SASKATCHEWAN RESEARCH COUNCIL

GEOLOGY DIVISION

REPORT No. 2

GEOLOGY and GROUND-WATER RESOURCES

of the

REGINA AREA SASKATCHEWAN

by

E. A. Christiansen

1961

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ABSTRACT

The Regina area (72-I), which comprises 5800 square miles, lies between 104°00′ and 106°00′ West Longitude and between 50°00′ and 51°00′ North Latitude in southeastern Saskatchewan. The average annual precipitation and temperature are about 15 inches and 35°F respectively. The Zonal Soils are Brown, Dark Brown, and Black.

The surficial sediment is mainly till, lacustrine silt and clay, and fluvial sand and gravel. The thickness of the drift ranges from a few feet on bedrock interfluvial areas to about 500 feet in the deeper bedrock valleys. During the Condiean Episode of glaciation in the Regina area, Condie Till was deposited at and north of the Condie Moraine, and Regina Clay was deposited south of and in the Qu'Appelle Valley. The advance of the Condiean Glacier was radiocarbondated at 10,150 ± 200 years B.P. which suggests that it is correlative with the Valderan. The base level of the Condiean Qu'Appelle Valley is about 100 feet above the base level of the pre-Condiean Qu'Appelle Valley. The drift is underlain by the Upper Cretaceous "Marine Shales", Bearpaw, Eastend, Whitemud, and Lower Ravenscrag Formations. The bedrock is exposed in the Qu'Appelle Valley and in the Missouri Coteau Escarpment. The topography of the bedrock surface shows an east-west trending, ice-marginal drainage pattern superposed upon a north-south trending, dendritic, preglacial drainage pattern. Bedrock exposures and slumped areas occur where the ice-marginal valleys have been cut into the preglacial interfluvial areas.

The two tills present in the Regina area are calcareous, generally oxidized but locally unoxidized. The Condie till, which contains two exposures of Waskana Creek Ash, is slightly more sandy and less clayey than the underlying till. The texture of the tills ranges from sandy clay loam to clay. The clay mineral content of the bedrock shales is essentially montmorillonitic but includes minor amounts of illite. In addition to these minerals, the till comprises minor amounts of kaolinite.

Slightly to highly mineralized water occurs in the Qu'Appelle Valley fill, in the Thunder Creek Valley fill, in surficial sands and gravels, in meltwater channels, in end moraines and in associated deltaic and outwash aprons, in sand and gravel lenses in till, in intertill sands and gravels, in buried bedrock valleys, and in the Eastend and Lower Ravenscrag Formations. Gravel occurs in fluvio-lacustrine plains, in valley bottoms (particularly on the inside of meanders), in interlobate areas which are well defined by V-shaped re-entrants in the washboard moraines, in kames, in eroded till plains, and in end moraines. Much of the gravel was derived from till which was eroded by meltwater.

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Location

The Regina area (72-I), which comprises 5800 square miles, lies between 104° and 106° West Longitude and between 50° and 51° North Latitude (Fig. 1). The cities of Regina and Moose Jaw lie within the area, the former being about 27 miles west of the east boundary and the latter about 20 miles east of the west boundary. The southern boundary of the area is approximately 70 miles north of the International Boundary between Saskatchewan and Montana. All of the ranges are west of the Second Meridian.

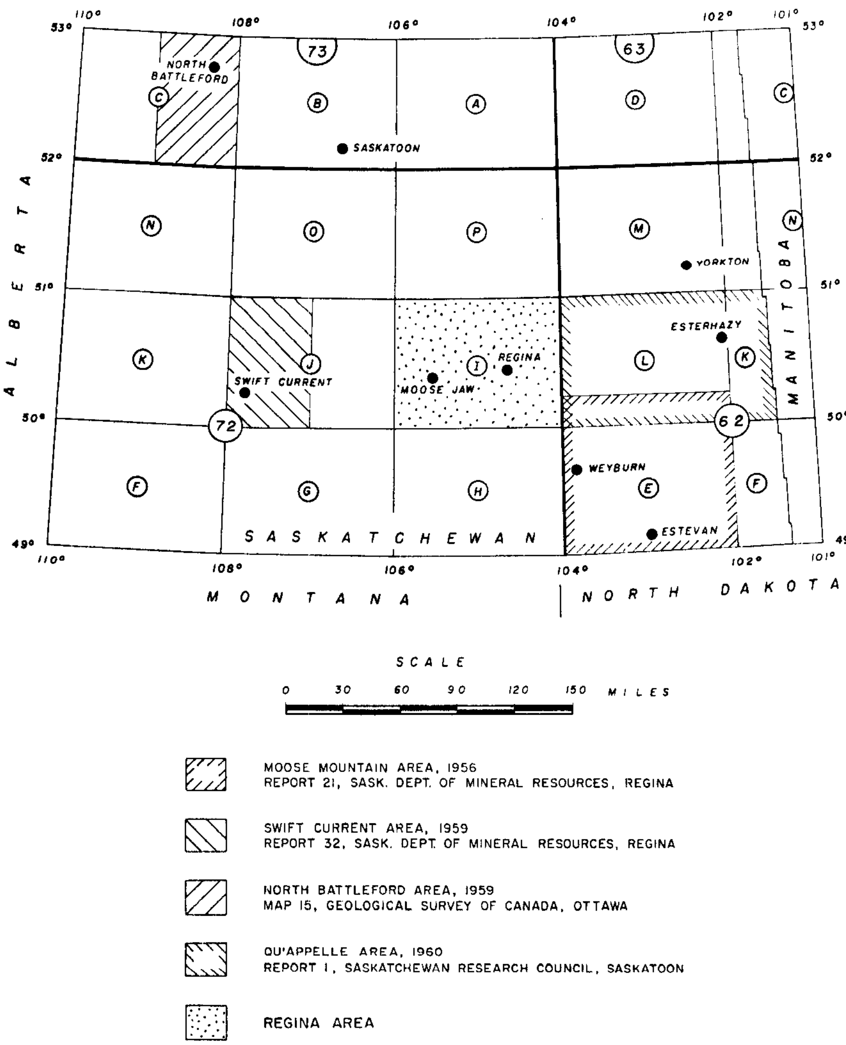


Figure 1.—Location of the Regina area

Previous Work

Fraser *et al.* (1935), in their study of the geology of southern Saskatchewan, mapped the bedrock geology of the Regina area on a scale of 1 inch to 8 miles. Stansfield (1918 and 1919), in his studies of surficial deposits of southeastern Saskatchewan, briefly described the soils and ground-water resources of the Regina area. Johnston and Wickenden (1930 and 1931) described the major land forms of the Regina area. Johnston *et al.* (1948) published a preliminary map of the surficial deposits in southern Saskatchewan west of the Second Meridian on a scale of 1 inch to 6 miles. Kupsch and Wild (1958) described surface lineaments in the Avonlea area which they interpreted as the surface expression of faults. Byers (1959) mapped in detail the structures exposed in the Dirt Hills near Claybank.

Mitchell *et al.* (1947) published a soil map of southern Saskatchewan on a scale of 1 inch to 6 miles. A recently compiled, unpublished map of the Regina area was made available to the writer by the Saskatchewan Soil Survey. Because the surficial geology can be interpreted, to a large degree, directly from these soil maps, they have greatly facilitated the study of surficial deposits in the Regina area.

Present Studies

The present report is based on field and laboratory work and on test drilling conducted in 1959 and 1960. Before beginning the field work, contacts of the surficial sediments, as interpreted from the soil maps and aerial photographs, were plotted on topographic sheets. With the aid of the preliminary maps and with further study of the aerial photographs, the land forms were classified. The preliminary interpretation was then checked and amplified in the field at which time the stratigraphy was studied and the test-drilling program carried out. The geology of the Regina area is shown in Plate 1.

A preliminary bedrock surface topographic map was compiled for the Regina area. This map is based on a study of subsurface data available at the Department of Mineral Resources, on Water Supply Papers, and on field geology (Plate 2).

The preliminary ground-water studies are based on Geological Survey of Canada Water Supply Papers (Table 2), seismic test-hole logs, structural test-hole logs, limited resistivity surveys, seismic refraction data, test drilling, and field geology. These data are interpreted and presented as a ground-water probability map (Plate 3).

Mapping was done on a base map compiled by the Canada Surveys and Mapping Branch on a scale of 1:125,000. Field work was done on 1:40,000 and 1:50,000 sheets. Aerial photographs were obtained from the Royal Canadian Air Force. Quadrangle mosaics on a scale of 1 inch to 1 mile and 1 inch to ½ mile were borrowed from the University of Saskatchewan Departments of Geology and Soil Science respectively. Figure 2 shows subdivisions according to the National Topographic system.

Acknowledgments

The manuscript was read critically by Professor W. O. Kupsch, Geology Department, University of Saskatchewan. The sections on ground-water and soils were read critically by Professor F. H. Edmunds, Geology Department, University of Saskatchewan and Mr. J. S. Clayton, Saskatchewan Soils Survey, respectively.

The author is grateful to Mr. H. W. Leggett, Superintendent, Dominion Experimental Farm, Regina, for providing excellent office and dormitory facilities. Mr. A. Lissey, City Engineering Department, Regina, provided subsurface data for which the writer wishes to record his thanks.

Drafting was done by the Saskatchewan Department of Mineral Resources, Regina. Mr. H. B. Sawatzky of that department determined the drift-bedrock contact on electric logs from structural test-holes. Their generous co-operation is gratefully acknowledged.

The writer was assisted in the field by Messrs. J. D. Chapman, P. P. David, J. G. Greer, and W. C. Ross. Mr. Ross also assisted in the laboratory studies. Resistivity and seismic refraction data were provided by the Physics Division, Saskatchewan Research Council.

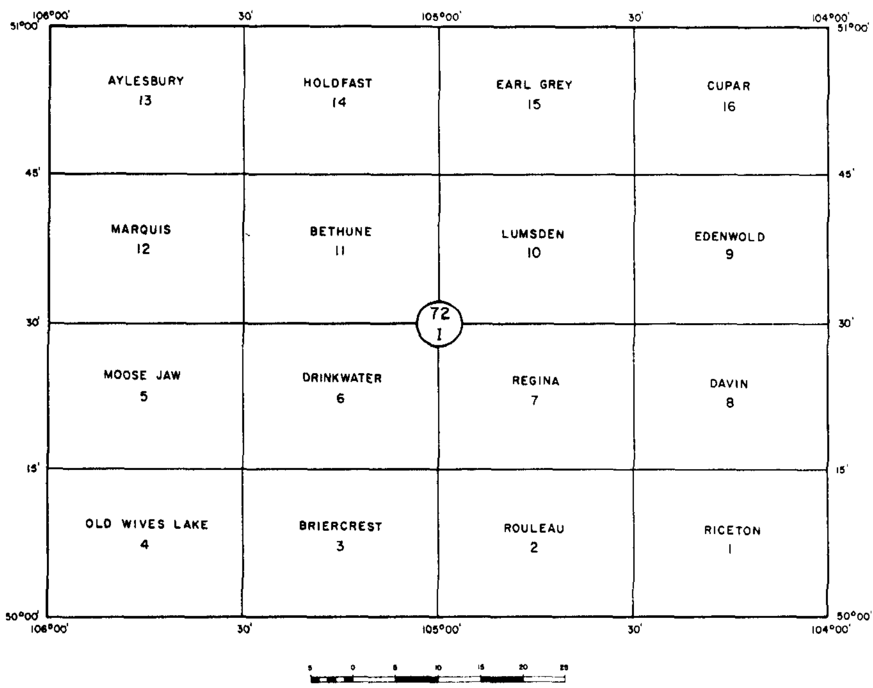


Figure 2.—Subdivisions of the Regina area according to the National Topographic System

PHYSIOGRAPHY

Climate

The precipitation recorded at the Regina Meteorological Station is shown graphically in Figure 3. The annual precipitation ranges from 6.26 to 23.73 inches or a total variation of 17.47 inches which is greater than the mean of 14.82 inches. The monthly precipitation ranges from a trace to 8.15 inches, the highest precipitation being in May, June, and July. Normally more than one half of the precipitation occurs during May, June, July, and August. This distribution of precipitation is not conducive to recharge of aquifers because the highest transpiration rates occur during the months of highest precipitation. The annual precipitation varies as much as 14 inches between successive years; consequently, it is difficult to forecast rainfall from one year to the next.

Based on records from 1884 to 1959, the mean annual temperature at the Regina Meteorological Station is 34.8°F. The recorded extremes of temperature are 110°F and –56°F. The coldest month on the average is January when the mean monthly temperature is –0.5°F., and the warmest month is July when the average monthly temperature is 65.3°F. The average temperature is below freezing from November to March inclusive. Because of the high transpiration during May, June, July, and August and the frozen condition of the soil during November, December, January, February, and March, the months of April, September, and October are the best months for ground-water recharge.

According to Currie (1954), the prevailing wind at Qu'Appelle is from the northwest during all months of the year.

Soils

The dominant soils in the Regina area are the Brown, Dark Brown, Black, Chernozemic, and Solonetzic Zonal types. The Soil Association or Catena is the fundamental mapping unit in the classification of Saskatchewan Soils. The Catena is defined as a group of closely associated Soil Series found in a recurring pattern within a natural soil land form and developed on a specific parent material. With the exception of recent alluvial deposits and bedrock exposures in escarpments and valley walls, the soils are developed on drift, dominantly till, lacustrine, and fluvial deposits.

The Ardill, Amulet, Claybank, Edgely, Oxbow, and Trossachs Catenas are developed on till; and the Asquith, Balcarres, Biggar, Blaine Lake, Bradwell, Chaplin, Cudworth, Elstow, Hatton, Meota, Regina, Sceptre, Tuxford, and Whitesand Catenas on fluvio-lacustrine deposits.

Because the Soil Catenas are based on parent material (surficial deposits), it is possible for the geologist to interpret the surficial sediment directly from the soil map. This is particularly true in Saskatchewan where the soils closely resemble the sediment upon which they are developed.

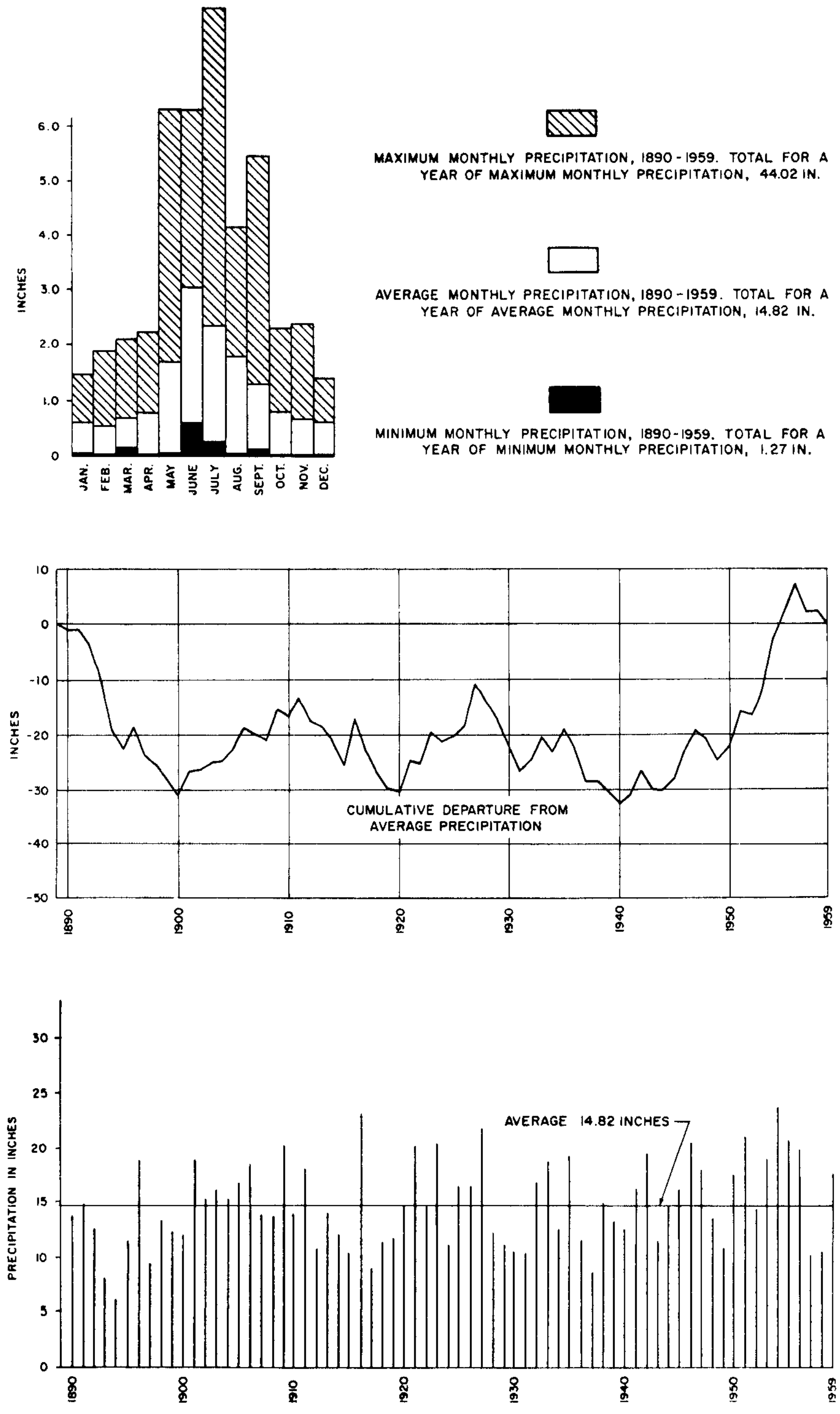
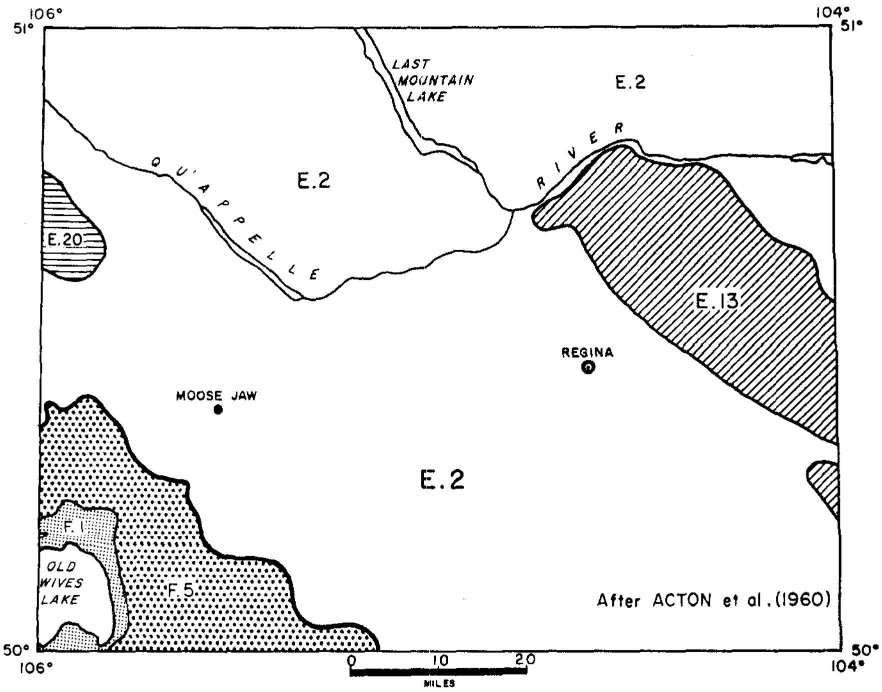


Figure 3.—Precipitation records. Regina Meteorological Station (1890-1959)

Acton *et al.* (1960), in their map on the Physiographic Divisions of Saskatchewan, have divided the Regina area into two physiographic regions: Saskatchewan Plains and Alberta High Plains (Fig. 4). They subdivided the Saskatchewan Plains into Assiniboine River Plain, Moose Mountain Hills Upland, and Eyebrow Hills Upland; and the Alberta



E. SASKATCHEWAN PLAINS

E.2 ASSINIBOINE RIVER PLAIN
E.13 MOOSE MOUNTAIN HILLS UPLAND
E.20 EYEBROW HILLS UPLAND

F. ALBERTA HIGH PLAINS

F.1 OLD WIVES LAKE PLAIN
F.5 MISSOURI COTEAU UPLAND

Figure 4.—Physiographic Divisions of the Regina area

High Plains into Old Wives Lake Plain and Missouri Coteau Upland. The Missouri Coteau Escarpment is the boundary between the Saskatchewan Plains to the northeast and the Alberta High Plains to the southwest.

The Old Wives Lake Plain is in the southwestern portion of the Regina area. The topography is undulating to gently rolling and has a total relief of about 400 feet. The Missouri Coteau Upland lies between the Old Wives Lake Plain to the southwest and the Assiniboine River Plain to the northeast. The topography is gently to strongly rolling and has a total relief of about 800 feet. The northeast facing Missouri Coteau Escarpment forms the boundary between the Missouri Coteau Upland

and the Assiniboine River Plain. There is generally an abrupt rise of up to 600 feet from the plain to the upland of the Coteau, but in places there are large re-entrants which have more gradual slopes.

The broad, relatively flat Assiniboine River Plain forms the lowland in the Regina area. Except for the Qu'Appelle and Arm River Valleys, which are deeply entrenched 100 to 300 feet into the plain, the topography is for the most part gently undulating and has a local relief which generally does not exceeed 10 feet. The Moose Mountain Hills Upland projects northwestward into the Assiniboine River Plain from the southeast. The broad, northwesterly trending upland rises up to 300 feet above the surrounding plain. The low, relatively narrow Eyebrow Hills Upland projects eastward for about 10 miles from the west boundary of the Regina area. The Eyebrow Hills Upland rises only about 25 feet above the surrounding Assiniboine River Plain in the Regina area. To the west, however, the upland is much more prominent.

Drainage

Streams in the southwestern portion of the region drain into Old Wives Lake (T. 13, R. 30) which has no visible outlet. The remainder of the area drains into the Qu'Appelle River which in turn drains into Lake Winnipeg by way of the Assiniboine and Red Rivers.

