd. 13, Sec. 19, Tp. 38, R. 12	0 - 15	Brown clayey till
		15 - 19	Bedrock; light-grey clayey sandstone with gypsum crystals
59	Lsd. 13, Sec. 30, Tp. 38, R. 12	0 - 3	Brown, fine grained, glacial sand
		3 - 11	Brown clayey till
		11 - 14	Bedrock; dark-grey shale
60	Lsd. 4, Sec. 28, Tp. 38, R. 12	0 - 16	Brown clayey till
		16 - 22	Grey clayey till
		22 - 24	Bedrock; greyish-blue sandstone, dark-grey shale
61	Lsd. 4, Sec. 28, Tp. 38, R. 12	0 - 11	Brown, fine-grained, glacial sand
		11 - 12	Brown clayey till
		12 - 16	Brown, medium grained glacial sand
		16 -	Water table
		16 - 22	Grey, medium grained glacial sand
		22 - 24	Bedrock; dark grey shale

Drill Hole No.	Location	Depth feet	Description of Material
62	Lsd. 8, Sec. 33, Tp. 38, R. 12	0 - 4	Brown, fine grained glacial sand
		4 - 11	Brown, coarse grained glacial sand
		11 - 12	Brown sandy till
		12 - 15	Very coarse glacial sand and gravel
63	Lsd. 8, Sec. 4, Tp. 40, R. 13	0 - 22	Recent alluvial silt and sand
		22 - 24	Brown clayey till
		24 - 50	Alluvial silt and sand
		40 -	Water table
		50 - 60	Bedrock; bluish-grey clay
64	Lsd. 16, Sec. 22, Tp. 39, R. 14	0 - 4	Brown, fine grained, glacial sand
		4 - 6	Light-brown soft clay
		6 - 15	Coarse grained, very impure, glacial sand
		15 - 25	Brown clayey till
		25 -	Water table
		25 - 40	Brown, soft clay to sandy clay
		40 - 60	Bedrock; dark-bluish-grey clay
65	Lsd. 16, Sec. 35, Tp. 38, R. 12	0 - 2	Dark brown clayey till; soil profile
		2 - 4	Light-brown silty till
		4 - 20	Brown clayey till
		20 - 24	Bedrock; clayey sandstone
66	Lsd. 5, Sec. 22, Tp. 38, R. 12	0 - 2	Dark-brown lacustrine clay
		2 - 4	Light-grey, limy, fine grained lacustrine clay
		4 - 15	Brown clayey till
		10 -	Water table
		15 - 19	Bedrock; dark-grey shale
67	Lsd. 13, Sec. 24, Tp. 38, R. 12	0 - 17	Brown clayey till
		17 - 20	Bedrock; dark-grey shale
68	Lsd. 5, Sec. 13, Tp. 38, R. 12	0 - 4	Brown sandy till
		10 -	Water table
		4 - 28	Brown clayey till
		28 - 38	Bedrock; dark-blue clay
69	Lsd. 16, Sec. 7, Tp. 38, R. 11	0 - 12	Brown clayey till
		12 - 14	Bedrock; brown oxidized shale
70	Lsd. 16, Sec. 19, Tp. 38, R. 11	0 - 10	Brown clayey till
		10 - 12	Bedrock; greenish-brown clayey sandstone

