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GLACIAL GEOLOGY
St. Ann Area

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GLACIAL GEOLOGY, ST. ANN AREA

INTRODUCTION

The St. Ann map area, containing approximately 4,000 square miles, lies 55 miles west of Edmonton, Alberta, between longitudes 114° and 116° West, and latitudes 53°7′ and 54° North. Map 24, "Preliminary Map, Glacial Geology, St. Ann Area", accompanies this report.

Three lines of the Canadian National Railways pass through the area. The main line to Jasper runs east and west through the centre of the map sheet and branch lines pass through Onoway and Sangudo in the north and through Thorsby and Sunnybrook in the southeast.

The Edmonton-Jasper highway parallels the main line of the C.N.R. and another highway (No. 41) turning from Carvell Corner through Onoway gives access to the northeastern section of the area. Other gravelled and improved roads service the eastern part of the area, but west of Pembina river transportation becomes a problem. However, there is a road north from Carrot creek which partly parallels the McLeod river connecting with highway 41 near Whitecourt; recently, a new forestry road has been completed which runs south from Carrot creek and gives access to the sparsely settled country around Rat creek.

The McLeod, Pembina and North Saskatchewan rivers flow through the map area. The first two rivers are tributaries of the Athabasca river, which continues north into the Mackenzie River system and on to the Arctic ocean. The North Saskatchewan river follows an easterly course and eventually empties into Hudson's Bay. Thus, within the map area there exists a narrow watershed between two great river systems. It is worthy of note that south of Evansburg this watershed is only about ten miles wide. All major rivers are passable by canoe, although the Pembina river in the vicinity of Evansburg has many shallow places where portaging is necessary.

Mixed farming forms the predominant industry, with some lumbering operations centred around Wildwood and Granada villages and open-pit coal mines in operation near Entwistle and on the north shore of Wabamun lake.

Widespread geophysical surveys have been made during the past few years and as a result some exploratory wells have been drilled in the search for oil in the region between Majeau lake and Glenevis and south of Chip lake. The Majeau Lake wells are known to be producers of heavy crude oil and gas.

After this survey was completed, a major petroleum field was developed in the Cardium sandstone in the Drayton Valley area.

This report presents the results of an investigation of the geology of the Pleistocene and Recent ages in the St. Ann area. It describes

the stratigraphic relationships of the various glacial and interstadial* deposits; a map was prepared to show the distribution of the glacial deposits and the topographical features with which the deposits are associated.

Glacial deposits are of considerable economic importance as they contain materials useful for heavy construction and it is possible that they may provide the necessary ingredients for the manufacture of bricks, tile, cement, etc. A study of the glacial deposits is important as they sometimes form the parent materials of the soils.

An attempt has been made to describe the preglacial drainage pattern of the major rivers. These patterns are of interest not only from the academic standpoint but also because they contain large gravel and sand deposits.

In 1952, H. Hominiuk and V. Sweetnam, student assistants, performed their duties in a capable manner. J. S. Groot, draftsman for the Research Council, prepared the accompanying map. The glacial problem of central Alberta was suggested by Dr. P. S. Warren, Chairman, Advisory Committee on Geology, Research Council of Alberta, and Head of the Department of Geology, University of Alberta.

PHYSICAL FEATURES

The physiography of the Province of Alberta has been divided by Allan (1943) into four main divisions, namely, mountains, foothills, plains, and Precambrian Shield area. The St. Ann district lies in a region between the foothills to the west and the true plains to the east. This region has a complex glacial history. The present investigations have only partially removed the problems of the extent, intensity and chronology of the Keewatin and Cordilleran glaciations.

The St. Ann district lies on the eastern limb of the Alberta syncline where the Paskapoo formation outcrops in a gentle scarp running north and south between Chip and Isle lakes. Thus the western part of the area is underlain by relatively soft Tertiary sandstones while the eastern part is underlain by sandstone, shale and coal beds of the Edmonton formation.

The surface of the area slopes gently from an elevation of 3,500 feet in the southwest to about 2,300 feet in the northeast. Three broad topographic divisions may be defined:

1. A sand plain with many surface indications of weathered Paskapoo sandstone in the southwest.
2. A large area of modified lake beds straddling the Pembina and North Saskatchewan rivers in the south and central region.
3. An area of moraine lying generally north of a line through Chip, Isle and Wabamun lakes.

