RESEARCH COUNCIL OF ALBERTA

Preliminary Report 55-1

GLACIAL GEOLOGY
Coronation District

by

C. P. GRAVENOR AND L. A. BAYROCK

Price 50 cents

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CORONATION DISTRICT, ALBERTA

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C. P. Gravenor and L. A. Bayrock

Research Council of Alberta
University of Alberta
Edmonton, Alberta
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GLACIAL GEOLOGY, CORONATION DISTRICT

Chapter I

INTRODUCTION

General Statement

The intent of this report is to present preliminary results of the mapping of glacial deposits in the Coronation district of Alberta. Three districts of similar size -- which lie to the west, northwest and north of the Coronation district -- will be mapped in the next two field seasons, and when this mapping has been completed a finalized report will be presented encompassing the entire area.

Much of the Coronation district lies in the Torlea flats, which is a north-south belt of relatively featureless ground moraine in east-central Alberta. Gently dipping Upper Cretaceous bedrock is found quite close to the surface in the Torlea flats and is exposed in the valleys of most of the easterly flowing streams.

The eastern side of the Torlea flats is bounded by the Viking moraine. This broad recessional moraine is made up of a series of segments which trend in a north-south direction north of the Coronation district. Just south of the Coronation district the Viking moraine swings to the east and crosses the Saskatchewan-Alberta border at approximately 52 degrees of latitude.

A large part of this report is devoted to the conditions of retreat of the last ice in this section of Alberta. From the nature of the regional topography and the form of glacial deposits, it is reasoned that the last retreat was marked by large-scale stagnation which proceeded in a down-slope direction.

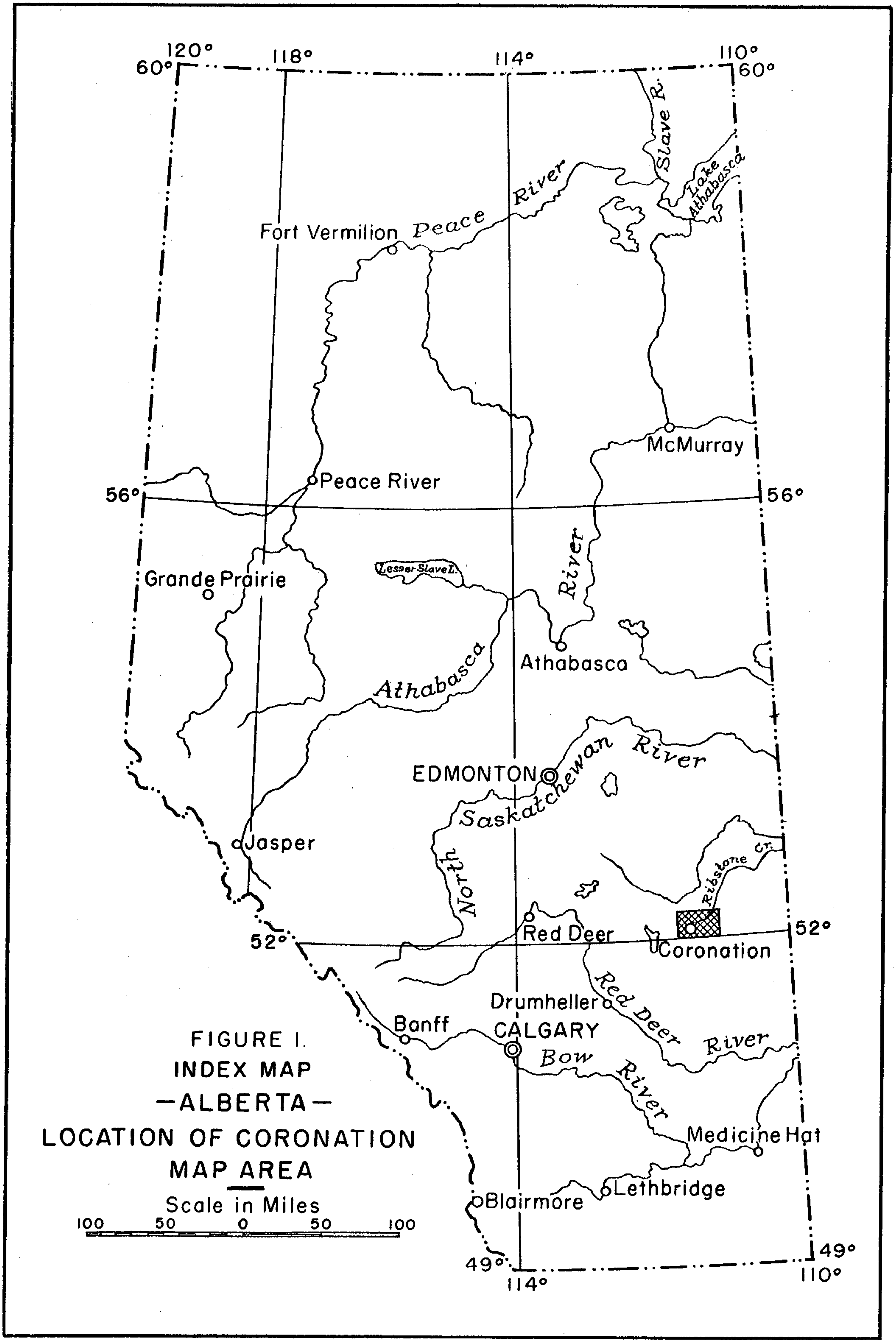

FIGURE I.
INDEX MAP
—ALBERTA—
LOCATION OF CORONATION
MAP AREA

Location of District

The district mapped is located in east-central Alberta (Fig. 1) and is bounded on the east by longitude 111°00' and on the west by longitude 111°35'; the northern limit is marked by latitude 52°15' and the southern limit by latitude 52°00'. The total area of the district comprises about 423 square miles. As the district lies west of the 4th meridian, all locations given in this report will have that interpretation.

Previous Work

Previous glacial geology studies in this portion of Alberta have been of a very general nature. Warren (1937) outlined the position of the western front of the Viking moraine and suggested that the moraine might be Illinoian or Iowan in age. He mentioned a broad area of flat ground moraine -- the Torlea flats -- which lies to the west of the Viking moraine.

Rutherford (1941) published a map showing the western border of the Viking moraine in much the same position as that given by Warren. Rutherford considered that the Viking moraine is possibly an early stage of the ice that formed the Altamont moraine. Bretz (1943) visited this part of Alberta and mapped the outlines of some major glacial forms. Bretz disagreed with both Warren's and Rutherford's positioning of the Viking moraine, and suggested that there is little age difference in the moraines west of the Altamont. Recently, Warren (1954) suggested that it would be unwise to correlate the western deposits with the Mississippi basin glacial sequence until much more information is gathered in Alberta.

Wyatt, Newton, Bowser and Odynsky (1938) mapped the soils of the Coronation district on a scale of 3 miles to 1 inch. The soil classification used by them was a number system which has since been superseded by a more flexible nomenclature. J. A. Allan wrote an appendix to that report and presented an outline of the bedrock geology, the water supply, and the origin of the surficial deposits.

Field Work

River sections and road cuts afforded a great deal of information, but most of the data was obtained through hand-auger borings and shallow diggings. A power-driven 6-inch auger provided a great deal of information on the stratigraphic sequence and depth of drift in upland areas. This drill is capable of drilling a 55-foot hole in about one hour. Little difficulty was encountered in drilling through till or bedrock, but coarse gravel beds inhibit the use of this drill.

Acknowledgements

The writers are indebted to Dr. P. S. Warren of the University of Alberta for his helpful suggestions on the geology of this region, and to the Soils Department at the University for providing the equipment to carry out the mechanical analysis. Mr. S. J. Groot, draftsman-compiler for the Research Council of Alberta, prepared the accompanying map and the figures.

