Preliminary Report of the Surficial Geology and Quaternary Stratigraphy of Edmonton, Map Area NTS 83H, 1983.

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Surficial Geology and Quaternary Stratigraphy of the Edmonton Map Area NTS 83H

Introduction

The continued expansion of the greater Edmonton area has placed more demand for not only geologic construction materials, but also on a more detailed understanding of the regional surficial geology and the properties of the deposits as they relate to construction and engineering design. A number of studies have focused on the surficial and Quaternary geology of the immediate area around Edmonton, but the expansion of the City of Edmonton has been so rapid that these reports are of limited value. Furthermore, except for a two dimensional 1:250,000 scale surfical geology map (Bayrock, 1972) most of the studies around Edmonton have been relatively detailed and have not considered the three dimensional regional distribution of the Quaternary deposits. As a consequence and in response to the perceived need for this three dimensional type of information, the Alberta Geological Survey initiated a study in 1978 of the Quaternary stratigraphy in the Edmonton map area 83H. The primary objective of the study was to not only define the origin and history of the stratigraphic units, but to also provide a data base for land use planners in making decisions regarding the development of the natural resources of the Edmonton area.

Previous Work

The earliest work on the surficial geology and Quaternary stratigraphy in the Edmonton area consists of studies by Tyrell (1887), Dawson (1899), Coleman (1909), Taylor (1934), Rutherford (1931), and Warren (1937) of the glaciolacustrine deposits that lie at the top of the stratigraphic sequence. More detailed studies of these lacustrine deposits were done by Warren (1954), Duff (1951), and Gravenor and Bayrock (1956) who named the glacial lake that deposited the silt and clay, Glacial Lake Edmonton. Detailed studies of the surficial geology around Edmonton were later done by Bayrock and Hughes (1962) Bayrock and Berg (1966), and Bayrock (1972) who prepared a 1:250,000 scale surficial geology map. McPherson and Kathol (1975) completed a comprehensive report on the urban geology of Edmonton, in which they defined construction and engineering related problems associated with the surficial units. Included in that report are a series of land use maps defining favorable and unfavorable areas for different land use.

One of the earlier stratigraphic studies is that of Warren (1954) who defined the following stratigraphy near Tofield, east of Edmonton:

(a) a relatively pebble free till called the Silt till, which overlies
(b) a stratified deposit called the Strathcona silt and sand, which overlies
(c) a sandy, consolidated Brown till with columnar joints, which overlies
(d) stratified sand, called the Tofield sand, which overlies
(e) a lowermost till, called the Gray till, which is clayey, commonly highly fractured or jointed, and which overlies either
(f) a basal sand and gravel unit, called the Saskatchewan sand and gravel, that lies at the base of the preglacial valleys, or
(g) bedrock

Later work by Westgate (1969) also defined a till stratigraphy similar to that of Warren's except that the "Silt" till was not recognized. Ramsden (1971) in his M.Sc. thesis demonstrated, by plotting pebble fabric orientations, that the lower till defined by Westgate, was deposited by a glacier flowing from the northwest, whereas the upper till was deposited by a glacier flowing from the northeast. May and Thompson (1978) examined the detailed stratigraphy of these tills in tunnel and subway excavations, with special interest in their geotechnical properties. Most recently, Shaw (1981) did a detailed sedimentological study of a number of sections west of Edmonton, focusing on the genesis and depositional environment of the tills at those sites.

Operations and Methods

Field work for this study commenced in 1978, and continued during the summer months of 1979, 1980, and 1981. During that period 84 dry auger testholes were drilled (figure 1), and numerous outcrops were examined, primarily those along the banks of the North Saskatchewan River and within gravel quarries in the Villeneuve area. Testholes were drilled to a maximum depth of about 48 m, or to bedrock, whichever was reached first. Samples were collected from each testhole on a 1 m interval, logged in the field, bagged, and sent to the laboratory for later analyses. Although the drill survey was designed on a rough grid pattern, emphasis was placed in mapping those areas where it was believed that the drift was thickest and hence, where the stratigraphic record might be expected to be most complete. Two physiographic areas became the prime targets: numerous buried valleys of preglacial and possibly glacial origin, and the thick hummocky moraine east of Edmonton known as the Cooking Lake Moraine.

Methods of Till Identification and Correlation

In this study the focus has been to characterize and differentiate the till units in the Quaternary stratigraphic section. The primary reason is that it is believed glacial sediment (till) contains or retains more inherent characteristics of its depositing agent (ice) than do any of the stratified intertill deposits. Furthermore, tills are generally more widespread and thus can be correlated more easily over a large area. In this study a suite of laboratory analyses have been performed on the till samples to supplement the field observations and to aid in the differentiation of the different units within a testhole. The methods used proved very successful in defining the till stratigraphy in the Sand River map area and therefore have been applied in this study. These analyses consist of:

(1) matrix texture analyses (%sand, %silt, %clay as well as % 1-2 mm coarse sand).

(2) matrix carbonate analyses, using the Chittick method (this method yields, volume CO_2, weight CO_3, and calcite to dolomite ratio).

(3) mineralogy of the 1-2 mm coarse sand fraction.

(4) moisture content.

As well as the analytical data, field criteria such as stratigraphic position, electric log "kicks", color, jointing, and nature of contacts were also used to differentiate till units. Supplemental borehole data from nearby testholes drilled by Alberta Environment and water-well drillers provided lithologic descriptions and in some cases elecric logs. A number of geologic cross-sections have been constructed (figure 1) showing the stratigraphic units at each testhole. Correlations have been attempted but the final synthesis remains to be done.

Scientific Findings

At present, the results of the stratigraphic study verify that the Quaternary stratigraphic section is best preserved within the Cooking Lake Moraine, and within segments of the buried valleys. Elsewhere, glacial or fluvial erosion has destroyed much of the record. Following is a description of the stratigraphy within each of these two geologic settings.

