

E. A. Christiansen Consulting Ltd.

CONSULTING GEOLOGIST

BOX 3087
SASKATOON, SASKATCHEWAN, CANADA
S7K 3S9

PHONE 374-6700

March 15, 1979

Municipal Lands Branch
Urban Division
Saskatchewan Municipal Affairs
1791 Rose Street
Regina, Saskatchewan S4P 3V7

Attention: Mr. Hilding O. Franson, Senior Planner

Dear Mr. Franson:

Enclosed are three copies of report 0016-003 on the "Geology of the Regina-Moose Jaw region, Saskatchewan" as called for in Part A of the contract for the Regional Studies Program. The report includes additions requested in the copy of your letter of February 22, 1979 to J.D. Mollard and Associates Limited.

If you have further queries concerning this report, please contact me.

Sincerely yours,



E.A. Christiansen

GEOLOGY OF THE REGINA-MOOSE JAW REGION
SASKATCHEWAN

by

E.A. CHRISTIANSEN CONSULTING LTD.

Box 3087, Saskatoon, Saskatchewan
S7K 3S9

Report 0016-003

for

PART A REGIONAL STUDIES PROGRAM
SASKATCHEWAN MUNICIPAL AFFAIRS

1791 Rose Street
Regina, Canada
S4P 3V7

March 15, 1979

E. A. Christiansen Consulting Ltd.

SUMMARY FOR LAND-USE PLANNERS

The purpose of this summary is to discuss briefly the role of geology in land-use planning and to give examples of this role in the Regina-Moose Jaw region. Geology, which is the study of the earth, forms the framework for land-use planning. In this Regional Studies Program, E.A. Christiansen Consulting Ltd. was commissioned to study the subsurface deposits (Part A), and J.D. Mollard and Associates Limited (Part B) and the Saskatchewan Institute of Pedology (Project A-6) were commissioned to investigate the surface deposits. J.D. Mollard and Associates Limited was further commissioned to compile land-use maps based on the results of the three investigating firms.

In as much as the role of geology may not be obvious in these land-use maps, the following are examples of the role of geology in land-use planning in the Regina-Moose Jaw region as it applies to: (1) location of groundwater, (2) location of sand and gravel for construction, (3) location of areas of slope instability, and (4) location of lands most suitable for urban development.

Before proceeding with these examples, it may be helpful to discuss the use of maps and cross sections which portray the geology of the surface and subsurface deposits. If we let a three-dimensional block represent a portion of the earth, then the surface of the block will represent a two-dimensional map (length x width), and the sides of the block will represent two-dimensional cross sections (length or width x depth). The shape of the surface of the block or topography is shown by contour lines which join points of equal elevation above sea level (Drawing 0016-003-01, in back of report). The depth or third dimension is shown by means of cross sections (Drawing 0016-003-02-18) in which the nature and structure of the subsurface deposits are shown. In addition to cross sections, the thickness of deposits is shown either by point thickness (Drawing 0016-003-19,20,21) or by lines drawn through points of equal thickness (Drawing 0016-003-22,23). These maps and cross sections show the three-dimensional nature of the Regina-Moose Jaw region.

In addition to the three dimensions of space, the fourth dimension of time must be considered. Time can be related to depth or retreatal phases of the last deglaciation when the surficial sediments were deposited. Because younger beds rest on older ones, the deeper you go the further you go back in time. Sketches (Figs. 15-24) are also used to show the changes that occur as time passes and, thus, portray the history and origin of the surface deposits on which we live.

With this background, let us now consider the role of geology in land-use planning in the Regina-Moose Jaw region under the above mentioned examples. Sand and gravel deposits are important for groundwater when water bearing and important for construction purposes when dry, near the surface, and close to market.

The location of water bearing sand and gravel in the Regina-Moose Jaw region is shown in maps (Drawings 0016-003-01,19,20,21,22) and cross sections (Drawings 0016-003-02-18). The base of groundwater exploration, below which the search is not recommended, is shown in the cross sections. The buried valleys and water bearing sands in the bedrock are shown in Drawing 0016-003-01; the water bearing sands and gravels, deposited during glaciation, are shown in Drawings 0016-003-19,20,21, and 22; and the water bearing sands, which, for the most part, were deposited in deltas where the Thunder and Qu'Appelle Spillways emptied into Lake Regina, are shown in Figures 18, 19, and 21.

Because of the economic restrictions of depth, sands and gravels for construction purposes are restricted to the Upper Floral Sand and Gravel (Drawing 0016-003-21), the Condie and Moose Jaw Moraines (Drawing 0016-003-22), and the apexes of deltas which formed where the Thunder and Qu'Appelle Spillways emptied into Lake Regina (Figs. 18,19,21).

Most landslides in the Regina-Moose Jaw region occur where the Qu'Appelle Valley and its tributaries were cut into bedrock silts and clays (Drawing 0016-003-01). In the Regina-Moose Jaw region, bedrock is not strong and hard as the term "rock" implies but is weaker than the tills of the region.

Knowledge of the geology of the surface and subsurface deposits is vital to locating the most suitable lands for urban development, particularly from an environmental impact point of view. If urban development extends south and west from Regina, for example, some of the most valuable agricultural lands will be taken out of production. If, for another example, polluting enterprises are permitted to locate over the Regina Aquifer or in the Condie Moraine which recharges this water bearing sand and gravel, this aquifer will eventually become unsuitable as a source of drinking water for the city of Regina.

In summary, a thorough understanding of the geology of the surface and subsurface deposits will form the basis for efficient and economic development that will cause a minimum impact on the environment. To provide such a thorough understanding, testholes at one-mile centers are recommended for urban and urban fringe areas in the Regina-Moose Jaw region. Such a geological understanding will not only provide a basis for land-use planning but will also provide a framework for all future site investigations whether they be for foundation conditions, groundwater supplies, or pollution monitoring, etc.

LIMITATIONS

The Saskatchewan Research Council geologic logs are based on cores, cutting samples, and electric logs and are believed to represent the geology at a specific site at the time studied. The other geologic logs are based on driller's logs and electric logs only which makes this information less reliable than SRC information. The oil and potash company information is in the form of electric logs mainly and was used primarily for identifying the bedrock deposits and the bedrock surface. The contacts between glacial deposits, which were determined in the geologic logs, were projected through the most likely depth in the geophysical logs.

Straight lines drawn between adjacent logs in cross sections are to guide the eye from contacts in one log to another and do not necessarily represent the actual contact between geologic units nor do they necessarily imply the nature of these units is the same as at the actual sites where the information was obtained.

Curved lines in cross sections represent the available geologic models that best fit the geologic information available at the time the cross sections were drawn. These lines do not necessarily represent the actual contacts between geologic units nor do they necessarily imply that the nature of these units is the same as at the sites where the information was obtained. Similarly, contour lines on the bedrock surface represent the available geologic models that best fit the information available at the time they were drawn.

This investigation is a compilation of existing information only. Much of the interpretation is inferred and requires more surface and subsurface information for verification. The degree of confidence of these interpretations depends on the nature and density of the information, on the complexity of the geology, and on the proposed land use. The nature and density of the information are shown in the maps and cross sections to enable the user to evaluate the degree of confidence of the interpretations and to assess where further information will be required for the intended use.