Chapter II

PHYSIOGRAPHY

General Statement

The Coronation district is composed of two major physiographic divisions. The first of these is the Viking moraine which is found in the eastern part of the Coronation district. The second is that area of ground moraine -- the Torlea flats -- which forms the main part of the district and lies to the west of the Viking moraine.

The Viking moraine is composed of a series of morainal segments which, in the Coronation district and also north of it, trend in a north-south direction. Just south of the Coronation district this moraine forms a broad lobe which swings to the east. In the northeastern part of the Coronation district several knobs of bedrock project about 350 feet above the level of the Viking moraine; these erosion remnants of bedrock are known collectively as the Neutral Hills.

The Torlea flats is a broad north-south belt of relatively flat ground moraine in east-central Alberta. It is about 200 miles in length and is bounded on the east by the Viking moraine and on the west by the Buffalo Lake moraine. The width of this belt varies from 25 to 50 miles, and is about 50 miles in width in the area of the Coronation district.

The flatness of the Torlea flats is broken in the northwestern portion of the Coronation district by the appearance of several local recessional and kame moraines. Small glacial lakes and areas of thin outwash are found in association with these minor moraines.

A major spillway exists in the southwestern part of the Coronation district. Waters which were responsible for the cutting of this spillway, probably originated in the Sullivan Lake basin west of the Coronation district. These waters eroded away the thin cover of till and exposed Edmonton sandstone over much of the spillway.

The Viking Moraine

With the exception of the Coteau moraine, the moraines of central Alberta occur in north-south trending belts. As compared to the moraines of southern Alberta and eastern North America, these moraines are extremely broad and are up to 30 miles in width in some places. The borders of the central Alberta moraines are usually strongly indented and poorly defined, and grade into the gently rolling topography of the surrounding ground moraine. Coupled with the fact that no additional tills have been found east of the moraines, this would suggest that these major morainic systems are recessional in character.

The Viking moraine is made up primarily of till mounds which have an average relief of 25 to 30 feet. Sand and gravel cones, which are generally higher than the surrounding till mounds, are scattered throughout the moraine. These conical mounds have the outward appearance of moulin kames. A series of steep-sided kame ridges are found on the western side of the Viking moraine in Sec. 3, Tp. 38, R. 8. The original topography of these northeast-southwest trending ridges has been partially destroyed by a local re-advance of the ice in this region.

Several till mounds, which from the air resemble giant doughnuts, are found on the southwestern border of the Viking moraine in Sec. 12, Tp. 35, R. 8. These mounds average 250 feet in diameter and 20 feet in height and usually have a central depression which is 3 to 4 feet lower than the outer rim of the mounds. Similar mounds have been found 14 miles east of Hemaruka, in the Buffalo Lake moraine area, and in the Coteau moraine in Saskatchewan. Henderson (1952) has described mounds of a similar type in the Watino area of Alberta.

Meltwaters collected in depressions on the western side of the Viking moraine and formed a series of small lakes. These lakes drained to the southeast around the southern end of the Viking moraine through Loyalist creek.

Neutral Hills

Bedrock hills, which rise from 100 to 300 feet above the level of the surrounding plains, are common features of east-central Alberta. Hills of this type -- the Neutral Hills -- are found in the northeastern part of the Coronation district in Tp. 37, R. 8 and 9 and in Tp.38, R. 9. The Neutral Hills were originally covered with a thin cover of till, but erosion has removed most of this material from the sides of the hills exposing sands and shales of the Bearpaw formation. However, a thin layer of till still remains on top of some of the hills; this till thickens on the northeastern side of the hills and grades into the Viking moraine.

Topographically, the Neutral Hills are composed of a series of ridges and valleys which, in the Coronation district, trend in a southeast-northwest direction. The ridges are nearly concordant in elevation, and this gives the hills an appearance of flatness when viewed from a distance.

Similar hills -- the Mud Buttes -- which are found about 9 miles south of Monitor, have been described in detail by Slater (1927) and Hopkins (1923). Exposed sections of the Mud Buttes show that the beds have been folded and thrust-faulted by glacial action. Consequently, it is believed that the ridge and valley appearance of the Mud Buttes and the Neutral Hills is due to disturbance of the strata by glacial action and later erosion.

Erosion on the southwestern side of Nose hill -- Tp. 37, R. 9 -- has produced a thin mantle of clay, sand and fine gravel over the ground moraine at the foot of the hill. This apron of stream-deposited debris (alluvial fan) is about 1 mile in width and 7 miles in length, circling the southern part of the hill, and slopes gently away from the foot of the hill. Similar alluvial fans are found around the hills to the north and east of Nose hill.

Torlea Flats

As mentioned previously, the Torlea flats is a north-south belt of relatively flat ground moraine in east-central Alberta. Road-cuts, stream-cuts and drilling operations indicate that the ground moraine is quite thin on the Torlea flats. This would indicate that the flatness is largely due to the lack of relief on the underlying Bearpaw shales and Edmonton sandstones, and to the uniformity of thickness of the ground moraine.

In the northwestern part of the Coronation district the flatness of the Torlea flats is broken by the appearance of two small recessional moraines and a few kame deposits. The recessional moraines are local in nature, segmented, and have a relief of about 30 feet. The kame deposits are formed of steep-sloped knobs and ridges of sand and gravel which vary from 10 to 35 feet in height above the surrounding plains. Several areas of outwash and lake plains are associated with these moraines. For the most part the outwash is made up of a thin cover of sand and gravel over ground moraine and, consequently, the topography of the outwash is largely regulated by the relief on the ground moraine. At one location -- Sec. 11 and 14, Tp. 37, R. 11 -- this outwash is composed of a series of gravelly hummocks which are about 5 feet in height and 50 to 100 feet in diameter. The intervening spaces between the hummocks are largely ground moraine, although in some instances there is a thin cover of sand and gravel.

In the southwestern part of the Coronation district a large southeast-trending spillway cuts across the Torlea flats. The water which moved through this spillway probably originated in the Sullivan Lake basin, west of the Coronation district. The section of this spillway in the Coronation district is marked by broad expanses of Edmonton sandstone which is overlain by a thin cover of alluvial sands. As the streams flowed in braided patterns, there are islands of till and bedrock left in the spillway. Sections of the spillway which had quieter water are marked by accumulations of sand and gravel. South of the Coronation district the spillway widens, and much of the glacial drift which was eroded from the north and west was deposited there.

At the present time most of the Coronation district is drained by Ribstone creek and its tributaries. The valley of the main trunk of this stream is from 50 to 150 feet in depth and up to one-half mile in width. The portion of the valley in the northern part of Tp.37,R.9 was possibly cut prior to the last glaciation; this is suggested by the fact that the valley widens there and contains lake deposits.

As a result of the clayey nature of the ground moraine and the underlying bedrock, much of the drainage in the Coronation district has a fine texture. This fact can be used to advantage since changes from fine to coarse texture mark changes from impermeable to permeable materials.

Chapter III

HEAVY MINERAL AND MECHANICAL ANALYSES

HEAVY MINERAL ANALYSIS

General Statement

In some places in Alberta, bedrock lies at the surface and the soil is developed on the bedrock. In many cases, however, a layer of sandy material from a few inches up to one foot in thickness overlies the bedrock. In such cases it is sometimes quite difficult to determine whether the upper sandy material is glacial in origin or has been developed from the sand-bearing bedrock by soil-forming processes. As the underlying Cretaceous bedrock is feldspar-bearing, it is not always possible to ascertain the origin of the upper sand by macroscopic or binocular examination; consequently, a preliminary examination of the heavy minerals of the bedrock and the upper sand was made to see if there are significant differences.

Separation of Heavy Minerals

A sand fraction (size, 100 - 200 mesh) was removed from each of the samples to be tested and placed in a separatory funnel containing acetylene tetrabromoethane (sp.gr. = 2.95). The heavy minerals were then removed from the separatory funnel, washed in acetone, and mounted in Aroclor (n = 1.66). Approximately 300 grains were counted on each slide, and the percentage distribution of the various minerals calculated. The results of these counts are tabulated in Table I.