GEOMORPHOLOGY

Glacial Land Forms

Ground Moraine

The topography of the ground moraine is undulating to gently rolling and has a relief of 5 to 30 feet, commonly less than 10 feet. Most of the ground moraine landscape is comprised of flat till plains. A land form, which comprises the transition between till plains and hummocky moraine, is included in the ground moraine. The ground moraine is traversed by many small, shallow meltwater channels which, in most places, show a lobate pattern. The sediment in the ground moraine is comprised essentially of till but includes minor amounts of sand and gravel in the form of lenses, small outwash plains, and ice-contact deposits. In places the ground moraine is covered by lacustrine silts and clays which are not sufficiently extensive to be shown on the map.

It is believed that the relief in till areas is mainly a function of the amount of englacial and superglacial material. If this is true, then the till plains resulted from the deposition of small amounts of englacial and little or no superglacial material whereas the more hummocky areas resulted from large amounts of englacial and superglacial material.

Hummocky Moraine

The topography is rolling to strongly rolling and has a relief of 20 to 40 feet. The landscape is characterized by till knobs, kames, kettles, rimmed kettles, moraine plateaus, and small, rimmed depressions which contain lacustrine silt and clay. The sediment is essentially till but includes sand and gravel in the form of kames and lenses. Lacustrine clay occurs in rimmed depressions and on moraine plateaus.

End Moraines

The Davin Moraine, Moose Jaw Moraine, Condie Moraine, and Rocky Lake Moraine are the four major end moraines in the Regina area. The Davin Moraine is a complex of kames, washboard moraines, and outwash plains whereas the other three moraines are ridge-like.

The Davin Moraine is about 12 miles east of Regina and trends in a southeasterly direction from Pilot Butte (T. 17, R. 18, Plate 1) to the eastern edge of the Regina area (Township 15) where its northeast boundary is the Manybone Creek Channel. The moraine ranges in width from 2 to 5 miles and is about 23 miles long. The Davin morainal complex is composed of sand and gravel in the form of kames and outwash plains and till in the form of washboard moraines and undulating to rolling areas. The Davin Moraine is truncated at Pilot Butte by the east-west trending Condie Moraine.

The Moose Jaw Moraine is about 7 miles southwest of Moose Jaw. The moraine forms a prominent ridge 16 miles long, ½ to 2 miles wide, and 15 to 100 feet high. The sediment in the moraine is composed of ice-contact sand and gravel in the form of kames, sand lenses, and till. Ice-contact gravel is exposed in Sections 10, 17 and 18, Township 16, Range 27. The eastern portion of the moraine is covered by aeolian sand which has been derived from the moraine.

The Condie Moraine, which marks the margin of the Condie till, is best developed 1½ miles south of Condie (T. 18, R. 20) where it forms a distinct ridge which can be seen for many miles. Throughout the Lake Regina Basin, the Condie Moraine is a well-defined ridge which ranges in height from 100 feet at Condie to a broad, gently sloping ridge 20 feet high at Keystone (T. 17, R. 23). Where the Condie Moraine lies outside of the lake basin, however, the prominent ridge grades into a washboard-moraine complex. The fact that the moraine is so well developed in the lake basin suggests that calving of the ice front may have been instrumental in the formation of the wall-like end moraine.

Where the Condie Moraine is represented by a complex of washboard moraines, the sediment is essentially till; where the moraine is represented by a ridge, however, the sediment is essentially ice-contact sand and gravel (S. 19, T. 18, R. 20; S. 23, T. 18, R. 21; S. 24, T. 18, R. 24; and S. 3, T. 22, R. 27). In the Pilot Butte area (T. 17, R. 18) the Condie Moraine is composed of ice-contact sand and gravel in the form of a rolling plain. Where the Condie Moraine lies in the Lake Regina Basin below an elevation of 2000 feet, the moraine was inundated by Lake Regina and is covered by Regina Clay.

The Rocky Lake Moraine is about 1 mile north of Rocky Lake (T. 19, R. 23). It is about 7 miles long, ½ mile wide, and 30 to 40 feet high. The moraine has an east-west trend, being approximately parallel to the Qu'Appelle Valley and to Rocky Lake which lies in an ice-marginal spillway in front of the moraine. Shallow exposures suggest that the sediment in the moraine is till and stratified drift of ice-contact origin. The moraine in Township 21, Range 19 is believed to be correlative with the Rocky Lake Moraine.

Washboard Moraine

Washboard moraine is very common in the Regina area, particularly north of the Condie Moraine. Although the areal pattern of washboard moraine is not apparent in the field, it is clearly apparent in aerial photographs, particularly in photo mosaics. The pattern is formed by a sequence of sub-parallel, generally arcuate swells and swales. The ridges or swells rise from 5 to 30 feet above the adjacent swales. In the Last Mountain Lake area there is a poorly developed set of till ridges which trend to about 90° to the washboard moraines. In this area the pattern is similar to that of crevasse fillings; however, because the best developed trend is parallel to ice-marginal channels (Arm River Channel), this land form has been mapped as washboard moraine. The sediment is mainly till but may include lenses of sand and gravel. In the Lake Regina Basin, the washboard moraine is covered with Regina Clay.

Gravenor and Kupsch (1959) concluded that both washboard moraines and crevasse fillings are related to failure zones in ice and that the ridges were formed by accelerated melting in these failure zones.

Push Moraine

The term push moraine is here used to describe a sequence of sub-parallel, generally arcuate swells and swales which have a relief of 30 to 200 feet and a width of about 1000 feet. This land form is externally similar to the washboard moraine except that the push moraine swells and swales are much larger. Hummocky moraine, which has a local relief of up to 30 feet, is draped over the push moraine. The sediment is mainly till and bedrock but includes minor amounts of sand and gravel.

In the Missouri Coteau Escarpment at Claybank (T. 12, R. 24), where the push moraine ridges intersect the escarpment, detailed structural analyses by Byers (1959) show that the bedrock is isoclinally folded and thrust faulted into a series of sub-parallel, overturned folds and thrust blocks. He concluded that the structures were produced by subglacial drag of a Pleistocene ice sheet.

Flutings

Flutings in the Regina area are discernible in aerial photographs but are difficult to see in the field. In aerial photographs they appear as a field of narrow, straight, parallel ridges and grooves. The ridges are 3 to 10 feet high, up to 7 miles long, and 200 to 300 feet wide. In the Lake Regina Basin the flutings are masked by Regina Clay. The sediment in the ridges is mainly till. The ridges trend parallel to the direction of ice movement.

Kames, Kame Moraine, and Kame-Eskerine Complexes

Ice-contact sands and gravels occur in the form of kames, kame moraine, and kame-eskerine complexes. Kames and kame moraine are common in end moraines of the Regina area. An extensive kame-eskerine complex lies in the re-entrant area near Earl Grey (T. 23, R. 20). Shallow exposures show the sediment to be mainly stratified, typically contorted, and heterogeneous in composition.

PROGLACIAL LAND FORMS

Glacial Lake Basins

General Remarks.—Lake Regina Basin, Lake Cupar Basin, and Lake Dysart Basin are the major glacial lake basins in the Regina area. Glacial Lakes Regina and Cupar were formed where the glacier provided the necessary closure to the north and west respectively. Because evidence of former strandlines is scarce and because lacustrine sediments are not deposited on the shores of these lakes, the glacial lake boundaries are determined largely from the elevation of drainage outlets.

Lake Regina Basin.—Although the Lake Regina Basin was recognized by members of the Saskatchewan Soil Survey and others prior to 1930, the lake basin was named by Johnston and Wickenden (1930) who described the basin in some detail. Low, poorly-developed sand beaches (T. 17, R. 17 and 18 and T. 16, R. 17) and a wave-cut cliff (T. 13, R. 15 and 16) mark the main level of Glacial Lake Regina. This level was governed by the Souris Spillway (1900 feet). Lacustrine sand, silt, and clay, which occur at a higher elevation and to the northeast of the above mentioned strandline (Plate 1), indicate that Glacial Lake Regina was somewhat higher prior to seeking its main level. The fact that these lacustrine sediments are restricted to the region south of the Condie Moraine suggests that the weight of the Condiean Glacier suppressed the ground sufficiently to cause the lake to be originally at this higher level. On melting of the ice rebound took place and forced the shoreline to regress to the lower, main level. The exact amount of regression is difficult to determine because distinctive strandline features were not formed in this area to indicate the maximum level of Lake Regina.

The glacier formed the topographic closure for Lake Regina to the north. The final outlet, which eventually drained Lake Regina, is in Township 21, Range 19. The field evidence shows clearly that the maximum elevation of this spillway is at 2000 feet, or 100 feet higher than the Souris outlet. Because Lake Regina could not spill out through the Qu'Appelle Spillway until the glacier uncovered an outlet either at the same elevation or lower than the Souris outlet, it is concluded that differential uplift has taken place after the drainage of Lake Regina, the northern part being uplifted 100 feet more than the southern part. This differential uplift has resulted in a gradient of about 1 foot per mile. Johnston and Wickenden (1930) observed this relationship and concluded that differential uplift has taken place.

The topography is flat to rolling and has a relief of 3 to 30 feet, commonly less than 5 feet. The surficial sediment is mainly clay which becomes silty and sandy near shore, particularly in the delta areas. The Regina Clay, which forms the surficial sediment for most of the basin, is up to 40 feet thick (T. 16, R. 19) but is commonly less than 20 feet thick (Fig. 13). In the Moose Jaw area (T. 16, R. 26) 30 feet of silt underlies the surficial clay.

Lake Cupar Basin.—The strandline of Lake Cupar, as suggested by the boundary between lacustrine sediments and till, ranges from 1850 to 1950 feet in the proglacial part of the lake. On the western side, where the lake was in contact with the retreating ice, the boundary between the lacustrine sediment and till is as low as 1825 feet. The fact that the lake strandline in the proglacial part of Lake Cupar Basin has a relief of about 100 feet suggests that this strandline was partly in contact with dead-ice. Dead-ice features in the lake basin, particularly near shore (S. 2, T. 22, R. 16) and in the surrounding till areas, suggests that Lake Cupar was on, and in contact with, dead-ice in many places in the basin.

The outlet for Lake Cupar was through the Loon Creek Spillway which must have been cut initially into dead-ice in order to account for lake sediments at an elevation of 1950 feet. If this is true, then there must have been at least 50 feet of dead-ice in the outlet area which now has a maximum elevation of about 1900 feet.

The topography of Lake Cupar Basin is flat to undulating and has a relief which commonly does not exceed 5 to 10 feet. The sediment is a silty clay which grades into a sand in the western portion of the basin. The lacustrine deposit is thin, commonly less than 5 feet thick. On topographically high areas the lacustrine sediment has been removed by erosion which has exposed the underlying till.

The thinness of the lacustrine sediments suggests a short duration for Lake Cupar. The duration of the lake was dependent upon the rate of downcutting of the dead-ice dam which would offer only temporary closure once it was overtopped by meltwater from Lake Cupar.

Lake Dysart Basin.—Although the Lake Dysart Basin is relatively small in areal extent, its origin is of particular importance because many small basins of this type, which are not mappable, occur in the ground moraine of the northeastern quarter of the Regina Area.

Lake Dysart Basin has an area of about 4 square miles and is completely enclosed by a ridge 5 to 10 feet high. In the southwest ¼ of Section 3, Township 23, Range 15 in a road cut along Highway 22, the ridge is composed of till and poorly sorted sand and gravel. The lake basin is surrounded by dead-ice moraine and does not have a visible outlet.

Hoppe (1952) and Stalker (1960) draw attention to the ridges which surround dead-ice hollows, and the former has named these features moraine ridges. Because the Lake Dysart Basin is not believed to be a "dead-ice hollow", the term rimmed depression is here used. This term draws attention to the depression as well as the rim which surrounds it.

The fact that the rim slopes more gently toward the depression than away from it suggests that the ice was in contact with the outside of the ridge. The gradational change in texture from clay in the center of the depression to sand near the ridge indicates that the source of the sediment was from the vicinity of the rim. Finally, the fact that the lacustrine sediments within the basin do not show collapse structures indicates that these sediments were deposited upon an ice-free surface. These observations suggest that Lake Dysart was surrounded by dead-ice which was the source of the lacustrine sediment and which either squeezed up the rim-ridge from underneath or dropped it by sliding off the ice as it melted.

Fluvio-Lacustrine Plains

Because it cannot be determined whether the sands and gravels which lie within the Lake Regina and Old Wives Basins are lacustrine, fluvial, or a combination of both, these parts of the lake basins are considered as fluvio-lacustrine plains. Much of the sediment is in the form of dunes and cover sand. Because the source material of these aeolian deposits is fluvio-lacustrine, the aeolian sediments are included in this land form. Although some of the sand and gravel areas are known to be outwash, they are included in the fluvio-lacustrine plains.

The topography is flat to undulating and has a local relief of 5 to 10 feet. Locally, where sand dunes are well developed, the relief may be as high as 25 feet. The sediment, which ranges in thickness from 5 to 20 feet, consists essentially of sands and gravels which are differentiated on the map. The sand and gravel areas southwest of Aylesbury (T. 22, R. 28), north of Keystone (T. 18, R. 23), west of Caron (T. 17, R. 29), along the northeast shore of the Lake Regina Basin, south of Lillestrom (T. 15, R. 29), around Old Wives Lake, and south of Regina Beach (T. 21, R. 22) constitute the major fluvio-lacustrine sand and gravel accumulations in the Regina area.

The sand and gravel area south of Aylesbury lies within the Lake Regina Basin. It is not known whether fluvial sedimentation continued after Lake Regina was drained. The occurrence of well-developed fans (T. 22, R. 28) suggests that stream deposition did take place in post-Lake Regina time. There are two main gravel areas within this region; one has the form of coalescing fans at the mouths of meltwater channels (T. 22, R. 28), and the other forms a delta-outwash apron in front of the Condie Moraine (T. 21, R. 27). In both places the sediment becomes coarser as the source area is approached from the lake basin. Shallow gravel pits show that the sand and gravel is at least 10 feet thick and is probably up to 20 feet thick in places. In the area between the gravel localities the lacustrine silt and clay is covered by 1 to 4 feet of aeolian cover sand. In Section 3, Township 22, Range 28 about 2 feet of cover sand overlies the lacustrine silt. A buried "A horizon" at a depth of about 1 foot suggests that at least two episodes of aeolian activity occurred.

The sand and gravel fan north of Keystone (T. 18, R. 23) has its apex at the confluence of the Qu'Appelle and Moose Jaw Creek Valleys. The surficial sediment is essentially aeolian sand and fluvial gravel. The gravel is at least 12 feet thick. The aeolian, fine-grained cover sand, which overlies lacustrine silt and clay, ranges in thickness from 1 to 7 feet.

The fluvio-lacustrine plain west of Caron (T. 17, R. 29) is part of a fluvio-lacustrine fan which extends beyond the Regina area. The topography is flat to rolling. The relief ranges from 5 to 10 feet, except where sand has been aggregated into dunes up to 30 feet high. The original sediment is sand and fine gravel which has been blown into dunes in the western part of the area and into cover sand in the northeastern part. Although the exact thickness is not known, the sediment is believed to be less than 15 feet thick.

The fluvio-lacustrine plains east of Regina are associated with the Davin Moraine, Condie Moraine, and Lake Regina Basin. The fluvio-lacustrine plain associated with the Davin Moraine is composed of fluvial sand and gravel in part covered by fine-grained, aeolian sand. The sediment is up to 30 feet thick in topographically low areas but is commonly less than 10 feet thick. The topography is undulating to rolling.

The fluvio-lacustrine plain associated with the Condie Moraine is a complex of ice-contact and outwash sand and gravel which is up to 50 feet thick (S. 8 and 9, T. 18, R. 18). The topography is rolling and typical of a morainic landscape.

In the northeastern portion of the Lake Regina Basin between its contact with the Davin Moraine and the strandline in the basin (Plate 1), a fluvio-lacustrine plain represents the sandy, shore facies of the Regina Clay. The surface is flat to undulating. The sediment, which covers the underlying lacustrine silt and clay, is essentially fine-grained, aeolian sand. In the northeast corner of Section 15, Township 17, Range 18, fine-grained, aeolian sand, 4 feet thick, overlies the lacustrine deposits. This fine-grained sand contains a buried "A horizon" at a depth of 2 feet.

The fluvio-lacustrine plain near Lillestrom (T. 15, R. 29) is a mixture of ice-contact and outwash deposits. The topography is undulating to rolling and has a relief of about 10 to 30 feet. The branching pattern of the ice-contact features is better developed in the northern part of the deposit. The texture also becomes coarser as the deposit is traversed from south to north. These relationships of texture and form suggest that the ice front, from which the sands and gravels were derived, was to the north. The exact thickness of the deposit is not known, but a gravel pit in Section 35, Township 14, Range 29 shows that the sediment is at least 10 feet thick.

Old Wives Lake is enclosed by sand and gravel of fluvio-lacustrine origin. The topography is undulating and has a relief which commonly does not exceed 10 feet. Much of the deposit is in the form of raised beaches which surround Old Wives Lake. An exposure in a gravel pit near the southeast corner of Section 24, Township 12, Range 30 (Section 9, Appendix) shows that the sands and gravels are at least 8 feet thick. A buried soil in this section indicates that there have been at least two episodes of fluvio-lacustrine sedimentation.

The fluvio-lacustrine plain south of Regina Beach (T. 21, R. 22) is an outwash plain which takes the form of a fan. The topography is undulating and has a relief which commonly does not exceed 10 feet. The sediment is mainly sand and gravel which is at least 10 feet thick as shown in gravel pits. This outwash fan was deposited by the Arm River when it flowed on its high-level terrace.

Eroded Till Plains

The term "eroded till plains" is here used to describe plains which have been carved out of till by meltwater flow. Because the meltwater streams were essentially erosional in character, they removed the sediment which they were competent to carry and left behind the coarser fraction as a lag deposit.

The topography is flat to undulating and has a relief which ranges from 5 to 10 feet. The sediment is commonly less than 5 feet thick and is composed of boulders, cobbles, pebbles, and sand. In areas favorable for deposition, however, such as the inside of meanders and on the downside part of islands in the meltwater channels, sand and gravel deposits up to 15 feet thick may occur.

Meltwater Channels

The term "meltwater channel" is here used to describe any channel that carried meltwater from the glacier. These channels may have carried meltwater under the ice, on top of the ice, parallel to, and away from the ice. Meltwater channels range in size from broad, shallow runways 10 feet deep and 1000 feet wide to deep trenches 150 feet deep and 3000 feet wide. The larger ones are outlined on the map whereas the smaller ones are indicated by a line.

Outwash sands and gravels in meltwater channels occur in terraces, in slip-off slopes on meanders, and under recent clays in the channel bottom. Till, colluvium, alluvium, and bedrock clays also occur in the meltwater channels.

A large number of meltwater channels such as Manybone Creek Channel and Arm River Channel are parallel to the washboard moraines, and like these mark successive positions of the retreating ice front.

Spillways

Channels which were formed as drainage outlets of glacial lakes are here called "spillways". Although there are numerous spillways in the Regina area, only the Qu'Appelle Spillway is described. The Qu'Appelle Spillway was the lower outlet of Lake Regina. The valley is about 200 feet deep, and the valley bottom is up to 1 mile wide. The Qu'Appelle Spillway includes the deeply eroded Qu'Appelle Valley, the eroded till plains and outwash plains that flank the valley discontinuously on both sides, eroded valley walls composed of till and bedrock, two sets of terraces along the valley walls, and an alluvial valley bottom.

Terraces

The Echo Lake and Tantallon Terraces of Christiansen (1960) have been correlated from the eastern boundary of the Regina area westward to Range 2 West of the Third Meridian (Fig. 5). The Rocky Lake and Arm River Terraces represent major drainage levels in tributaries to the Qu'Appelle Valley. The terrace surfaces are underlain by less than 5 feet of sand and gravel which in turn is underlain by either till or shale of the "Marine Shales" Formation. The Rocky Lake Terrace is correlative with the Echo Lake Terrace in the Qu'Appelle Valley, and the Arm River Terrace is correlative with the Tantallon Terrace. Because these correlations are consistent with the glacial history of the area, the correlations shown in Figure 5 are believed to be valid.

Partly Filled Valleys

Partly filled valleys are recognized in aerial photographs by the alignment of lakes and depressions. Where these features cross the Arm River Valley, a marked thickening in the drift in the valley walls can be observed. It cannot be determined whether they are pre-Condiean valleys covered by Condie Till or stream trenches in the sense of Gravenor and Bayrock (1956) who have demonstrated that some of the partly filled valleys in Alberta were formed contemporaneously with the last glaciation.

Glacial Lake Strandlines

Glacial lake strandlines occur near the northeastern boundary of Lake Regina Basin (T. 17, R. 17 and 18; T. 16, R. 17; and T. 13, R. 15). The strandlines in the first two localities are marked by a low beach of fine-grained sand which is about 100 feet wide and 3 feet high in the northeast corner of Section 21, Township 17, Range 18. Because this poorly-defined ridge of sand is consistent with the elevation of Lake Regina as determined by the drainage outlets, it has been interpreted as a beach ridge of former Lake Regina.

Surrounding the salient of a topographic upland in Township 13, Range 15 is an escarpment which is up to 20 feet high in Section 7. Because the elevation of the base of this escarpment is consistent with the elevation of the beach and drainage outlet, it has been interpreted as a wave-cut cliff correlative with the sand beach farther north.

Postglacial Land Forms

Lake Rouleau Basin

The fact that part of the Lake Rouleau Basin is surrounded by a wave-cut cliff which is developed in Regina Clay, together with the fact that Rouleau Clay overlies Regina Clay indicate that the Lake Rouleau Basin is post-Lake Regina or postglacial in age.