Drill Hole No.	Location	Depth feet	Description of Material
71	Lsd. 5, Sec. 31,	0 - 18	Brown clayey till
	Tp. 38, R. 11	18 - 20	Bedrock; brown to bluish-grey sandy shale
72	Lsd. 16, Sec. 4,	0 - 6	Brown clayey till
	Tp. 39, R. 11	6 - 12	Bedrock; brown oxidized shale
73	Lsd. 16, Sec. 33,	0 - 8	Brown clayey till
	Tp. 38, R. 11	8 - 9	Bedrock; iron concretions
74	Lsd. 16, Sec. 10,	0 - 4	Brown clayey till
	Tp. 39, R. 11	4 - 6	Bedrock; light-brown shale
75	Lsd. 16, Sec. 21,	0 - 10	Brown clayey till
	Tp. 38, R. 11	10 - 12	Bedrock; brown sandy shale
76	Lsd. 8, Sec. 21,	0 - 7	Dark greyish-brown lacustrine clay
	Tp. 38, R. 11	7 - 16	Brown clayey till
		16 - 20	Grey clayey till
		20 - 23	Bedrock; yellowish-green clayey sandstone
77	Lsd. 4, Sec. 34,	0 - 3	Brown clayey till
	Tp. 39, R. 13	3 - 7	Bedrock; yellow shale with iron concretions
78	Lsd. 13, Sec. 16,	0 - 10	Brown clayey till
	Tp. 39, R. 13	10 - 22	Grey clayey till
		22 - 28	Bedrock; greyish-blue sandy shale
79	Lsd. 4, Sec. 15,	0 - 14	Brown clayey till
	Tp. 39, R. 13	14 - 17	Bedrock; yellowish-brown clayey sandstone
80	Lsd. 4, Sec. 15,	0 - 6	Dark-brown lacustrine clay
	Tp. 39, R. 13	6 - 7	Coarse glacial sand and gravel
		7 - 9	Bedrock; grey clayey sandstone
81	Lsd. 13, Sec. 9,	0 - 7	Brown clayey till
	Tp. 39, R. 13	7 -	Water table
		7 - 14	Brown fine to medium grained sand
		14 - 17	Bedrock; dark-grey shale
82	Lsd. 4, Sec. 20,	0 - 3	Brown clayey till
	Tp. 39, R. 13	3 - 5	Bedrock; brown oxidized shale

Drill Hole No.	Location	Depth feet	Description of Material
83	Lsd. 13, Sec. 8, Tp. 39, R. 13	0 - 14	Brown clayey till
		14 - 16	Grey clayey till
		16 - 18	Bedrock; dark-green sandy shale
84	Lsd. 4, Sec. 18, Tp. 39, R. 13	0 - 15	Bedrock; dark-grey to light-brown clay
85	Lsd. 6, Sec. 35, Tp. 39, R. 13	0 - 1	Dark-brown fine grained sand
		1 - 3	Glacial outwash; boulders and gravel
		3 - 10	Brown clayey till
		10 - 11	Fine grained impure glacial sand
		11 - 17	Brown clayey till
		17 - 28	Grey clayey till
		28 - 33	Bedrock; dark-grey shale
86	Lsd. 15, Sec. 33, Tp. 40, R. 11	0 - 15	Light-brown clayey till
		15 - 30	Dark-brown clayey till
		30 - 55	Dark-grey clayey till
87	Lsd. 4, Sec. 3, Tp. 41, R. 11	0 - 10	Brown clayey till
		10 -	Water table
		10 - 30	Brown clayey to sandy till
		30 - 55	Grey clayey till
88	Lsd. 4, Sec. 34, Tp. 40, R. 11	0 - 17	Brown clayey till
		17 - 55	Grey clayey till
89	Lsd. 4, Sec. 34, Tp. 40, R. 11	0 - 17	Brown clayey till
		17 - 21	Brown, fine grained glacial sand
		21 - 27	Brown clayey till
		27 - 28	Brown, fine grained glacial sand
		28 - 40	Brown clayey till
90	Lsd. 4, Sec. 35, Tp. 40, R. 11	0 - 37	Brown clayey till
		37 - 40	Brown, fine to medium grained glacial sand
		40 - 50	Brown clayey till
		50 -	Water table
		50 - 55	Brown sandy till
91	Lsd. 13, Sec. 10, Tp. 40, R. 11	0 - 34	Brown clayey till
		34 - 67	Coarse grained glacial sand
92	Lsd. 13, Sec. 10, Tp. 40, R. 11	0 - 10	Brown clayey till
		10 - 50	Brown, fine grained, glacial sand
		12 -	Water table
		50 - 55	Brown silt and clay