Table I
HEAVY MINERAL ANALYSES
(per cent)

Sample No.	20	21	22	55	56	73	100
Opaques	70.2	76.3	39.6	40.6	43.8	41.0	23.0
Hornblende	2.7	5.7	19.6	27.5	9.4	25.3	39.8
Garnet	4.1	7.3	9.0	12.3	10.5	11.7	13.4
Epidote	7.8	2.0	7.8	4.2	9.4	4.3	3.0
Pyroxenes (mono.)	--	1.7	2.2	2.4	1.4	Tr	2.2
Pyroxenes (ortho.)	Tr	Tr	1.6	3.3	1.0	3.4	2.1
Staurolite	Tr	--	Tr	Tr	Tr	1.5	Tr
Kyanite	--	--	--	--	1.0	Tr	Tr
Tourmaline	Tr	Tr	2.8	2.1	1.0	Tr	Tr
Titanite	Tr	Tr	Tr	1.2	1.7	Tr	Tr
Rutile	Tr	--	--	--	--	Tr	Tr
Chloritoid	Tr	--	--	--	--	--	--
Zircon	2.0	1.3	3.7	Tr	2.0	1.2	Tr
Monazite	Tr	Tr	1.6	Tr	1.7	--	Tr
Sillimanite	--	--	Tr	Tr	Tr	--	Tr
Andalusite	--	Tr	Tr	--	--	2.5	Tr
Biotite	1.0	Tr	--	Tr	1.7	2.2	Tr
Axinite	--	--	--	--	Tr	Tr	--
Topaz	--	--	--	Tr	--	--	Tr
Apatite	--	Tr	1.6	Tr	2.4	1.5	2.8
Zoisite	--	--	1.3	--	2.0	--	--
Corundum	--	--	Tr	--	--	--	--
Chlorite	--	--	--	--	Tr	--	Tr
Cassiterite	--	--	--	--	Tr	--	--
*Unidentified	8.9	Tr	7.2	2.4	9.1	Tr	3.8

*Badly altered grains   Tr = Trace (less than 1%)

Description of Samples

Sample #20: Location -- Lsd.9, Sec. 14, Tp. 36, R. 11 -- railroad cut west of Coronation. This sample was taken from the Edmonton formation, 26 inches below the surface. It is a grey sandy siltstone. Clay in the matrix contains some montmorillonite. Large amounts of salts (calcium and sodium sulphates) are present. The presence of glauconite indicates that this part of the Edmonton formation is marine. The bedding has been distorted by glacial action.

Sample #21: Location -- same as for sample #20. This sample represents a mixture of Edmonton formation and glacial material taken directly above sample #20 and 9 inches from the surface. It was taken from the "B" soil horizon, which is brown in colour and blocky in appearance and has a high salt content. At this location the "B" horizon has a thickness of 5 inches. The material is more sandy than the underlying Edmonton formation.

Sample #22: Location -- same as for sample #20. This sample is glacial material taken directly above sample #21 and 4 inches from the surface. It occurs in the "A" horizon, which is sandy in appearance and contains small feldspar fragments and granules of igneous and metamorphic material. At this location the "A" horizon has a thickness of about 7 inches.

Sample #55: Location -- Lsd. 8, Sec. 14, Tp. 36, R. 11. The sample was taken 3 inches from the surface in what appears to be glacial sand. At this location the sand has a thickness of 8 inches and overlies silty sandstone of the Edmonton formation. The profile shows no well developed "B" horizon and fresh bedrock occurs directly below the glacial sand.

Sample #56: Location -- same as for sample #55. This sample was taken 9 inches below sample #55, that is, 12 inches from the surface. It was taken from silty sandstone of the Edmonton formation and contains a large amount of sulphates.

Sample #73: Location -- Lsd. 15, Sec. 33, Tp. 36, R. 10. This is a sample of till taken 4 feet below the surface and just below the B_{ca} soil horizon. The till is grey in colour, contains few pebbles, and is clayey in texture.

Sample #100: Location -- Vermilion area, Alberta. This sample number was given to the average values for 30 heavy mineral suites taken from tills in the Vermilion area, Alberta (Bayrock, 1954).

Interpretation of Results

With the exception of samples #73 and #100, the above samples were taken to investigate the origin of a thin sand layer which is found above the bedrock in the Coronation district. The problem was to determine whether these thin sand layers were developed from the underlying bedrock by soil-forming processes or are glacial in origin. Samples #73 and #100 are included for comparative purposes as their glacial origin is assured. The results in Table I show that there is a strong similarity among samples #22, #55, #73 and #100. However, since the percentages shown in Table I are controlled by the amount of opaques present in each sample, ratios between individual mineral species are, in some cases, more significant when making comparisons. The ratios of hornblende to garnet have been calculated and are shown in Table II.

Table II
RATIOS OF HORNBLENDE TO GARNET

Sample No.	20	21	22	55	56	73	100
Depth below surface, in.	26	9	4	3	12		
Hornblende/garnet	0.67	0.77	2.17	2.24	0.92	2.16	2.96

Table II shows that samples 22, 55, 73 and 100 have hornblende-to-garnet ratios of over 2, whereas samples 20, 21 and 56 have values of less than 1. Since samples 73 and 100 are glacial in origin, the above ratios appear to indicate that samples 22 and 55 are also glacial in origin and not derived by soil-forming processes from the underlying bedrock.

Under soil-forming processes hornblende is generally a less stable mineral than garnet and hence the hornblende-to-garnet ratio usually decreases toward the surface. As the reverse is true for samples 22 and 55, this would seem to support the view that the upper sand at these locations is glacial in origin.

This heavy ~~mineral~~ material technique could be applied to any mineral where there is doubt about its glacial origin. In many places in Alberta glacio-lacustrine deposits are quite similar to the unconsolidated bedrock, and it is possible that they might be differentiated on a heavy mineral basis. It should be emphasized, however, that samples of the known local bedrock should be obtained for comparative purposes.

MECHANICAL ANALYSIS

General Statement

During the course of performing the mechanical analysis it was found that ordinary wet screening methods did not remove all the clay from the sand particles; however, it was found that boiling the samples in distilled water removed a great deal of the clay from the sand and so this procedure was adopted in all cases.

A great deal of difficulty was encountered in dispersing those samples which contained large quantities of dissolved salts and gypsum. Repeated washing of these samples usually aided the dispersion; however, when appreciable amounts of gypsum were present the washing had little effect. A technique using an ammonium chloride treatment to remove gypsum is now being tested by the Soils Department of the University of Alberta and, to date, shows promise of being successful.

The gravel component constitutes one of the main problems in the mechanical analysis of tills. If the gravel is included in the total analysis, then the presence of one large pebble can markedly affect the result. The problem can be solved either by using very large samples or by discarding the material larger than 10-mesh. As the use of very large samples is usually impractical, the latter method was adopted for comparative purposes. It should be noted that, in most instances, the material larger than 10-mesh comprised less than 2% of the sample.

The procedure employed can be divided into two parts: first, the mechanical analysis of the sand fraction and second, the analysis of the silt and clay fraction. Sieve sizes are those of the U.S.Standard sieve series.

Procedure

A. Sand fraction

1. A dried 150-gm. sample was sieved through a 10-mesh screen and the portion larger than 10-mesh was dried and weighed.
2. The material passing through the 10-mesh screen was boiled in distilled water and sieved through a 230-mesh screen. Boiling with fresh quantities of distilled water and screening was repeated until no clay or silt remained on the 230-mesh screen.

3. The material retained on the 230-mesh screen was dried, weighed and sieved with the following screens: 18, 35, 45, 60, 80, 100, 170, 200 and 230. The material resting on each screen was weighed.