Before the advent of the Pleistocene glaciations, the existing topography must have been the result of long erosion on sandstones

*Interstadial refers in this report to the time interval between till deposits. Stratigraphically the time interval may be interglacial or interstadial.

and shales of Tertiary and late Cretaceous age. Consequent drainage flowed from the mountains in broad valleys, as can be deduced from the widespread occurrence of "Saskatchewan" gravels and sands which overlie the Edmonton and Paskapoo formations.

At the contact between these formations the beds have eroded to form a cuesta. This structure has resisted glacial advance and the distribution and relative thickness of the till sheets have been controlled largely by the differences in elevation of bedrock throughout the area.

Modification of lacustrine deposits has produced a distinctive undulating topography that one would not expect in a normal water-laid sequence. The mechanism of this modification, discussed in detail later, has been related to erosion and deposition under boreal conditions and the action of solifluction. Meltwater from the receding ice has resulted in expansive areas of reworked till, from which the finer matrix has been washed out leaving beaches of gravel and sandy material. Where glacial lakes have lapped around ground moraine deposits, the till swells have remained as upstanding islands within the area of lacustrine deposits, giving rise to gently rolling topography.

DRAINAGE

The three major rivers in the area—the North Saskatchewan, Pembina and McLeod—follow northeasterly courses, which is in keeping with the regional pattern for Central Alberta.

The high land in the southwest is drained northward by a dendritic pattern of small streams. In the southern part of the area the tributaries flowing into the Pembina river form a fairly regular northwest-southeast trellis, a pattern which is predominant throughout the area and one which could be explained either by the control effected by a northeasterly retreating ice-sheet or by the influence of bedrock causing true subsequent drainage.

The larger lakes drain eastward and are generally elongated in that direction. Rutherford (1928) suggests that the lakes of the central part of the area are remnants of much larger postglacial water bodies. This statement is borne out by the occurrence of wide areas of postglacial lake deposits throughout the district, as well as by the fact that lacustrine clays grade laterally through recent swamp into present-day lakes.

The great number of small lakes within the moraines also show a tendency to have their long axis parallel in a northeasterly pattern, although many of the lakes are devoid of outlet.

Table I shows the stratigraphic succession of the various glacial tills and glacial deposits which occur in the region.

It should be stated here that the term "Saskatchewan gravels", as used in this paper, applies rather to a particular association of water-laid pebbles rather than a formation with a definite time significance. Thus, although they are placed stratigraphically below the Grey Till in Table I, there are many localities where similar gravel deposits are undoubtedly of later age.

GENERAL GEOLOGY

TABLE I

TABLE OF FORMATIONS

System	Series	Formation	Description
	Recent	Postglacial	Soils and lake clays.
Quaternary	Pleistocene	Silt Till	Light buff coloured silty till, locally without pebbles.
		Interstadial*	Cross-bedded sands with some dark carbonaceous bands.
		Brown Till	Brown columnar till with pebbles dominately silt-clay. Keewatin types—granite and gneiss.
		Interstadial*	Medium-sized brown sands grading upward into gravels.
		Grey Till	Grey-coloured plastic clay with coal fragments and pebbles. Keewatin types—granite and gneiss.
		Preglacial "Saskatchewan" sands and gravels	Water-laid gravels and sands. Cordilleran arkose, quartzites and chert pebbles.
Tertiary	Paleocene	Paskapoo	Sandstones
Cretaceous	Upper	Edmonton	Sandstone, bentonitic shales, coal seams.

*Interstadial—Term used to include interglacial, as the time interval and the correlation with eastern North American formations are not properly understood.

Duff (1951) reports on a glacial section on the North Saskatchewan river at L.S. 1, Sec. 11, Twp. 52, Rge. 25, W. of the 4th Mer.* The section here can be correlated with other sections exposed in the Lake St. Ann area, notably on the Pembina river west of Moon lake (Figure 1) and at a small tributary of Strawberry creek half a mile north of Telfordville. The Silt Till, however, was not found exposed anywhere in a complete glacial section with the Brown and Grey Till sheets.

The three tills are all of Keewatin type, abundant in Precambrian material and generally lacking in pebbles of Cordilleran origin. The most widespread till is the Brown Till, forming a recessional moraine in the northern half of the sheet and scattered areas of ground moraine in the south. These southern remnants appear to

*Duff's section on the North Saskatchewan river is included in Table III.

be a part of a much more extensive till sheet which has since been modified by meltwater erosion and covered by later lake deposits and the Silt Till.

The Silt Till was deposited by an ice lobe which entered the eastern part of the area from the north with its long axis stretching southwest from Sandy lake to Brightbank.