TABLE OF CONTENTS

	<u>Text</u>	Page
1.	INTRODUCTION -----	1
	1.1 Terms of Reference and Objective-----	1
	1.2 Location -----	3
	1.3 Previous Work -----	3
	1.4 Present Study -----	5
2.	BEDROCK STRATIGRAPHY -----	5
	2.1 Introduction -----	5
	2.2 Lower Colorado Group -----	6
	2.3 Lea Park Formation and Upper Colorado Group -----	6
	2.4 Judith River Formation -----	6
	2.5 Bearpaw Formation -----	8
	2.6 Frenchman, Whitemud, and Eastend Formations -----	8
	2.7 Ravenscrag Formation -----	8
3.	BEDROCK SURFACE TOPOGRAPHY-----	9
	3.1 Introduction -----	9
	3.2 Glacial Erosion -----	9
	3.3 Fluvial Erosion -----	10
	3.3.1 Introduction -----	10
	3.3.2 Preglacial Fluvial Erosion -----	10
	3.3.3 Glacial Fluvial Erosion -----	10
	3.3.4 Postglacial Fluvial Erosion -----	14
	3.4 Collapse -----	14
4.	GLACIAL STRATIGRAPHY -----	14
	4.1 Introduction -----	14
	4.2 Empress Group -----	14
	4.3 Sutherland Group -----	15
	4.4 Saskatoon Group -----	16
	4.4.1 Introduction -----	16
	4.4.2 Floral Formation -----	16
	4.4.3 Battleford Formation -----	17
	4.4.4 Moose Jaw Moraine -----	19
	4.4.5 Condie Moraine -----	19
	4.4.6 Surficial Stratified Drift -----	21

	<u>Text</u>	<u>Page</u>
	4.4.7 Qu'Appelle Alluvium -----	22
5.	GEOLOGICAL PROCESSES -----	22
	5.1 Introduction -----	22
	5.2 Glacial Thrusting -----	22
	5.3 Collapse Caused by Dissolution of Salt -----	26
	5.4 Collapse Caused by Melting Ice -----	29
6.	GEOLOGICAL HISTORY -----	31
	6.1 Cretaceous Period -----	31
	6.2 Tertiary Period -----	31
	6.3 Quaternary Period -----	31
	6.3.1 Introduction -----	31
	6.3.2 Pleistocene Epoch -----	31
	6.3.3 Recent Epoch -----	33
7.	HISTORY OF DEGLACIATION -----	33
	7.1 Introduction -----	33
	7.2 Phase 1 of the History of Deglaciation -----	33
	7.3 Phase 2 of the History of Deglaciation -----	37
	7.4 Phase 3 of the History of Deglaciation -----	37
	7.5 Phase 4 of the History of Deglaciation -----	40
	7.6 Phase 5 of the History of Deglaciation -----	40
	7.7 Phase 6 of the History of Deglaciation -----	44
	7.8 Phase 7 of the History of Deglaciation -----	44
8.	GEOTECHNOLOGY -----	44
	8.1 Introduction -----	44
	8.2 Groundwater Geology -----	48
	8.2.1 Introduction -----	48
	8.2.2 Base of Groundwater Exploration -----	48
	8.2.3 Groundwater Occurrence -----	48
	8.3 Slope Instability -----	49
	8.3.1 Introduction -----	49
	8.3.2 Landslides -----	49
	8.3.3 Spring Sapping -----	49
	8.3.4 Brecciation and Slickensiding -----	51
	8.4 Tills -----	51
	8.5 Gravel -----	51

	<u>Text</u>	Page
8.6	Boulder Pavements -----	52
8.7	Expansible Clays -----	52
8.8	Stratigraphic Control of Subsurface Drainage -----	52
8.9	Waste Disposal Sites -----	53
9.	RECOMMENDATION FOR FURTHER STUDIES -----	54
9.1	Introduction -----	54
9.2	Recommendations -----	54
10.	LITERATURE CITED -----	56

Illustrations

Figure

1.	Location of the Regina-Moose Jaw region -----	4
2.	Schematic cross section in the Canadian Great Plains -----	7
3.	Origin of the Hatfield Valley -----	11
4.	Origin of the Muscow Valley -----	12
5.	Cross section of the Hatfield, Muscow, and Qu'Appelle Valleys -----	13
6.	Boulder pavement between Floral and Battleford Formations --	18
7.	Cross section across Condie Moraine and Regina -----	20
8.	Schematic diagram showing the process of glacial thrusting -	23
9.	Omission of beds in ice-thrust depression -----	24
10.	Repetition of drift and bedrock by glacial thrusting -----	25
11.	Thickness of salt in Devonian, Elk Point Group -----	27
12.	Seismic cross section of the Crater Lake structure -----	28
13.	Slickensides in collapsed Surficial Stratified Drift -----	30
14.	Geo-environmental map of the Regina-Moose Jaw region -----	34
15.	Phase 1 of the history of deglaciation of Regina-Moose Jaw--	35
16.	Phase 3 of the history of deglaciation of southern Sask. ---	36
17.	Phase 2 of the history of deglaciation of Regina-Moose Jaw--	38
18.	Phase 3 of the history of deglaciation of Regina-Moose Jaw--	39
19.	Phase 4 of the history of deglaciation of Regina-Moose Jaw	41
20.	Phase 4 of the history of deglaciation of southern Sask. ---	42
21.	Phase 5 of the history of deglaciation of Regina-Moose Jaw--	43
22.	Phase 5 of the history of deglaciation of southern Sask. ---	45

Illustrations

Figure	Page
23. Phase 6 of the history of deglaciation of Regina-Moose Jaw--	46
24. Phase 7 of the history of deglaciation of Regina-Moose Jaw--	47
25. Diagrammatic cross section of landslide -----	50

Drawings

0016-003-01 Bedrock geology and topography -----	in back
02 Cross section AA' -----	in back
03 Cross section A'A" -----	in back
04 Cross section BB' -----	in back
05 Cross section B'B" -----	in back
06 Cross section CC' -----	in back
07 Cross section C'C" -----	in back
08 Cross section DD' -----	in back
09 Cross section D'D" -----	in back
10 Cross section EE' -----	in back
11 Cross section E'E" -----	in back
12 Cross section FF' -----	in back
13 Cross section GG' -----	in back
14 Cross section HH' -----	in back
15 Cross section II' -----	in back
16 Cross section JJ' -----	in back
17 Cross section KK' -----	in back
18 Cross section LL' -----	in back
19 Empress Group-----	in back
20 Lower Floral Sand and Gravel -----	in back
21 Upper Floral Sand and Gravel -----	in back
22 Condie and Moose Jaw Moraines -----	in back
23 Isopach of Surficial Stratified Drift -----	in back

Appendices

Appendix 1. Name and location of logs -----	59
---	----

1. INTRODUCTION

1.1 Terms of Reference and Objective

The following are the Terms of Reference supplied by the Saskatchewan Department of Municipal Affairs.

A. GEOLOGICAL FRAMEWORK INCLUDING RELEVANT ASPECTS OF DEGLACIATION

Objective

The objective is to conduct an investigation of surficial and subsurface geology in the Regina-Moose Jaw region as outlined in Figure 1. Such investigation will provide the geological framework of the bedrock and glacial or postglacial deposits for the purpose of determining possible constraints and advantages of locating urban and related developments within certain parts of the region. This geological framework will be used in the preparation of special land use maps.

The geological framework will provide a better understanding of the region and assist decision makers in determining the best use of lands (and waters) within the region. The work shall identify as closely as possible: 1) the location of aquifers suitable for domestic and/or industrial water supplies; 2) the location of aquifer recharge areas which should be protected from certain land uses, native vegetation clearing practices, or pollution; 3) the location of sands and gravels for construction purposes; 4) the location of areas unsuitable for urban development due to slope instability, potential erosion, unsatisfactory foundations and so on; and 5) the location of lands most suitable for urban developments (industrial, commercial, residential, transportation corridors, pipelines, potential waste disposal, and effluent irrigation areas, etc).

The Work

The following shall be specifically noted:

- a) Lithologic logs shall be compiled in such a manner so as to enable the reader to relate the lithology of the electric logs if necessary.
- b) The cross sections, 1:125,000, shall illustrate the base of exploration (at least to bedrock) and all overlying deposits.
- c) The cross sections shall be prepared at approximately twenty mile intervals east and west and twenty mile intervals north and south—suggest 4 east to west and 6 north to south. At least one of the cross sections shall pass through the cities of Regina and Moose Jaw in each direction.
- d) The consultant is encouraged to provide additional cross sections where sufficient data are available and where variation in geology warrants and where such differences are significant to a better understanding of the geological framework of the region.
- e) To meet the objective of these terms of reference, the following maps (1:250,000) are required:
 - Bedrock geology and topography
 - Isopach map of Empress Group
 - Isopach map of Floral Formation sands and gravels
 - Isopach map of surficial stratified drift (Glacial Lake Regina deposits to be used in Part C).
- f) Using an annotated series of sketches, a history of deglaciation shall be provided in so far as they help to explain the origin of various deposits and their significance to developing sound growth management policies.
- g) In addition to the foregoing, it is emphasized that the environmental constraints and opportunities inherent in these geologic formations must be reflected in the work identified in Part B. While it is recognized that the consultant responsible for Part B of this work must assume direct responsibility for producing maps and criteria for evaluating and presenting such data, it is included in the foregoing to ensure there is adequate consultation between consultants.
- h) Based upon the completion of the work and the interpretation of

currently available data, the consultant shall indicate where more detailed investigations would be desirable and/or essential to make positive recommendations regarding the suitability of certain lands in the region being allotted for certain uses.