Till Stratigraphy in the Cooking Lake Moraine

Cross-section E2 (figure 3) shows that four tills can be mapped within the Cooking Lake Moraine. The upper till is named the Elk Island till, the next lower till is named the Cooking Lake till, the third till is named the Chipman till, and the lowest till is named the Lamont till. The Elk Island and Cooking Lake till are grouped into one package, called the Upper Till Package.

Upper Till Package

The Elk Island and Cooking Lake tills have a similar coarse sand mineralogy, but are separated on the basis of texture and stratigraphic position: the Elk Island till is much sandier and overlies the Cooking Lake till (cross-section E2, figure 3). The Elk Island till is composed of about 40% sand, 25% silt, and 35% clay. The till is found sporadically at the top of a high relief stagnation moraine which suggests that it may be an ablation facies of the Cooking Lake till. The Cooking Lake till is widespread throughout the Cooking Lake Moriane. It is a sandy-clay till composed of about 30 - 35% sand, 22 - 30% silt, and 38 - 43% clay. The 1-2 mm coarse sand fraction contains about 48 - 64% igneous-metamorphic rocks, 21 - 38% quartz, 1 - 2% quartzites, 1 - 3% Athabasca sandstone, 3 - 7% limestone, 2 - 6% dolostone, and 2 - 20% local rock fragments. Calcareous material makes up about 5 - 10% of the -200 silt-clay fraction, with a calcite to dolomite ratio that ranges between .2 to 6.

Both the Elk Island and Cooking Lake tills are soft, moist, and easy to penetrate with a dry auger. The Cooking Lake till characteristically has a significantly lower resistivity response than that of the underlying Chipman till (figure 2). In places stratified sediment composed of sand, silt and clay separates the Cooking Lake till from the underlying Chipman till. Elsewhere the Cooking Lake till has generally a sharp contact with the Chipman till.

Chipman Till - Middle Till

The Chipman till is a clayey-sand till, composed of about 39 - 46% sand, 25 - 28% silt, and 29 - 36% clay. The 1-2 mm coarse sand fraction contains about 42 - 52% igneous-metamorphic rocks, 30 - 40% quartz, 0 - 3% quartzites, 2 - 6% Athabasca sandstone, 4 - 11% limestone, 5 - 10% dolostone, and 3 - 9% local rocks fragments. Calcareous material makes up between 8 - 12% of the -200 silt-clay fraction, with a calcite to dolomite ratio that ranges between .2 and .4.

Although no buried weathered profiles were recognized on the surface of the Chipman till, testhole samples near the top of the unit commonly have a more olive-gray unoxidized color, compared with the dark gray unoxidized color of the overlying Cooking Lake till. The Chipman till is also consolidated and more difficult to penetrate with a dry auger, compared to the overlying till units. In those places where the Cooking Lake till lies directly overtop the the Chipman till, the resistivity responses within the Chipman till show an abrupt increase at the contact. In places stratified sediment separates the Chipman till from the underlying Lamont till.

Lamont Till - Lower Till

The Lamont till has been mapped in only a few testholes within the Cooking Lake Moraine and is not believed to be very extensive. The till is composed of about 33 - 38% sand, 22 - 25% silt, and 36 - 42 % clay. The mineralogy of the 1-2 mm coarse sand fraction contains about 55 - 64% igneous-metamorphic rocks, 27 - 36% quartz, 1 % quartzites, .5 - 2% Athabasca sandstone, 2 - 4% limestone, 2 - 3% dolostone, and 3 - 6% local rock fragments. Calcareous material makes up between 5 - 8% of the -200 silt-clay fraction, with a calcite to dolomite