The basal Grey Till has been recognized in sections as a thin deposit lying in the low places, suggesting that its deposition was followed by a long erosional period. Therefore, present surface deposits of Grey Till would be restricted to areas of low elevation. They would certainly be greatly modified during later periods of glaciation to a point where, if they were not completely covered, they would be so reworked as to render them unrecognizable in a reconnaissance survey of this nature.

DESCRIPTION OF FORMATIONS

The identification of a till in the field, especially where it forms surface material and has been subjected to erosion and modification, is a difficult one. Recognition of the different tills was based mainly on their stratigraphic position where an interstadial bed was exposed either above or below it; but recourse was made to certain basic differences in colour, pebble content and general physical appearance to decide upon the age of a till in cases where this sequence was not apparent.

Saskatchewan Gravels and Sands

Deposits of this type in Central Alberta were discussed by Rutherford (1937). In discussing them, he states:

> "The beds are composed of material apparently derived from the mountains to the west and do not contain material common to the glacial deposits of the north and the east. Although all graduations occur between gravel and sand, the thicker arenaceous beds are confined to lower places and the thicker gravel beds are more commonly found at higher elevations and somewhat removed from the lower parts of the old drainage channels and valleys. The coarse materials of the gravel beds are of two types, namely, pieces of undecomposed bedrock of local derivation, and pebbles and boulders derived from the west. The latter are composed essentially of chert, quartzitic sandstones and arkosic sandstones, and are usually somewhat rounded and smooth."

Referring to the deposits in the Huff gravel pit—Secs. 6 and 7, Twp. 54, Rge. 1, W. 5th Mer.—he continues:

> "Unconsolidated gravel interbedded with layers or lenses of sand constitute the material exposed in the pit. The boulders are sandstones and dominantly light-coloured, smooth, and subangular to rounded, averaging less than six inches in diameter. Although the pebbles are smooth, many are pitted with small, irregular holes. A thin section revealed that pitting is due to the leaching of carbonates, and a freshly broken surface will effervesce in dilute acid at numerous spots. Both the ease of breaking and the thin sections show that the parent rocks were sandstones, well indurated but not metamorphosed or recrystallized to quartzites. Chert and arkosa pebbles are second in abundance, with chert probably the more prevalent. The chert pebbles are usually smooth-surfaced and moderately rounded. Dark grey to black colours prevail, and the pebbles show marked similarity to siliceous beds common at certain horizons in the Paleozoic strata of the Rocky Mountains. The arkose pebbles are particularly noticeable because of their usual dark red coloration which is uniformly distributed through-

out the pebbles if fine grained but more confined to bands or patches in the coarser grained."

The foregoing description serves equally well for other deposits of the gravels and sands which were encountered further west and whose locations are shown on the accompanying map.

Their occurrence was first mentioned by Tyrell in 1886. Dawson and Coleman in describing them suggested that they were derived from outwash or a reworking of Cordilleran ice-sheet deposits which they thought were laid down prior to the Keewatin glaciation.

The distribution of these gravels in the eastern half of the St. Ann map sheet is confined to what is thought to be an old drainage course which trends northward from Moon lake south of Entwistle to the Huff pit at Heatherdown.

Regarding the possible source of these gravels, it was noticed that on approaching the front ranges of the Rocky Mountains east of Jasper, pebbles of the "Saskatchewan" type become larger and lose the smooth discoidal form of those that make up the deposits under discussion. Along Fiddle creek, within Jasper Park, large angular boulders of red arkose were found to be abundant, and on the northeast shoulder of Roche Miette, at an elevation of about 6,000 feet, boulders of quartzite and the red arkose were again observed. Therefore it appears that the source rock for these boulders must lie further to the west.

Grey Till

The glacial section at four localities contained as the earliest deposit a dark grey coloured till with small Keewatin pebbles (averaging two inches in diameter) and fine fragments of fresh-looking coal. The similarity in outward appearance of these four isolated till deposits is striking. In each case the exposure occurred in a low cut and was overlain by interglacial sand or the Brown Till. When wet, the clay matrix of the Grey Till is very plastic; when dry it crumbles into small angular fragments. Its grain size distribution covers a wide range and a cut of the more coarse-grained material shows a large proportion of coal fragments up to ⅛ inch in size while cuts of the finer material show an even greater preponderance of dark carbonaceous materials derived from the Edmonton formation.

As this till represents the first glacial deposit of the area, it is likely that it would include large amounts of plant debris which would have accumulated during a previous climatically favourable period. Tills deposited during subsequent substages would be less influenced by this residual material and consequently would be lighter in colour.