- 1) It is proposed that the required work for the Regina-Moose Jaw region be completed and delivered in manuscript form (three copies), including maps, on or before February 16, 1979.

1.2 Location

The Regina-Moose Jaw region extends from 49°45' to 51°00' North Latitude and from 103°30' to 106°30' West Longitude. This region includes 62E-13; 62L-4,5,12,13; 72G-16; 72H-13-16; 72I-1-16; and 72J-1, 8,9,16 (Fig.1).

1.3 Previous Work

Geology and groundwater maps showing geology, bedrock surface topography, cross sections, and base of groundwater exploration have been published for the Regina-Moose Jaw region (Christiansen, 1971a,b; Whitaker, 1967, 1970, 1974a, b). In addition to these, a cross section of drift and bedrock between Condie and Craven was published (Christiansen, 1972).

Information on the surficial geology was obtained from Christiansen (1956, 1960, 1961), Christiansen (et al. 1977), Parizek (1964), and Whitaker (1965). The soil information used in the compilation of the geo-environmental map was published by Head (1979), and the framework for the history of deglaciation was obtained from Christiansen (1979).

Groundwater reports have been published for the city of Regina and surrounding area (Lissey, 1962; Meneley and Christiansen, 1975). and for a potential effluent irrigation area south of Moose Jaw (Meneley, 1975). Papers on collapse structures (Christiansen, 1971c; Gendzwill and Hájnal, 1971) and on Pleistocene stratigraphy

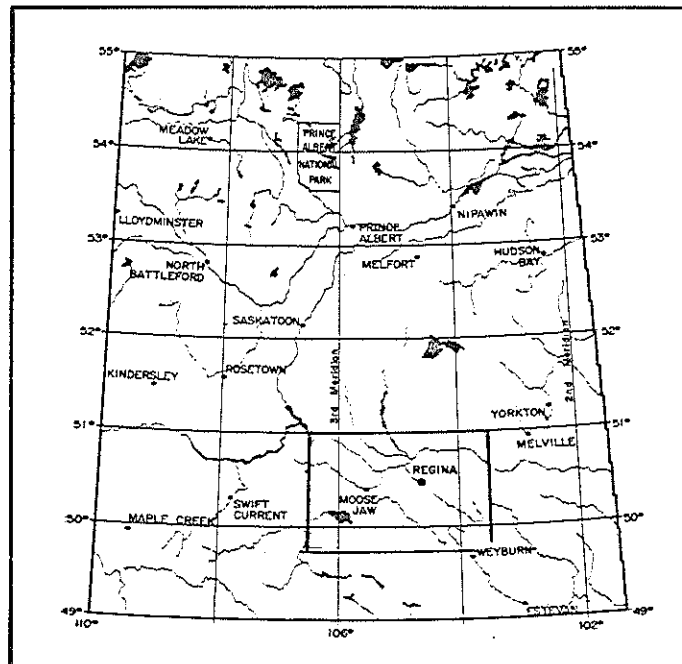


Figure 1. Location of the Regina-Moose Jaw region.

(Christiansen, 1968a, 1968b and Westgate *et al.* 1977) formed the basis for these discussions. The bedrock nomenclature was taken from McLean (1971) and Caldwell (1968). Geological and electrical logs from the Saskatchewan Research Council (SRC); oil and potash companies; and the Family Farm Improvement Branch (FFIB), Saskatchewan Department of Agriculture provided the subsurface information. Many of the SRC logs include carbonate depth curves which are important criteria for separating tills in the Regina-Moose Jaw region. In response to a special request, FFIB supplied logs up to and including 1977.

1.4 Present Study

From the geological and electric logs, a bedrock geology and topography map (Drawing 0016-003-01), seventeen cross sections (Drawings 0016-003-02-18), a map of the Empress Group (Drawing 0016-003-19), maps of the Lower and Upper Floral Sand and Gravel (Drawings 0016-003-20,21), a map of the Condie and Moose Jaw Moraines (Drawings 0016-003-22), and an isopach map of the Surficial Stratified Drift in the glacial Lake Regina basin (Drawing 0016-003-23) were constructed.

The nature and values of the data points are shown on the maps to enable the reader to evaluate the accuracy of the interpretation. The cross sections were constructed by taping matte positive logs on the cross section paper which enables the geologist to have all of the information before him when making the interpretations and to show the reader the basis for these interpretations. These drawings of maps and cross sections are in the back of the report.

2. BEDROCK STRATIGRAPHY

2.1 Introduction

The bedrock deposits in the Regina-Moose Jaw region include: Lea Park Formation and Upper Colorado Group; Judith River and Bearpaw Formations; the Frenchman, Whitemud, and Eastend Formations, undifferentiated; and

the Ravenscrag Formation (Drawing 0016-003-01). In addition to these deposits, the upper part of the Lower Colorado Group is also shown in most of the cross sections.

The base of the Second White Speckled Shale and the Eagle Shoulder constitute the most extensive structural marker beds in the Regina-Moose Jaw region. Because of their wide areal extent and ease of interpretation in electric logs, they were used as the bases of exploration for this geological investigation.

2.2 Lower Colorado Group

The Lower Colorado Group in the Regina-Moose Jaw region is composed of about 400 feet (122 m) of gray, marine, noncalcareous silt and clay. The lower Colorado Group has a lower electrical resistance than the overlying Lea Park Formation and Upper Colorado Group (see resistance logs on right side of electric logs in cross sections).

2.3 Lea Park Formation and Upper Colorado Group

Because the Lea Park Formation cannot be differentiated from the Upper Colorado Group in electric logs, they were combined into one unit. The Lea Park Formation and Upper Colorado is composed of 830 to 1150 feet (253-351 m) of gray, marine silt and clay which becomes slightly sandy as the overlying Judith River Formation is approached. The upper part of the Lea Park Formation and upper Colorado Group is noncalcareous, whereas the lower part is composed of calcareous, white speckled shales.

2.4 Judith River Formation

The Judith River Formation (McLean, 1971) is composed of 0 to 200 feet (0-61 m) of nonmarine, interbedded, fine-grained sand, silt, and clay with carbonaceous and concretionary zones. The Judith River Formation is a deltaic sediment which extends eastward into the marine deposits (Fig.2). The Judith River Formation is exposed in the Swift Current

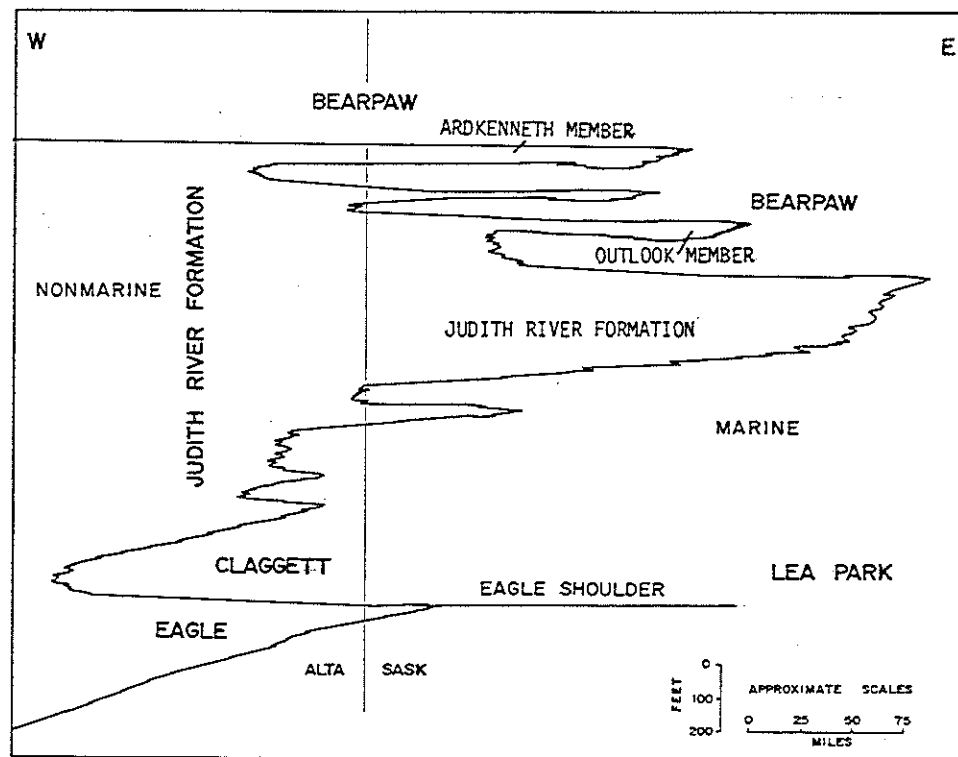


Figure 2. Schematic cross section of intertongued nonmarine sands and silts and clays in the Canadian Great Plains. From McLean (1971).

and Hatfield Valleys (Drawing '0016-003-01). The Formation is poorly developed in the southeastern half of the map-region where it is represented by what appears in electric logs to be thin sand or silt beds and concretionary zones. The Judith River Formation is 30 feet (9 m) thick in the Fort Qu'Appelle area where it forms the most eastward protruding tongue of the Formation (Christiansen *et al.* 1977).