Drill Hole No.	Location	Depth feet	Description of Material
93	Lsd. 5, Sec. 27, Tp. 38, R. 12	0 - 20	Brown, fine to medium grained glacial sand
		20 - 21	Glacial gravel
94	Lsd. 2, Sec. 24, Tp. 40, R. 13	0 - 4	Brown, fine grained, impure, glacial sand
		4 - 7	Brown clayey till
		7 - 7.5	Brown, fine grained, glacial sand
		7.5 - 15	Brown clayey till
95	Lsd. 10, Sec. 2, Tp. 41, R. 13	0 - 4	Brown sandy till
		4 - 15	Brown clayey till
		15 - 25	Brown, fine grained, glacial sand
		25 - 33	Brown clayey till
		33 - 34	Brown, fine grained glacial sand
		34 - 37	Brown clayey till
96	Lsd. 1, Sec. 35, Tp. 38, R. 8	0 - 10	Brown, silty to sandy, lacustrine clay
		10 - 25	Brown, lacustrine clay
		25 -	Water table; water came up to 15 feet
		25 - 35	Brown lacustrine clay
		35 - 45	Greyish-brown lacustrine clay
		45 - 46	Black lacustrine clay
		46 - 65	Brown clayey till
97	Lsd. 14, Sec. 35, Tp. 38, R. 8	0 - 1	Glacial gravel
		1 - 2	Coarse grained, clean, glacial sand
		2 - 10	Medium grained, glacial sand
		10 - 15	Medium grained, very impure, glacial sand
		22 -	Water table
		15 - 40	Coarse grained glacial sand
98	Lsd. 9, Sec. 26, Tp. 38, R. 8	0 - 12	Brown-grey lacustrine clay
		12 - 30	Coarse grained glacial sand
		30 - 35	Dark-grey clayey till
		35 - 40	Bedrock; dark-green to light-green bentonite
99	Lsd. 5, Sec. 5, Tp. 40, R. 12	0 - 8	Brown clayey till
		8 - 12	Glacial sand and gravel
		12 - 20	Bedrock; fine to medium grained green sandstone

Drill Hole No.	Location	Depth feet	Description of Material
100	Lsd. 7, Sec. 31,	0 - 15	Fine to medium grained glacial sand
	Tp. 38, R. 12	15 -	Water table
		15 - 25	Grey clayey till
		25 - 35	Bedrock; dark-grey bentonitic shale
101	Lsd. 16, Sec. 22,	0 - 5	Brown lacustrine clay
	Tp. 38, R. 11	5 - 8	Brown clayey till
		8 - 10	Medium grained glacial sand
		10 - 13	Brown clayey till
		13 - 20	Bedrock; yellowish-brown glauconitic sandstone

APPENDIX C

(a) MECHANICAL ANALYSIS OF TILL SAMPLES

Procedure

The following flowsheet shows the main steps involved in the mechanical analysis procedure:

(1) 150 grams of the dried sample was weighed out.
(2) Material above 2 mm. size was removed by wet sieving.
(3) Then the material finer than 0.062 mm. was removed by wet sieving.
(4) The fraction between 2 mm. and 0.062 mm. was dried and then sieved using the following U.S. Standard screens:

10 mesh	-	2.00 mm.
18 mesh	-	1.00 mm.
35 mesh	-	0.50 mm.
45 mesh	-	0.351 mm.
60 mesh	-	0.250 mm.
80 mesh	-	0.177 mm.
100 mesh	-	0.147 mm.
120 mesh	-	0.125 mm.
170 mesh	-	0.088 mm.
200 mesh	-	0.074 mm.
230 mesh	-	0.062 mm.