First Interstadial Sands

The first or lower interstadial sands show great variety of size distribution as they represent local accumulations of glacio-fluviatile origin. They are rudely sorted into layers of buff-coloured, well-rounded, medium-sized sands separated by thin beds of small gravels sometimes admixed with clay. Maximum thickness is about 20 feet (Figure 2). The best exposures of these sands exist at

the Pembina River section west of Moon lake, at the Strawberry Creek section near Telfordville, and in road cuts near Wabamun creek in N.W. ¼ Sec. 28, Twp. 51, Rge. 3, W. 4th Mer. In this last area the sands include marl beds up to two feet thick and contain abundant gastropod shells.

In the northeast of the map area—at Alberta Beach and Onoway —these sands are exposed in plan and are overlain in section by the Brown Till sheet. These exposures of sands are conspicuous in road cuts where the upper contact is overlain by a dense brown clay till.

Brown Till

This till forms widespread surface deposits throughout the northern half of the map area and is responsible for the formation of areas of recessional moraine. It is a well-consolidated, columnar till which in section forms vertical bluffs and exhibits a fairly constant brown colour. The included glacial debris is of Keewatin type and varies enormously in size from boulders about five feet in diameter to pebbles and sands. However, material of cobble and pebble size is the more prevalent and is made up of subangular to rounded pieces of gneiss, granite and sedimentary rock. The larger boulders usually occur at the surface in areas where their enveloping matrix has been washed away by erosion or by beaching action. Areas so eroded now form flat beaches.

Many drumlinoid structures were found in a Brown Till moraine in the region between Isle and Wabamun lakes (Figure 3). Their occurrence in this particular area coincides with the zone mapped as a preglacial valley and it is noteworthy that the drumlins usually have at their centre a core of Saskatchewan gravels and sands which preserves a rude stratification and is little disturbed by the later plastering of the Brown Till material over them.

In size and shape these drumlinoid structures are greatly varied: some were indistinctly separated from their neighbours, thus forming lobate ridges, while others form isolated mounds elongated in one direction. Several of the larger mounds measured 500 feet by 200 feet with an average height of approximately 100 feet.

In the extensive area of lake deposits between Sangudo and Moon Lake villages, the flat lake-bed topography is interrupted periodically by swells. The core of the swells are composed of Brown Till material. When studied in plan they present an obscure picture of the age relationship between the till and lake deposits. The till appears to overlie the lake deposit. When, however, the swells are examined in section the age relationship becomes obvious, the Brown Till representing older hummocks which subsequently formed islands in the lake during the deposition of the clays. It is interesting to note that the lake deposits change from varved clays on the inner limits of the shore lines to heavy structureless buff clays where the water was deeper.

The extensive area of typical recessional moraine formed by the Brown Till between Sangudo and Onoway has been mapped as a glacial unit. The country presents a series of rugged sub-parallel ridges trending east-northeast and alternating with valley depressions 100 feet or more deep. The building of improved roads, which

cross-cut the morainal structures, has exposed excellent sections of a single till up to 100 feet in total thickness.

The southwesterly extent of this till is suggested by its occurrence in three areas in the southern half of the map sheet and by the numerous smaller exposures within the lake deposits which already have been discussed. The three larger areas have extensive beaches of sand and gravel around their perimeters. Brown Till ridges appear to follow an erosional "high", reflected by the thin cover of till over remnants of the Edmonton formation in which small coal seams are exposed.

Second Interstadial Sands and Clay

In the Pembina River section the second interstadial beds represent a normal sequence of deposition in waters fronting an ablating ice sheet. They show systematic gradations from stratified gravels at the base followed by coarse cross-bedded sands and silts passing upwards into massive clays with varved clays at the top (Figure 4). These clay beds form the greater part of the surface material throughout the southwest and west parts of the sheet and represent the area most widely settled. From sections mapped along the gorge of the Pembina river near Evansburg it is apparent that continuous lacustrine beds extended west and their deposition preceded the incision of this topographic feature.

The clay beds show marked post-laking modification which may be best seen in the vicinity of Magnolia village, at the west end of Lake Isle. Here, what is assumed to have been at one time a flat lake surface is now an area of undulating topography. Field work has shown no post-laking glacial deposits and no evidence of stream or beach erosion of a normal type. Modification may therefore be explained either by erosion in a climatic zone of permafrost where only certain areas were vulnerable to the action of solifluction or by wasting of ice trapped below the clays causing internal slumping.