2.5 Bearpaw Formation

The Bearpaw Formation is composed of 0 to 1400 feet (0-427 m) of gray, marine, noncalcareous silt and clay with two sand interbeds, the Outlook and Ardkeneth Members. The Bearpaw Formation, which is the most extensive bedrock in the Regina-Moose Jaw region, was removed by fluvial and glacial erosion in the Swift Current and Hatfield Valleys.

2.6 Frenchman, Whitemud, and Eastend Formations

Because these Formations are not distinguishable in geologic and electric logs, they are grouped into one unit (Whitaker, 1974a). The Eastend Formation is composed of marine and nonmarine sand and silt and carbonaceous and calcareous zones; the Whitemud Formation is composed of kaolinitic sand, silt, and clay with carbonaceous zones; and the Frenchman Formation is composed of interbedded sand, silt, and clay with carbonaceous zones.

2.7 Ravenscrag Formation

The Ravenscrag Formation is composed of interbedded sand, silt, clay, and lignite with local carbonaceous, kaolinitic, concretionary, and calcareous zones (Whitaker, 1974a). This Formation is restricted to two localities in the southern part of the map-region.

3. BEDROCK SURFACE TOPOGRAPHY

3.1 Introduction

The bedrock surface in the Regina-Moose Jaw region was formed mainly by glacial and fluvial erosion, and, locally, this surface was modified by collapse. The processes of glacial erosion and collapse will be discussed in more detail in Chapter 5.

3.2 Glacial Erosion

Glacial erosion, which was the most important process that shaped the bedrock surface in the Regina-Moose Jaw region, was described by (Christiansen and Whitaker, 1976). In as much as glacial erosion is believed to be such an important erosional process, this model, with its upward-facing concave surfaces, has been used to draw the bedrock surface or surfaces on which tills were deposited.

Glacial erosion has widened and deepened the Swift Current and Hatfield Valleys (Drawing 0016-003-01). North of Mortlach (T.19, R.1, W3), the Swift Current Valley was completely removed by glacial erosion leaving a broad depression. South of Fort Qu'Appelle (T.20, R.13, W2), the southwest side of the Hatfield Valley was greatly modified by glacial erosion. Most of the broad depressions on the bedrock surface, such as the one under Edenwold and Indian Head, is attributed to glacial erosion (Drawings 0016-003-01; 17, Logs 92-280). The bedrock surface was eroded by younger glaciers (Drawing 0016-003-06) as well as the older ones (Drawing 0016-003-03). It is not inconsistent to show a glacially eroded surface beneath the Empress Group (Drawing 0016-003-06) because this Group is glacial in origin at this site and is believed to have been glacially eroded prior to deposition at the Empress Group.

3.3 Fluvial Erosion

3.3.1 Introduction

The bedrock surface of the Regina-Moose Jaw region was also modified considerably by fluvial erosion during preglacial, glacial, and post-glacial times.

3.3.2 Preglacial Fluvial Erosion

Chert and quartzite gravels in the base of the Swift Current Valley fill near Swift Current suggest that the Swift Current Valley in the Regina-Moose Jaw region is preglacial in age. If such gravels were deposited in the Swift Current Valley in the map-region, they were removed subsequently by glacial erosion.

3.3.3 Glacial Fluvial Erosion

The Hatfield (Fig. 3) and the Muscow(Fig.4) Valleys were formed as glacial fluvial valleys. The Hatfield Valley was formed as a regional ice-marginal Channel (Fig. 3) which carried meltwater from the melting continental glacier and the extraglacial water from the southwest. The Hatfield Valley is believed to have formed during the first continental glaciation when the valley was glacially eroded during the advance of the ice and filled with glacial sand and gravel during retreat.

The Muscow Valley was cut and filled between the deposition of the Sutherland Group and the Floral Formation (Fig.5). This valley was also a regional ice-marginal channel. As the glacier advanced up the north-facing slope at the Touchwood Uplands, meltwater from the continental glacier and the extraglacial area to the southwest flowed through the lowland at Fort Qu'Appelle between the Touchwood Uplands to the north and the Moose Mountain Upland to the south (Fig. 4) and cut the Muscow Valley.

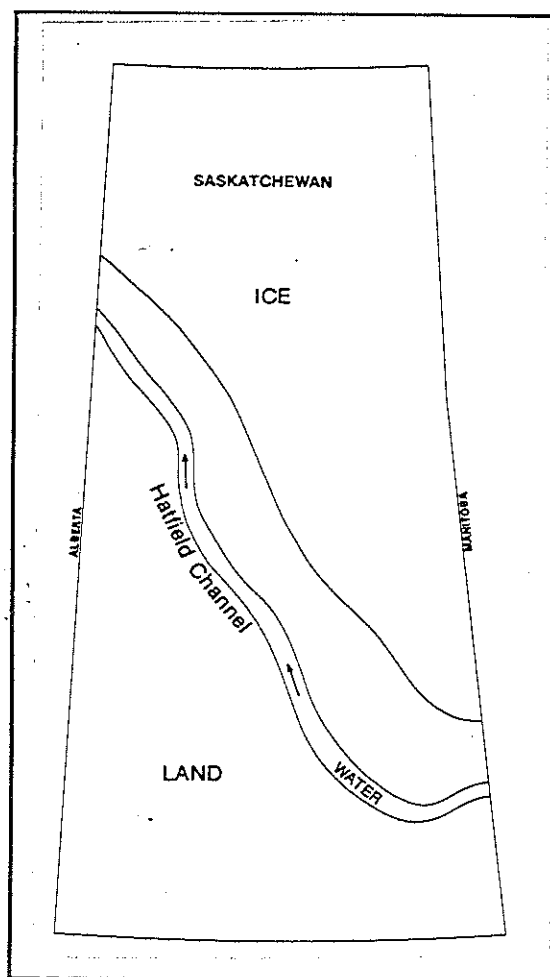


Figure 3. Origin of the Hatfield Valley. From Christiansen et al. (1977).

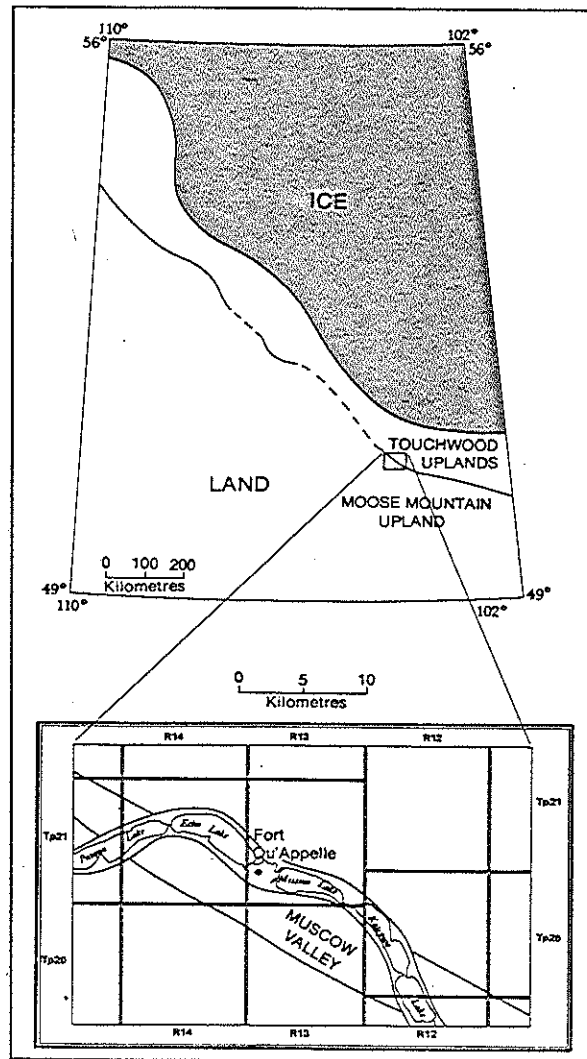


Figure 4. Origin of the Muscow Valley. From Christiansen et al. (1977).