B. Silt and clay fraction

1. Two duplicate dried 10-gm. samples of the material passing 10-mesh were treated with hydrogen peroxide to remove organic matter. Soluble salts and oxidized organic matter were removed in a centrifuge.
2. One of the samples was then dried and weighed to determine the loss in weight involved in the removal of organic matter and soluble salts.
3. The other sample was dispersed in a milk-shake machine containing baffles. Dispersion was aided by the addition of 10 ml. of dispersing agent (35.7 gm. of Calgon and 7.9 gm. of sodium carbonate per litre of water). The dispersed sample was placed in a 1000 ml. sedimentation tube and filled with distilled water to the 1000 ml. mark. The sedimentation tube was shaken and then placed in a constant temperature bath set at 24°C. At the end of 5 hr. and 33 min. a 25 ml. portion of the suspension was withdrawn from a position 8 cm. below the surface, dried, weighed, and the amount of minus 2-micron suspensoid determined. The proportion of clay in the total sample was then calculated.
4. The amount of silt was determined by difference.

Interpretation of Results

The results of the mechanical analysis are shown graphically in Figures 2 and 3. Figure 2 gives the results of the mechanical analysis of the soil profiles mentioned in the discussion on heavy minerals. The differences noted between the bedrock and the upper glacial sand in the heavy mineral analysis do not show up so strongly in the mechanical analysis. There

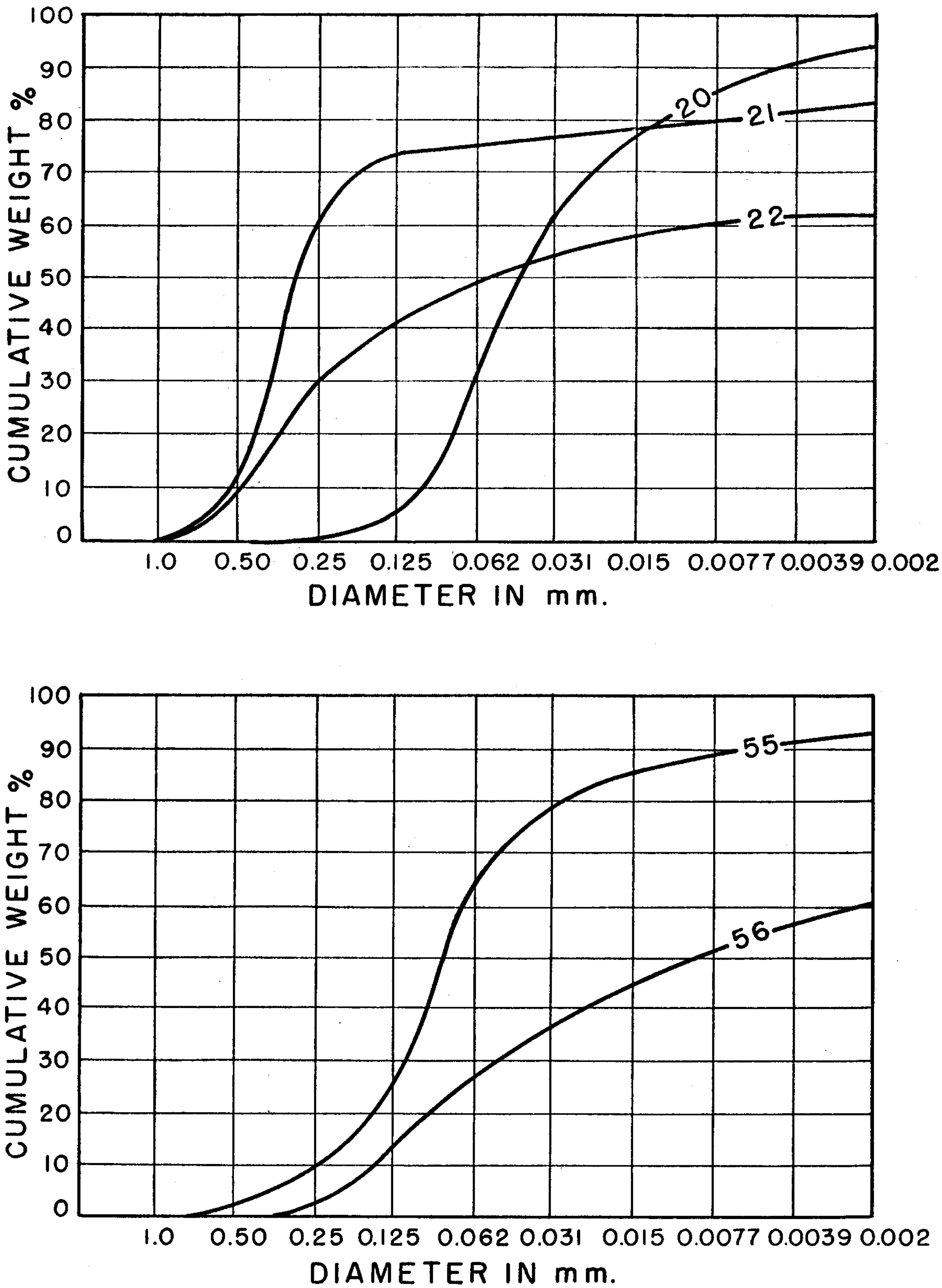

Figure 2. Mechanical analyses of sample from soil profiles described under section on heavy minerals.