Silt Till

The region west of Kilini creek and bounded on the south by the North Saskatchewan river has been mapped as the Silt Till, and the area is known as the Carvel moraine (Figure 5).

This till is conspicuous because of its light buff colour when dry and its extremely silty texture. At certain localities that have been described as being typical of the deposit, the till was entirely devoid of stones, raising problems as to the origin of this "moraine".

Although restricted exposures along the Jasper highway were devoid of boulders, traverses both north and south of the highway have shown that the deposit is quite a normal till with a variety of Keewatin boulders and a silty matrix. Topographically the area consists of swells and swales, having smooth rounded forms and almost lacking in evidence of stream erosion. The swales, usually without outlet, are often swampy and sometimes filled with material brought there by sheet wash. In places the till includes layers of coarse stratified sands ranging from a thickness of a few inches to ten feet. These are best exposed in the vicinity of Edmonton Beach and along the east-west roads through that area.

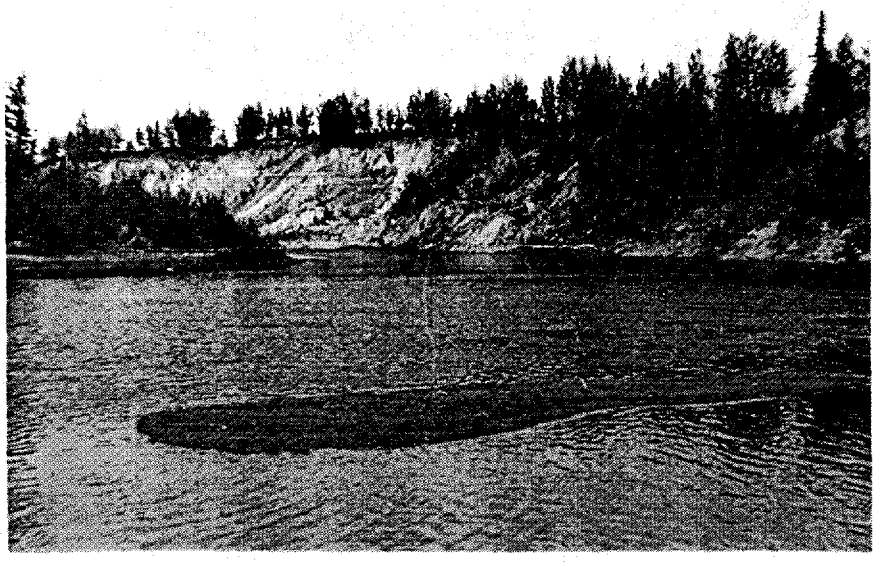

Figure 1—Pembina River exposure: Lacustrine deposits; Brown Till; First Interstadial; Grey Till. Township 52, range 7, west of 5th meridian.

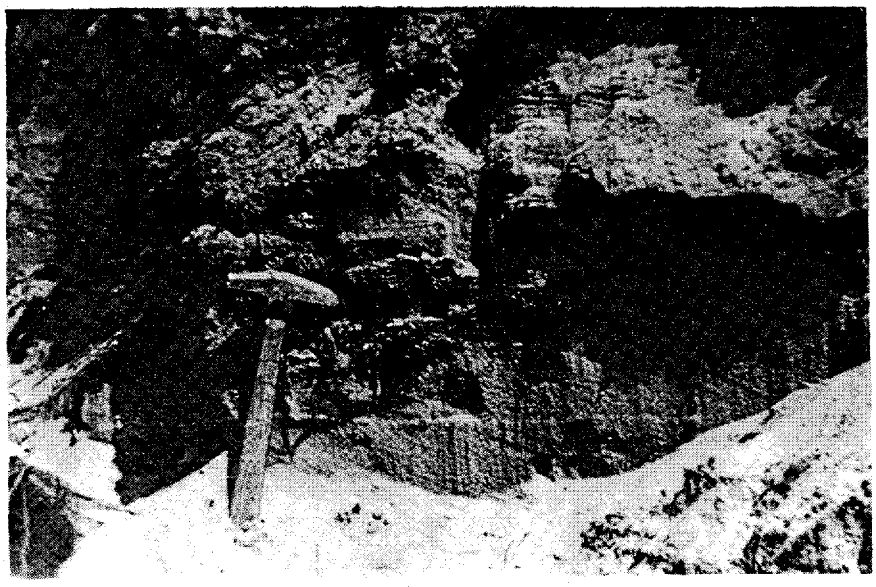

Figure 2—First Interstadial sand, Pembina River section; township 52, range 7, west of 5th meridian.