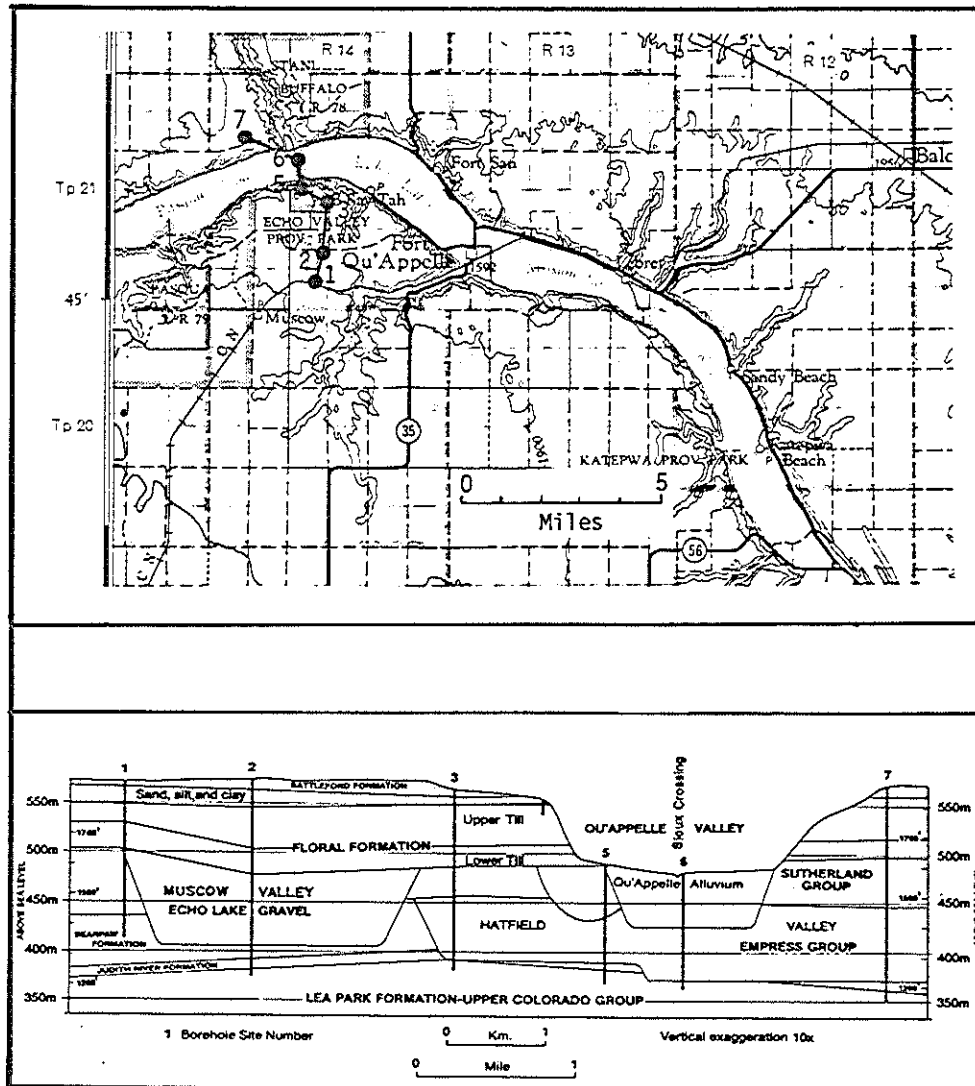


Figure 5. Cross section of the Hatfield, Muscow, and Qu'Appelle Valleys.
From Christiansen et al. (1977).

3.3.4 Postglacial Fluvial Erosion

Almost all of the Qu'Appelle Valley and parts of the Thunder, Arm, and Last Mountain Valleys were cut into bedrock by meltwater and extraglacial water during the last deglaciation (Chapter 7).

3.4 Collapse

The bedrock surface of the Regina-Moose Jaw region has been affected by collapse (Drawings 0016-003-07, 16; Logs 79-88, 248-254) as shown by the drop of the marker beds under this bedrock surface depression. In addition to this depression, numerous other depressions in the bedrock surface in the Regina-Moose Jaw region are attributed to collapse (T.22, R.15; T.20, R.24; T.22, R.28, Drawing 0016-003-01).

4. GLACIAL STRATIGRAPHY

4.1 Introduction

The glacial deposits (drift) in the Regina-Moose Jaw region have been divided into the Empress, Sutherland, and Saskatoon Groups. Geological units less than 10 feet (3 m) thick cannot be shown in the cross sections; consequently, the boundaries of the Surficial Stratified Drift, for example, may not agree with the boundaries in the map (Drawing 0016-003-23) or with the boundaries in the Part B study by J.D. Mollard and Associates Limited. Where there is not sufficient information to separate the glacial deposits, they are shown as "drift" in the cross sections.

4.2 Empress Group

The Empress Group, which was named by Whitaker and Christiansen (1972) and which was used by Christiansen (1972) near Regina, is composed of gravel, sand, silt, and clay lying between bedrock and till. In the Regina-Moose Jaw region, the Empress Group was divided into: 1) mainly silt and 2) mainly sand and gravel (Drawing 0016-003-19).

In the vicinity of Regina and in the southwestern part of the region, the Empress Group is composed of 0-233 feet (0-71 m) of predominately silt but includes minor amounts of sand and, locally, a basal ironstone and chert gravel. The silt is either brown or gray. The brown color appears to be primary, and the gray colored silt is commonly carbonaceous. The ironstone and chert gravels are preglacial, and the brown and carbonaceous silts may also be preglacial. Those preglacial sediments in the bedrock surface uplands should be assigned to the bedrock, probably as Tertiary deposits. Because there isn't sufficient information to separate these preglacial sediments at this time, however, they are included with the Empress Group.

In the Hatfield and Swift Current Valleys and in the other depressions in the bedrock surface, the Empress Group is composed mainly of sand and gravel with lesser amounts of silt and till. To date, only glacial deposits have been encountered in these sediments, but it is possible that preglacial deposits will be encountered in the Swift Current Valley which is known to be preglacial at Swift Current.

4.3 Sutherland Group

The Sutherland Group, which was named by Christiansen (1968b) and which was traced to the Regina-Moose Jaw region by Christiansen (*in Westgate et al.* 1977), is composed of 0 to 200 feet (0-61 m) of till and minor amounts of stratified drift. The tills of the Sutherland Group are less calcareous and have a lower electrical resistance than the tills of the Floral and Battleford Formation of the Saskatoon Group (see electric logs and carbonate curves plotted on electric logs in cross sections).

Where the weathered zone in the upper part of the Sutherland Group was not removed by erosion, it appears as a unique olive gray color with yellowish brown staining, the upper part of which may be diminished of carbonate by leaching.

4.4 Saskatoon Group

4.4.1 Introduction

The Saskatoon Group in the Regina-Moose Jaw region is composed of the Floral Formation, Battleford Formation, Moose Jaw Moraine, Condie Moraine, Surficial Stratified Drift, and Qu'Appelle Alluvium. The Moose Jaw and Condie Moraines are used herein as morphostratigraphic units. The Floral and Battleford Formations are shown as one unit in the cross sections because the Battleford Formation is either too thin to be shown or there are not sufficient differences in the physical or electric properties to separate them. The Saskatoon Group and the Floral and Battleford Formations were named by Christiansen (1968a,b).

4.4.2 Floral Formation

The Floral Formation is composed of: 1) Lower Floral Sand and Gravel (Drawing 0016-003-20), 2) Lower Till, 3) Interglacial Sediments, 4) Upper Floral Sand and Gravel (Drawing 0016-003-21), and 5) Upper Till. The Lower and Upper Tills of the Floral Formation are not shown in the cross sections because there isn't sufficient information to trace these units.

The Lower Floral Sand and Gravel (Drawing 0016-003-20) which lies between the Sutherland Group and the Lower Till of the Floral Formation (Drawing 0016-003-15, Logs 231-233), is composed of sand and gravel with interbeds of silt and till.