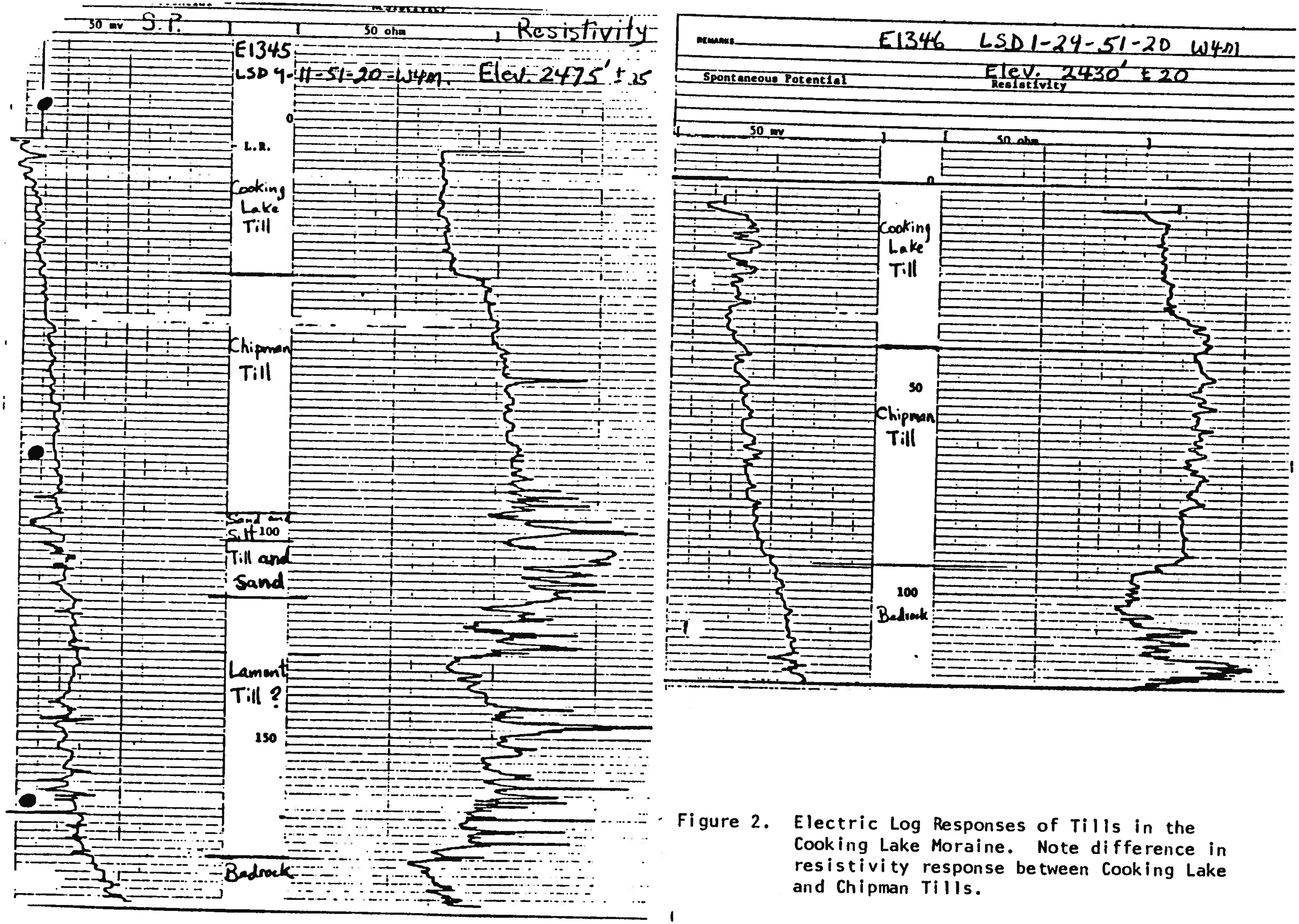


Figure 2. Electric Log Responses of Tills in the Cooking Lake Moraine. Note difference in resistivity response between Cooking Lake and Chipman Tills.

ratio of about .2.

The Lamont till overlies either bedrock, or Empress Formation stratified deposits within the buried valleys.

Differentiation of Tills in the Cooking Lake Moraine

The Elk Island till is differentiated from the Cooking Lake till by its sandier texture. Both tills have a similar coarse sand mineralogy which suggests that they may be textural facies of one single till sheet. The Cooking Lake till is differentiated from the Chipman till on the basis of texture and mineralogy. The Chipman till is much sandier, it has almost twice as much carbonate and noticeably more Athabasca sandstone in the coarse sand fraction, and it has a higher resistivity response (figure 2). As well, within a number of testholes the Chipman till has noticeably less igneous and metamorphic rock fragments than does either the Cooking Lake or Elk Island till. The Lamont till is differentiated from the Chipman till on the basis of texture and mineralogy. The Lamont till is much more clayey, it contains significantly more igneous-metamorphic rock fragments and, it contains less Athabasca sandstone fragments than does the Chipman till. If the Chipman till is absent within a stratigraphic section the Lamont till may be difficult to differentiate from the Cooking Lake till because their textural and mineralogic properties are similar.

Till Stratigraphy in the Buried Valleys

Testhole R80ED-36 in cross-secton N3 (figure 4) shows that within the buried valley southwest of Whitford Lake in the northeast part of the map area two tills can be mapped, separated by lacustrine silt and clay deposits. Both tills have a similar sandy-clay texture, but can be differentiated by the following properties: the lower till has a greater amount of carbonate rock fragments, more quartz, and fewer igneous and metamorphic rock fragments than does the upper till. On the basis of the higher carbonate rock and lower igneous-metamorphic rock content, the lower till at this site correlates with the Chipman till, even though it is much more clayey than the till within the Cooking Lake Moraine. On the basis of its clayey texture, relatively high igneous-metamorphic rock content, and stratigraphic position, the upper till at this site correlates with the Cooking Lake till in the Cooking Lake Moraine. Farther northeast along the buried valley, at testhole R80ED-35, two tills are also present, separated by stratified sediment. Both units are very sandy but the upper till has more carbonate rock fragments than the lower till. On the basis of carbonate content the upper till at this site can be correlated with the stratigraphically lower, high carbonate till at site R80ED-36. Therefore, the lower till at R80ED-35 may correlate with the Lamont till in the Cooking Lake Moraine, even though it is not as clayey, nor does it contain as much igneous-metamorphic rock fragments. Further work is required to resolve the stratigraphy in these buried valleys.