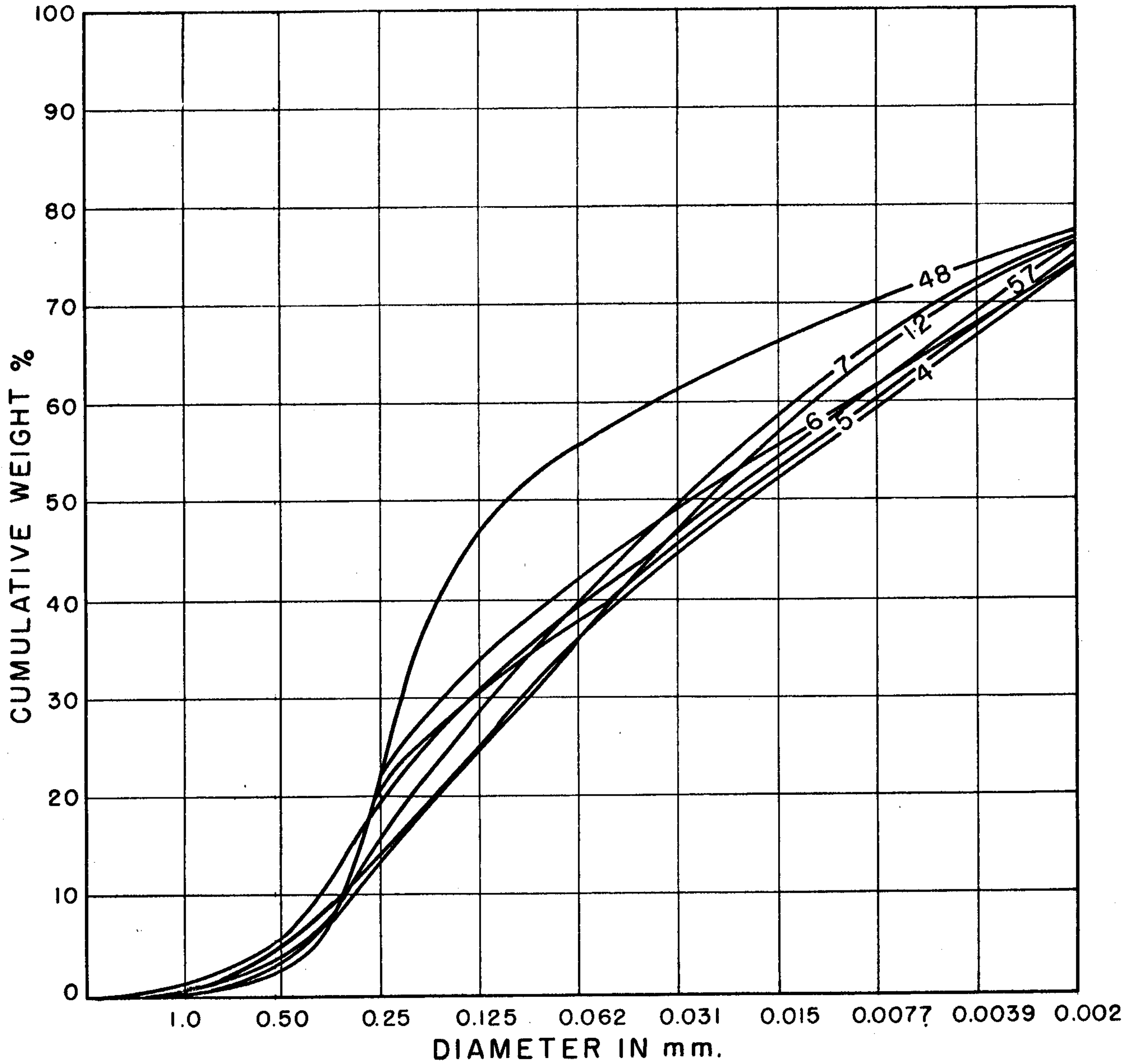

Figure 3. Mechanical analyses of miscellaneous till samples.

Location:

48 - Lsd.15, Sec.33, Tp.37, R.9
7 - Lsd. 6, Sec.17, Tp.35, R.8
12 - Lsd.13, Sec.12, Tp.35, R.8

57 - Lsd. 4, Sec.2, Tp.37, R.11
6 - Lsd. 1, Sec.25, Tp.35, R.9
5 - Lsd.10, Sec.29, Tp.35, R.9
4 - Lsd. 9, Sec. 1, Tp.36, R.11

is a similarity in the curves for samples 21 and 22 (glacial sand) which separates them from the curve for sample 20 (bedrock), and the sorting is apparently much better in the bedrock than in the glacial sand. However, there is a reversal of this trend in samples 55 and 56, in which the glacial sand is better sorted than the bedrock. Judging by the results obtained from these samples, there is apparently no obvious criterion by which mechanical analysis can differentiate between glacial and bedrock materials. It should be mentioned, however, that no gravel-sized material was found in the two bedrock samples, whereas the glacial sand above the bedrock contained 1 to 3% gravel.

Figure 3 gives the results of mechanical analysis on a group of tills from different locations in the Coronation district. It should be noted that with the exception of sample 48, the tills are remarkably uniform and contain approximately equal amounts of sand, silt and clay; generally, only a small amount of gravel-sized material was present.

Chapter IV

GLACIAL HISTORY

Glacial Stratigraphy

River sections, road cuts and drill holes have shown only one till overlying the bedrock in the Coronation district. Some road cuts through the Viking moraine show that the top part of the till, to a depth of 5 to 6 feet, is brown in colour and overlies grey till. This variation in colour gives the appearance of two tills, but upon close examination it is found that the brown till grades directly into the grey till and thus represents only an oxidized phase of the grey till.

The fact that only one till has been found would suggest two possibilities: first, that the area has been glaciated only once or, second, that all evidence of previous glaciations was removed by the action of the last ice advance. As there is evidence of multiple glaciation in the Edmonton district to the north, the Red Deer district to the west, and the Lethbridge district to the south, it would seem impossible for the Coronation district to have escaped previous glaciations.

The ground moraine in the Coronation district is quite thin (see Appendix B), and in many places bedrock is exposed at the surface. This condition persists in the region west of the Coronation district where large areas of bedrock are exposed at the surface in the Sullivan Lake district. As many of these local "driftless areas" occur on upland tracts, and as there is no evidence of erosion, it must be assumed that little or no till was deposited in these areas. It should be pointed out that erratics are found on these areas of bedrock exposure and, consequently, the term "driftless area" does not imply that the ice did not cover these areas.

The fact that only one till is found, and that this till is quite thin, requires explanation. The explanation may rest in the nature of the underlying bedrock. The Bearpaw shales and basal Edmonton sandstones contain large amounts of bentonite which is quite plastic, especially when wet. The plastic nature of the bedrock is also indicated by the deformation of the Neutral Hills and Mud Buttes by glacial action. It is suggested that the last ice advance removed all pre-existing drift and then the basal ice became packed with bentonitic clays. Friction between the clay-packed ice and the bentonitic bedrock would be quite low and hence the ice would slide along without removing further material. Plucking action would be at a minimum since any openings in the bedrock would be squeezed shut by the weight of the ice.

Direction of Ice Advance

No evidence of the direction of glaciation has been found in the Coronation district. No striations have been found on the soft bedrock. Drumlins, eskers and flutings are also missing. If the ice is considered to have retreated in the same direction as it advanced, then the north-south alignment of the Buffalo Lake and Viking moraines might suggest that the advance was from the east. However, flutings found on the ground moraine in the Red Deer district indicate that the ice moved in a south to southwesterly direction. As there is no reason to suspect that the ice direction was much different in the Coronation district from that of the adjoining Red Deer area, it is evident that the long dimensions of the Buffalo Lake and Viking moraines do not lie at right angles to the ice advance direction, but at about 45°. The retreat probably followed a downslope direction to the east, rather than in the direction of advance.

Retreat of the Ice

Except for local variations, the retreat of the last ice in central Alberta proceeded in a downslope direction. This fact has an important bearing on the interpretation of glacial form and materials. For example, waters from the mountains to the west, which normally flow in an easterly direction, were dammed in front of the ice. Added to this water was the water from the melting ice. As a result of this damming, extensive shallow lake deposits and outlet channels are common features over much of central Alberta. The lack of eskers and related ice-contact deposits over much of central Alberta is also a direct result of this downslope retreat as meltwaters forming back in the ice would not run upslope, except under special conditions of closed esker tunnels.

It is believed that in the Coronation district the last ice retreated mainly by stagnation. Features which are normally found in stagnant ice zones -- such as eskers, crevasse fillings, superglacial till, etc. -- are lacking in the Coronation district, but certain other features are found which would point to that conclusion.

The first of these features is a thin cover of sand, with some gravel, which is found overlying the ground moraine in some parts of the district. Commonly, this layer of sand lies within the soil zone, and the underlying till forms a "D" horizon, but in a few localities the soil is developed entirely in the sand and the sand forms the "C" horizon. It is believed that this sand was formed, largely, on the surface of a stagnant ice zone, that is, it is similar in origin to superglacial till. However, it is less stony and shows more water-sorting action than most superglacial till.

The lack of stones in this sand is, in part, explained by the fact that the major source for the glacial debris is the underlying unconsolidated Cretaceous shales and sandstones. The few stones which are found in the till have been derived from the Precambrian Shield and from localized Tertiary gravels. It has been noted by many writers that Precambrian boulders break down when subjected to rigorous climatic conditions. The disintegration of pebbles on top of stagnant ice has been noted by Sharp (1949) in his studies of the superglacial debris on the Wolf Creek glacier in the Canadian Yukon. Consequently, it is thought that the lack of stones in the upper sand is partly due to disintegration of pebbles in the superglacial environment.

To summarize, the lack of pebbles in the upper sand would appear to be due, firstly, to the general lack of stones in the glacial debris, secondly, to the breakdown of pebbles in the superglacial environment and, thirdly, to sorting action of waters on top of stagnant ice. When this sand is found above the B_2 horizon of solidized solonetzic soils, and does not show rapid variations in thickness or some evidence of water sorting, its origin must be treated with care as soil-forming processes can give rise to a clay-poor sand in the A_1 and A_2 soil horizons.