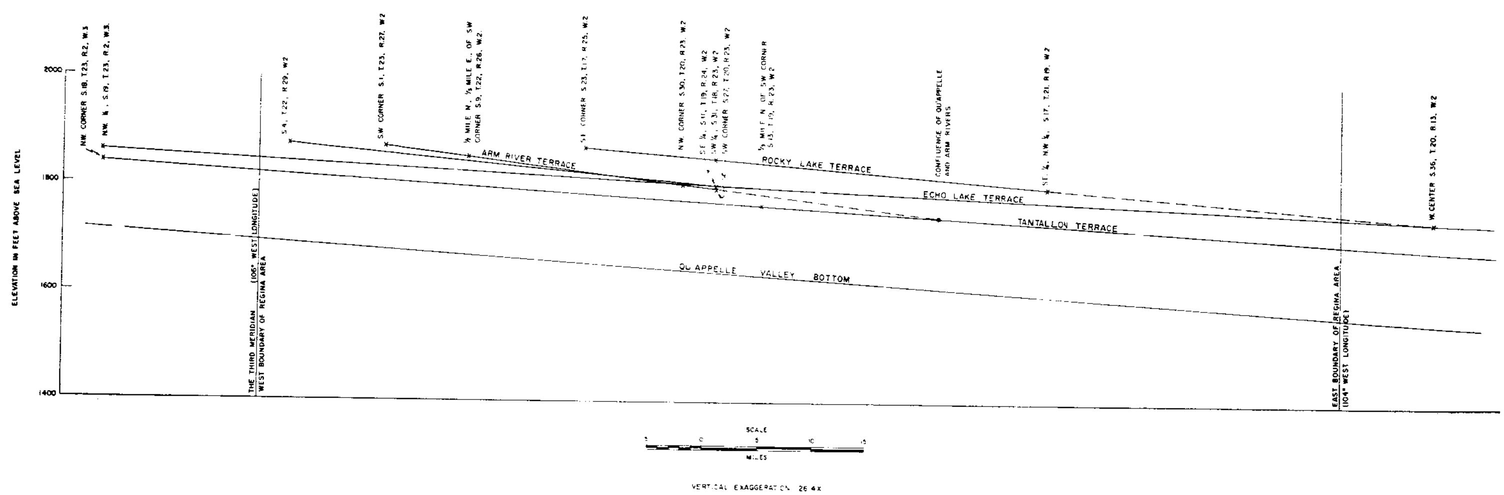


Figure 5.—Long profile of the Qu'Appelle Valley Bottom and the Tantallon, Arm River, Echo Lake, and Rocky Lake Terraces. Elevations recorded with an Air Force altimeter

The topography of the Lake Rouleau Basin is flat and has a relief that commonly does not exceed 5 feet. In a test-hole in the northwest corner of Section 11, Township 14, Range 23 a thickness of 11 feet of Rouleau Clay was encountered (Section 19, Appendix). The Rouleau Clay is grey which makes it easily distinguishable from the olive-grey Regina Clay. Rouleau Clay is composed of 78 per cent clay, 21 per cent silt, and 1 per cent sand. In a strip along the foot of the wave-cut cliff along the northeast strandline of Lake Rouleau Basin, the sediment is reworked Regina Clay which was derived from the cliff by wave action.

The fact that the color of the Rouleau Clay in the southwest part of the basin is similar to that of the Upper Cretaceous sediments exposed in the Dirt Hills near Claybank and the fact that the streams which entered the lake headed in the Dirt Hills indicate that the sediments in the Lake Rouleau Basin were derived from the dissected Missouri Coteau Escarpment of which the Dirt Hills are a part.

Lake Rouleau was drained either because of sedimentation which resulted in a loss of storage or because of headward erosion of Moose Jaw Creek which formed the outlet for the lake or because of abnormally high precipitation which caused the lake to overtop its basin or a combination of these factors. A decrease in storage because of sedimentation and an increase in precipitation would contribute to overtopping of the lake basin. The fact that Moose Jaw Creek immediately northwest of the Lake Rouleau Basin has fewer tributaries suggests that the lake overflowed its basin, and because of this, the upper part of Moose Jaw Creek below the Lake Rouleau Basin formed quickly without sufficient time for the development of tributaries.

Piedmont Alluvial Plains

Piedmont alluvial plains occur at the base of the Missouri Coteau Escarpment where the escarpment slopes steeply as at the Cactus and Dirt Hills. The plains have a gradual slope away from the escarpment and have flat to undulating topography, the relief being commonly less than 5 feet. The sediment, which is commonly less than 5 feet thick, is alluvial silt and clay.

Alluvial Flood Plains

Alluvial flood plains occur in the Qu'Appelle, Thunder Creek, and Arm River Valleys. The alluvial fans, which flank the valley walls in places, are here included in the flood plains. The topography is flat to undulating and has a relief that commonly does not exceed 5 feet. In the Thunder Creek Valley 4 feet of fine-grained alluvial sand overlies Regina Clay. The alluvial sediments in the Qu'Appelle Valley range in thickness from 20 to 40 feet.

Slump Areas

Landslides of the rotational slump-type are common in the Qu'Appelle and Arm River Valleys and in many tributaries to the Qu'Appelle Valley where the streams have penetrated the drift-bedrock contact. The slump blocks are topographically expressed as a series of sub-parallel ridges in the valley walls (Fig. 6). The occurrence of slumping is stratigraphically controlled because it occurs only where streams have penetrated the drift-shale contact. This stratigraphic control, which also is well illustrated in the Swift Current area (Christiansen, 1959, p. 21-23), has been particularly helpful in determining the depth to bedrock in valleys exhibiting slumped walls.

A landslide of the slump-type occurred in the summer of 1960 (Fig. 7) in a road cut along Highway 20, 2 miles east of Lumsden (T. 19, R. 21). The road cut is in the toe of and parallel to an ancient slump block which had already moved in early postglacial time. Examination of the landslide shows that the drift-bedrock contact was penetrated and that the failure surface is defined in part by the highly bentonitic bedrock which has a very low internal shear resistance. It is to be expected that further movements will take place when the pore pressures are built up during spring thaws and rains.

Dissected Escarpments

Dissected escarpments occur in the more steeply sloping parts of the Missouri Coteau Escarpment (Dirt Hills and Cactus Hills, T. 12, R. 24, and T. 13, R. 26). The topography is strongly rolling and has a maximum relief of about 500 feet. The escarpment has been severely dissected by streams. The sediment, into which the streams have cut, consists of bedrock sands and clays of the Upper Cretaceous Series and of till. The dissected escarpment is the source area for the lacustrine sediments which were deposited in Lake Rouleau Basin.

Bedrock Topography

The bedrock topographic map (Plate 2) is based on elevations of outcrops, on field geology, and on subsurface data obtained frcm oil wells, structural test-holes, seismic shot-holes, seismic refraction data, limited resistivity surveys, and water wells. In places the Saskatchewan Department of Mineral Resources determined the elevation of the drift-bedrock contact for the writer from oil wells and structual test-hole data. Most of the water-well data were obtained from Water Supply Papers (Table 2). In areas where bedrock crops out, the elevation of the drift-bedrock contact was determined with the aid of an Air Force altimeter. As explained above the occurrence of slumped areas is stratigraphically controlled. Where slumped areas occur along valley walls, it is assumed that the streams have penetrated the drift-bedrock contact.

The data from structural test-holes were assumed to be correct. The water-well data are subject to error because they may be based on interviews with persons who had to rely on memory rather than on written logs. Furthermore, in areas of thin drift many of the water wells penetrate the bedrock to a great depth, and the depth of the drift-bedrock contact is not given in the Water Supply Papers. The water-well data, therefore, were subjected to a great deal of personal evaluation. Because the bedrock

Figure 6.—**Slump areas in Arm River Valley north of Bethune. The restriction in valley width occurs where the valley lies wholly in drift.**—*Photo Saskatchewan Photographic Services*

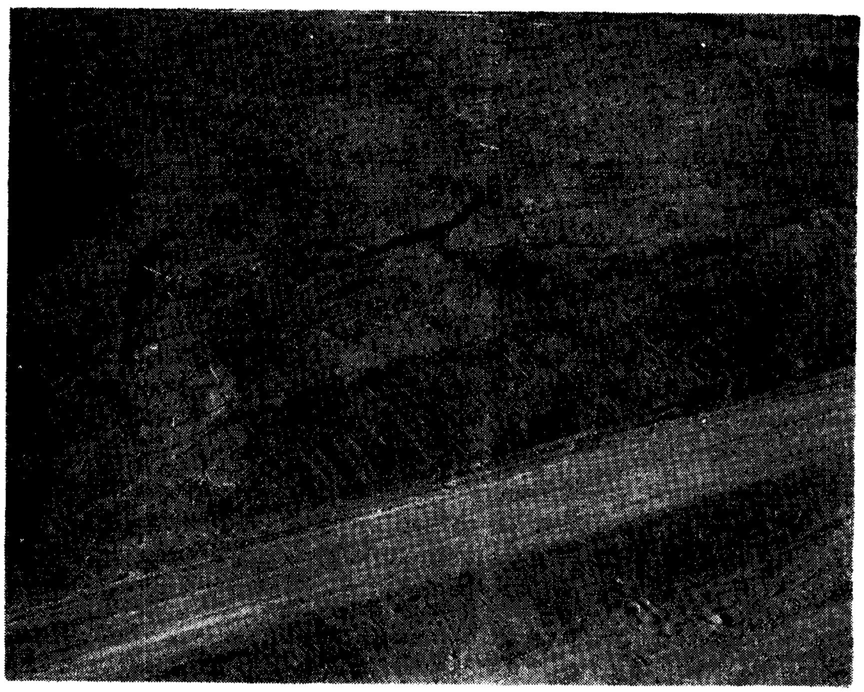


Figure 7.—**Landslide in road cut along Highway 20, 2 miles east of Lumsden.** —*Photo Saskatchewan Photographic Services*

lithology is believed to be more or less homogeneous, the drainage pattern is assumed to be essentially dendritic.

Because the elevations are placed on the map, it was considered unnecessary to classify the contour lines as to degree of accuracy. In general, most of the interpretation is conjectural. The well-integrated drainage pattern which shows no glacial control is believed to be preglacial in age.

The bedrock surface in the Regina area slopes gently northward. The total relief is about 1200 feet, the highest point being in the Missouri Coteau (T. 12, R. 26) where the bedrock surface rises to an elevation of about 2600 feet, and the lowest point being in the Regina Valley in the Last Mountain Lake area where the elevation is about 1400 feet. Most of the preglacial valleys head in the Missouri Coteau and converge in the Last Mountain Lake area. The Missouri Coteau is the most striking bedrock-surface feature in the Regina area. It rises to a height of about 600 feet above the bedrock plain to the northeast. The interfluvial areas between the preglacial valleys north of the Missouri Coteau form a plain, of which the mean elevation is about 1800 feet above sea level. A preglacial drainage divide occurs in the northeastern part of the area (Plate 2) which divides the north-trending valleys from the eastward-trending Avonhurst Valley. The preglacial drainage system forms a dendritic pattern. The parallel, ice-marginal Arm River and Qu'Appelle Valleys are superposed upon and normal to the preglacial valleys.

The Regina, Madrid, and Avonhurst Valleys are the largest preglacial valleys in the Regina area. Adams Valley is a tributary to the Regina Valley. The Regina Valley is up to 300 feet deep and 3 miles wide in Township 19, Range 20, and it has a gradient of about 4 feet per mile. The scarcity of tributaries in the lower part of its course as shown on the map is probably due to lack of data. In Township 20, Range 20 the base of the Regina Valley lies about 100 feet below the base of the superposed Qu'Appelle Valley.

The Madrid Valley heads in the Missouri Coteau and continues northward into the Last Mountain Lake area. The valley can be traced northward from Township 18 through the Qu'Appelle and Arm River Valleys where the lack of slumping suggests that the drift-bedrock contact lies below the present valley bottoms. The Madrid Valley is up to 3 miles wide and 200 to 300 feet deep, and it has a gradient of about 5 feet per mile.

The Avonhurst Valley trends in a northeasterly direction from near Regina. The valley is broad, up to 300 feet deep, and has a gradient of about 10 feet per mile. If the interpretation is correct, then capture of the Regina Valley was about to be initiated in Township 17, Range 19.

The east-west trending ice-marginal Qu'Appelle and Arm River Valleys were cut into bedrock in the interfluvial areas between the north-south trending preglacial valleys. The Qu'Appelle Valley is cut in bedrock except where it cuts across drift-filled preglacial valleys. It is about 1 mile wide, 200 feet deep, and has a gradient of about 2 feet per mile. The origin and age of the Qu'Appelle Valley is discussed under Glacial History. The interpretation of the history of that part of the Qu'Appelle Valley which lies to the north of Buffalo Pound Lake, is based on the observed, thick drift sections at both ends and on resistivity data which were obtained from a north-south traverse along a line north of Findlater (T. 21, R. 25).

The Arm River Valley is cut into bedrock in the interfluvial areas between the preglacial valleys. The bedrock valley, therefore, appears to be segmented. The history and origin of this valley, which is Condiean in age, is shown in Figure 23.

STRATIGRAPHY

Upper Cretaceous Series

Bearpaw Formation—"Marine Shales" Formation

The Bearpaw Formation and its lateral equivalent the "Marine Shales" Formation are the most wide-spread bedrock formations in the Regina area (Fig. 8). The Bearpaw Formation occurs in the western part of the Regina area whereas the "Marine Shales" Formation constitutes the most common bedrock in the eastern portion of the area. The "Marine Shales" Formation is equivalent to the Bearpaw, Belly River, and older formations farther west (Fraser *et al.* 1935). Scattered exposures of these formations (Plate 2) occur in Qu'Appelle Valley and its tributaries, particularly Waskana Creek, in the Last Mountain Lake Spillway (T. 21, R. 22), along Highway 1 near Moose Jaw, in the Arm River Valley, and in Township 12, Ranges 21 and 22. These formations are composed of grey, montmorillonitic clay which is locally bentonitic (west valley wall, Waskana Creek Valley, S. 17, T. 18, R. 21 and north valley wall, Qu'-Appelle Valley along Highway 20, S. 3, T. 20, R. 21). In the southwest wall of the Arm River Valley near Aylesbury (S. 10, T. 23, R. 27), the clay contains fine-grained sand which occurs in blebs throughout the clay. In the southwest side of the Qu'Appelle Valley (S. 17, T. 21, R. 28), more than 35 feet of well sorted, fine to medium-grained sand underlies 10 feet of grey clay. The total thickness of the Bearpaw Formation and the "Marine Shales" Formation is not known. The difference in elevation between the Bearpaw-Eastend contact and the lowest point in the Bearpaw Formation penetrated by test-drilling, shows that the Bearpaw is at least 650 feet thick.

Eastend Formation

The Eastend Formation is best exposed in the Dirt Hills (T. 12, R. 24) and along Avonlea Creek (T. 12, R. 22). According to Fraser *et al.* (1935, p. 25), the Eastend Formation is gradational between the underlying marine Bearpaw Formation and the overlying non-marine Whitemud Formation. The Eastend Formation is composed of yellow, yellowish-brown, or grey and greenish-grey, sand, silt, and clay which contain a

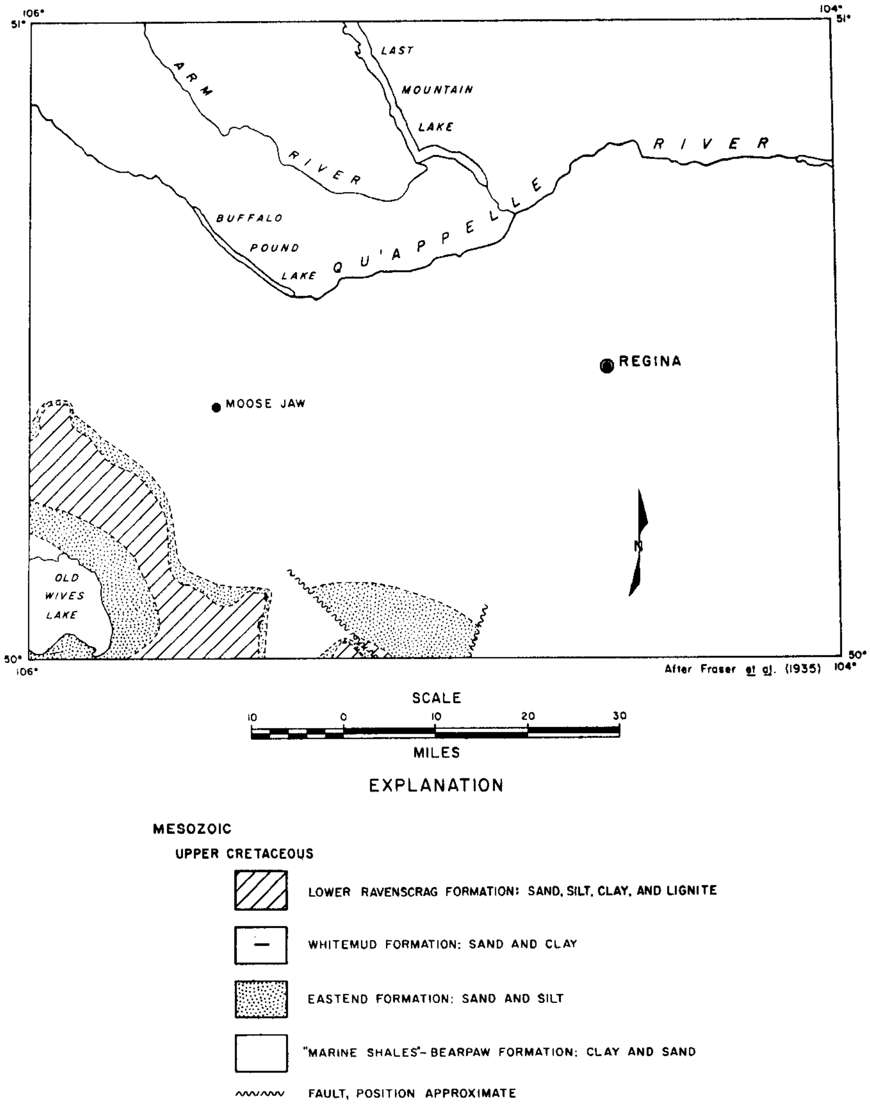


Figure 8.—Bedrock geology of the Regina area. Geology based on Fraser *et al.* (1935)

large number of reddish-brown ironstone concretions. In the Dirt Hills, the Eastend Formation is at least 142 feet thick (Byers, 1959).

Whitemud Formation

The Whitemud Formation is well exposed in the Dirt Hills (T. 12, R. 24) and the Cactus Hills (T. 13, R. 26) where it consists of interbedded, light-grey sand, silt, clay, and lignite. In the Dirt Hills the Whitemud Formation attains a thickness of at least 55 feet (Byers, 1959).

Lower Ravenscrag Formation

The Lower Ravenscrag Formation is poorly exposed in the Regina area. Small exposures in the Dirt Hills show grey to reddish-brown silts, sands, and numerous ironstone concretions and lenses. The Lower Ravenscrag Formation is at least 12 feet thick in the Dirt Hills.

Pleistocene Series

General Statement

The stratigraphic interpretations in the Regina area are based on the stratigraphic sequence of tills, intertill deposits, and proglacial sediments, as well as on one radiocarbon date near Kenaston and on the position of till margins as indicated by end moraines and ice-marginal channels. At least two tills occur in the Regina area, the uppermost of which, the Condie till, is well defined by sections and an end moraine. A lower till is well exposed in the Waskana Creek Valley (Section 2, Appendix); although its terminus may be the Moose Jaw Moraine, this is not definitely known, and hence no formal stratigraphic name has been assigned to the till.

The best-developed sections are in preglacial valleys where the deposits were protected from the erosional action of subsequent glaciers. Commonly the interfluvial areas are covered with only one till. The location of the sections and their generalized lithological descriptions are shown in Figure 9. A detailed description of the more important sections is given in the Appendix. Most of the sections are in the Qu'Appelle Valley, in the Waskana Creek Valley, and in the Cottonwood Creek Valley.

Lower Till

Because the base of the lower till is not exposed and because its stratigraphic relationship to the Moose Jaw Moraine is uncertain, the till has not been named but is referred to as the Lower Till. It is quite possible, however, that the Moose Jaw Moraine marks the terminus of the Lower Till. In the Waskana Creek Valley the Lower Till is at least 55 feet thick. The till is calcareous, grey, unoxidized, montmorillonitic, and has the texture of sandy clay loam to clay loam.

Lower Stratified Drift

The Lower Stratified Drift lies between the underlying Lower Till and the Condie Till north of the Condie Moraine. The drift, which ranges in thickness from 2 to more than 38 feet, is composed of clay, sand, gravel, and boulders which occur as a boulder pavement.

Condie Till

The name Condie Till is proposed for the till which is exposed north of the Condie Moraine (Fig. 9). The Condie Till, which forms the surface deposit for most of this area, lies below the Regina Clay between the

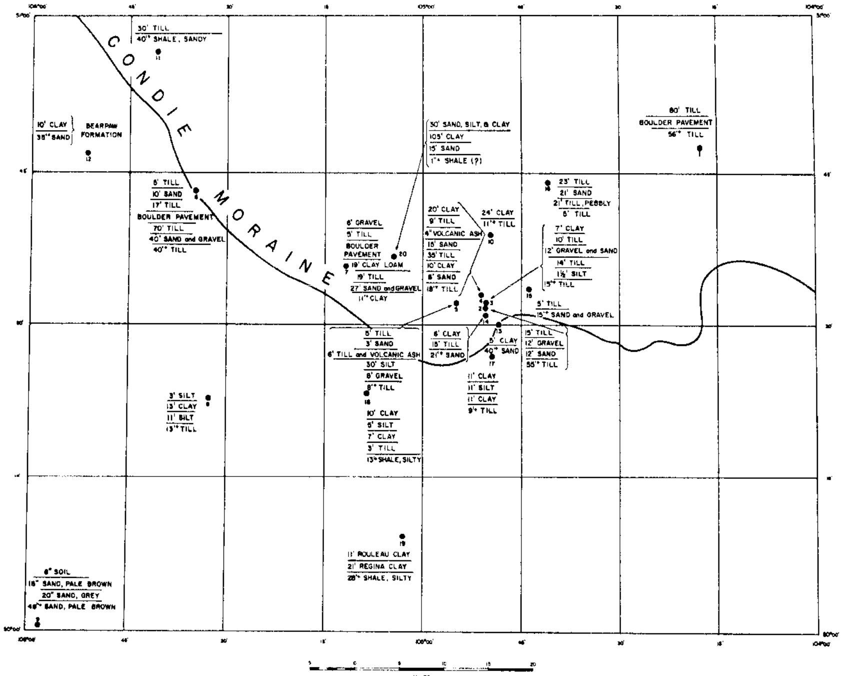


Figure 9.—Location and generalized lithology of sections

Condie Moraine and the Qu'Appelle Valley. The name Condie is taken from the hamlet of Condie which lies near the north flank of the Condie Moraine (T. 18, R. 20). The reference section is in the east valley wall of the Waskana Creek Valley about 3000 feet west and 1000 feet south of the northeast corner of Section 21, Township 18, Range 21 (Section 3, Appendix). The Condie Till is also well exposed in the Cottonwood Creek Valley (Section 5, Appendix) and in the Qu'Appelle Valley (Sections 1, 6, and 7, Appendix). In Section 7 (Fig. 10) the Condie Till can be divided into two units, the upper one of which was deposited during a local re-advance of the Condiean Glacier (Fig. 11). The Buffalo Pound Section (Section 6, Appendix), which lies in the Condie Moraine, comprises at least four tills which are believed to have been deposited during minor fluctuations of the Condiean Glacier. In the reference section, 10 feet of Condie Till is overlain by 7 feet of Regina Clay and underlain by 12 feet of intertill gravel and sand.