Figure 3—Drumlin with Saskatchewan gravel core covered by Brown Till mantle.

Figure 4—Varved clays; Post-Brown Till lacustrine deposit. Pembina River section; township 52, range 7, west of 5th meridian.

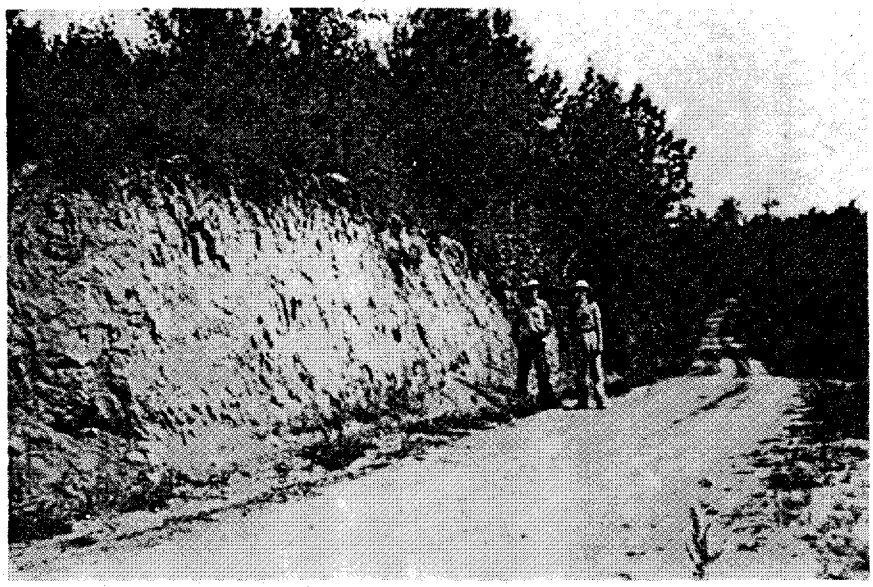

Figure 5—Silt Till exposure; township 53, range 1, west of 5th meridian.

Figure 6—Onoway Plain: Brown Till ground moraine; township 54, range 7, west of 5th meridian.

TABLE II

SIEVE ANALYSES of TYPICAL SAMPLES of SAND AND TILL

Tyler screen No.	Cumulative percent				
	1	2	3	4	5
28	.14	.18	4.43	6.2	4.0
35	2.04	3.76	8.20	10.8	6.83
48	67.12	86.00	14.46	16.17	11.20
65	83.12	97.06	19.63	24.0	17.63
100	91.70	99.18	24.73	33.7	24.40
150	95.58	99.42	30.23	39.43	29.40
200	98.84	99.56	36.19	45.20	33.40
Bottoms	99.86	99.70	99.99	100.00	100.00

Samples:

1. Eolian sand—Whitecourt area
2. Interstadial sand—North of Carvel Corner
3. Silt Till—Carvel moraine
4. Brown Till—Pembina River section
5. Grey Till—Pembina River section

Two miles north of Duffield, Silt Till is seen to contain pockets of the typical Brown Till. These exposures provide evidence that the Silt Till is younger than the Brown Till.

In the vicinity of Wabamun creek, about two miles north of the North Saskatchewan river, as one travels west along the road the Silt Till becomes darker in colour and includes pockets of dark grey lacustrine clay. This may represent a reworking of the second interstadial beds by the Silt Till ice advance.

North of Stony Plain, on the height of land, bedrock is exposed, indicating that the areal extent of the moraine is controlled by bedrock topography and that the Silt Till is generally a thin deposit.

Postglacial Deposits

The eastern boundary of the Silt Till is represented by a sharp topographical discontinuity between the rolling Silt Till country and the flatter postglacial beach deposits and sand plains to the east. The boundary is shown by beach deposits south of Stony Plain, where stratified gravel and sand overlain by dark peaty soils are exposed in road ditches. Again, further south, beach deposits occur periodically along the Thorsby-Sunnybrook road and along the highway extension into the Calmar district.

The final postglacial deposits along the bend of the North Saskatchewan river are extensive areas of rudely bedded coarse-grained sands. These are deposits of sand conspicuously outlined by natural pine tree parkland.