The second feature which suggests stagnation is a group of till mounds found on the southwestern side of the Viking moraine. These mounds were described in the chapter on physiography. Mounds of this type are quite commonplace in Alberta and, indeed, the Buffalo Lake moraine appears to be made up, for the most part, of these mounds. Henderson (1952) suggests that similar mounds in the Watino district of Alberta were formed as a result of the ice wedging which occurred in a periglacial environment. Gravenor (1955) has raised several objections to the "periglacial theory" and suggests that the mounds are ice depositional features. According to this latter theory, under certain conditions ablation of a glacier would give rise to a heterogeneously-distributed cover of debris. Melting of the ice would be more rapid in those areas where the superglacial cover is thinnest, and consequently pits would form similar to those found on the Malaspina and Wolf Creek glaciers. Pits could also form by the collapse of roofs over solution caves in the ice. This latter method of pit formation would probably be important where there was a high water-table in the ice, that is, under conditions of retreat in a downslope direction. These pits would fill with debris by washing-in and mass wasting. When the remaining ice melted, these pit-fillings would be left as isolated mounds.

If this theory is correct, then it means that much of the morainic material in Alberta -- especially the Buffalo Lake moraine -- is a result of stagnant ice conditions and not due to dumping at the end of a static glacier. This might account for the fact that no true, ridge-like, recessional moraines are found in east-central Alberta, except on a local scale. It might also explain the great width -- up to 30 miles -- of the moraines and the fact that certain of them contain large quantities of water-worked materials; the Duffield moraine west of Edmonton is a notable example.

As the ice retreated in the Coronation district, meltwaters collected in local depression areas and small glacial lakes were formed. Lakes formed in the northwestern part of the district probably drained to the north, through the present site of Bulwark, into the Battle river. Lakes which formed on the western side of the Viking moraine drained to the south through Loyalist creek. Deposition in these lakes has continued into Recent time and, in many cases, it is difficult to classify the materials as Pleistocene or Recent.

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APPENDIX A

GRAVEL DEPOSITS

The materials shown on the map as "outwash over till" are usually unsuitable for construction purposes. Kame sands and gravels are usually only fair in quality but are usable. Spillway gravels are the best in quality, but usually form only a thin layer and overlie till or bedrock.

Location	Extent of gravel	Description of gravel
Lsd.6,Sec.23, Tp.34,R.11	Gravel occurs in oval-shaped hills overlying till. Most of the gravel deposits in this region are thin (10-15'). South of this location these thin gravel deposits are quite extensive (they are exposed over 5 miles in road cuts), and represent tremendous reserves of gravel.	Spillway deposit. Fairly well rounded, river-sorted gravel. The gravel found in the hills is quite bouldery, but between the hills the deposits become sandy.
Lsd.13,Sec.23, Tp.37,R.11	Limited reserves at this location. Occurs in a series of north-south trending ridges and knobs which flatten out to the north.	Kame deposit. Poorly sorted, fairly well rounded. Rapid variations from gravel to sand. Blobs of till found in the gravel. Quality of the gravel is best near the southern part of the ridge.
Lsd.4,Sec.29, Tp.36,R.11	Very limited in extent. Suitable only for local use.	Kame deposit. Poorly sorted, with rapid variations from sand to gravel. Fairly well rounded.
Lsd.13,Sec.33, Tp.37,R.11	Limited extent. The gravel and sand form a thin deposit over till. Possibly suitable for local use.	Kame deposit. Mixture of silt, sand and gravel. Poorly sorted.
Lsd.12,Sec.18, Tp.36,R.11	Much of the high-grade gravel in this pit has been removed. However, south and east of this location there is still some gravel, but it is thin and sandy. The gravel in this area is only 10-15' thick and overlies till.	Spillway deposit. Fairly well sorted and rounded. Remaining gravel is sandy.

Location	Extent of gravel	Description of gravel
Sec.16,Tp.35 R.11	The gravel in this area is quite extensive on the surface, but the deposits are quite thin and it is doubtful if they could be utilized for large-scale operations.	Spillway. The gravel is fairly well sorted but quite sandy.
Sec.3,Tp.38, R.8	Deposits are quite extensive and have a thickness up to 25'. However, the gravel tends to become sandy toward the west and it is doubtful if the greater part of this material could be used as construction material.	Kame. Poorly sorted, there being rapid variation in size of material. Occurs as a series of northeast-trending ridges. Part of this gravel has a thin layer of till (2-3') on top of it.
Sec.1,Tp.38, R.9	Very extensive, covering about two sections. Drill holes indicate thickness up to about 35' of sand containing sporadic occurrences of gravel.	Kame. Poorly sorted and very sandy. Only a small amount of coarse gravel was encountered, but there are probably some good deposits in the area.

APPENDIX B

DRILL HOLES

Drill hole No.	Location	Depth, feet	Description of material
1	Lsd.4,Sec.6, Tp.37,R.8	0 - 3	Silt and sand, fine, bedded.
		3 - 5	Sand and gravel.
		5 - 40	Till.
2	Lsd.16,Sec.35, Tp.36,R.9	0 - 5	Mainly silt, bentonitic, dark grey.
		5 - 20	Brown till.
		20 - 40	Grey till without stones; contains pieces of grey shale, probably of the Bearpaw formation.
3	Lsd.1,Sec.3, Tp.37, R.9	0 - 40	Brown till.
4	Lsd.13,Sec.27, Tp.37,R.9	0 - 30	Grey alluvial sand (water-bearing over the lower 10 feet).
		30 - 38	Grey sand with some clay lenses.
		38 - 40	Apparently grey till, but only seen on the drill bit.
5	400 feet north of Hole No. 4	0 - 35	Grey, fine- to medium-grained sand; quicksand with clay lenses.
		35 - 40	Dark grey clay (no bedrock or stones were observed).
6	Lsd.4,Sec.14, Tp.36,R.10	0 - 20	Bedrock, Bearpaw formation; shale, brown with iron stainings; bedding planes visible in places.
		20 - ?	Hard sandstone layer.
7	Lsd.4,Sec.13, Tp.36,R.10	0 - 5	Brown clayey till.
		5 - 8	Sand and gravel, very clayey.
		8 - 8.5	Grey till.
		8.5- 24	Brown clayey till.
		24 - 28	Bedrock, Bearpaw formation; dark grey bentonitic shale containing gypsum crystals; difficult to drill.
8	Lsd.8,Sec.18, Tp.35,R.11	0 - 4	Slough and lake material (clayey).
		4 - 6	Bedrock, Edmonton formation; greenish shale with iron stainings.

Drill hole No.	Location	Depth, feet	Description of material
9	Lsd.9,Sec.18, Tp.35,R.11	0 - 12	Brown sandy till.
		12 - 14	Medium-grained sand.
		14 - 16	Brown sandy till.
		16 - 18	Medium-grained glacial sand.
		18 - 20	Sandy till.
		20 - 38	Medium-grained glacial sand.
		38 - ?	Water-table at 38 feet.
10	Lsd.8,Sec.19, Tp. 35, R.11	0 - 3	Clay and fine sand.
		3 - 5	Brown and grey sand.
		5 - 6	Gravel and grey sand.
11	Lsd.9,Sec.19, Tp.35,R.11	0 - 28	Bedrock, Bearpaw formation; brown clay with iron stainings.
12	Lsd.8,Sec.12, Tp.36,R.11	0 - 10	Brown till.
		10 - 14	Sandy till.
		14 - 20	Brown clayey till.
		20 - 22	Bedrock, Bearpaw formation; grey silty clay.
13	Lsd.2,Sec.6, Tp.36,R.10	0 - 18	Brown clayey till.
		18 - 26	Brownish-grey till; more clayey than the upper till.
		26 - 33	Medium-grained, grey glacial sand.
		33 - 36	Brown clayey till; darker than the upper brown till.
		36 - ?	Glacial sand, medium-grained, grey; water-table at 36 feet.
14	Lsd.1,Sec.4, Tp. 36, R.10	0 - 8	Brown clayey till.
		8 - 10	Grey clayey till.
		10 - 15	Grey sandy till.
		15 - 16	Brown clayey till.
		16 - 22	Grey sand, water bearing; hardpan (clayey) layer or piece of bedrock found in sand.
		22 - 42	Grey sandy till; wet, but not water producing.
15	Lsd.1,Sec.2, Tp.36,R.10	0 - 10	Brown till; clayey in the upper part, more sandy and wet at bottom.
		10 - 18	Bedrock, Bearpaw formation; grey shale, with sandstone lenses.