The Condie Till is calcareous; olive brown to light-brownish grey where oxidized and grey to greyish brown where unoxidized; montmorillonitic; and sandy clay loam to clay loam. Measured thicknesses range from 10 to 185 feet.

Waskana Creek Ash

The name Waskana Creek Ash is proposed for a stratigraphic unit which consists mainly of volcanic ash associated with lacustrine sediments, and which is overlain by till and underlain by clay and sand. The volcanic ash, which is up to 4 inches thick, is in most places associated with a

4 inch bed of lacustrine clay. The reference section is in the west side of the Waskana Creek Valley (Fig. 12), ¼ mile south of the northeast corner of Section 29, Township 18, Range 21 (Section 4, Appendix). The name is taken from Waskana Creek. Although the ash has an areal extent of less than 50 feet, it has been named because of its possible importance as a stratigraphic marker bed. Volcanic ash is also exposed in the east side of the Cottonwood Creek Valley (1/5 mile south of the N.W. corner S. 24, T. 18, R. 22; Section 5, Appendix). The ash is silty, white, and is composed of plate-like glass shards.

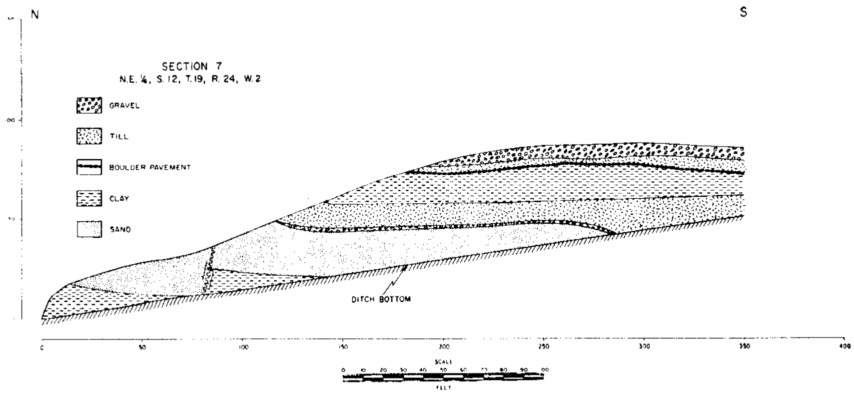


Figure 10.—Structural cross section of Section 7

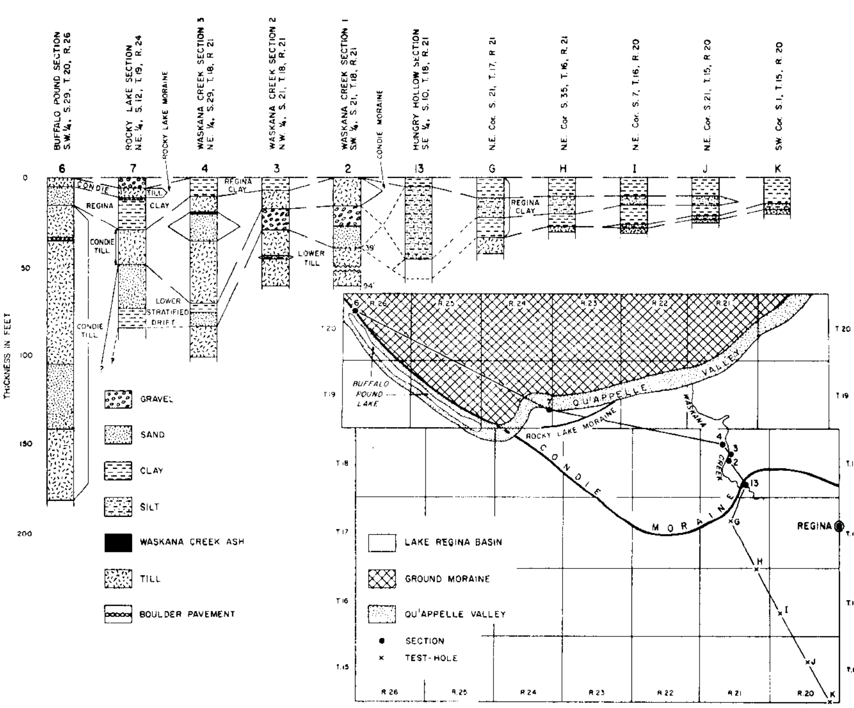


Figure 11.—Stratigraphic cross section of the Regina area

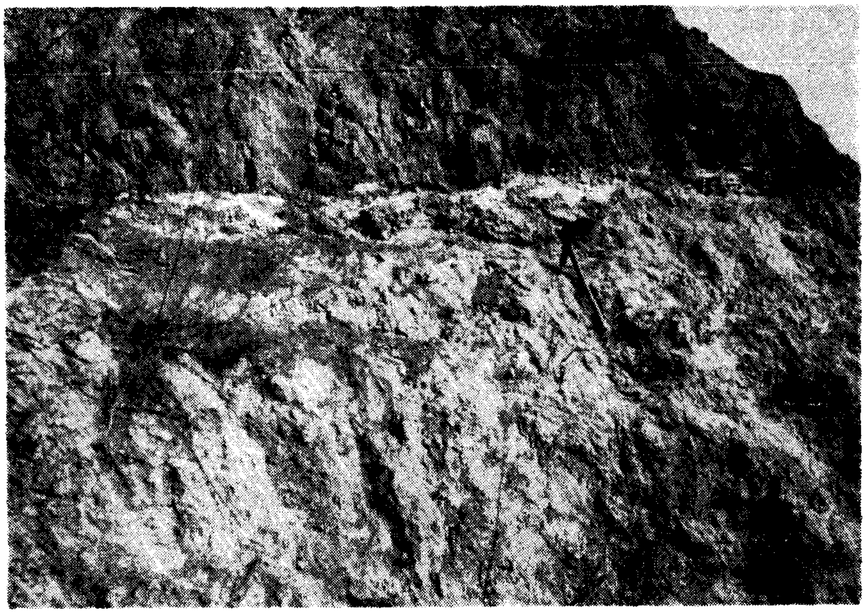


Figure 12.—Waskana Creek Ash. White volcanic ash, 2 to 4 inches thick, is overlain by till and underlain by poorly sorted sand

The Waskana Creek Ash in the reference section is associated with a lens of sand and clay which is either a part of the Condie Till or of the Lower Stratified Drift. The following observations in the reference section should be kept in mind when the stratigraphic position of the Waskana Creek Ash is considered:

(1) the ash is associated with lacustrine clay,

(2) the ash is underlain by a lens of 15 feet of poorly-sorted sand which is less than 50 feet wide,

(3) the lens, ash, and associated clay pinch out and join the contact between the underlying clay-rich till and the overlying clay-poor till at a point about 30 feet north of the ash exposure,

(4) the Regina Clay, which covers the clay-poor till, is contorted and has a gradational contact with the underlying till.

The fact that the Regina clay is contorted and has a gradational contact with the underlying clay-poor till suggests that this clay was deposited upon dead-ice and subsequently collapsed during melting of the dead-ice. It follows then that the clay-poor till is to be regarded as of englacial origin, let down during ablation. The fact that the ash and its associated deposits of clay and poorly-sorted sand are lens-shaped and separate ablation till from basal till (clay-rich till), suggests that the lens resulted from deposition in a depression on the ice and that the clay-poor till slid over it from lateral, higher parts of the ice surface. The volcanic ash lens is therefore not regarded as an intertill deposit. If the above conclusion is valid, the Waskana Creek Ash is to be regarded as Condiean in age.

Regina Clay

The name Regina Clay is proposed for the silt and clay which was deposited in the Lake Regina Basin (Fig. 13). The name is taken from the city of Regina. South of the Condie Moraine samples from test-holes show that the Regina Clay overlies oxidized Lower Till disconformably. North of the Condie Moraine samples from test-holes show that the Regina Clay overlies unoxidized Condie Till conformably. Section 7 (Fig. 10) shows that the Regina Clay interfingers with the Condie Till. In the Moose Jaw area the Regina Clay overlies silts which are believed to represent a fine-grained facies of the sands and gravels in the Sandy Creek area (T. 17, R. 29). The reference section of the Regina Clay is in a test-hole in the northeast corner of Section 21, Township 17, Range 21 (Section 17, Appendix).

The Regina Clay is composed of clay, silty clay, and silt. The silt and silty clay, which are overlain and underlain by clay, become thicker as the Condie Moraine is approached from the south (Fig. 13). This silty unit terminates abruptly at the Condie Moraine which indicates that its source was the Condiean Glacier. If the silt and silty clay are removed from the stratigraphic unit of which the thickness is shown on the isopach map of the Regina Clay, it can be seen that the thickness of the clay is about the same on the north side as on the south side of the Condie Moraine. This suggests that most of the clay was transported into the basin from proglacial areas to the west and not derived directly from the melting glacier. The clay is calcareous, olive brown, montmorillonitic, and unoxidized. The silty unit is calcareous, light-greyish brown, and unoxidized. Locally, the clay unit contains 6 to 10 feet of till-like material, the thickness of which was not included in the clay unit in the isopach map. Because the till-like material is stony, lens-like, and higher in clay content than the tills of the area, it has been interpreted as an ice-rafted deposit.

Sections and test-holes show that the Regina Clay south of the Condie Moraine is weakly varved and evenly bedded whereas the Regina Clay north of the Condie Moraine is well varved and highly contorted (Fig. 14). A dead-ice landscape in the Lake Regina Basin north of the Condie Moraine, as indicated in aerial photographs, and the highly contorted nature of the Regina Clay show that the clay in this part of the basin was deposited upon dead-ice and subsequently collapsed during the melting of the ice.

The isopach map (Fig. 13) shows that the Regina Clay is thickest in the Condie Moraine re-entrant near Regina. This is to be expected because much meltwater gathered here which brought in the sediments. The Regina Clay in the western part of the basin is thin or absent possibly because of currents set up by the incoming water from the west which prevented deposition. The sediment is also thin in the Thunder Creek Valley where most of the clay was eroded by the meltwater channel. In the eroded till plain along Moose Jaw Creek northeast of Moose Jaw, the Regina Clay was completely removed during the drainage of Lake Regina.

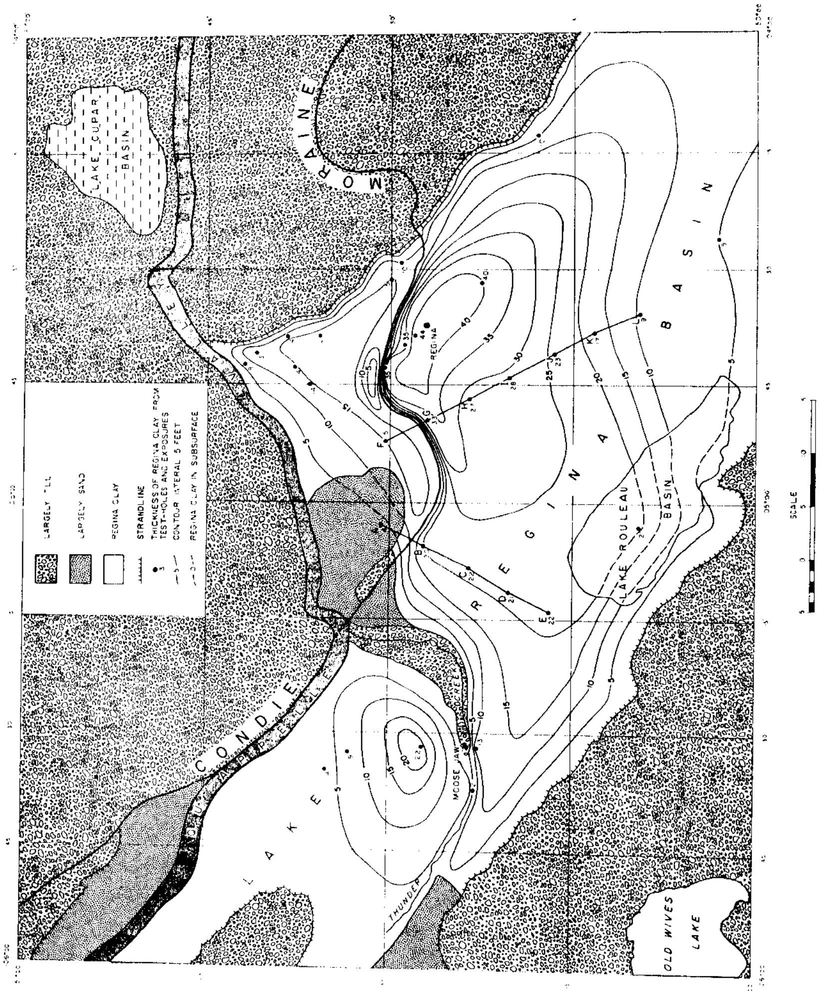


Figure 13a.—Isopach map of Regina Clay

When constructing the isopach map of the Regina Clay north of the Condie Moraine, values of clay thickness on pronounced, local uplands and depressions were not used. It is believed that these thicknesses are no longer equal to the original thickness of the sediment when it was deposited because of postglacial erosion from the knolls and deposition in the depressions. Because actual values of thickness of the Regina Clay are placed on the map, which conveys the density of control points (Fig. 13), it was considered unnecessary to classify the contour lines as to degree of accuracy. Where the Regina Clay is covered by younger sediments the contour lines are dashed. The interpretation, for the most part, is conjectural.

The absence of Regina Clay beneath the Condie Till between the Qu'Appelle Valley and the Condie Moraine (Fig. 11) suggests that either the clay was not deposited during the advance of the Condiean Glacier or, if it was deposited, that it was incorporated into the Condie Till.

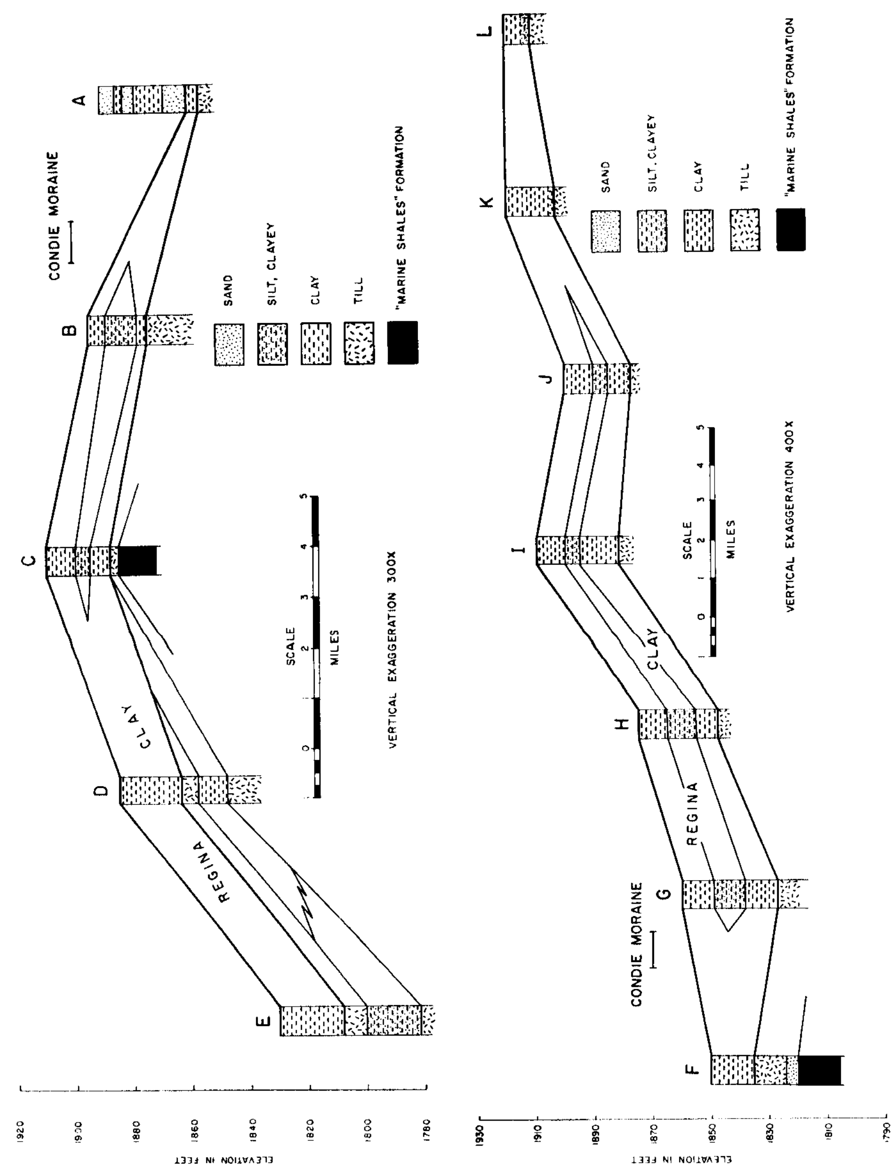


Figure 13b.—Cross sections along lines shown in Figure 13a

Rouleau Clay

The name Rouleau Clay is proposed for the stratigraphic unit which comprises the surficial sediments of the Lake Rouleau Basin. The name is taken from the village of Rouleau (T. 14, R. 22). Rouleau Clay lies conformably upon Regina Clay. The reference section is in a test-hole in the northwest corner of Section 11, Township 14, Range 23 (Section 19, Appendix) where 11 feet of Rouleau Clay overlies 21 feet of Regina Clay which in turn overlies bedrock clay of the "Marine Shale" Formation.

Rouleau Clay is calcareous, montmorillonitic, grey, unoxidized, and massive. Southwest of Moose Jaw Creek the Rouleau Clay is readily

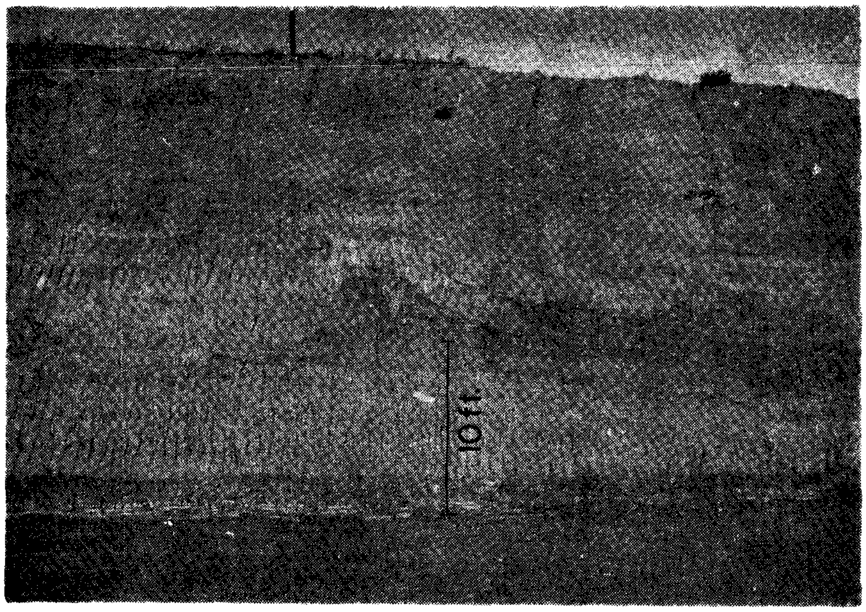


Figure 14.—Road cut along Highway 11 southeast of Lumsden. Note the contortions of the clay and the gradational contact between the Regina Clay and the underlying Condie Till

separated from Regina Clay because of its color; the Regina Clay is olive whereas Rouleau Clay is grey. Along the northeast and north shore of Lake Rouleau Basin, however, the Rouleau Clay has been derived from Regina Clay by wave action and, consequently, is similar to it. The fact that most of the streams, which enter the Lake Rouleau Basin, have their head waters in the Missouri Coteau Escarpment (Dirt Hills, T. 12, R. 24) and the fact that the color of Rouleau Clay is similar to the bedrock clays exposed in the Dirt Hills suggest that Rouleau Clay was derived from bedrock in the Missouri Coteau Escarpment.

Qu'Appelle Valley

A structural cross section of the Qu'Appelle Valley, which shows the bedrock surface, the pre-Condiean and Condiean Qu'Appelle Valley bottoms, and the Qu'Appelle River, is shown in Figure 15. The cross section is based on one driller's log (S.E.¼, S. 24, T. 22, R. 1, W. 3) and two sample descriptions by the writer (Section 20 and 21, Appendix), on topographic maps, scale 1:50,000 and 1:40,000, on geological field work, and on the bedrock surface map of the Regina area (Plate 2).

There are three mappable units below the present Qu'Appelle Valley bottom which in ascending order are: the Lower Stratified Drift, the Regina Clay, and the Qu'Appelle Alluvium.