The Lower Till of the Floral Formation lies between the Lower Floral Sand and Gravel and the Interglacial Sediments or between the Lower and Upper Floral Sand and Gravel (Drawing 0016-003-15, Logs 231-233). Where the Lower Floral Sand and Gravel is missing beneath the Interglacial Sediments, the Lower Till lies between the Sutherland Group and these Interglacial Sediments.

The Interglacial Sediments, which are between the Lower and Upper Till or between the Lower Till and the Upper Floral Sand and Gravel, are composed of 0 to 368 feet (0-112 m) of fossiliferous, carbonaceous, silt, sand, and gravel (Drawing 0016-003-07,16). These sediments are restricted to the collapse structure under the city of Regina (Drawing 0016-003-01). The fossiliferous and carbonaceous nature of these sediments indicate they are interglacial in age. The origin of these deposits will be discussed further in Chapter 5 under the collapse process.

The Upper Floral Sand and Gravel lies between the Interglacial Sediments and the Upper Till (Drawing 0016-003-15, Logs 231-233). In addition to sand and gravel, this unit is composed also of interbedded till and silt.

The Upper Till of the Floral Formation, which lies between the Interglacial Sediments and the Upper Floral Sand and Gravel and the Battleford Formation, is composed of till and minor amounts of sand, gravel, and silt. Where the upper part of the Upper Till is weathered, it is commonly yellowish brown with iron oxide staining on well-developed joint surfaces.

4.4.3 Battleford Formation

The Battleford Formation is composed of mainly soft, unjointed, and unstained till. In some localities, this Formation is also composed of a harder, lower till which contains comminuted weathered till of the underlying Formation. Commonly, only the upper, softer till, which is generally less than 5 feet thick (1.5 m), represents the Battleford Formation. The harder, lower till is interpreted as a "basal till", whereas the softer, upper till is considered to be "ablation till" released during the melting of the glacier.

The contact between the Battleford Formation and the underlying Floral Formation is commonly marked by a well-developed boulder pavement (Fig. 6) whose boulders were pressed into the weathered Floral Formation

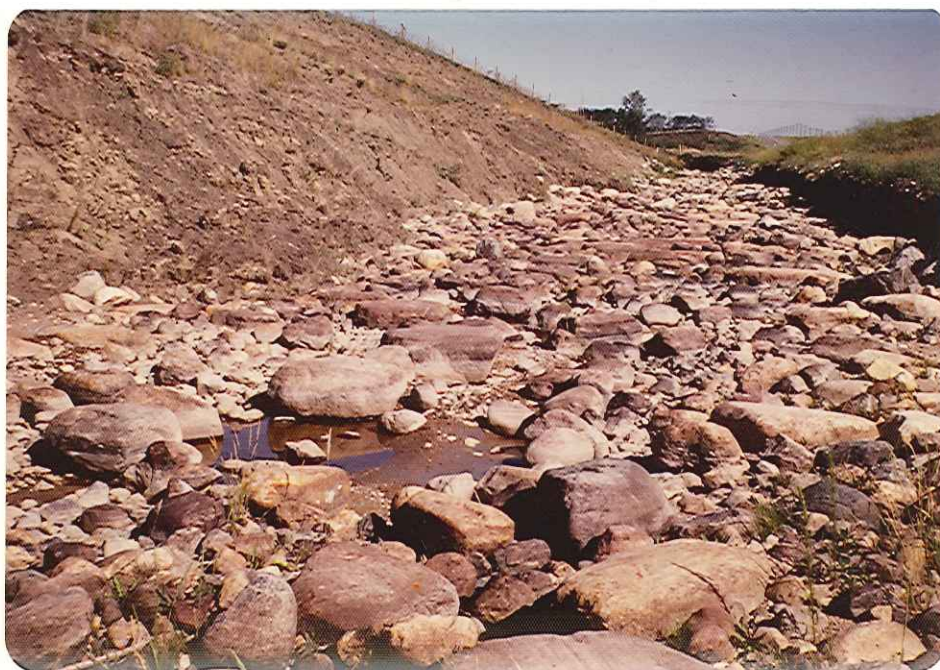


Figure 6. Boulder pavement between the Floral and Battleford Formations north of Tisdale, Saskatchewan. The pavement was exhumed by water erosion in the ditch along Highway 35. Notice the flat-topped, striated, in-situ boulders which were formed by glacial erosion.

with their flat and striated surfaces in contact with the overlying, unweathered or less weathered Battleford Formation. These boulders are believed to have been deposited by the glacier that deposited the Battleford Formation.

The upper contact with the overlying Surficial Stratified Drift is gradational with commonly a mixed zone of till and glacial lake silt and clay separating the two units. The origin of this mixed zone will be discussed in Chapter 5 under "Collapse Caused by the Melting of Ice".

4.4.4 Moose Jaw Moraine

The Moose Jaw Moraine, which was named by Christiansen (1961), is composed of a 0 to 149-foot (0-45 m) core of sand and gravel with a 0 to 48-foot (0-15 m) blanket of silt to the southeast (Drawing 0016-003-22). The Moraine was formed during Phase 3 of the history of deglaciation (Fig. 18) when both glacial meltwater and extraglacial runoff was flowing southeastward along the glacier margin. The sediments in the Moose Jaw Moraine becomes progressively finer grained from gravel in the northwestern part to silt in the southeastern part. More Specifically, Meneley (1975) envisioned that the Moose Jaw Moraine was deposited in an ice-walled channel cut in stagnant ice.

4.4.5 Condie Moraine

The Condie Moraine, which was named by Christiansen (1961), is composed of a 0 to 119-foot (0-36 m) wedge of sand and gravel flanked to the south with a 0 to 37-foot (0-11 m) apron of sand and silt (Drawing 0016-003-22). In detail, the apron is composed of a lower wedge of sand and an upper blanket of silt, both of which become progressively thinner and finer grained to the south (Fig. 7). Most of the sand and gravel core of the Condie Moraine is covered with 0 to 23 feet (0-7 m) of till deposited presumably by a slight re-advance of the glacier (Drawing 0016-003-22). After the glacier retreated, the Moraine was covered with Lake Regina silt and clay.