Drill hole No.	Location	Depth, feet	Description of material
16	Lsd.4,Sec.16, Tp.37,R.9	0 - 6	Brown bentonitic clay with iron stainings.
		6 - 42	Sand and sandy clay; water-bearing near base of hole.
17	Lsd.1,Sec.1, Tp.36,R.10	0 - 18	Brown clayey till; few stones present.
		18 - 23	Bedrock, Bearpaw formation; blue-grey bentonitic shale.
18	Lsd.14,Sec.29, Tp.35,R.9	0 - 16	Brown clayey till; few stones.
		16 - 23	Bedrock, Bearpaw formation; green-brown clayey sandstone.
19	Lsd. 7,Sec.28, Tp.35,R.9	0 - 12	Brown sandy clay till; numerous stones.
		12 - 19	Grey stony clay till.
		19 - 23	Bedrock, Bearpaw formation; blue-grey clayey sandstone.
20	Lsd.13,Sec.22, Tp.35,R.9	0 - 16	Brown clayey till.
		16 - 22	Grey-brown clayey till.
		22 - 26	Bedrock, Bearpaw formation; blue-green clayey sand with iron stainings in the top part; water at 22 feet.
21	Lsd.7,Sec.23, Tp.35,R.9	0 - 10	Brown clayey till.
		10 - 22	Bedrock, Bearpaw formation; bright yellow-brown sand to clayey sand.
22	Lsd.13,Sec.18, Tp.35,R.8	0 - 15	Brown clayey till.
		15 - 18	Yellow medium-grained loose sand.
		18 - ?	Hardpan; impenetrable.
23	Lsd.3,Sec.17, Tp.35,R.8	0 - 3	Brown till, clayey with iron stainings.
		3 - 22	Brown sandy till; water at 22 feet.
		22 - 27	Bedrock, Bearpaw formation; sandy shale, brown at top and sky blue at bottom.
24	Lsd.12,Sec.14, Tp.35,R.8	0 - 3	Light-brown silty to sandy till; very dry.
		3 - 10	Light yellow-brown glacial sand; little silt or clay in the sand.
		10 - 12	Gravel; coarse, subangular stones.
		12 - 50	Coarse sand, little fines, grading to finer sand at base.

Drill hole No.	Location	Depth, feet	Description of material
25	Lsd.2,Sec.14, Tp.35,R.8	0 - 18	Brown clayey till; tough.
		18 - 22	Dark grey clayey till; tough.
		22 - 30	Grey sandy till, gradually grading downward to a brown more sandy till.
		30 - 50	Brown till, grading downward into grey till; clayey in texture.
26	Lsd.1,Sec.6, Tp.38,R.11	0 - 7	Brown to red-brown loose sand; water at 7 feet.
		7 - 35	Blue-grey sand; possibly Bulwark formation.
27	Lsd.13,Sec.7, Tp.37,R.11	0 - 3	Silty clay with salts.
		3 - 6	Gravel and sand.
		6 - 13	Bedrock, Bearpaw formation; shale, oxidized from 6-foot to 10-foot levels.
28	Lsd.4,Sec.6, Tp.38,R.11	0 - 3	Light-brown sand.
		3 - 8	Bedrock, Bulwark formation; unconsolidated brown to grey sand.
29	Lsd.9,Sec.6, Tp.38,R.11	0 - 15	Brown sandy clay till.
		15 - ?	Bedrock, Bulwark formation; blue-grey sandstone.
30	Lsd.16,Sec.34, Tp.37,R.11	0 - 2	Clay and silt.
		2 - 4	Brown sandy clay till.
		4 - 4.6	Brown and coarse sand.
		4.6 - 7	Brown till.
		7 - 12	Grey till.
		12 - 16	Coarse grey sand.
		16 - 40	Bedrock, Bearpaw formation; blue-grey fine sand.
31	Lsd.8,Sec.22, Tp.35,R.10	0 - 2	Light-brown sand.
		2 - 16	Brown sandy till.
		16 - 30	Grey clayey till; few stones.
		30 - ?	Bedrock, Bearpaw formation.
32	Lsd.8,Sec.27, Tp.35,R.10	0 - 2	Light-brown sandy till; full of salts.
		2 - 8	Brown sandy till; numerous stones.

Drill hole No.	Location	Depth, feet	Description of material
33	Lsd.12,Sec.2, Tp.38,R.9	0 - 1.5	Light-brown loose sand.
		1.5- 4	Light-brown sandy till.
		4 - 25	Brown sand; loose (unconsolidated sandstone).
		25 - 35	Dark brown sandy clay; partly consolidated.
34	Lsd.12,Sec.1, Tp.38,R.8	0 - 33	Brown sand; variable in texture from coarse to fine.
35	Lsd.7,Sec.4, Tp.38,R.8	0 - 6	Yellow to brown fine sand; loose, few stones.
		6 - 35	Green-brown sand; no stones.
36	100 yards south of No. 35	0 - 15	Yellow-brown sand.
		15 - 40	Grey-brown silt; a few ironstone nodules.
		40 - 45	Grey clay; possibly Bearpaw formation.
37	Lsd.7,Sec.3, Tp.39,R.9	0 - 10	Bedrock, Bearpaw formation; grey-brown massive sandy clay.
38	Lsd.5,Sec.1, Tp.38,R.9 (on top of a hill)	0 - 4	Light yellow-brown silty sand; loose.
		4 - 10	Grey-brown to brown silty till; loose.
		10 - 37	Light-grey to grey-brown coarse sand; loose, with clayey lenses.
		37 - 40	Grey-brown till.
		40 - 45	Grey sandy and clayey till.
39	Lsd.5,Sec.1, Tp.38,R.9 (100 feet north of No. 38, in valley)	0 - 4	Grey-brown to grey fine sandy clay; loose.
		4 - 8	Grey-brown to yellow-brown sand; loose.
		8 - 40	Grey-brown sandy to clayey till; contains sand lenses.
		40 - ?	Grey-brown to grey silty till.
40	Lsd.12,Sec.14, Tp.37,R.9	0 - 8	Grey-brown to brown, sandy to clayey till.
		8 - 18	Bedrock, Bearpaw formation; grey-brown to grey bentonitic shale.
41	Lsd.8,Sec.26, Tp.37,R.9	0 - 3	Light-brown sandy clay to clay.
		3 - 8	Light-brown to brown sandy till; wet.
		8 - 25	Grey sandy till; wet.
		25 - 30	Quicksand in grey till.

Drill hole No.	Location	Depth, feet	Description of material
42	Lsd.15,Sec.35, Tp.37,R.9	0 - 3	Brown bentonitic clay.
		3 - 7	Light-brown to brown sand; few stones.
		7 - 15	Brown sandy till; stones common.
		15 - 17	Medium-grained clayey sand.
		17 - 40	Brown clayey till; stones common; tough.
43	Lsd.4,Sec.31, Tp.37,R.8	0 - 3	Brown clayey till.
		3 - 16	Brown sandy till.
		16	Water-table.
		16 - 22	Brown sandy till.
		22 - 44	Grey sandy till.
		44 - 45	Grey clayey till.
44	Lsd.4,Sec.22, Tp.36,R.11	0 - 12	Brown clayey till; wet at 10-foot depth and sandy at that point.
		12 - 15	Grey clayey till; few stones.
		15 - 18	Bedrock, Edmoton formation; grey-blue medium-grained bentonitic sandstone.
45	Lsd.8,Sec.20, Tp.36,R.11	0 - 12	Brown clayey till; few stones.
		12 - 17	Brown sandy till; wet.
		17 - 40	Grey sandy till; coarse; water-saturated.
46	Lsd.10,Sec.19, Tp.36,R.11	0 - 12	Brown clayey till; stones common.
		12 - 17	Bedrock, Edmonton formation; grey medium-grained bentonitic sandstone; some gypsum.
47	Lsd.4,Sec.24, Tp.36,R.10	0 - 10	Bedrock, Bearpaw formation; brown to yellow-brown shale with selenite crystals and iron stainings.
		10 - 13	Bedrock, Bearpaw formation; grey-blue sandy shale.
48	Lsd.3,Sec.7, Tp.38,R.9	0 - 8	Yellow-brown sandy to silty till.
		8 - 11	Brown medium-grained sand.
		11 - 12	Brown clayey till.
		12 - 24	Brown sand.
		24 - 30	Brown clayey till; stones common; contains coal fragments.
		30 - 36	Grey clayey bentonitic till; few stones.
		36 - 38	Clean medium-grained sand; water-saturated.