(5) Each sand fraction separated in step (4) was weighed and the material finer than 0.062 mm. was added to the minus 0.062 portion of the sample obtained in step (3).

Location of Samples

Sample No.	Location	Drill Hole No.	Feet below Surface	Description
1	NW corner of Sec. 32, Tp. 40, R. 12	8	20	Brown clayey till
2	NW corner of Sec. 34, Tp. 40, R. 11	13	35	Grey clayey till
3	NW corner of Sec. 33, Tp. 38, R. 14	41	35	Grey clayey till

Sample Results

Size		Sample No. 1.		2.		3.	
mm.	mesh*	wt. in gms.	%	wt. in gms.	%	wt. in gms	%
2.00	10	1.16		1.59		2.91	
1.00	18	1.18	0.8	1.76	1.2	1.90	1.3
0.50	35	3.26	2.2	4.02	2.7	5.09	3.5
0.351	45	4.36	2.9	6.08	4.1	5.82	4.0
0.250	60	6.53	4.4	7.58	5.1	8.09	5.5
0.177	80	10.38	7.0	14.23	9.6	11.74	8.0
0.471	100	3.09	2.1	3.57	2.4	2.17	1.5
0.125	120	4.93	3.3	5.57	3.7	4.03	2.8
0.088	170	10.16	6.8	10.27	6.9	9.29	6.1
0.074	200	8.57	5.8	7.79	5.2	7.51	5.1
0.062	230	0.21	0.1	0.08	0.0	0.15	0.1
Total sand		52.67	35.4	60.95	40.9	55.79	37.9
Total silt and clay		96.17	64.6	87.46	59.1	91.30	62.1
Total sand, silt and clay		148.84	100.00	148.41	100.00	147.09	100.00

* U. S. Standard sieves

Averages

Average of mechanical analyses of till samples made by Bayrock (1955) - 36 samples, and Gravenor and Bayrock (1955) - 7 samples

Total No. of samples	% of sand	% of silt and clay
43	40.1	59.9

Average of samples analyzed in this report

Total No. of samples	% of sand	% of silt and clay
3	38.2	61.8

(b) PEBBLE COUNTS

Location of Samples

Sample	Location	Description	No. of pebbles counted
P 1	Lsd. 4, Sec. 28, Tp. 40, R. 13	Glacial outwash gravel	331
P 2	Lsd. 17, Sec. 8, Tp. 40, R. 13	Kame gravel	352

Pebble Count Results

	Sample P1		Sample P2	
Rock type	no. of pebbles	%	no. of pebbles	%
Limestone	10	3.0	4	1.1
Dolomite	16	4.8	28	7.9
Upper Cretaceous sandstone	9	2.7	24	6.8
"Athabasca" sandstone	106	32.1	80	22.7
Chert	4	1.2	3	0.8
Jasper	1	0.3	--	--
Arcose	3	0.9	1	0.3
Ironstone nodule	16	4.8	25	7.1
Quartzite	78	23.5	58	16.5
Gneissic quartzite	1	0.3	--	--
Cone-in-cone gypsum	--	--	1	0.3
Petrified wood (chert)	--	--	6	1.7
Granite	38	11.5	49	14.0
Syenite	4	1.2	9	2.6
Dionite	6	1.8	8	2.3
Gabbro	4	1.2	4	1.1
Pegmatite	5	1.5	8	2.3
Gneiss -- acid	19	5.7	18	5.1
Gneiss -- basic	7	2.1	21	6.0
Amphibolite	3	0.9	4	1.1
Basalt	1	0.3	1	0.3
Total:	331	100.00	352	100.00

Summary of Pebble Counts

	% of Pebbles	
Rock type	Sample P1	Sample P2
Quartzites, including "Athabasca" sandstone	55.6	39.3
Sedimentary	17.8	25.8
Acid igneous	16.1	21.0
Metamorphic	8.1	11.3
Basic igneous	2.4	2.6
Total	100.0	100.0