The Lower Stratified Drift lies between the "Marine Shales" Formation and the Regina Clay except in the Regina Valley where it lies on till. The Lower Stratified Drift is composed of medium to coarse-grained, pebbly sand which ranges in thickness from 10 to 15 feet (Sections 20 and 21, Appendix).

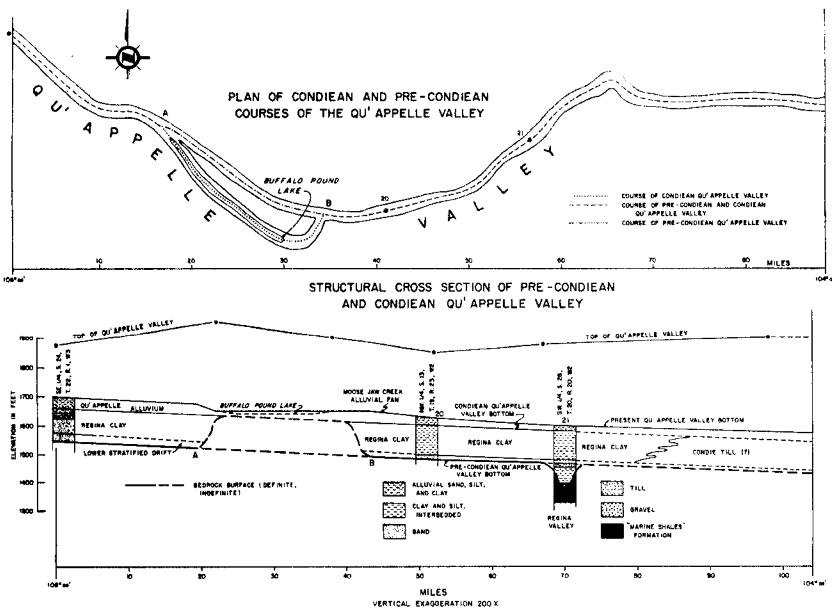


Figure 15.—Structural cross section of the Qu'Appelle Valley

The Regina Clay lies between the Lower Stratified Drift and the Qu'Appelle Alluvium in the Qu'Appelle Valley. West of Buffalo Pound Lake the Regina Clay comprises 100 feet of interbedded sand, silt, clay, and gravel. A seismic shot-hole along Highway 6 and two test-holes (Sections 20 and 21, Appendix) indicate that the Regina Clay extends at least as far east as Highway 6. Sections 20 and 21 (Appendix) show that the Qu'Appelle Alluvium is underlain by 105 feet of interbedded silt and clay of the Regina Clay. Because it is believed that the glacier blocked the Qu'Appelle Valley east of Highway 6, which would provide closure for the lake that developed in the pre-Condiean Qu'Appelle Valley, Condie Till is shown in this part of the valley.

The name Qu'Appelle Alluvium is applied to the sediments which overlie the Regina Clay in the Qu'Appelle Valley and which form the surficial sediment in the valley. The reference section of the Qu'Appelle Alluvium is in a test-hole in the Qu'Appelle Valley in the northwest corner of Section 13, Township 19, Range 23, West of the Second Meridian (Section 20, Appendix) where it comprises a lower unit of very fine-grained, silty sand which is 12 feet thick, a middle unit of silty clay which is 3 feet thick, and an upper unit of clayey silt which is 15 feet thick. The sediments are calcareous, unoxidized, and range in color from light-greyish brown to light-brownish grey. Their brownish hue makes it possible to distinguish them from the underlying Regina Clay which is grey. The Qu'Appelle Alluvium ranges in thickness from 20 to 40 feet. The greatest thickness is at the mouth of Moose Jaw Creek where a low alluvial fan has been deposited in the Qu'Appelle Valley which provides closure for Buffalo Pound Lake.

Drift and Bedrock Studies

The glacial and bedrock sediments of the Regina area were subjected to mechanical analyses, to heavy mineral studies, and to an investigation of the clay mineral content. Figure 9 shows the distribution of the Condie Till and the location and general lithological description of each section and test-hole. The textural and mineralogical studies were conducted to find some physical or chemical criteria by which the stratigraphic units might be differentiated and correlated.

The sediments were analysed by the hydrometer method following the procedure described by Bouyoucos (1951). The sands were divided into five size fractions by sieving (Table 1). The texture of the tills ranges from sandy clay loam to clay (Figure 16).

Although there are not enough analyses to show a definite trend, the data suggest that the texture is finer in the older till. The Condie Till is generally more sandy and less clayey than the Lower Till. More analyses

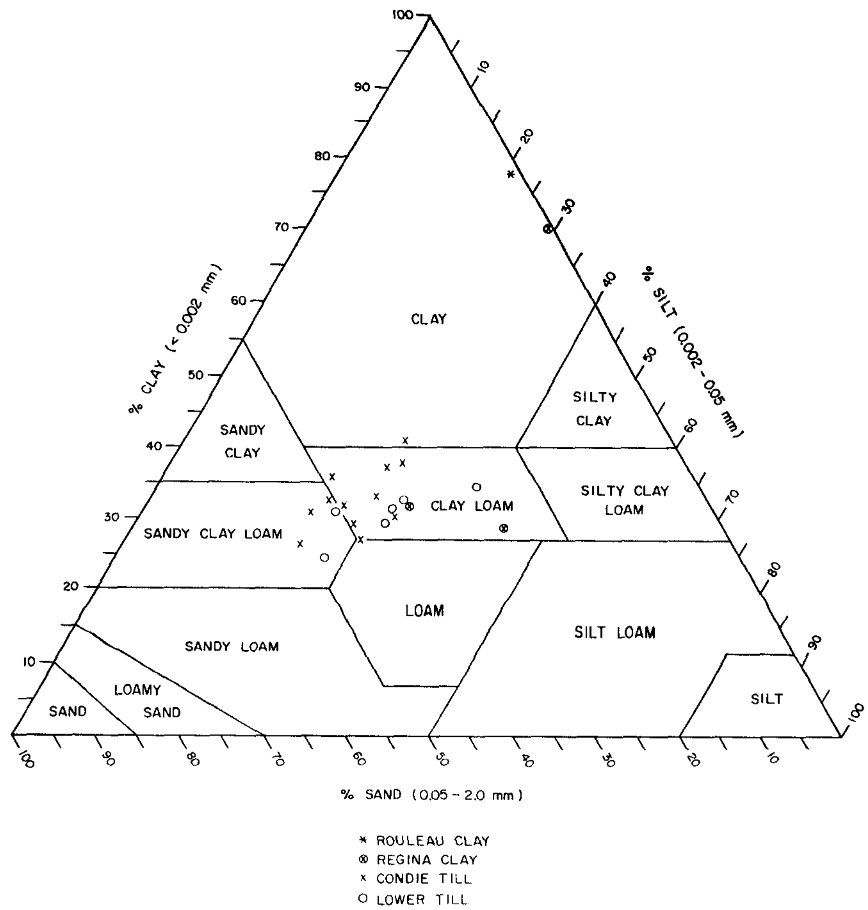


Figure 16.—Texture of tills, Regina Clay, and Rouleau Clay in the Regina area

Table 1.—Texture, median size, and sorting coefficient of till, lacustrine clay, and "Marine Shales" in the Regina area

Section No.	Location	Stratigraphic Unit	% Clay ∠0.002 mm	% Silt 0.05-0.002mm	% Sand 2.0-0.05 mm	2.0-1.0 mm	1.0-0.5 mm	% Sand 0.5-0.25 mm	0.25-0.1 mm	0.1-0.05 mm	Cumulative Curve Data Md	So
1	S.W.¼, S.22, T.21, R.17	Condie Till	30.5	30.7	38.8	4.9	9.8	18.3	36.2	30.8	.025	12.1*
		Lower Till	29.6	30.1	40.3	5.7	11.0	20.0	34.7	28.6	.028	12.7*
2	S.W.¼, S.21, T.18, R.21	Condie Till	26.6	21.3	52.1	8.9	11.4	16.9	31.4	31.4	.053	11.5
		Lower Till	31.3	23.3	45.4	7.0	10.7	19.2	31.1	32.0	.035	14.0*
3	N.W.¼, S.21, T.18, R.21	Condie Till	27.2	28.1	44.7	4.9	10.5	19.0	37.7	27.9	.035	9.1
		Lower Till	32.9	30.4	36.7	7.2	11.4	21.0	33.4	27.1	.018	13.5*
		Lower Till	31.6	29.8	38.6	5.5	11.1	19.5	31.2	32.7	.024	11.5*
4	N.E.¼, S.29, T.18, R.21	Condie Till	29.4	26.0	44.6	5.4	9.7	17.5	34.0	33.4	.040	12.0*
		Condie Till	33.4	26.8	39.8	4.3	8.1	16.0	29.7	41.9	.025	14.0*
		Lower Till	34.9	38.3	26.8	4.9	11.8	21.9	34.7	26.7	.095	9.1*
6	S.W.¼, S.29, T.20, R.26	Condie Till	32.0	23.6	44.4	7.8	11.5	19.4	34.8	26.5	.037	16.3*
		Condie Till	38.0	27.7	34.3	3.8	6.9	13.1	30.1	46.1	.016	15.0*
		Condie Till	41.5	26.4	32.1	3.9	8.0	14.7	33.0	40.4	.016	12.9*
7	N.E.¼, S.12, T.19, R.24	Condie Till	36.0	20.2	43.8	4.6	8.3	17.0	36.1	34.0	.035**	13.6*
		Regina Clay	31.9	31.6	36.5	0.0	0.3	1.3	4.5	93.9	.018	9.1*
		Regina Clay	28.7	44.7	26.6	0.0	0.6	1.2	16.1	82.1	.015	6.5
		Condie Till	37.5	26.3	36.2	5.4	11.0	20.7	36.8	26.1	.013	15.6*
		Lower Stratified Drift	48.3	41.7	10.0	1.0	4.7	15.2	32.9	46.2	.002	7.1*
8	S.29, T.16, R.26	Lower Till	24.7	25.1	50.2	5.4	9.0	17.0	37.6	31.0	.05	7.7
18	N.W.¼, S.32, T.16, R.23	"Marine Shales"	49.3	46.2	4.5							
19	N.W.¼, S.11, T.14, R.23	Rouleau Clay	77.8	21.3	0.9							
		Regina Clay	70.3	29.1	0.6							
	N.E.¼, S.22, T.20, R.17	Till from Edgely Assoc.	31.0	20.3	48.7	9.5	8.7	16.2	31.5	34.1	.047	15.9*
	N.E.¼, S.32, T.20, R.17	Till from Weyburn Assoc.	33.0	21.7	45.3	9.8	8.9	17.4	32.2	31.7	.030	13.3*

*75% Quartile Estimated. **50% Quartile Estimated.

may show that the tills in the Regina area can be differentiated and correlated on their texture.

Fine sand (0.25-0.1 mm) from tills in Sections 3, 4, and 6 were subjected to heavy mineral analysis. Tetrabromoethane (specific gravity of 2.96) was used to separate the light and heavy minerals. Of the 27 heavy mineral species identified hornblende and spinel-garnet are the most abundant; the former ranges from 25 to 50 per cent and the latter ranges from 25 to 40 per cent.

Preliminary studies suggest that there is as much variation within tills as between tills. This relationship suggests that the source of the tills is similar and that little weathering took place during interglacial or interstadial times.

The clay mineral content ($\angle$.002 mm) was determined in the Condie Till, the Lower Till, the Regina Clay, the Rouleau Clay, and clay from the "Marine Shales" Formation. The clay minerals in the drift are mainly montmorillonite but include minor amounts of illite and kaolinite. The "Marine Shales" Formation, although similar in its content of montmorillonite and illite, does not appear to contain any kaolinite. Presumably, the montmorillonite and illite in the drift were derived largely from the "Marine Shales" Formation whereas the kaolinite may have been derived from the Precambrian rocks.

Stratigraphic Interpretation

Figure 17 shows a summary of the Pleistocene and Recent stratigraphy in the Regina area. The summary is based on information from surficial geology, from stratigraphic sections, and from test-holes which are shown graphically in Figure 11 and which are described in the Appendix.

Although the evidence is scanty, it appears that the Buffalo Pound Section lies in the pre-Condiean Qu'Appelle Valley fill. If this is true, then all of the sediments in this section are Condiean or younger. That the Condiean in the Buffalo Pound Section would then comprise at least four tills and three intertill deposits does not pose a problem, because the Buffalo Pound Section lies in the Condie Moraine where the glacier probably advanced and retreated several times for short distances during the accumulation of the moraine.

The stratigraphic sections show that at least two tills occur north of the Condie Moraine. Whether the Moose Jaw Moraine marks the terminus of the Lower Till is not known, but probably it does; if this is so, then the surficial till south of the Moose Jaw Moraine is a third till in the Regina area.

Age and Correlation

A piece of spruce (*Picea* sp.) was encountered in a test-hole about 12 miles east-northeast of Kenaston (S.W. ¼, S. 12, T. 30, R. 1, W. 3, northwest of the Regina area) at a depth of 145 feet. This wood (S-97) was dated at 10,150$\pm$ 200 years B.P. at the laboratory for radiocarbon

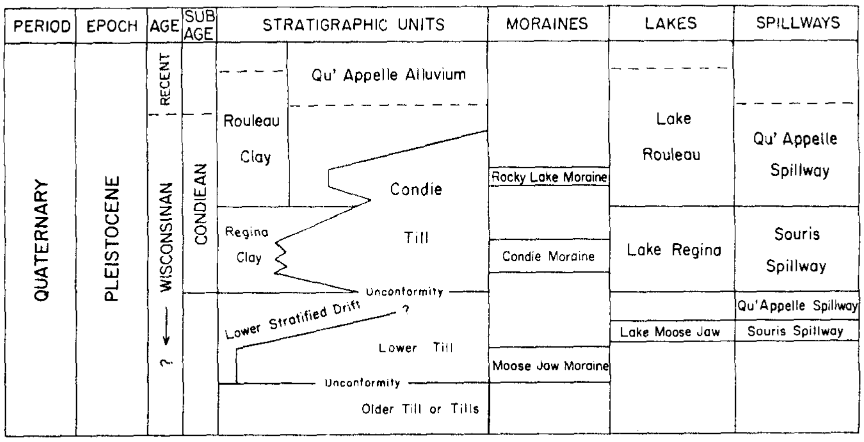


Figure 17.—Summary of Pleistocene and Recent stratigraphy in the Regina area

dating, Saskatchewan Research Council, under the direction of Dr. K. J. McCallum, University of Saskatchewan. Because no stratigraphic discontinuities were found in the overlying sediment, the wood is believed to lie below one till. The rather great thickness of this till can be explained by the fact that the site is in a morainic area with a local relief greater than 50 feet.

Preliminary, unpublished studies west of the Regina area by J. S. Scott, Geological Survey of Canada and the writer indicate that the Kenaston Site is north of the Condie Moraine. It is concluded, therefore, that the till which overlies the wood in the Kenaston Site is the Condie Till and that the glacier presumably advanced over the site 10,150± 200 years B.P. If this is true, then the Condiean is correlative with the Valderan in the Mid-Western United States. The date at the Kenaston Site is correlative with the date at the Herbert Site (10,000±300 years B.P., McCallum and Dyck, 1960) which was then ice free. If the Kenaston date is correct, it follows that the glacier stood about 50 miles north of the Herbert Site 10,000 years ago and not 300 to 350 miles as suggested by Kupsch (1960). According to Kupsch (1960) the climate near Herbert 10,000 years ago was colder and wetter than the present. The nearness of the glacier (50 miles) at this time would account for this colder and wetter climate. If the Kenaston date is accepted as dating the advance of the glacier in this area, then the ice front could not have stood at the The Pas Moraine during the Valderan as suggested by Elson (1957).

GLACIAL HISTORY

General Statement

Seven significant phases dominate the glacial history of the Regina area. Each of these phases is shown in a map (Figs. 18-24) in which the ice front at a particular time is drawn. The ice margins were reconstructed to explain the origin of prominent glacial features and to explain the glacial stratigraphy. Geomorphological features such as end moraines, ice-marginal channels, and washboard moraines, as well as the stratigraphy provide the most important information for reconstructing the glacial history. No attempt has been made to estimate the time intervals between successive phases. The phases will be named and correlated later in a regional study, of which the Regina Area will be a part.

Phase No. 1

Phase No. 1 of the glacial history of the Regina area is correlative with the Weyburn Lobe in Phase No. 5 of the Moose Mountain area and with Phase No. 3 of the Qu'Appelle area as described by Christiansen (1956 and 1960). It is further suggested that this phase of the glacial history is correlative with the Neidpath Channel Phase No. 2 of the glacial history of the Swift Current area (Christiansen, 1959).

Prior to Phase No. 1 of the glacial history of the Regina area, the glacier advanced to a position south of the Regina area. The glacier then presumably retreated to a position north of the Moose Jaw and Davin Moraines and then re-advanced to the position shown in Figure 18. During this phase the ice stood at the Moose Jaw and Davin Moraines. There was not much erosion or deposition by meltwater in front of the Moose Jaw Moraine because both the meltwater and the proglacial water from the west were compelled by the ice to use the Neidpath Channel. Because the northern part of the Regina area was later covered by a younger till, the ice margin is indefinite in this part.

Phase No. 2

Phase No. 2 is correlative with the Thunder Creek Phase of the glacial history in the Swift Current area (Christiansen, 1959). It is not known whether the glacier covered part of the Qu'Appelle area (62L) at this time, but presumably it did.

During Phase No. 2 the ice front stood at the Riceton Moraine (Fig. 19) and formed the northeastern boundary of Lake Moose Jaw. Although the western part of the Lake Moose Jaw Basin is now about 100 feet higher than its outlet near Weyburn, this difference was presumably much less during Phase No. 2 when the northwestern portion of the Lake Moose Jaw Basin was differentially depressed by the glacier. Because Lake Moose Jaw was long and relatively narrow and because large quantities of meltwater from the proglacial areas to the west and the glacial areas nearby flowed through this lake, Lake Moose Jaw may be considered as a slow-flowing stream. During Phase No. 2 sands and gravels were deposited by this stream west of Moose Jaw (T. 17, R. 29). The fine sand and silt at Moose Jaw (Section 8, Fig. 9) and the silt and clay southeast of Moose Jaw (E, Fig. 13) were deposited to the southeast of the sand and gravel as deltaic sediments. These sediments become progressively finer in texture downstream. During Phase No. 3 most of these sediments were covered by Regina Clay. The sediments of Lake Moose Jaw are at least 60 feet thick in topographically low areas on the