Drill hole No.	Location	Depth, feet	Description of material
49	Lsd.15,Sec.36, Tp.37,R.8	0 - 3	Clay-poor sand to sandy silt; contains stones.
		3 - 22	Brown clayey till; few stones; water-table at 22 feet.
		22 - 45	Brown clayey till; contains coarse sand lenses; water-saturated.
50	Lsd.1,Sec.1, Tp.35,R.8	0 - 7	Loose brown sand; contains a few stones; reasonably well-sorted.
		7 - 12	Brown sandy till; few stones.
		12 - 17	Bedrock, Bearpaw formation; brown bentonitic shale.
51	Lsd.16,Sec.1, Tp.38,R.8	0 - 2	Yellow sandy till.
		2 - 8	Brown clayey till; few stones.
		8 - 22	Brown sandy till.
		22 - 45	Grey sandy till; few stones.

RESEARCH COUNCIL OF ALBERTA

LEGEND

CENOZOIC

QUATERNARY

RECENT

9	Alluvium and colluvium* (thin over bedrock): sand, silt and clay
8	Alluvial fan: sand, silt and clay, local lenses of gravel

PLEISTOCENE

GLACIO-LACUSTRINE

7	Sand, silt and clay

GLACIO-FLUVIAL

6	Spillway: sand; sand and gravel
5	Outwash (thin over till): mainly sand with some gravel
4	Kame: silt, sand and gravel; inclusions of till

GLACIAL

3	Recessional moraine: mainly till; some surface sand and gravel
2	Ground moraine (thin over bedrock)
1	Ground moraine—till: unsorted clay, silt, sand and boulders; some lenses of sorted sand and gravel

*In part 6 in age

Bedrock outcrop X

Gravel pit .... G.P.

Geology by C. P. Gravenor and L. A. Bayrock

Main highway

Local road, well travelled

Local road, not well travelled

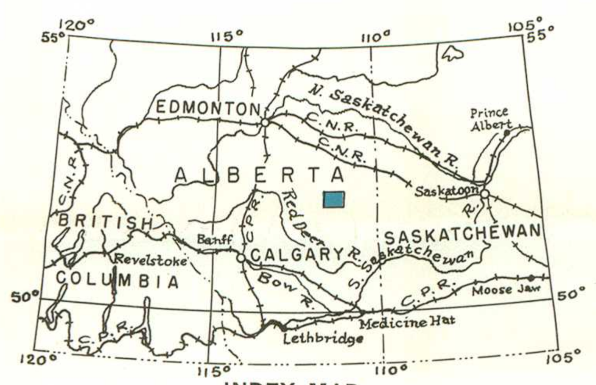
Railway

Township boundary

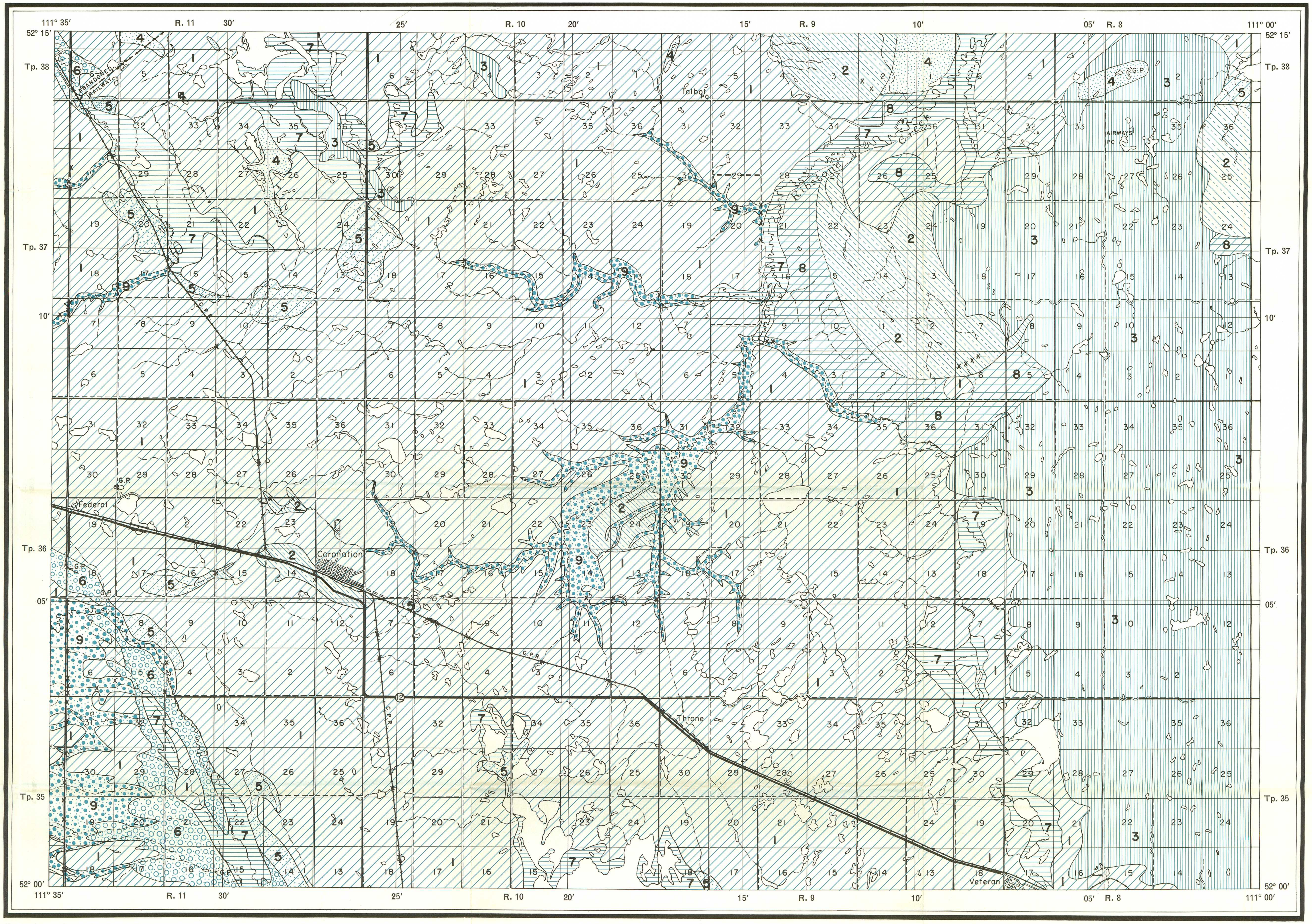
Section line

Post office .... P.O.

Cartography taken from Department of Lands and Forests, Alberta, Aerial Survey Sheet No. 73 D/5 and part of Sheet No. 73 D/4



INDEX MAP



Map to be used in conjunction with Preliminary Report No. 55-1

PRELIMINARY MAP 55-1

GLACIAL GEOLOGY

CORONATION DISTRICT, ALBERTA

WEST OF FOURTH MERIDIAN

Scale: One Inch to One Mile = 1/63,360

Miles

Published in 1955