In the central part of the map area, where larger lakes exist, the shore lines and the lower areas between the lakes have suffered postglacial modification leaving beach accumulations of sands and gravel. In particular, the narrow neck between Isle lake and the west end of Wabamun lake has, as a beach deposit, a mantle of sands derived from the arenaceous Paskapoo formation.

Preglacial drainage in central Alberta has been interpreted by Warren (1944) as being controlled regionally by the northeast slopes of the preglacial surface and he attributes control of present drainage to the alteration of the normal surface by glacial debris.

Within the mapped area field evidence was found to support this picture of drainage in that the rivers, where not interrupted by prominent glacial features, adhere to their original pattern. The deposits of Saskatchewan type gravels have been found as bedded accumulations along the line from Moon lake to Heatherdown. These deposits are assumed to be in the channel of a preglacial river.

The two major rivers in the area show various stages of development. The Pembina river at Entwistle flows through a scenic canyon with bluffs of sandstones overlying shales. The Pleistocene cover is comprised of Brown Till overlain by clays of the second interstadial which show vertical sections on both banks. Incision of the gorge must have postdated deposition of the lake deposits, and the development of the river was a final phase of the lake drainage which was restricted to a northerly direction during the Silt Till ice advance in the east.

The present Pembina river in the southwest flows from a mature valley into a young segment with incised meanders for twelve miles,

and then it passes again into a mature valley north of Entwistle. At one time when these mature segments were isolated by a high bedrock ridge they must have had separate watersheds. The northern mature valley connected with the Chip Lake drainage by an ancestral Lobstick river. The southern mature valley flowed through the broad depressions occupied by the present lakes. This hypothesis is supported by the fact that the north shores of both Isle and Wabamun lakes have cliffs which suggest a pattern of fluvial dissection by such a river system much larger than the present drainage system.

The short length of the North Saskatchewan river included in the survey forms part of an elbow where the river alters its course from a normal northeast direction to an easterly one. Within this segment of the river there is a noticeable discontinuity in form; where the river abuts against the Silt Till moraine near Genesee it takes on a more youthful character. This contrast in stage can be seen from a topographic map, and it is undoubtedly due to the Silt Till lobe which diverted the river from an unknown but probable northerly course in pre-Silt Till time.

Kilini creek, a small stream occupying a broad, mature valley, begins obscurely in the Silt Till moraine and continues northeast in its misfit valley. The evidence that this route had been previously occupied as a drainage course is the occurrence of Saskatchewan gravels below the valley floor. Its present broad, mature form is related to the action of meltwaters of the ablating Silt Till lobe under static glacial conditions, along the line of contact of the Silt Till with the Brown Till moraine.

PHYSIOGRAPHIC UNITS

Central Ground Moraine

The northeast-southwest axis of the mapped area consists of a Brown Till moraine extending from south of Wabamun lake and the east bank of the Pembina river to Lake St. Ann and south of Sangudo on the Pembina river. An area of Brown Till moraine extends across the Pembina river and forms the height of land between the McLeod and Pembina drainage systems. The central area of this moraine is of high relief, but the perimeter has been water-worked or beached during the time periods in which large lakes extended over most of the lowlands. The maximum thickness of the till is probably close to 100 feet. Beaching action, which has reduced the ground moraine to a rolling plain, has left a residual deposit of large Keewatin type boulders in the northeast. Along the Jasper highway between Gainford and Evansburg, highs in the Brown Till topography are completely surrounded by mantles of varved lacustrine clays. It is considered that the meltwater from the Silt Till lobe of the Carvel moraine, draining radially to lakes in the northwest and south, had produced the beached areas south of the North Saskatchewan river and north of Onoway village (Figure 6).

Carvel Moraine—Silt Till Lobe

The final ice advance in the Edmonton area has deposited a till that has special characteristics. The Silt Till consists of fine silts, in many sections devoid of stones. Sieve analyses generally indicate that 10 per cent of the matrix is finer than 200-mesh.

Topographically, the Carvel moraine is an area of high relief consisting of knobs and kettles. The kettles are circular depressions in which small lakes or ponds develop during wet seasons. This moraine has blocked the North Saskatchewan drainage and occupied the old valley channel that passed in a northeasterly direction. The subsequent channel, after abutting against the southern edge of the moraine, turns abruptly east in a youthful valley passing through the city of Edmonton.

Deposits of Silt Till have been found as far east as Oliver in the Edmonton district and take the form of swells and swales of a ground moraine. A dark soil profile has developed upon this silt material and alters its appearance except in deep road cuts where its true nature is exposed.