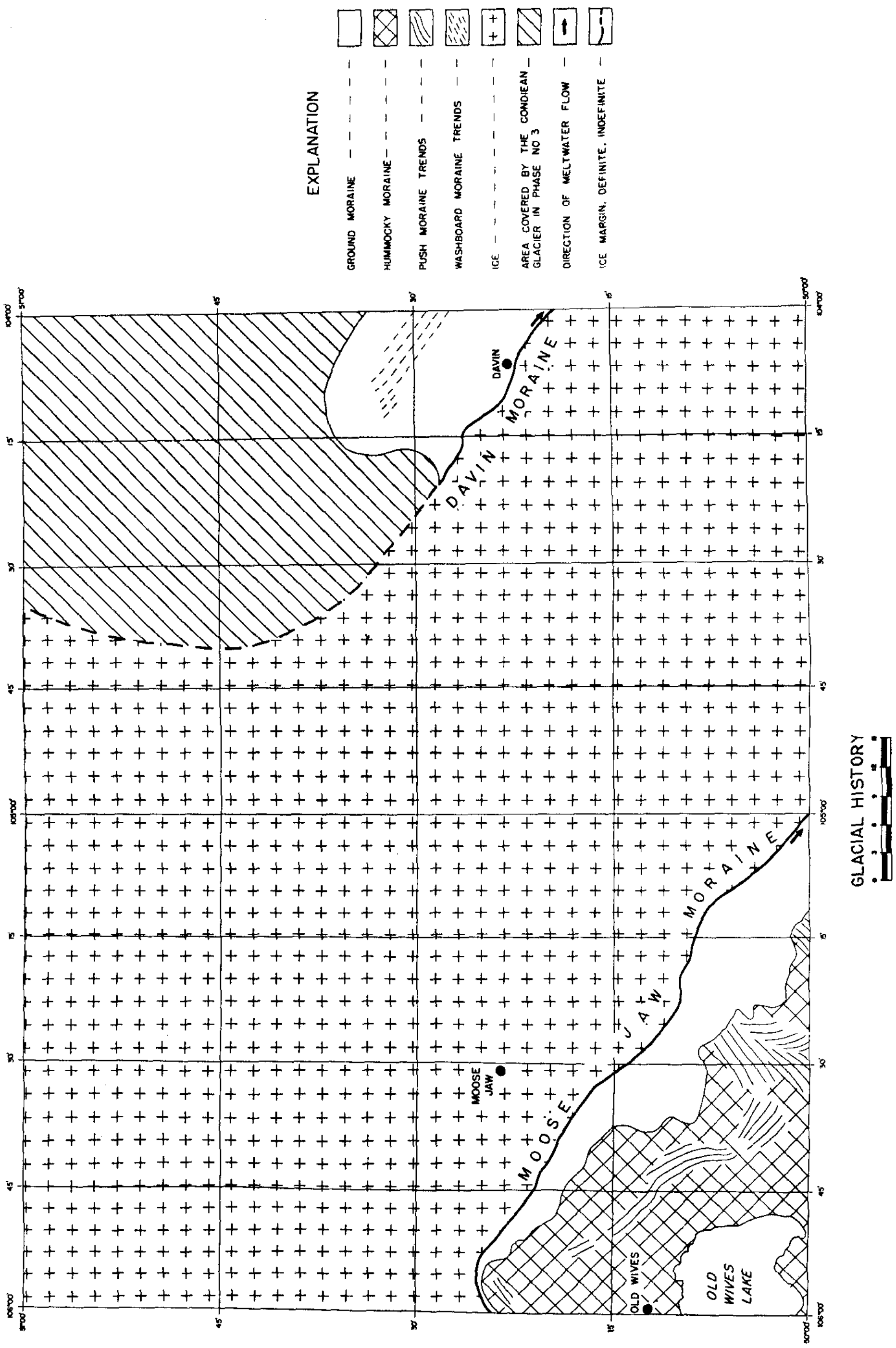


Figure 18.—Phase No. 1 of glacial history

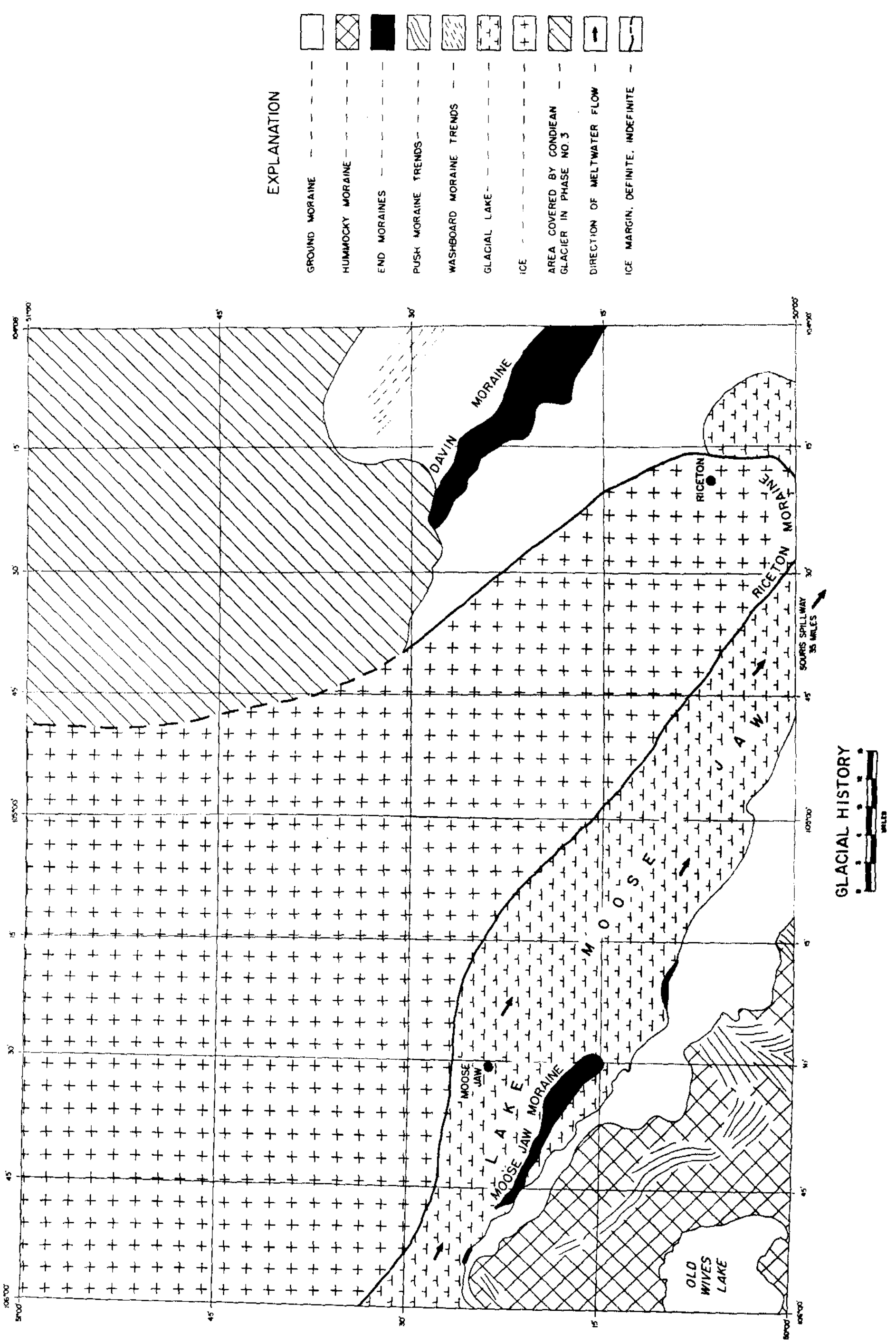


Figure 19.—Phase No. 2 of glacial history

underlying till surface. East of Range 24, they are thin or absent. In the area near Section 19 (Appendix) the underlying till was completely eroded away at this time, and Regina Clay was subsequently deposited directly on the "Marine Shales" Formation. Because the northern part of the Regina area is covered by a younger till, the ice margin is indefinite in this part.

Phase No. 3

Phase No. 3 is correlative with Phase No. 4 of the Glacial History of the Qu'Appelle area as described by Christiansen (1960). During the interval between Phases No. 2 and No. 3, the glacier presumably retreated to a position north of the Regina area and then re-advanced to the position shown in Figure 20. During this interval the pre-Condiean Qu'Appelle Valley (Fig. 15) was formed. During Phase No. 3 of the glacial history of the Regina area the glacier stood at the Condie Moraine (Fig. 20), in front of which was Lake Regina. With the exception of a small area south of the Moose Jaw Moraine, all of the Lake Moose Jaw Basin was inundated during this time. The Souris Spillway was the outlet for Lake Regina. Regina Clay was deposited during this phase.

Phase No. 4

Prior to Phase No. 4 the glacier retreated at least as far north as the Qu'Appelle Valley (Section 7, Appendix) before it re-advanced to the position shown in Figure 21. The glacier stood at the Condie Moraine in the northwestern part of the Regina area, at the Rocky Lake Moraine, and at the Fairy Hill Moraine. A large fluvio-lacustrine plain was formed at the mouths of the Qu'Appelle Spillway and Moose Jaw Channel. It is not known whether this represents an outwash plain or a delta. Lake Regina drained through the Qu'Appelle Spillway during this phase.

Phase No. 5

During the interval between Phases No. 4 and No. 5, Lake Regina drained through the Rocky Lake Spillway, the Cottonwood Creek Channel, the Waskana Creek Channel, the Boggy Creek Channel, the Flying Creek Channel, and the Moose Jaw "Collecting Channel" which in turn drained into the Qu'Appelle Spillway. The Qu'Appelle Valley was cut to the level of the Echo Lake Terrace (Fig. 5) at this time.

The glacier stood at the position indicated in Figure 22. Lake Cupar was formed in contact with the glacier in the northeast sector of the Regina area. A large interlobate area, well marked by washboard moraines, was formed west of Lake Cupar. This interlobate area is the cause of the anomalous bend of the Qu'Appelle Spillway at this point in its course. Lake Rouleau was formed between Phases No. 4 and 5.

Phase No. 6

During the interval between Phases No. 5 and No. 6, Lake Cupar drained through the Loon Creek Channel into the Qu'Appelle Spillway. The glacier stood immediately northeast of the Arm River Channel (Fig. 23), and thus accounts for the side-hill position of the channel. The

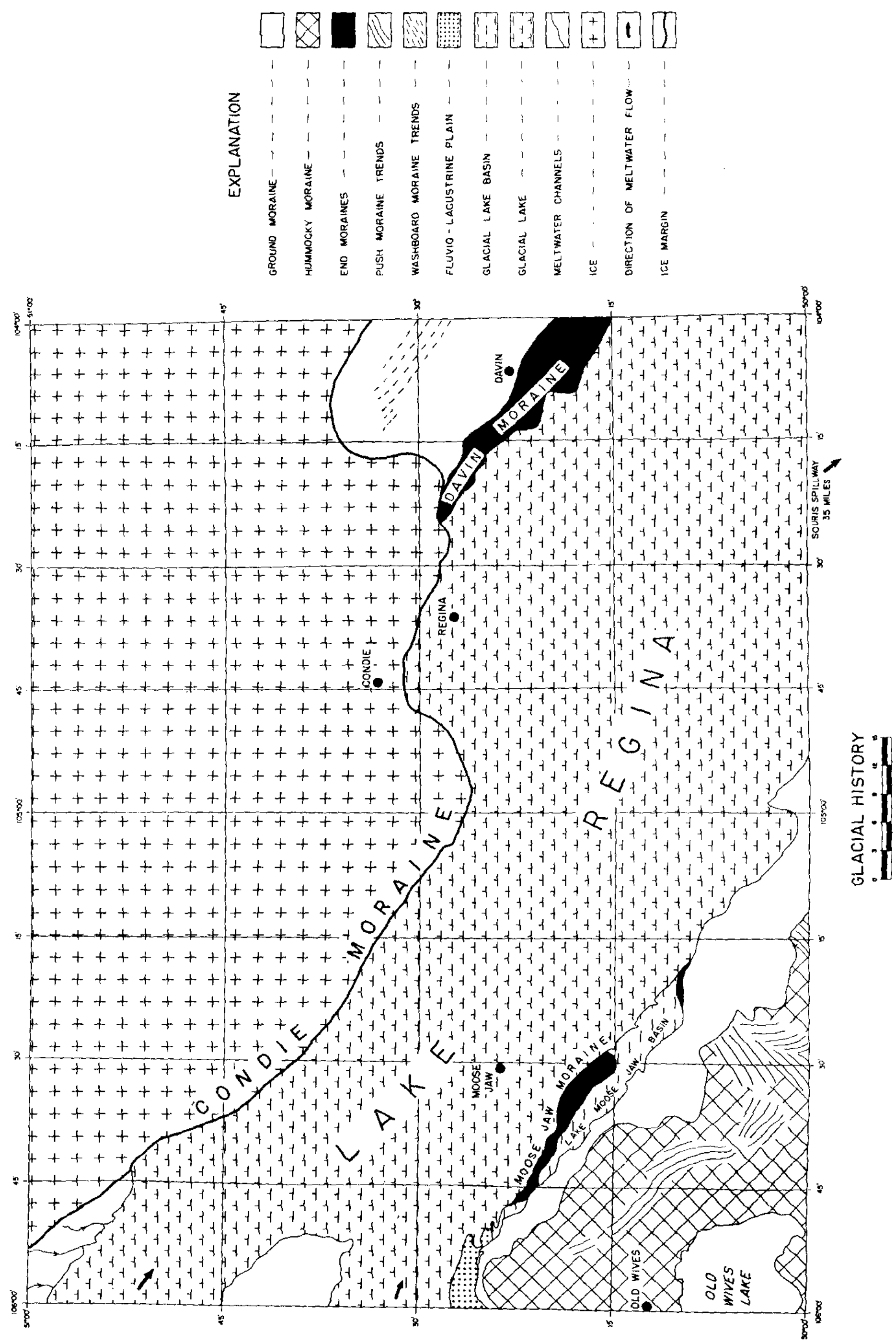


Figure 20.—Phase No. 3 of glacial history

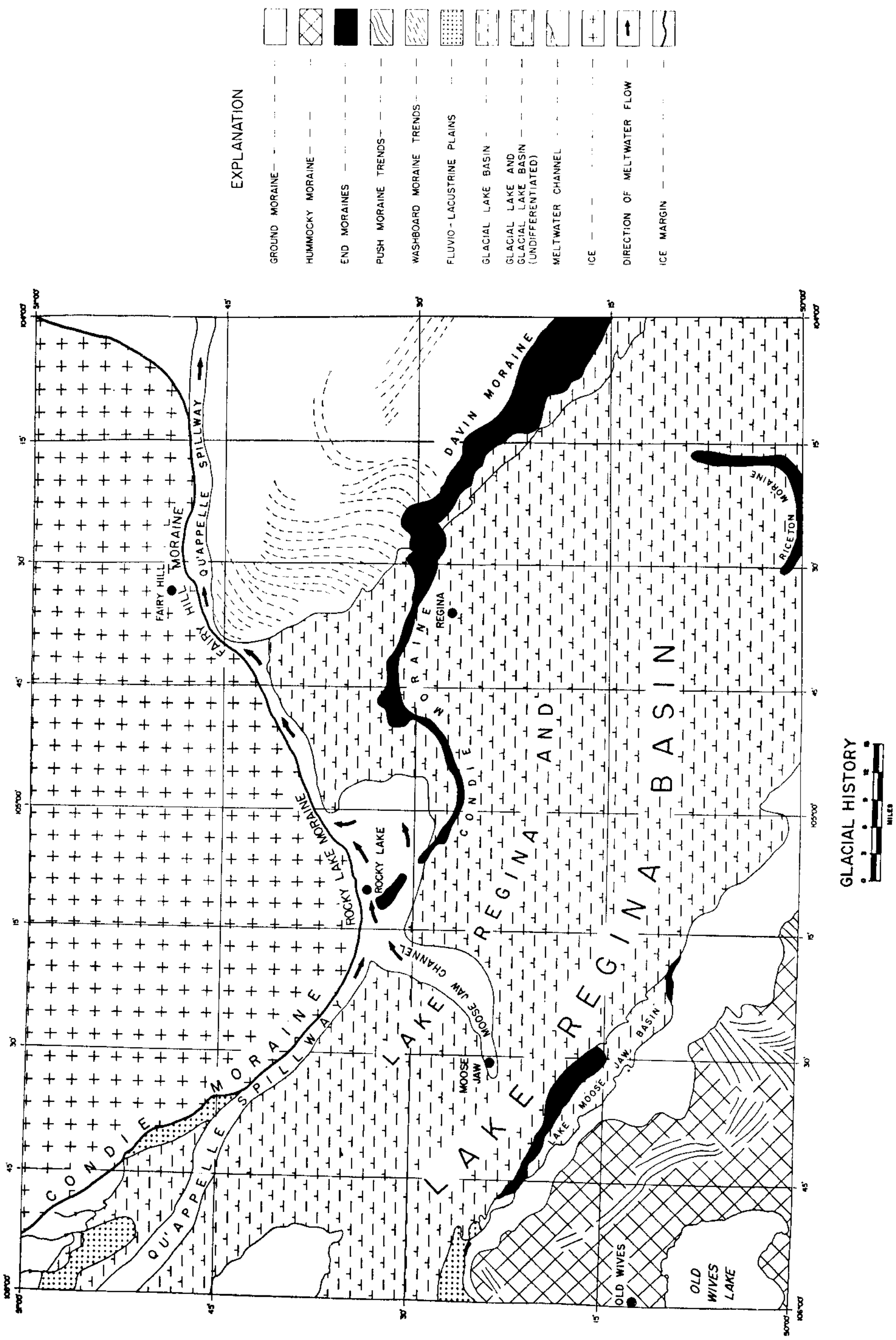


Figure 21.—Phase No. 4 of glacial history

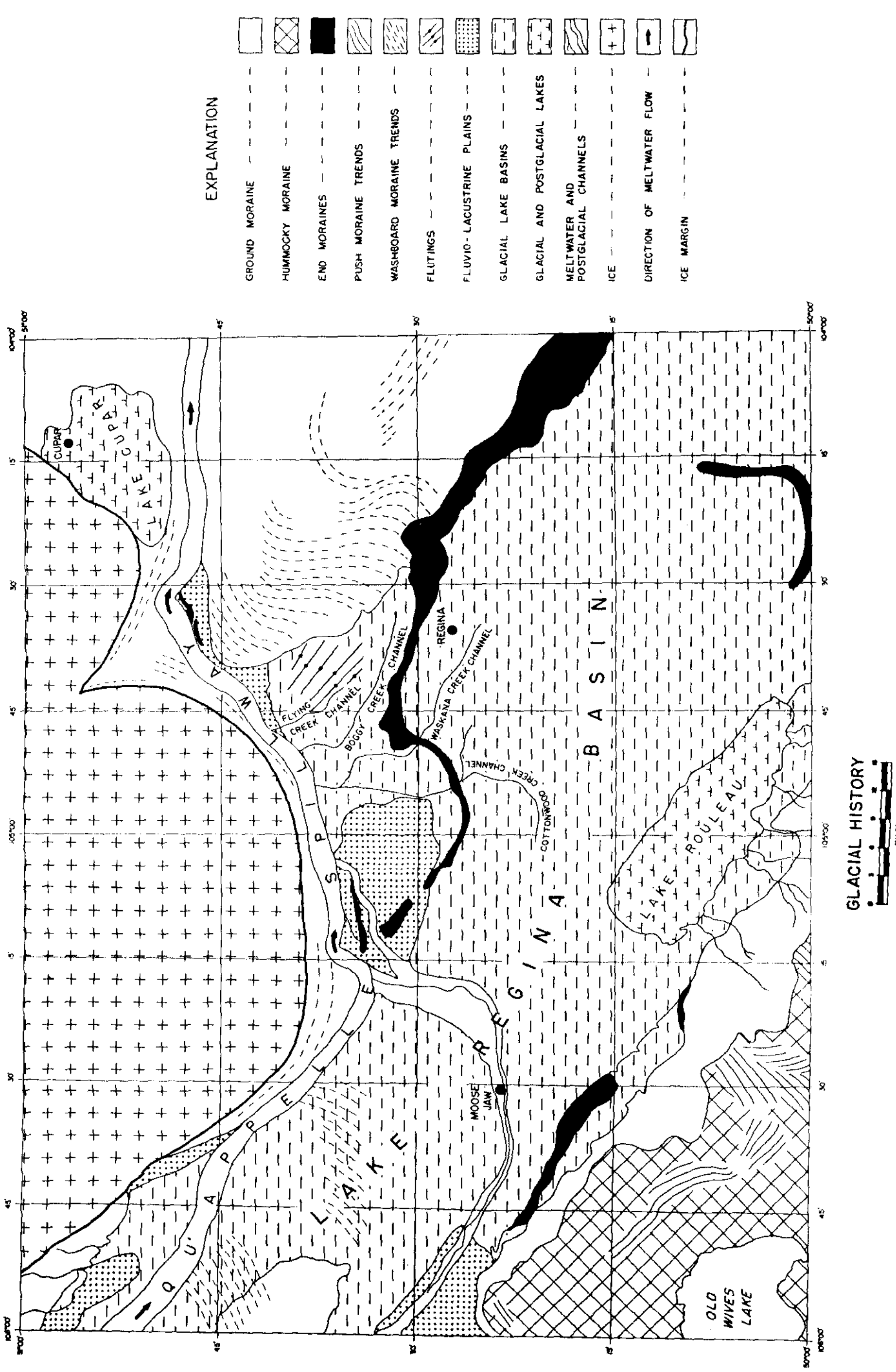


Figure 22.—Phase No. 5 of glacial history

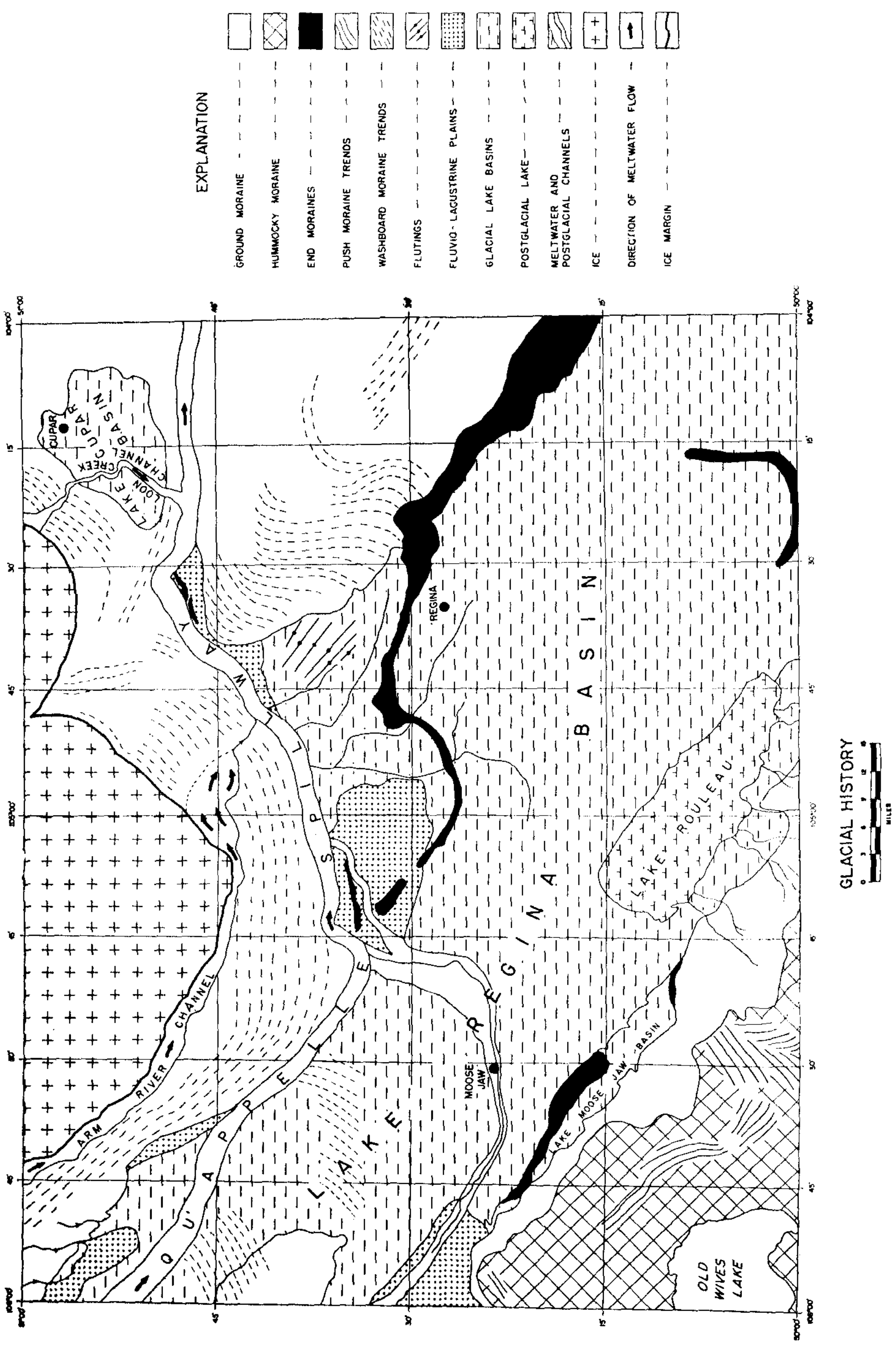


Figure 23.—Phase No. 6 of glacial history

meltwater cut the Arm River Terrace (Fig. 5) and formed an outwash plain near its confluence with the Qu'Appelle Spillway. Meltwater from the Arm River Channel continued down the Qu'Appelle Spillway at the level of the Tantallon Terrace (Fig. 5). The interlobate area, which was formed in Phase No. 5, was northwest of its position in Phase No. 5.