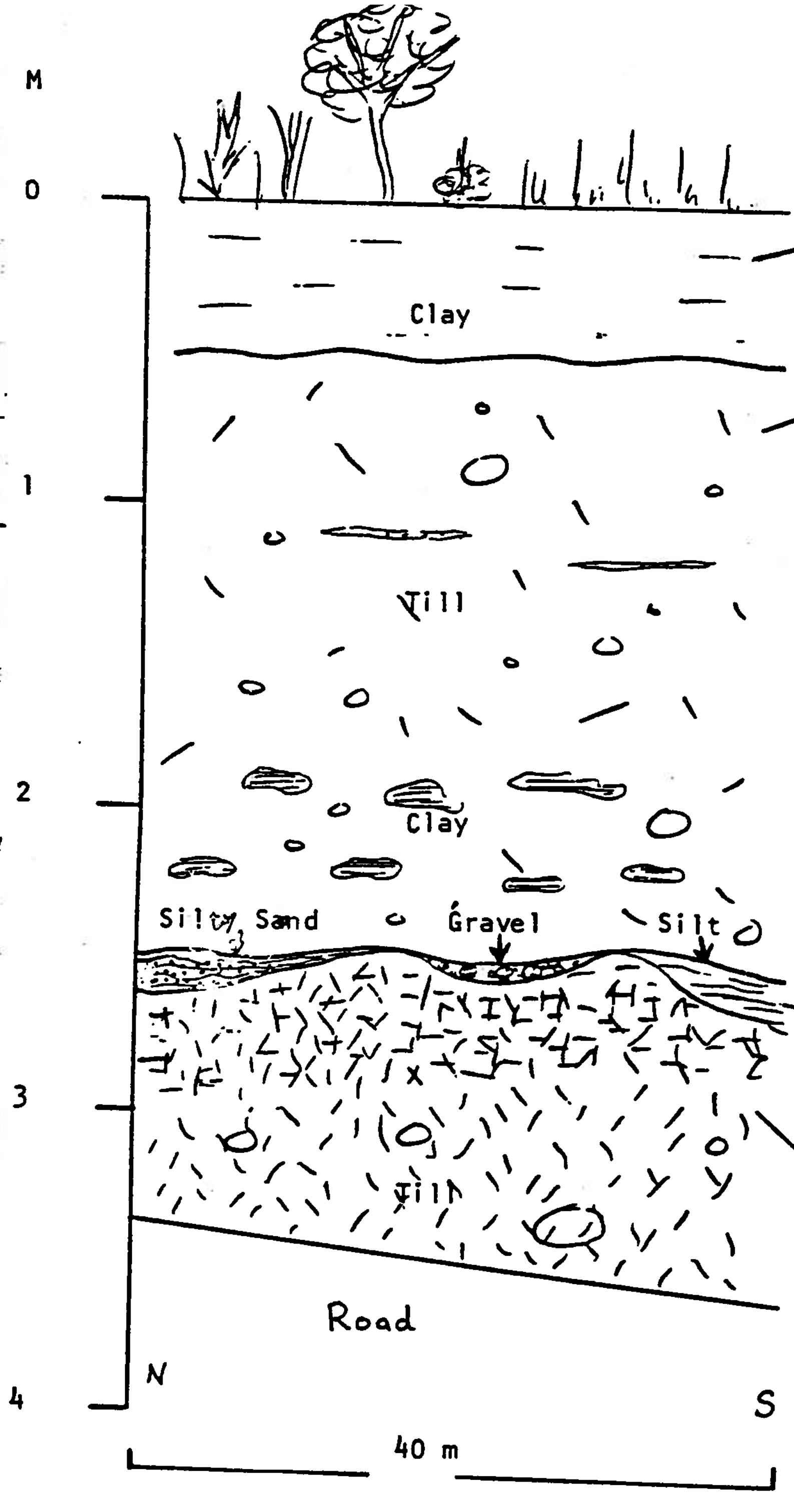
A recently located outcrop situated along the Riviere Qui Barre (LSD 4 Sec 15 Tp 54 Rg 26 W4M), and above the buried Onoway valley, shows an exposed sequence of till and intertill stratified deposits (figure 5, and plate 1a, 1b). The section consists of four exposed units:

Unit 1 - A thin (<1 m thick) dark gray-brown colored surface lacustrine silt and clay deposit that overlies

Unit 2 - A clayey till, composed of about 24% sand, 23% silt, and 53% clay, and which contains increasing amounts of irregular shaped clasts or masses of soft clay near the base. In outcrop this till has a dark gray-brown weathered color and is massive to slightly fissile. The till is moderately stony and commonly in this outcrop granules or sand grains appear to be concentrated along layers or partings. The unit is relatively moist and sticks to a pick or shovel when excavated. This units overlies stratified deposits of

Unit 3 - A thin deposit of stratified silty-sand to gravel. The unit ranges in thickness from about .1 m to .5 m. Figure 5 shows that along the northern end of the outcrop the units consists primarily of ripple laminated sand (plate 1c), whereas at the southern end the unit is composed of rusty-brown, coarse lag gravel. This unit forms a sharp, erosional contact with the top of

Unit 4 - A sandy till composed of about 38% sand, 30% silt, and 32% clay. In outcrop this till has a more oxidized olive brown weathered color and is highly



Unit 1 - Very dark grey brown massive clay with black organic material; Glaciolacustrine deposit.

Unit 2 - Dark grey brown clayey till; massiv to slightly fissile; contains blebs or masses of soft clay; some thin sand and granule lenses or partings moderately stoney. Texture 24% sand, 23% silt, 53% clay.

Matrix Carbonate

Vol CO_2	14.5 ml/g
% CO_3	6.2
Ca/Do	.90

Pebble Lithology	%
Igneous - Metamorphic	31
Metaquartzites (Cordilleran)	20
Local Bedrock	14
Limestone	12
Athabasca Sandstone	8
Dolestone	6
Chert	5
Volcanic Rocks (Cordilleran)	4

Unit 3 - Stratified sediment, varied thickness from 0 -.5 m; wavy bedded silty-sand in north end of section, rusty colored coarse gravel in center of section, silt in south end

Unit 4 - Olive brown sandy till; highly jointed and fractured with Fe and Mn staining along joint surfaces; consolidated, hard, less stony than above till. Texture 38% sand, 30% silt, 32% clay.