The contrast between Silt Till and Brown Till is well developed on the township boundary line between the St. Ann sheet and the Edmonton sheet, north of the Jasper highway. Traversing north on Silt Till, one passes into Brown Till one mile north of the township boundary between townships 54 and 53. At this point there is no break in the topography, but over a narrow zone of less than one mile, marked textural change is noted between the light buff Silt Till and the heavy Brown Clay Till with many Keewatin boulders.

On the southeast boundary of the Silt Till area there is a beach deposit which is exposed as shallow beds of pea-sized gravel at road level. This eastern boundary of the Silt Till of the Carvel moraine is produced by water action upon the silt and sorting of the fractions. The western contact of the Carvel moraine, one mile north of Duffield, shows pockets of the earlier Brown Till included as large pockets in Silt Till. At the southern extent of the western boundary a group of sand hills upon which a jack-pine park is developed has been mapped, but the extract stratigraphic relationships between the sands and the glacial deposits are unknown.

Inter-Stage Deposits

Heavy grey clay deposits of more than one age are developed in old lake basins. Field evidence has been found that these lacustrine deposits are of at least three ages relative to the glacial till deposits.

Chip lake, in the west-central portion of the mapped area, is a typical remnant of the larger bodies of water that covered the lowlands between the moraines and the ablating ice-front. Reconnaissance mapping in the Red Deer River valley has shown that this river drained large lakes south of the St. Ann map area, but the exact connections between the two drainage systems has not been found.

Post-Brown Till lacustrine deposits are exposed along the valley of the Pembina river between Evansburg and Sangudo. The upper three feet of varved clays overlying massive buff clays is typical of this deposit. These lacustrine clays were deposited prior to the

cutting of the Pembina gap at Evansburg. The age of the piracy of the Pembina river was post-Silt Till and resulted from the water flow developed by the escape of meltwaters of the final glacial stage.

GLACIAL SECTIONS

The glacial sections of the St. Ann map area are shown in Table III. Sieve analyses of typical samples of sand and till from these glacial sections were previously shown in Table II.

CONCLUSIONS

The three till sheets—the Grey Till, the Brown Till and the Silt Till—all show remarkable lithological continuity over a wide area of west-central Alberta and can be correlated with the type section on the big bend of the North Saskatchewan river west of Edmonton.

Nowhere in the sections studied do the till deposits show deep weathering, oxidation, or mature soil profile development. From this evidence it is deduced that the till sheets all represent substages of the final or Wisconsin glacial stage.

The till deposits studied are all of Keewatin origin and represent debris accumulating at or near the maximum westerly advance of glacial ice sheets.

The typical pebble content of the fluviatile Saskatchewan gravels —red arkose, pitted limestones, and blue-black chert—was rarely found as stones within the Keewatin glacial debris. However, these same pebbles are found in the alpine glacial sequence in the foothills of the mountains. Similar material originating during early alpine glaciations must have supplied large quantities of pebbles now making up the water-laid Saskatchewan gravels that underlie the glacial sequence in the Lake St. Ann area.

TABLE III

GLACIAL SECTIONS OF ST. ANN MAP AREA

Ronan Village	*Pembina River*	*Onoway Road*	*Strawberry Creek*	*Weed Creek*	*Big Bend Section*
Tp. 56, R. 9, W. 5	Tp. 53, R. 7, W. 5	Tp. 54, R. 2, W. 5	Tp. 49, R. 2, W. 5	Tp. 49, R. 1, W. 5	Tp. 52, R. 25, W. 4
N. of Chip lake	Entwistle	N. of Carvel Corner		E. of Thorsby	W. end of Edmonton on Saskatchewan river
	2500′ elevation	2500′ elevation	2450′ elevation	2500′ elevation	
6′ + varved clays	2.4′ lake clay varved at top		5′ varved clay	6′ varved clay	
	12′ water-laid massive buff clays				
12′ + Brown Till	35′ Brown Till	3′ Brown Till	15′ Brown Till	10′ Brown Till	33′ Brown Till
	12′ bedded sand and silts	23′ interglacial sand	5′ brown sandy clay till		
	9′ + well-sorted sand with clay bands		4.5′ interglacial sand banded with carbonaceous material	2′ interglacial sand, fine-grained	2′ interglacial sand
			3′ finely-banded grey clay, water-laid		
	6′ Grey Till	2′ + Grey Till	10′ + Grey Till with large fragments of coal and mixed boulders	8′ + Grey Till with coal fragments	12′ Grey Till
	40′ Edmonton formation				73′ Saskatchewan gravel

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