Phase No. 7

During Phase No. 7 of the Glacial History the glacier stood north of the Regina area (Fig. 24). Meltwater flowed into the Qu'Appelle Spillway from the Last Mountain Lake Channel and the Loon Creek Channel. Lake Rouleau, which originated as a remnant of Lake Regina between Phases No. 4 and No. 5, is believed to have been still in existence during Phase No. 7.

ECONOMIC GEOLOGY

Ground Water

General Statement

The paucity of hydrological and subsurface information necessitates a preliminary rather than a detailed ground-water investigation. The study is concerned primarily with the occurrence of permeable zones in the drift and bedrock, because hydrological data, for the most part, are lacking. With the exception of the southwest part of the Regina area where fine sands occur in the bedrock, the glacial sediments are believed to be the only source for ground water. The surface data were obtained from geological field mapping and from Mitchell *et al.* (1947). The subsurface data were obtained from exposures along streams, from Water Supply Papers (Table 2), from seismic shot-hole and structural test-hole data, and from test-holes drilled by the Saskatchewan Research Council and by the City of Regina. A ground-water probability map was compiled from these sources of information (Plate 3).

Occurrence

Qu'Appelle Valley Fill.—Preliminary studies show that the Qu'Appelle Valley is partly filled with three groups of sediment which are from top to bottom: Qu'Appelle Alluvium, Regina Clay and Condie Till, and sand and gravel of the Lower Stratified Drift (Fig. 15). The Qu'Appelle Alluvium is composed of interbedded sand, silt, and clay (Section 20, Appendix) and ranges in thickness from 20 to 40 feet. The sand unit in the alluvium is 10 to 12 feet thick in Sections 21 and 20 (Appendix), respectively. The alluvial sediments in the Qu'Appelle Valley generally have low transmissibility and are, therefore, of little importance for large supplies of ground water.

The Regina Clay is believed to interfinger with the Condie Till in the eastern part of the Regina area. Whether this facies change occurs within the Regina area is not known. Between Highway 6 and the confluence of Moose Jaw Creek and the Qu'Appelle Valley, the Regina clay is composed

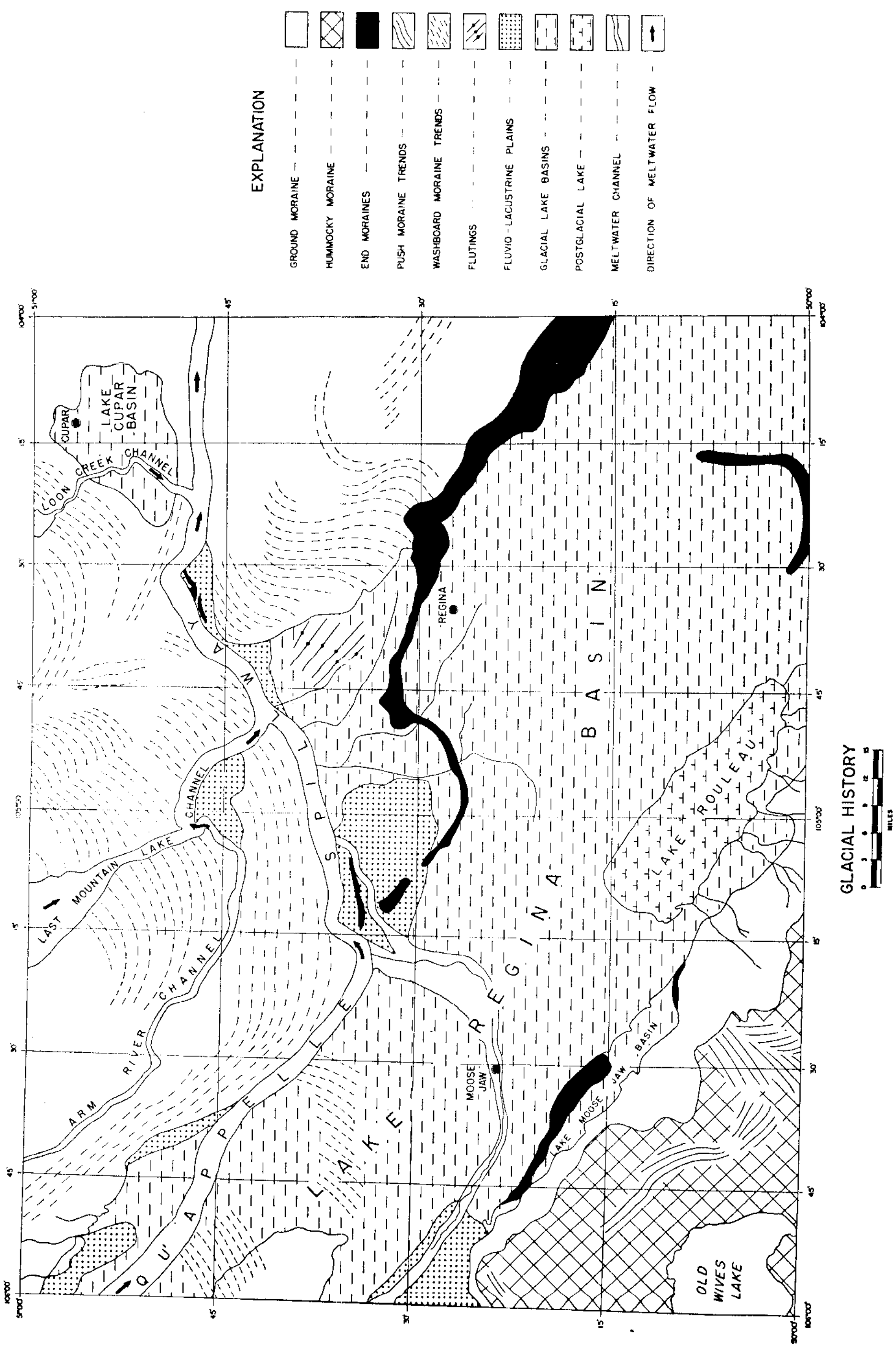


Figure 24.—Phase No. 7 of glacial history

Table 2.—Water Supply Papers of the Regina Area.
(Published by the Geological Survey of Canada, 1936)

Rural Municipality	Name	Water Supply Paper
97	Wellington	40
98	Scott	4
99	Caledonia	2
100	Elmsthorpe	10
101	Terrell	9
102	Lake Johnston	16
127	Francis	83
128	Lajord	122
129	Bratt's Lake	123
130	Redburn	124
131	Baildon	125
132	Hillsborough	47
157	South Qu'Appelle	104
158	Edenwold	134
159	Sherwood	135
160	Pense	136
161	Moose Jaw	137
162	Caron	138
187	North Qu'Appelle	153
189	Lumsden	154
190	Dufferin	155
191	Marquis	156
217	Lipton	162
218	Cupar	163
219	Longlaketon	164
220	McKillop	165
221	Sarnia	166
222	Craik	167

of about 105 feet of silt and clay. West of Buffalo Pound Lake, however, the Regina Clay is composed of about 100 feet of interbedded fine gravel, sand, silt, and clay. The coarser grained sediments should have transmissibilities sufficiently high to produce enough water for towns.

A glacial sand, which lies on bedrock in the Qu'Appelle Valley except where the valley intersects preglacial valleys, ranges in thickness from 10 to 15 feet (Sections 20 and 21, Appendix). This basal sand is believed to constitute the best aquifer in the Qu'Appelle Valley fill.

Thunder Creek Valley Fill.—A test-hole (Section 23, Appendix) shows that 11 feet of saturated, medium to coarse-grained sand occurs on top of the bedrock in the Thunder Creek Valley bottom. The sand is water bearing and has sufficient transmissibility for farm supplies. It is not known whether this sand is continuous in the Thunder Creek Valley; geological evidence, however, suggests that it may be so.

Surficial Sands and Gravels.—Surficial sands and gravels are subdivided into gravel thicker than 5 feet, gravel less than 5 feet thick, and sand thicker than 5 feet. Surficial sands and gravels, 5 to 20 feet thick, occur in outwash and fluvio-lacustrine plains whereas gravels less than 5 feet thick occur in eroded till plains.

Surficial sands and gravels also occur in areas favorable for deposition on eroded till plains. The stratified deposits are composed of lag sand, gravel, and boulder pavements which are commonly less than 5 feet thick.

In areas favorable for deposition, such as the inside of meanders, the sediment may be thicker than 5 feet. These deposits were formed by running water which has partly removed the underlying till.

Surficial sand is also common in the Regina area. These deposits are of fluvial, lacustrine, and aeolian origin. The sediment, for the most part, is fine grained and is commonly less than 10 feet thick. In Section 33, Township 18, Range 22, the dead-ice hollows contain at least 10 feet of fine-grained sand in which the water table lies 7 feet below the surface.

In evaluating surficial sand and gravel for ground-water supplies the following factors should be considered: (1) thickness of sediment, (2) transmissibility, (3) amount of closure upon the underlying till or clay surface, (4) the areal extent of the sand and gravel, and (5) the position of the water table. A few test-holes generally define the surface of the deposit, the water table, and the underlying till surface. It is then possible to calculate the volume of saturated sediment and, if the specific yield is known, the storage can be calculated.

Meltwater Channels.—Sands and gravels are associated with meltwater channels in alluvial fans, in slip-off slopes on meanders, in high-level terraces, and in channel bottoms under recent alluvium. These sediments are commonly 5 to 10 feet thick but locally may be up to 20 feet thick.

End Moraines.—Sands and gravels occur as ice-contact deposits in end moraines which are wall-like features. The Condie Moraine near Regina is composed of great thicknesses of sand and gravel, the lower part of which is saturated. In the Moose Jaw Moraine (S. 9, T. 16, R. 27) ice-contact sands and gravels discharge water to form Snowdys Spring which in turn discharges into Snowdys Coulee. Near Regina, a deltaic apron of sand and gravel is associated with the Condie Moraine. This deposit lies under Regina Clay in the interlobate area southeast of the moraine near Regina. East of Rowatt (T. 16 and 17, R. 19) flowing artesian wells derive water from gravel which underlies 40 feet of Regina Clay.

Sand and Gravel Lenses.—Sand and gravel lenses occur throughout the tills. These lenses vary from shoestring to blanket deposits which range in thickness from 5 to 20 feet. It is not possible to predict the location of subsurface lenses from studies of surficial deposits. Their position can be determined only from subsurface methods, such as drilling and geophysical surveys.

Intertill Sands and Gravels.—Sands and gravels occur between till sheets as channel and outwash deposits. If the present surface were covered by a till, the buried surficial sand and gravel would constitute intertill deposits. The paucity of subsurface data has made it difficult to detect this occurrence of sand and gravel. In Waskana Creek Valley, however, sand and gravel occur between two tills. Unfortunately, these deposits have been drained by Waskana Creek. In the northeast sector of the Regina area (T. 23, R. 20) a channel sand lies between two tills, the upper one of which is about 30 feet thick.

Buried Bedrock Valleys.—Bedrock valleys, which have been completely filled with glacial sediments, occur in the Regina area (Plate 2). Preliminary data, based on two test-holes (Sections 21 and 22, Appendix) and resistivity surveys, suggest that sand and gravel is not continuous in the Regina Valley. No preglacial sands and gravels occur upon the bedrock surface in the valley bottom. This is to be expected, however, because the valley has its beginning in the "Marine Shales" Formation, and consequently, there was no source of granular material. The gravel zones, which occur in buried bedrock valleys, are glacial in origin. In general, it is believed that the preglacial valleys have had only local control on the deposition of sand and gravel in the Regina area. Because the bedrock surface map of the Regina area is preliminary, the buried bedrock valleys are only broadly outlined (Plate 3).

Eastend and Lower Ravenscrag Formations.—Fine sands of the Eastend and Lower Ravenscrag Formations occur under glacial sediments in the southwestern portion of the Regina area. According to the Water Supply Papers, aquifers in the Lower Ravenscrag and Eastend Formation have low transmissibilities and are not very continuous in this area.

Springs

Springs are quite common along valley walls in the Regina area, particularly along the Qu'Appelle Valley. They occur as contact springs which drain intertill and surficial sands and gravels. South of Disley the water in the surficial, high-level sand and gravel is discharged into the Qu'Appelle Valley as a contact spring. In Section 13, Township 20, Range 21 the occurrence of shrubs below the intertill sand and gravel-till contact suggests that water is being discharged from this sand and gravel in one or more contact springs. Ground water is also discharged in contact springs along the northwest facing wall of the Qu'Appelle Valley (S. 12, T. 21, R. 20). Many more springs undoubtedly occur in the Regina area, but they have not been mapped.

Quality

Table 3 shows the quality of ground water in the Regina area. Analyses of water quality are available for the following ground-water occurrences: sand and gravel in till, surficial sand and gravel, and bedrock.

Water in sand and gravel in till ranges from 520 to 5080 p.p.m. in total dissolved solids, from 160 to 3000 p.p.m. in hardness, from 150 to 785 p.p.m. in alkalinity, from 20 to 730 p.p.m. in CaO, from 18 to 673 p.p.m. in MgO, from 107 to 3124 p.p.m. in SO_4, from 20 to 1347 p.p.m. in Na_2O, and from 10 to 482 p.p.m. in chloride. The water samples with high chloride content are believed to be in contact with bedrock water (Table 3).

Water in surficial sand and gravel ranges from 400 to 2040 p.p.m. in total dissolved solids, from 220 to 1350 p.p.m. in hardness, from 0 to 440 p.p.m. in alkalinity, from 70 to 180 p.p.m. in CaO, from 36 to 230 p.p.m. in MgO, from 41 to 1066 p.p.m. in SO_4, from 11 to 456 p.p.m. in Na_2O, and from 14 to 34 p.p.m. in chloride (Table 3).

Table 3.—Quality of ground water in the Regina area

Occurrence	Location				Depth	TDS	Hardness			ALK	CaO	MgO	SO_4	Na_2O	Cl
	¼	S	T	R			Total	Perm	Temp						
	SW	27	12	18	28	520	500	280	220	335	150	65	107	20	10
	SW	24	12	20	175	2980	1000	1000	0	150	120	173	1599	947	253
	SW	1	17	18	60	5080	2300	2300	0	435	380	396	3124	1295	45
	NE	4	17	18	40	3320	800	800	0	495	70	112	1681	1336	222
	SW	17	16	20	183	2160	500	280	220	445	170	79	1022	774	171
	NW	3	16	21	109	1500	800	700	100	535	60	389	619	109	48
	W½	6	16	21	100	3080	1900	1900	0	795	270	151	1468	935	32
	NW	10	16	21	80	1740	900	650	250	495	200	151	816	413	39
	SW	14	16	21	212	1520	850	750	100	510	170	158	623	322	40
	NE	36	16	21	84	1600	900	850	50	485	200	173	689	347	44
	NE	22	18	19	52	1960	1250	1100	150	355	180	209	1037	402	39
	NE	11	16	26	117	980	160	80	80	415	40	18	369	448	29
Sand and gravel within tills, between tills, and between till and bedrock	SE	1	17	25	185	1360	850	700	150	595	30	140	426	405	14
	SW	1	17	25	250	2580	1800	1200	600	785	20	252	1103	82	40
	NW	36	18	27	194	2940	1000	700	300	445	130	115	1525	106	150
	NW	23	19	20	86	4520	3000	3000	0	345	590	673	2755	428	142
	NW	36	12	25	11	1120	700	700	0	355	170	94	500	231	24
	NW	33	13	15	30	2060	900	850	50	585	150	184	931	603	103
	SW	14	13	19	225	3020	1250	1050	200	535	280	202	1050	810	482
	SE	10	13	19	148	3020	750	450	300	635	50	112	1271	1347	414
	NE	7	15	21	200	3940	1900	1800	100	580	230	328	2295	1103	25
	SW	9	15	21	96	3040	1300	1050	250	730	360	274	1374	547	30
	NW	5	15	22	163	2480	350	120	230	685	100	40	972	1030	172
	NW	8	15	22	200	2200	450	100	350	685	20	61	820	998	184
	NE	12	15	24	172	2820	850	500	350	705	220	144	959	902	364
	SE	36	15	28	105	2880	1250	1050	200	340	180	191	1650	815	36
	NE	18	17	17	198	1700	340	0	340	500	140	76	632	—	34
	SW	2	19	17	25	2080	1700	1500	200	430	120	270	1132	500	59
	NE	30	19	17	47	3280	2600	2500	100	240	730	418	2099	69	24
	NW	18	20	17	63	2940	2800	2000	800	475	440	414	1673	262	18
	NE	36	20	17	80	2560	2000	1500	500	380	260	288	1468	497	52
	NE	21	16	19	45	2180	750	550	200	515	40	112	1095	880	81

Table 3.—(*Continued*)

Occurrence	Location				Depth	TDS	Hardness			ALK	CaO	MgO	SO_4	Na_2O	Cl
	¼	S	T	R			Total	Perm	Temp						
	SW	14	17	19	40	1100	750	550	200	380	70	94	472	335	21
	SE	1	16	27	35	940	500	360	140	265	170	65	403	176	47
Surficial sand and gravel	NW	10	14	25	20	400	220	140	80	200	90	36	41	11	16
	NW	7	15	29	6	920	800	550	250	340	150	101	398	158	14
	SW	18	15	29	6	1360	950	600	350	375	100	122	636	375	34
	NE	18	17	17	0	400	196	49	147	0	140	43	48	—	15
	SE	25	20	17	4	2040	1350	1200	150	440	160	230	1066	956	31
	NE	28	16	28	4	1455	950	900	50	225	180	144	787	258	32
	NW	35	16	29	12	880	700	600	100	360	70	115	201	199	15
	SE	31	20	16	6	1600	1250	1100	150	425	140	191	754	313	15
Bedrock	NW	20	12	22	54	4120	100	15	85	655	70	72	2132	1712	94
	SW	16	18	28	300	2400	1400	1100	300	480	202	1214	502	2205	50
	SE	8	22	22	418	4770	90	20	70	240	50	25	127	225	2425
	NW	21	23	24	126	6380	1050	950	100	260	160	198	3130	2524	944
*Qu'Appelle Valley	NW	13	19	23	135	—	410	Fe=3 p.p.m.			—	—	—	—	6125

*Hach Water Test Kit, Saskatchewan Research Council. The remainder of analyses are from Geological Survey of Canada Water Supply Papers (Table 2) All analyses are reported in parts per million.
TDS =Total dissolved solids
Perm =Permanent hardness
Temp =Temporary hardness

Water in bedrock ranges from 2400 to 6380 p.p.m. in total dissolved solids, from 90 to 1400 p.p.m. in hardness, from 240 to 655 p.p.m. in alkalinity, from 50 to 202 p.p.m. in CaO, from 25 to 1214 p.p.m. in MgO, from 127 to 3130 p.p.m. in SO_4, from 225 to 2524 p.p.m. in Na_2O, and from 50 to 2425 p.p.m. in chloride (Table 3).

In general, the total dissolved solids in water which occurs in surficial sand and gravel is less than in water which occurs in sand and gravel in till. The chloride content of bedrock water is, almost without exception, much higher than that of drift water. If the chloride content of water is greater than 300 p.p.m., it can be surmised that the water is either derived from bedrock or from the base of the drift.

The dissolved solids are mainly sodium, magnesium, and calcium sulfates, sodium chloride, and calcium and magnesium carbonates. There does not appear to be any correlation between the chemical analyses of the ground water and depth which suggests that not much leaching has taken place.

Gravel

General Statement

Because the Department of Highways is conducting extensive studies on the location, quantity, and quality of gravel, it suffices here to classify these deposits and to give guidance for future prospecting. In general, there are two main types of gravel deposits in the Regina area; those deposited at or near the ice front (ice-contact gravel and proglacial gravel) and those derived from the erosion of till by proglacial meltwaters. These gravel deposits are shown in Plate 1.

Occurrence

General Remarks.—Preliminary studies indicate that the gravel deposits in the Regina area are restricted to the following occurrences: fluvio-lacustrine plains, valley bottoms, interlobate areas, kames, eroded till plains, and end moraines.

Fluvio-Lacustrine Plains.—Gravel occurs in fluvio-lacustrine plains which were associated with the ice front (south of Lillestrom in T. 14, R. 29; Pilot Butte in T. 18, R. 18; south of Davin in T. 16, R. 16; and southwest of Chamberlain in T. 21, R. 27) or with meltwater channels (Findlater in T. 21, R. 25; west of Aylesbury in T. 22, R. 29; south of Regina Beach in T. 21, R. 22; northwest of Markinch in T. 23, R. 18; and around Rocky Lake in T. 18 and 19, R. 23 and 24). These deposits are well sorted and stratified. Commonly they contain a large percentage of medium and coarse sand. The sediment ranges from 5 to 15 feet in thickness.

Valley Bottoms.—Thick deposits of gravel occur in valley bottoms, particularly on the inside of meanders. This type of deposit is well illustrated in the Arm River Valley (S. 14, T. 21, R. 25) where the gravel is about 20 feet thick (Fig. 25).

Interlobate Areas.—Gravel occurs in the interlobate area west of Gibbs (T. 22, R. 21). This deposit is composed of ice-contact and proglacial sediments which lie in a linear, shallow trench 10 miles long and up to 1 mile wide. Locally the shallow trench is completely filled with stratified deposits of ice-contact and proglacial origin.

Kames.—Gravel interspersed with sand, silt, clay, and till occurs in kames in the Davin Moraine east of Regina. The sediments are heterogeneous and contorted in a manner typical of ice-contact deposits of this type. The gravel occurs as lenses which are up to 30 feet in diameter.

Eroded Till Plains.—Gravel occurs on till plains which were eroded by meltwater. In most places the eroded till plain is covered with less than 5 feet of sand, gravel, and boulders which were left behind as a lag deposit or pavement. In locations favorable for deposition, however, the gravel deposits may attain a thickness of 10 to 15 feet.