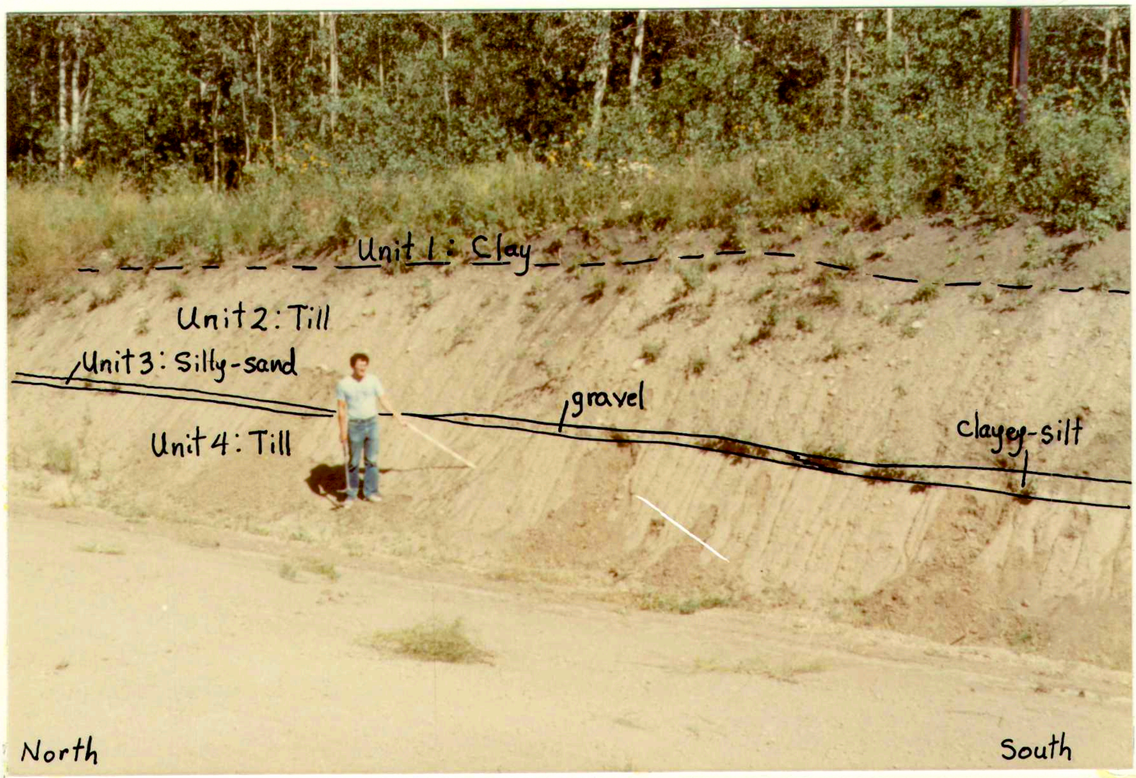
Matrix Carbonate

Vol CO_2	14.6 ml/gm
% CO_3	6.1
Ca/Do	.31

Pebble Lithology	%
Igneous - Metamorphic	37
Metaquartzite (Cordilleran)	20
Athabasca Sandstone	12
Limestone	11
Local Bedrock	9
Dolestone	8
Chert	4

Figure 5. Stratigraphy at Riviere Qui Barre Section.

Plate 1a. Stratigraphic Units at Riviere Que Barre Section (LSD 4 Sec. 15 Tp 54 Rg 26 W4M)



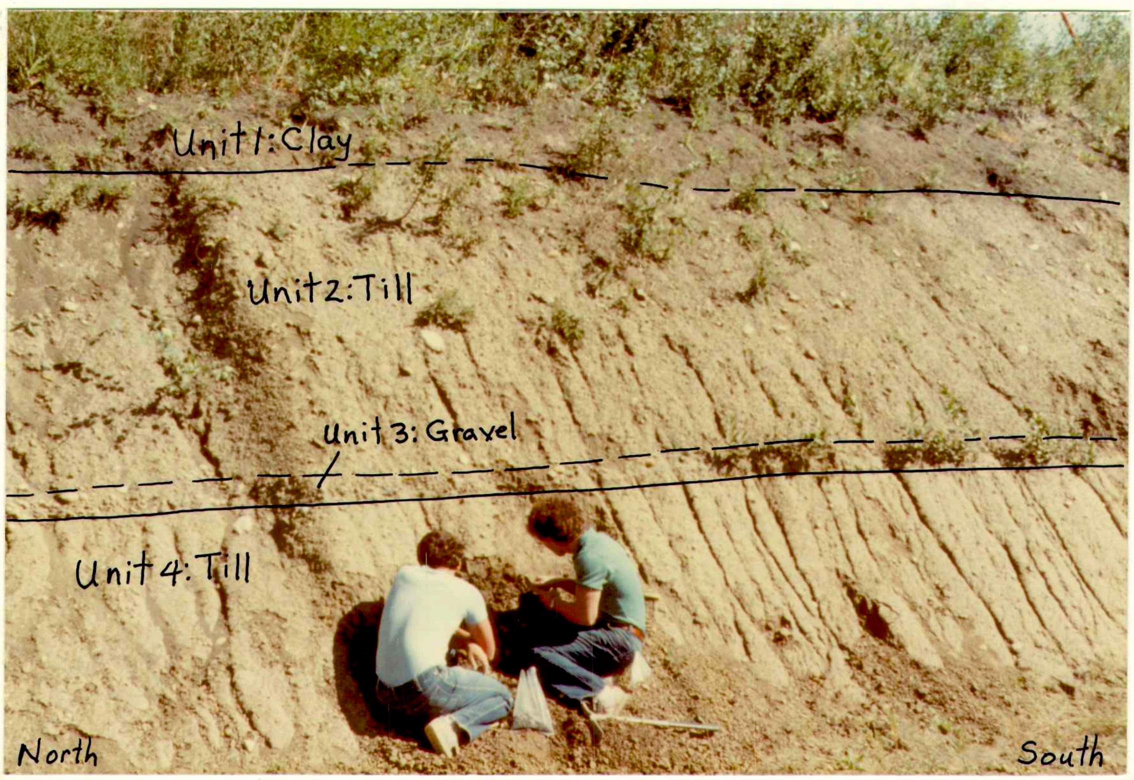


Plate 1b. Riviere Qui Barre Section
Note differences in weathered color and erosion between Unit 2 till and Unit 4 till.

Plate 1c. Wavy bedded silty-sand. Gradational contact with Unit 2 till, erosional contact with Unit 4 till.