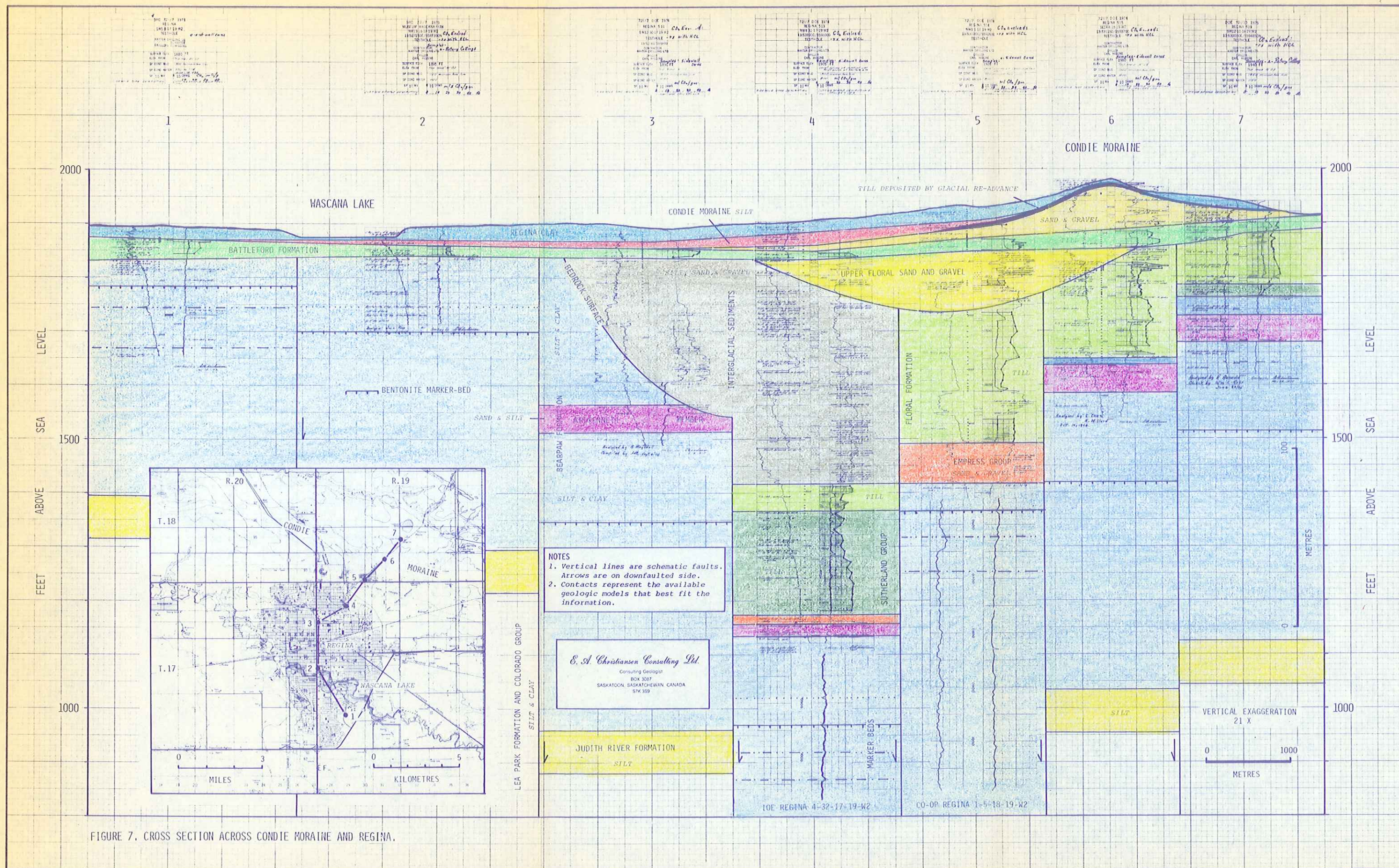


FIGURE 7. CROSS SECTION ACROSS CONDIE MORaine AND REGINA.

The Condie Moraine was deposited during Phase 4 of the history of deglaciation (Fig. 19) as an end moraine. The Condie Moraine is interpreted as an end moraine rather than an ice-walled channel fill as suggested by Meneley (1975) for the Moose Jaw Moraine because the silt blanket developed at right angles to the Condie Moraine (Drawing 0016-003-22), indicating the meltwater was flowing away from the glacier rather than along its margin as in the case of the Moose Jaw Moraine (Drawing 0016-003-22).

4.4.6 Surficial Stratified Drift

The Surficial Stratified Drift in the Regina-Moose Jaw region is composed of inwash which was derived from the erosion of till in extraglacial and glaciofluvial valleys and outwash which was derived from the melting glacier.

In the Lake Regina Basin (Drawing 0016-003-23), the inwash is composed of deltaic sand and gravel. The delta in the vicinity of Mortlach (T.18, R. 1, W3) was formed by the Thunder Spillway during Phase 4 of the history of deglaciation (Fig. 19), and the delta north of Stony Beach was formed by the Thunder Spillway during Phase 5 of the history of deglaciation (Fig. 21). Lakeward from these deltas, 0 to 50 feet (0-15.2 m) of lacustrine silt and clay from the Thunder Spillway were deposited in the deeper parts of Lake Regina (Drawing 0016-003-23). The texture of the Surficial Stratified Drift in the Lake Regina basin grades progressively from gravel in the apex of the deltas to clay in the deeper parts of the basin. Most of these silts and clays are believed to be inwash.

The Condie Moraine, as mentioned previously, is an outwash deposit derived from the melting glacier (Fig. 7). This outwash was deposited contemporaneously with the inwash in Lake Regina and was subsequently covered by lacustrine silt and clay (Fig. 7). The sand and gravel deposits, east of Range 27 and north of the Qu'Appelle Valley (Drawing 0016-003-23), are probably a combination of inwash from the

Qu'Appelle Spillway and outwash from the glacier.

4.4.7 Qu'Appelle Alluvium

The Qu'Appelle Alluvium, which was named by Christiansen (1961), is composed of 0 to 320 feet (0-98 m) of carbonaceous clay, silt, sand, and gravel in the form of floodplains and flanking piedmont alluvial fans, along the valley walls. Most of the alluvium is derived from the valley walls and tributary valleys. Near the valley walls, the alluvial sediments are interbedded with colluvial deposits. The Qu'Appelle Alluvium was deposited when and since the Qu'Appelle Valley functioned as a glacial spillway (Christiansen *et al.* 1977, p. 23-25).

5. GEOLOGICAL PROCESSES

5.1 Introduction

Glacial thrusting of drift and bedrock and collapsing of sediments because of dissolution of salt or melting of ice were important geological processes during glaciation in the map-region.

5.2 Glacial Thrusting

Glacial thrusting occurred near the margin of the glacier where drift and/or bedrock was eroded from ice-thrust depressions and carried upward along diverging flowlines (Fig. 8) to form repetition of beds by overthrusting. Christiansen and Whitaker (1976) demonstrated that the depression east of Tyner, Saskatchewan (Fig. 9) is an ice-thrust depression. They further showed that The Dirt Hill Moraine, southwest of Regina is composed of a stack of drift and bedrock formed by glacial thrusting (Figure 10).

The glacial thrusting model (Fig. 8) was used to explain the upward facing concave surfaces and the structures of some of the

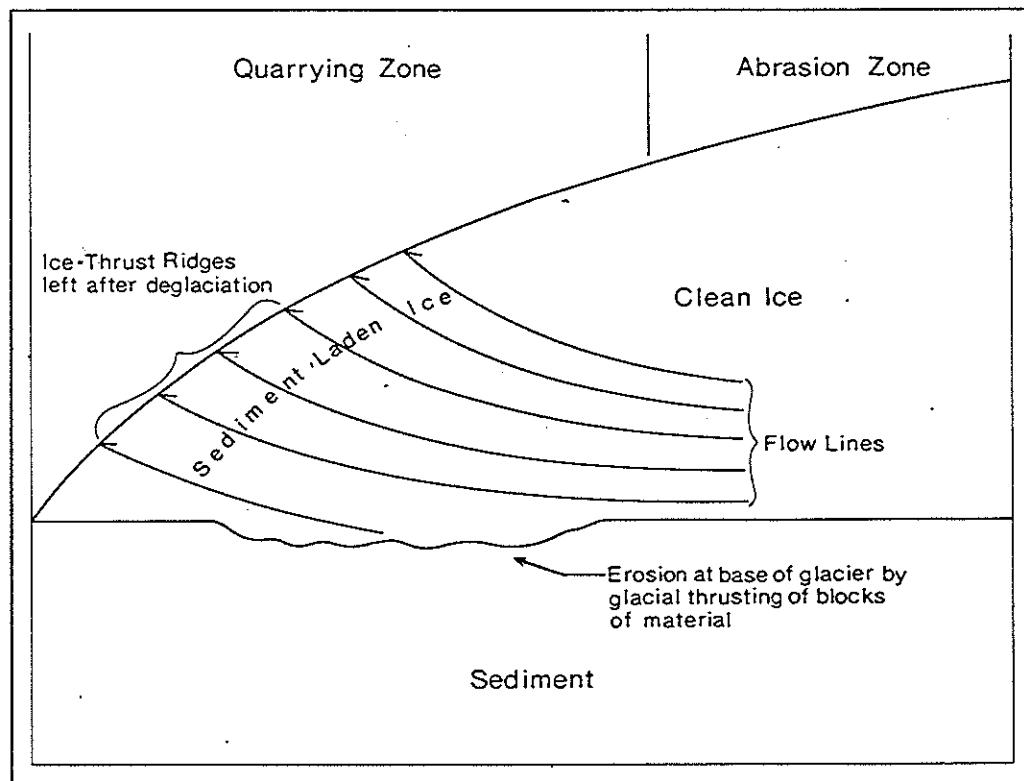


Figure 8. Schematic diagram showing the process of glacial thrusting. From Christiansen and Whitaker (1976).