End Moraines.—Ice-contact gravels occur in the Condie Moraine (S. 19, T. 18, R. 20; S. 23, T. 18, R. 21; S. 24, T. 18, R. 24; and S. 3, T. 22, R. 27) and in the Moose Jaw Moraine (S. 10, 17, and 18, T. 16, R. 27). The gravels are interspersed with sand, silt, clay, and till.

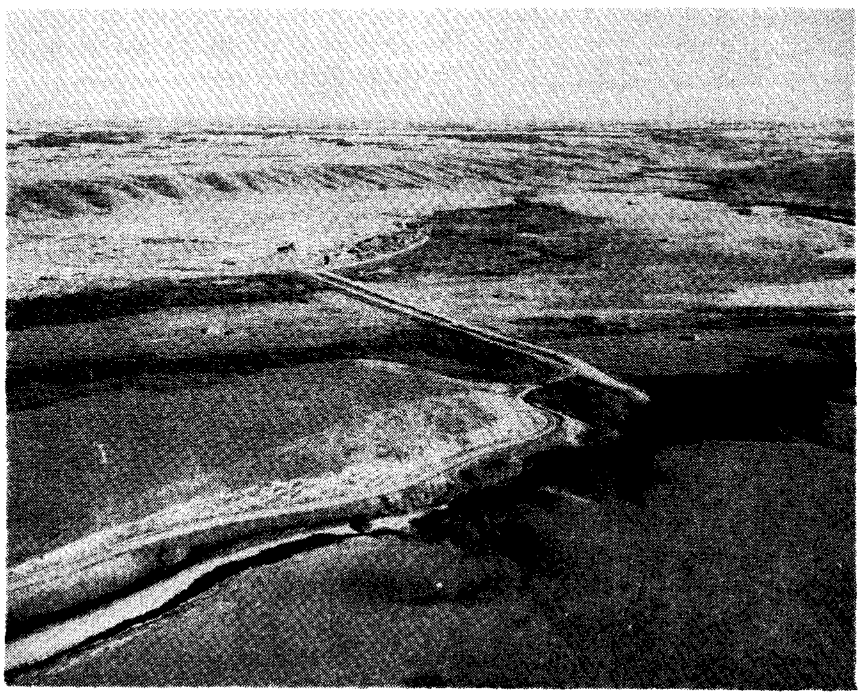


Figure 25.—Gravel deposit in the Arm River Valley near Findlater. The gravel occurs in a terrace deposit on the inside of a meander (S. 14, T. 21, R. 25).—*Photo Saskatchewan Photographic Services*

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APPENDIX

Stratigraphic Sections*

Section 1.—Cupar Section. Section is in road cut in north valley wall of Qu'Appelle Valley, 1/5 mile north of S.W. corner S. 22, T. 21, R. 17, W. 2.

Deposit	Thickness (feet)
Condie Till	
Till, calcareous, clay loam, light-brownish grey (2.5 Y 6/2**, when dry), unoxidized, locally oxidized, jointed. Unit is exposed in several separated road cuts. Base of unit is distinct and regular.	80
Lower Stratified Drift	
Boulders, gravel, and sand, lenses of channel gravel and sand, up to 8 feet thick. Locally, boulder pavements occur which have striations that range in strike from 85° to 105°. This unit is interpreted as an intertill deposit.	1-8
Lower Till	
Till, calcareous, clay loam, pale yellow (2.5 Y 8/4, when dry), oxidized. Basal 40 feet poorly exposed.	56+

Section 2.—Waskana Creek Section 1. Section is in the east valley wall of Waskana Creek Valley, 2/3 mile west and 1/4 mile north of S.E. corner S. 21, T. 18, R. 21, W. 2.

Deposit	Thickness (feet)
Condie Till	
Till, calcareous, sandy clay loam, light-yellowish brown (2.5 Y 6/4, when dry), oxidized. Basal 1 foot of unit has lenses of gravel which, apparently, were brought up along shear zones into the till from the underlying gravel. The base of till is distinctive and regular.	15
Lower Stratified Drift	
Gravel, containing coarse sand, pebbles, and a few cobbles, cross-bedded. Contact with underlying unit is distinct, irregular, and has a relief of about 5 feet.	12

*The location and general lithology of sections is shown in Figure 9.

**From Munsell soil color chart.

Sand, noncalcareous to slightly calcareous, medium to coarse grained, pale yellow, oxidized, well stratified. Contact with underlying unit is distinctive. This unit and the overlying gravel are interpreted as an intertill deposit.	12
LOWER TILL	
Till, calcareous, sandy clay loam, grey (2.5 Y 5/0, when dry), unoxidized. Upper 5 feet is light-brownish grey (2.5 Y 6/2, when dry), oxidized. Base of unit is not exposed.	55+

Section 3.—WASKANA CREEK SECTION 2. The section is in the east valley wall of Waskana Creek Valley, 3/5 mile west and 1/5 mile south of N.E. corner S. 21, T. 18, R. 21, W. 2.

Deposit	Thickness (feet)
REGINA CLAY	
Clay and silt, varved, formed in glacial Lake Regina. Contact with underlying unit is distinct and regular.	7
CONDIE TILL	
Till, calcareous, loam, olive brown (2.5 Y 4/2, when moist), oxidized. Contact with underlying unit is distinct and regular.	10
LOWER STRATIFIED DRIFT	
Gravel, coarse sand to pebbles, lower part of unit is mainly sand. Contact with underlying unit is distinct and irregular. This unit is interpreted as an intertill deposit.	12
LOWER TILL	
Till, calcareous, clay loam, dark-greyish brown (2.5 Y 4/2, when moist) where unoxidized to olive brown (2.5 Y 4/4, when moist) where oxidized. The upper third of the unit is oxidized whereas the lower third is essentially unoxidized. The contact between the oxidized and unoxidized parts is gradational. A boulder 2 feet in diameter, which lies on the till surface, has N-S trending striations.	14
Silt, calcareous, very fine sand, brownish grey, unoxidized, interbedded with clay beds (1/2-3 inches thick), varved. The upper 4 inches of the unit is partly oxidized. The unit, which is poorly exposed, is interpreted as a lens.	1½

Till, calcareous, clay loam, very dark-greyish brown 2.5 Y 3/2, when moist), unoxidized. Base of unit not exposed.	15+

Section 4.—WASKANA CREEK SECTION 3. Section is in west valley wall of Waskana Creek Valley, 1/4 mile south of N.E. corner S. 29, T. 18, R. 21, W. 2.

Deposit	Thickness (feet)
REGINA CLAY	
Clay and silt, varved, contorted, till-like near base. It is believed that the clay and silt were deposited in part upon dead-ice and subsequently collapsed.	20
CONDIE TILL	
Till, calcareous, clay loam, light-olive brown (2.5 Y 5/4, when moist), oxidized. The upper part of the unit contains more sand and is interpreted as ablation till.	9
WASKANA CREEK ASH	
Volcanic ash, light grey, platy shards of glass, silt to fine sand in texture, associated with lacustrine clay.	1/3
CONDIE TILL	
Sand, coarse grained, pebbly, oxidized, poorly sorted and stratified. The unit is lens-like and probably less than 50 feet long. This unit and the overlying ash is interpreted as having been deposited in a depression on dead-ice, and subsequently was covered by ablation till.	15
Till, calcareous, clay loam, greyish brown (2.5 Y 5/2, when dry), unoxidized. Upper 1-4 feet is olive brown (2.5 Y 4/4, when moist), oxidized.	35
LOWER STRATIFIED DRIFT	
Clay, noncalcareous, very dark grey (2.5 Y 3/0, when moist), unoxidized, except for iron oxide staining along joints, massive. The unit contains a few thin stringers of sand and becomes more poorly sorted as the valley wall is approached from the creek. It contains numerous concretions from the "Marine Shales" Formation. It is believed that this unit is an alluvial-colluvial sediment derived largely from the "Marine Shales" Formation. Base of unit is distinct and regular.	10

Sand, coarse grained, pebbly at base, fine to medium grained at top of unit. The lens-shape suggests a channel sand.	8
LOWER TILL	
Till, calcareous, clay loam, very dark grey (2.5 Y 3/3, when moist), unoxidized. Base of unit is not exposed.	18+

Section 5.—COTTONWOOD CREEK SECTION. Section is in the east valley wall of Cottonwood Creek Valley, 1/5 mile south of N.W. corner S. 24, T. 18, R. 22, W. 2.

Deposit	Thickness (feet)
CONDIE TILL	
Till, calcareous, olive brown (2.5 Y 4/4, when moist), oxidized, friable.	5
Sand, calcareous, medium grained, locally coarse grained and pebbly, steeply dipping, oxidized, lens-like. Base is not exposed.	3
Till, calcareous, very dark grey (10 Y R 3/1, when moist), unoxidized. The lower 2 feet contains stringers of volcanic ash up to 1 cm thick.	6
LOWER STRATIFIED DRIFT	
Silt, calcareous, grey, unoxidized to yellowish grey, oxidized, well stratified, strata 1-2 cm thick. Base of unit is distinct and regular.	30
Gravel, coarse sand, pebbly, oxidized, containing unoxidized silt beds up to 5 cm thick, cross-bedded. The contact with the underlying unit is distinct, irregular, and has a relief of 8 feet.	8
LOWER TILL	
Till, calcareous, very dark grey (10 Y R 3/1, when moist), unoxidized. Base of unit is not exposed.	8+

Section 6.—BUFFALO POUND SECTION. The section is on the north side of Highway 2 in the northeast valley wall of Qu'Appelle Valley, 1/5 mile north and 1/2 mile east of S.W. corner S. 29, T. 20, R. 26, W. 2.

Deposit	Thickness (feet)
CONDIE TILL	
Till, calcareous, clay loam, yellowish brown, oxidized. Most of the unit has been removed by postglacial erosion.	5

REGINA CLAY

Sand, fine grained, yellowish grey, grades laterally into coarse sand and gravel. The contact with the underlying till is distinct and irregular and has a relief of 5 feet.	10

CONDIE TILL

Till, calcareous, sandy clay loam, yellowish brown, oxidized to clay loam, dark grey, unoxidized. The basal 11 feet is unoxidized whereas the upper 7 feet is oxidized. The contact between the oxidized and unoxidized till is gradational. Base of unit is distinct and regular.	17
Boulders, cobbles, pebbles, and sand. The boulders form a horizontal boulder pavement which is locally underlain by channel sands up to 7 feet thick. The base of the unit is distinct and irregular and has a relief of 7 feet.	1-8
Till, calcareous to slightly calcareous, clay loam, dark grey, unoxidized, containing numerous lenses of sand and gravel up to 20 feet thick in the lower 35 feet of the unit. The base of the unit is distinct and regular.	70
Gravel, composed essentially of pebbles, cobbles, and beds of coarse sand. The unit contains a till lens. The base of the unit is distinct and irregular and has a relief of about 2 feet.	18
Sand, medium to coarse grained, well stratified, cross-bedded, greyish brown, poorly sorted.	10
Clay, calcareous, light-olive brown (2.5 Y 5/4, when moist), massive.	4
Sand, medium grained, containing a few pebbles, pale brown, well stratified and cross-bedded.	2
Sand, slightly calcareous, fine to medium grained, light-yellowish brown (2.5 Y 6/4, when dry), oxidized. The unit is well stratified and sorted and is locally cross-bedded. The sand contains a large number of sphaerid valves which show little wear. The fine texture of the sand and the fact that the valves are not broken suggest quiet water deposition and not much transportation.	6
Till, calcareous, clay, olive brown (2.5 Y 4/4, when moist), oxidized. The upper 4 inches is highly oxidized but not leached. The base of the unit is not exposed.	40+

Section 7.—ROCKY LAKE SECTION. Section is in a road cut in the south valley wall of the Qu'Appelle Valley in the N.E. 1/4, S. 12, T. 19, R. 24, W. 2.

Deposit	Thickness (feet)
Gravel, cobbles and boulders, well sorted. Base of unit is distinct and regular.	2-6
CONDIE TILL	
Till, calcareous, clay loam, brown (10 Y R 5/3, when dry), oxidized. Base of unit is distinct and regular.	5
Boulder pavement, composed of scattered boulders which rest in the upper part of the underlying clay loam. The top of the boulders marks the contact between the overlying till and underlying clay loam. Striations on three boulders show trends of N50W and N20W.	1
REGINA CLAY	
Clay loam, calcareous, yellowish brown (10 Y R 5/6, when moist) where oxidized and grey (10 Y R 5/1, when moist) where unoxidized, massive. Base of unit is distinct and regular.	19
CONDIE TILL	
Till, calcareous, clay loam, olive brown (2.5 Y 4/4, when dry), oxidized. The base is distinct, irregular, and has a relief of 10 feet.	19
LOWER STRATIFIED DRIFT	
Gravel, composed mainly of pebbles and cobbles, and minor amounts of sand.	2
Sand, calcareous, medium grained, locally pebbly, brownish yellow (10 Y R 6/6, when dry), oxidized, well sorted and stratified, containing beds of clay up to 1 foot thick. Carbonate concretions occur in clay bed near top of unit.	25
Clay, calcareous, silty, grey (10 Y R 6/1, when dry), unoxidized, locally reddish yellow (7.5 Y R 6/6, when dry) and light-yellowish brown (2.5 Y 6/4, when dry), oxidized. This unit is rich in ostracods. Base of unit is not exposed. The clay lies on both sides of a normal fault which cuts the section. The clay also occurs in a slump block 300 feet down the valley wall. The normal fault (Fig. 10) was caused by slumping.	11+

Section 9.—OLD WIVES LAKE SECTION. Section is in a gravel pit near the S.E. corner of S. 24, T. 12, R. 30, W. 2, landward from the sandy beaches south of Old Wives Lake.

Deposit	Thickness (inches)
Recent soil (A and B horizons)	6 inches
Sand, calcareous, coarse grained, pebbly, very pale brown (10 Y R 4/4, when dry), oxidized, well stratified, fluvio-lacustrine in origin.	16 inches
Sand, calcareous, coarse grained, pebbly, light-brownish grey (10 Y R 6/2, when dry). This unit is interpreted as a buried A horizon.	3 inches
Sand, calcareous, coarse grained, pebbly, light grey (10 Y R 7/2, when dry) where unoxidized, brownish yellow (10 Y R 6/6, when dry) in places where oxidized, containing at least one dark grey organic zone. This unit is interpreted as an accretion soil, the oxidized portion of which represents an incipient B horizon.	17 inches
Sand, calcareous, coarse grained, pebbly, stratified, pale brown (10 Y R 4/4, when dry), oxidized, containing 1 to 3 inch thick beds of grey, medium sand. Base of unit is not exposed. This unit is of fluvio-lacustrine origin.	48+ inches

INTERPRETATION OF SECTION: The presence of a buried soil, which is underlain and overlain by fluvio-lacustrine sand, indicates that there were at least two episodes of fluvio-lacustrine activity which suggests that major climatic changes have taken place.

Section 17.—ADAMS TEST-HOLE. Section is in a test-hole in the N.E. corner S. 21, T. 17, R. 21, W. 2.

Deposit	Thickness (feet)
REGINA CLAY	
Clay, calcareous, silty, containing a few very coarse sand grains, greyish brown (2.5 Y 5/2, when dry), unoxidized, massive.	11
Silt, calcareous, clayey, light-greyish brown (2.5 Y 6/2, when dry), unoxidized.	11
Clay, calcareous, containing a few coarse sand grains, light-greyish brown (5 Y 5/2, when dry), unoxidized, massive. Contact with underlying till appears to be gradational.	11

LOWER TILL	
Till, calcareous, light-olive brown (2.5 Y 5/4, when dry), oxidized.	9+

Section 19.—ROULEAU TEST-HOLE. Section is in a test-hole in the N.W. corner S. 11, T. 14, R. 23, W. 2.

Deposit	Thickness (feet)
ROULEAU CLAY	
Clay, calcareous, grey (2.5 Y 5/1, when dry), unoxidized, massive.	11
REGINA CLAY	
Clay, calcareous, olive grey (5 Y 5/2, when dry), unoxidized, massive.	21
"MARINE SHALES" FORMATION	
Clay, slightly calcareous, silty to very fine sandy, grey (5 Y 5/1, when dry), unoxidized.	28+

Section 20.—QU'APPELLE VALLEY TEST-HOLE 1. Section is in test-hole in N.W. Corner of S. 13, T. 19, R. 23, W. 2.

Deposit	Thickness (feet)
QU'APPELLE ALLUVIUM	
Silt, calcareous, clayey, light-brownish grey (2.5 Y 6/2, when dry), unoxidized.	15
Clay, calcareous, light-greyish brown (2.5 Y 6/2, when dry), unoxidized, containing wood and a few pebbles.	3
Sand, very fine grained, calcareous, silty, light-brownish grey (2.5 Y 6/2, when dry), unoxidized, water bearing.	12
REGINA CLAY	
Clay, noncalcareous to slightly calcareous, grey (5 Y 5/1 to 6/1, when dry), unoxidized, containing blebs of organic matter.	20
Clay, calcareous, locally silty, grey (5 Y 6/1, when dry), unoxidized, containing blebs of organic matter and pieces of wood, fossiliferous (particularly at a depth of 60 to 75 feet where numerous gastropods and pelecypods were observed).	80
Clay, calcareous, sandy, grey (5 Y 5/1, when dry), unoxidized.	5

LOWER STRATIFIED DRIFT	
Sand, slightly calcareous, medium grained, containing a few coarse sand grains. Water bearing, piezometric level 30 feet below surface.	15
"MARINE SHALES" FORMATION	
A 1-inch core of clay was encountered in the bottom of the hole. It was not possible to deepen the hole because of damaged casing. This clay is interpreted as probably belonging to the "Marine Shales" Formation.	1 inch

Section 21.—QU'APPELLE VALLEY TEST-HOLE 2. Section in test-hole in the S.W. 1/4, S. 28, T. 20, R. 20, W. 2. Surface elevation 1599 feet; bedrock elevation 1377 feet. Log based on samples obtained from City of Regina.

Deposit	Thickness (feet)
QU'APPELLE ALLUVIUM	
Clay, calcareous, silty, olive grey (when dry), unoxidized.	10
Sand, calcareous, medium to coarse grained, poorly sorted.	10
REGINA CLAY	
Clay, calcareous, silty, olive (when wet), unoxidized, containing coarse sand grains which are believed to have fallen in from above.	5
Silt, calcareous, clayey, olive (when dry), unoxidized, pebbles believed to be cavings.	5
Clay, calcareous, olive grey (when dry), unoxidized.	10
Silt, calcareous, light-olive grey (when dry), laminated, contaminated with pebbles from above.	10
Clay, calcareous, silty, grey (when dry), unoxidized.	5
Silt, calcareous, light-olive grey (when dry), lower 5 feet is clayey and laminated.	10
Clay, calcareous, light-olive grey (when dry), unoxidized.	10
Silt, calcareous, clayey, olive grey (when wet), unoxidized, laminated.	10
Clay, calcareous, grey (when dry), unoxidized.	15
Silt, calcareous, olive (when dry).	5
Clay, calcareous, grey (when dry), unoxidized, massive.	20

LOWER STRATIFIED DRIFT	
Sand, coarse grained, pebbly, poorly sorted.	10
TILL	
Till, calcareous, grey (when dry), unoxidized.	15
STRATIFIED DRIFT	
Clay, calcareous, locally silty, grey (when dry), unoxidized, massive, contaminated in upper part with pebbles from above.	40
Silt, calcareous, clayey, grey (when dry), unoxidized, laminated.	10
Clay, calcareous, grey (when dry), massive.	5
Gravel, coarse-grained sand, pebbles of limestone, shale, and igneous rocks.	10
Clay, calcareous, grey (when dry), unoxidized, laminated.	5
"MARINE SHALE" FORMATION	
Clay, noncalcareous, grey (when dry), unoxidized, massive.	57+

Section 22.—REGINA TEST-HOLE. Test-hole is in the N.E. corner of S. 36, T. 17, R. 20, W. 2. Surface elevation 1900 feet; bedrock elevation 1425 feet. Log based on samples obtained from City of Regina.

Deposit	Thickness (feet)
REGINA CLAY	
Clay, calcareous, olive grey (when dry).	30
Clay, calcareous, silty, light-olive grey (when dry).	20
Silt, calcareous, light-olive grey (when dry).	7
DRIFT UNDIFFERENTIATED AS TO STRATIGRAPHIC RANK	
Till, calcareous, light-brownish grey (when dry), oxidized.	5
Till, calcareous, greyish brown (when dry), unoxidized, locally oxidized.	11
Till, calcareous, grey (when dry), unoxidized.	90
Silt, calcareous, grey (when dry).	10
Till, calcareous, grey (when dry), unoxidized.	18
Till, as above with white specks.	9
Till, calcareous, grey (when dry), unoxidized.	176

Gravel, coarse sand and pebbles, contaminated by drilling mud.	11
Till, calcareous, grey (when dry), unoxidized.	80
Gravel, coarse sand, and pebbles.	8
"MARINE SHALES" FORMATION	
Shale, calcareous, grey (when dry), indurated, laminated.	1+

Section 23.—MOOSE JAW TEST-HOLE. Section in test-hole in the S.W. corner of S. 35, T. 16, R. 27, W. 2. Surface elevation 1800 feet (altimeter); bedrock elevation 1765 feet (altimeter).

Deposit	Thickness (feet)
Sand, calcareous, fine grained, olive grey.	4
Clay, calcareous, olive grey (Regina Clay).	2
Sand, calcareous, fine to medium grained, containing a few coarse and very coarse sand grains. Not water bearing.	4
Sand and clay, interbedded with 1 foot clay beds at 10 and 16 feet. Sand, fine to coarse grained, poorly sorted, containing pebbles 30 to 40 mm in diameter. Not water bearing.	13
Clay, calcareous, grey, containing silt laminae and a few pebbles.	1
Sand, calcareous, medium to coarse grained, well sorted, water bearing.	11
"MARINE SHALES" FORMATION	
Clay, noncalcareous, silty, grey, unoxidized, fossiliferous.	4+