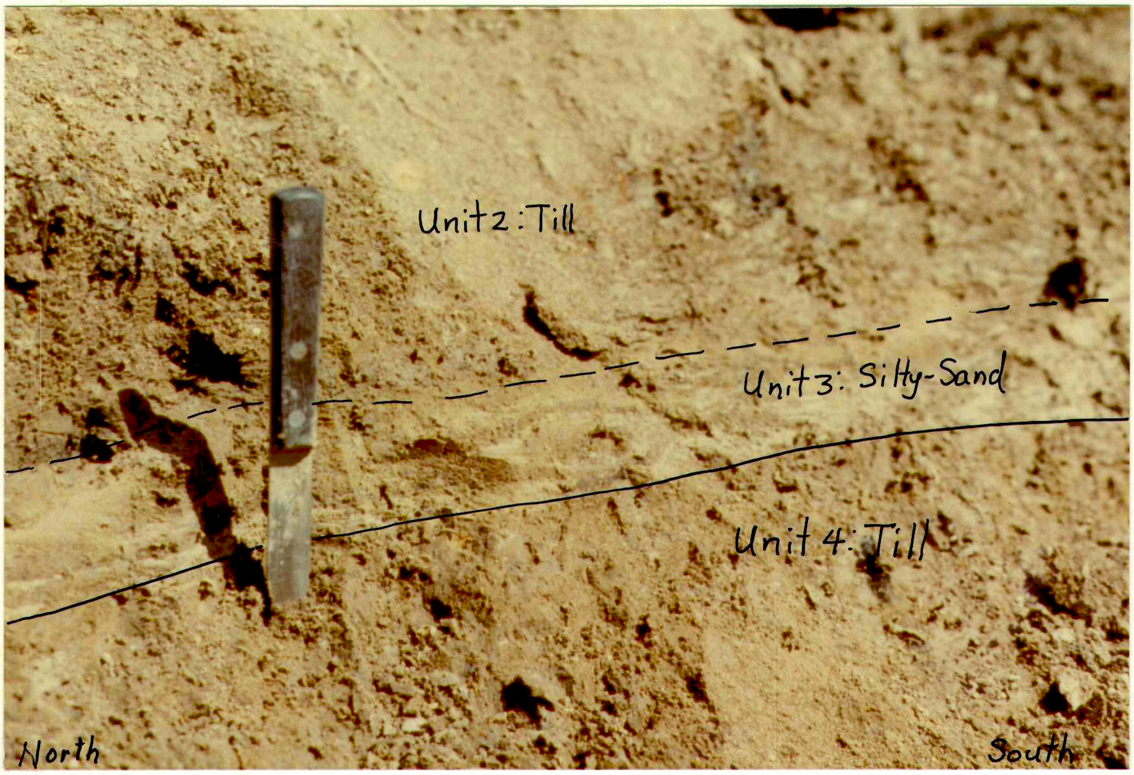


Plate 1d. Fractured, strongly jointed structure of top of Unit 4 till. Note iron and manganese staining along fracture planes.

jointed or fractured near the top (plate 1d). Iron and manganese staining is common along the fracture surfaces, but this staining does not pervade throughout the individual blocks of till. The unit is much more consolidated, appears to be drier, and peels off in shards or small blocks when excavated with a pick.

Initial results from pebble counts from each of the tills indicate that the pebble lithologies are not too dissimilar, though the lower till may have marginally more igneous-metamorphic rocks and more Athabasca sandstone fragments. Carbonate rock contents are essentially about the same for both tills. Coarse sand mineralogies have not yet been determined for samples from either of these tills.

The significance of this section in this part of the map area is that it demonstrates the presence of two tills in an area where previous workers in the nearby gravel quarries have found only one. Within the nearby pits the sandy. lower till has been mapped and the upper clayey till appears to be absent. Typically in the gravel pits this sandy till is thick (>5 m) and forms vertical to near vertical faces, indicating that it is very consolidated and strong. As well, the till has a characteristic columnar joint pattern, with joints on a spacing of about a 1 m interval. In one outcrop a thin, very dark gray, highly fractured, clayey till underlies the sandy till, the two separated by a thin, discontinuous glacial gravel lense. Elsewhere, the sandy, columnar jointed till overlies Empress Formation sand and gravel deposits.

Origin, History, and Correlations

The oldest Quaternary deposits in the Edmonton map area consists of quartzite and chert sand and gravel deposits that lie on the floors of the buried valleys. These are commonly called Saskatchewan sand and gravel, and are considered to have a preglacial origin, deposited by rivers flowing east from the Rocky Mountains during the Tertiary and early Quaternary. These deposits correlate with unit 1 of the Empress Formation which lies at the base of the buried valleys in the Sand River map area. It is likely that some of these preglacial valleys in the Edmonton area have been reoccupied by glacial meltwater and interglacial drainage systems. Evidence for this consists of outcrop observations of gravel quarries in which minor amounts of igneous and metamorphic rocks derived from the Canadian Shield can be found within the basal gravel deposits that are composed primarily of preglacial Cordilleran rock types. The presence of these Shield rocks indicates that glacial meltwater has reworked and redeposited some of the preglacial deposits and that many of the deposits previously believed to be preglacial in age are much younger.

The first glacial advance in the map area deposited the Lamont till, of which remnants can be mapped at the base of the Cooking Lake Moraine and possibly within buried valleys. This till cannot be correlated easily with any of the tills in the lowlands surrounding the moraine, but possibly the Lamont till may be the same thin, dark gray, fractured till that was found at the base of the Quaternary section in a few outcrops along the gravel quarries in the Villeneuve area. Perhaps this may also be the lower, Gray till defined by Warren in the Tofield area. The age of this till is unknown, and it cannot be correlated at this time with any of the known units in the Sand River map area. Stratified sediment that lies on top of the Lamont till in a few places indicates that following the deposition of the till, the area was ice-free sufficiently long enough for glacial meltwater sediments to be deposited.

The next glaciation deposited the Chipman till which is relatively widespread throughout the Cooking Lake Moraine, and perhaps most of the map area. It is believed that the Chipman till lies within many of the buried valleys and probably is the lower till at the Riviere Qui Barre section, though at that section the till does not contain appreciably more carbonate rock fragments in the pebble-size fraction which is characteristic of the Chipman till in the Cooking Lake Moraine. The Chipman till can be correlated with the Marie Creek Formation in the Sand River map area on the basis of its relatively higher carbonate rock content in the coarse sand fraction, its sandier texture, and its more oxidized weathered outcrop color. It is believed that the Chipman till may correlate with the consolidated, columnar jointed brown till described by previous workers in the Edmonton area as the Upper till.

Meltwater associated with either that retreating glacier, or the advancing glacier that followed, deposited glaciolacustrine sand, silt and clay overtop the Chipman till both within the Cooking Lake Moraine, and within the lowlands flanking the moraine. Sand associated with these deposits may correlate with the Tofield sand, defined by Warren from his observations in a coal strip mine near Tofield Alberta.

The last glaciation in the map area deposited the clayey Cooking Lake till, and the sandy Elk Island till, both of which are found primarily in the Cooking Lake Moraine. Samples of organic material from a testhole drilled in the Elk Island National Park, indicate that this glacier advanced overtop and incorporated grasses growing in the interglacial deposits of lacustrine silt and clay. A C14 age date from these grasses indicates that the last glacial advance occurred no earlier than 26,000 +,- 100 B.P., which means that the Elk Island and Cooking Lake tills are of late Wisconsinan age.

Although it is believed that this last glaciation was extensive throughout the map area, the Cooking Lake till is not well preserved over much of the study area. The Cooking Lake till appears to lie within some of buried valleys northeast of the Cooking Lake Moraine, but to the east and southeast, the till is either absent, or it cannot be differentiated from the underlying till units. In fact, cross-section N3 shows that the sandy Chipman till appears to lie at the surface in many places surrounding the Cooking Lake Moraine. Geomorphic evidence such as crevasse fillings and linear disintegration features on the present land surface, combined with a very thin cover of Quaternary sediment the east part of the map area suggests that the last glacier may have been relatively thin and advanced under extended flow conditions. The result of this is that the ice may have been relatively debris-free and subsequently little glacial sediment (till) was deposited. Further work is required to resolve the stratigraphy and origin of the Quaternary deposits in these flat lands.

West of the Cooking Lake Moraine, the absence or discontinuous distribution of the upper Cooking Lake till may be explained by lacustrine erosion rather than by non-deposition. The remnant of the Cooking Lake till at the Riviere Qui Barre section suggests that the till may have been widespread, but was subsequently eroded either during the development of Glacial Lake Edmonton, or during the drainage of Glacial Lake Edmonton through the Gwynn outlet to the south. East-west cross-sections through the map area in fact show that the sandy Chipman till that is buried in the Cooking Lake Moraine, is exposed in the surrounding lowlands.

The absence of a present day widespread distribution of the last glacial till in the Edmonton area may have a profound impact in the interpretation of the Quaternary history of the deposits in the Edmonton area. Because the physical properties of the Cooking Lake and Chipman tills are significantly different, likely the geotechnical properties will be considerably different as well. Consequently, any investigation that on the basis of stratigraphic position correlates the first till encountered in a testhole for example, with till of the last glaciation may be erroneous. In fact, for most of the Edmonton area Glacial Lake Edmonton deposits quite possibly directly overlie stratigraphically older tills that were deposited prior to the Late Wisconsinan.

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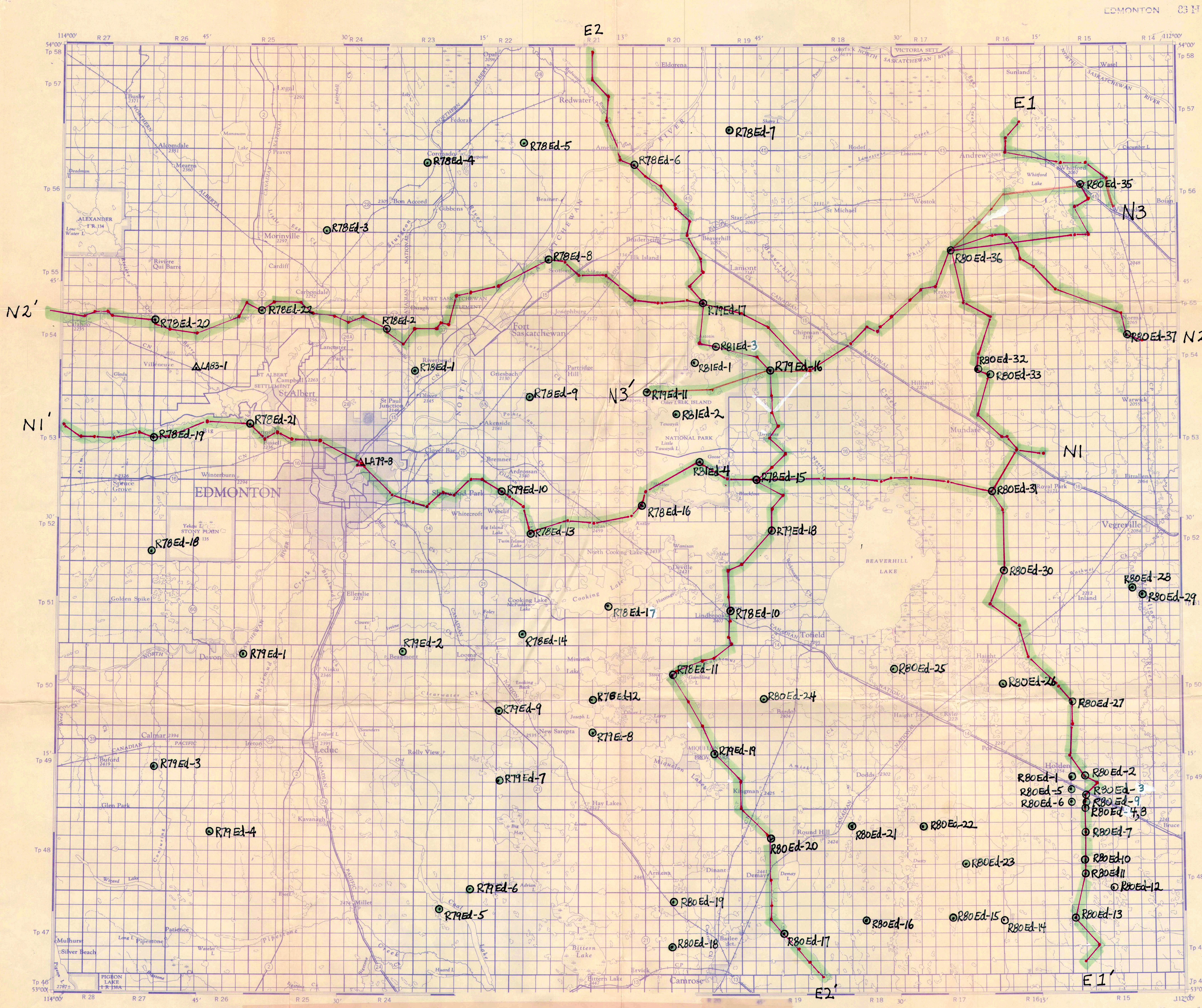

Figure 1. Location of Alberta Geological Survey Dry Auger Testholes and Geologic Cross-sections.

R78 testholes drilled in 1978
R79 " " " 1979
R80 " " " 1980
R81 " " " 1981

Figure 3. Cross Section E2 - E2' Cooking Lake Moraine

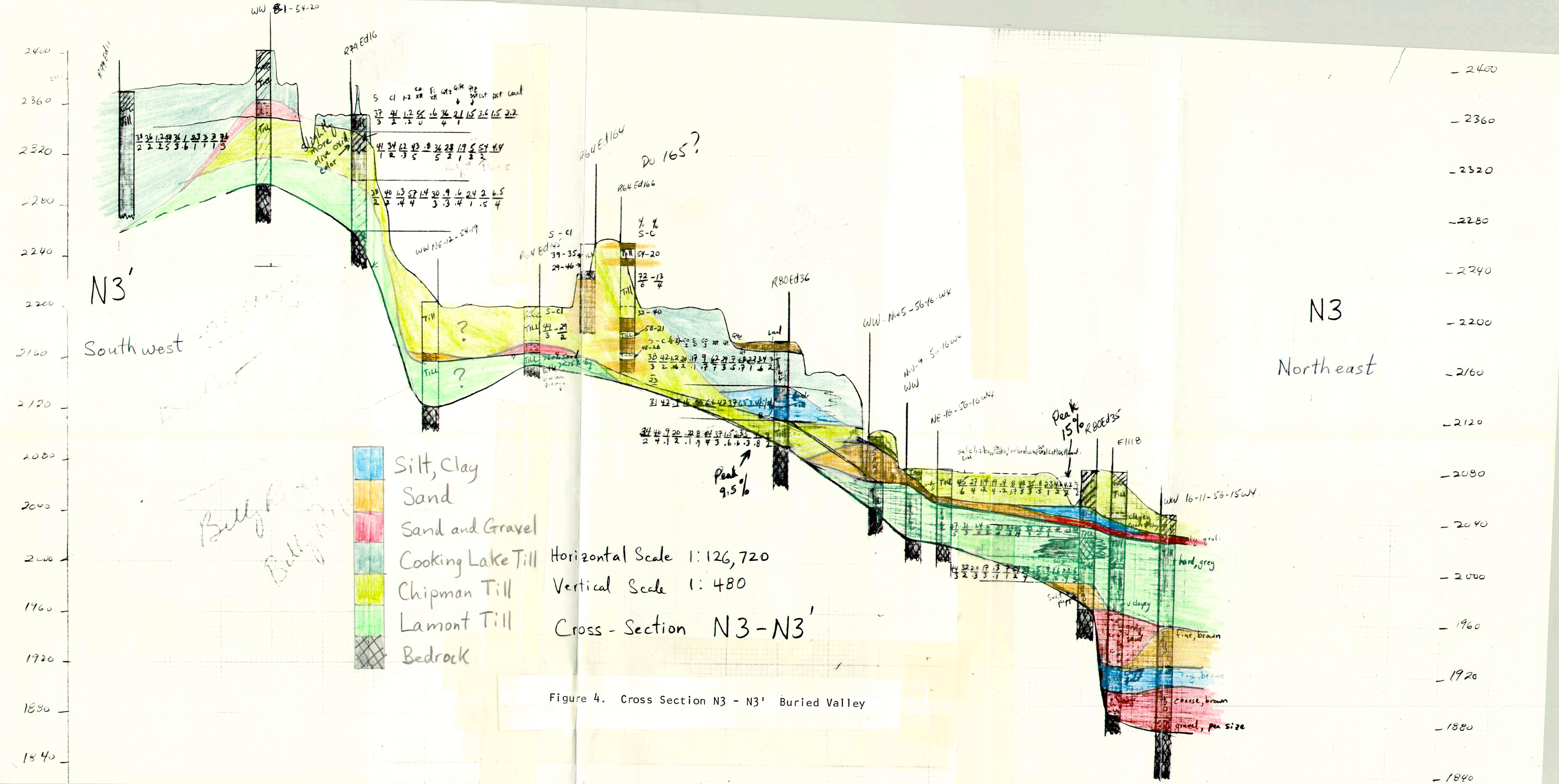

Figure 4. Cross Section N3 - N3' Buried Valley