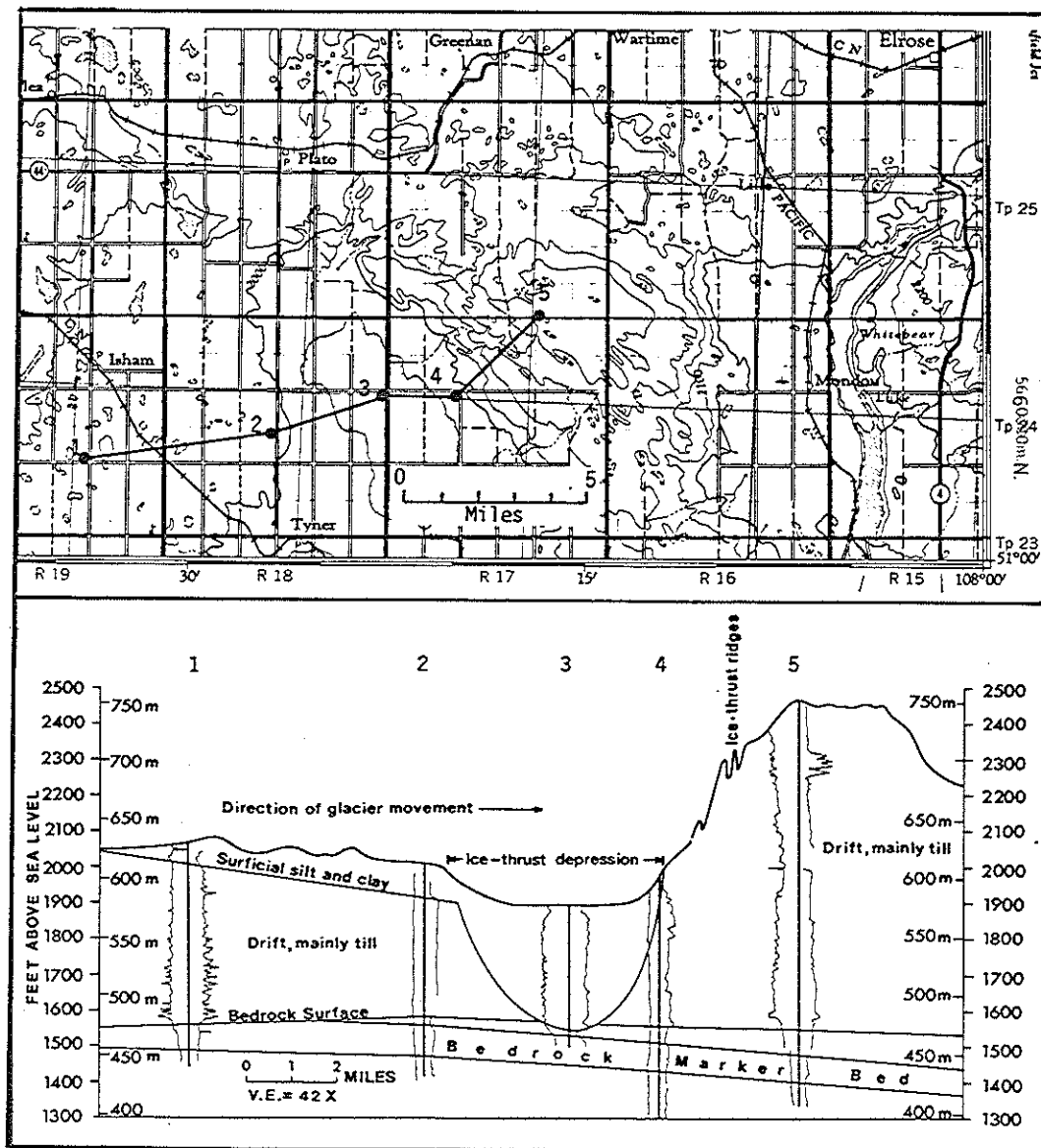


Figure 9. Omission of beds in ice-thrust depression east of Tyner, Saskatchewan. From Christiansen and Whitaker (1976).

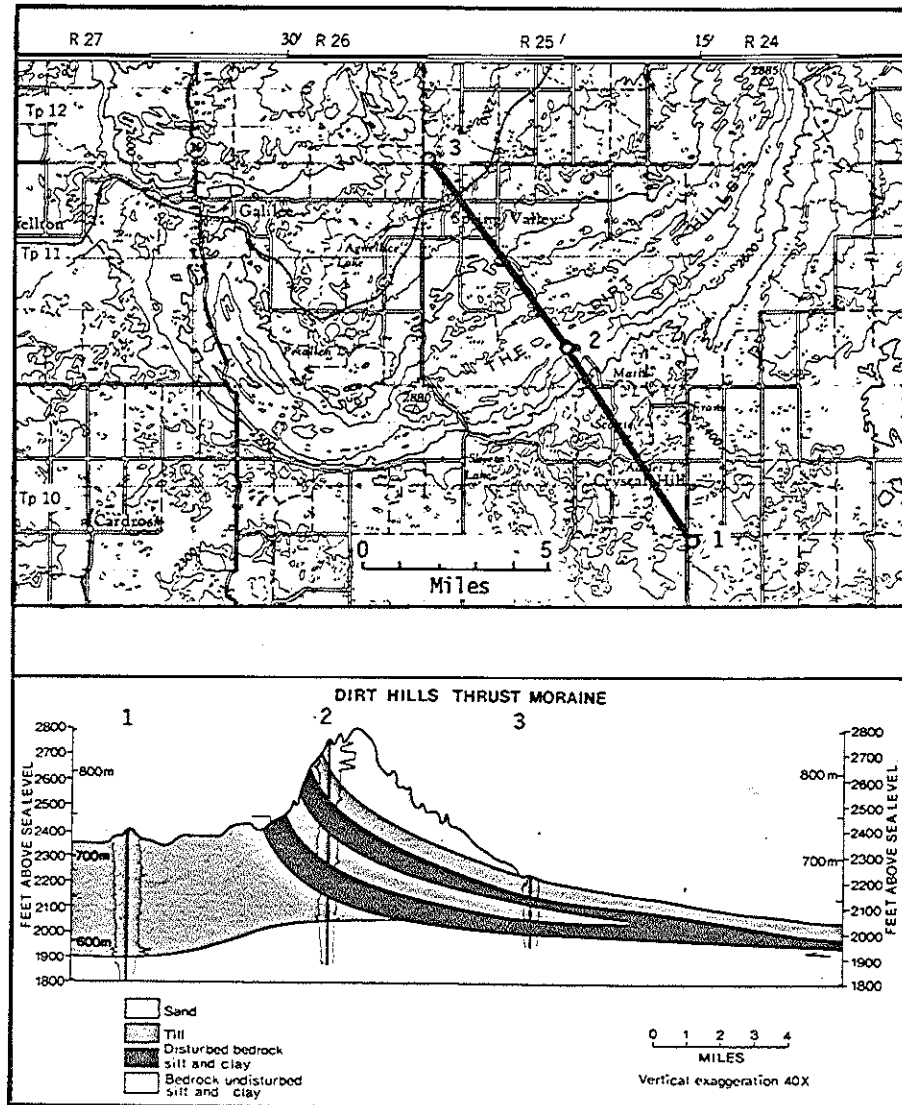


Figure 10. Repetition of drift and bedrock by glacial thrusting in The Dirt Hills Moraine. From Christiansen and Whitaker (1976).

glacial deposits, particularly the disturbed bedrock (Drawing 0016-003-02, Log 3). Figure 8 shows the origin of these upward-facing concave surfaces which form the contacts between most of the units shown in the cross sections of the Regina-Moose Jaw region. Most of the larger closed depressions in the bedrock surface of this region are interpreted as ice-thrust depressions, and The Dirt Hills Moraine is accepted as an ice-thrust moraine composed of stacked drift and bedrock (Fig. 10).

5.3 Collapse Caused by Dissolution of Salt

Christiansen (1967) showed that the bedrock deposits in the Saskatoon Low were collapsed and inferred that the depression on the bedrock surface above the collapse structure was also caused by collapse. Christiansen (1971c) demonstrated that Crater Lake lies in a collapse structure which formed about 13,600 years ago, and Gendzwill and Hajnal (1971) showed that the collapse was caused by the removal of salt (Fig. 11) from the Devonian, Elk Point, Prairie Evaporite Formation (Fig. 12).

The Major collapse structure is the Regina- Moose Jaw region is in the vicinity of the city of Regina (Drawings 0016-003-01,07,16). In Cross sections C'C" and JJ' (Drawings 0016-003-07,16), the bedrock and Empress and Sutherland Groups are clearly collapsed, and the Interglacial Sediments fill the collapsed depression (Drawing 0016-003-16, Logs 250,251).

The absence of older glacial deposits beneath the Interglacial Sediments in Log 249 (Drawing 0016-03-16) suggests that these older glacial deposits were glacially eroded before these Interglacial Sediments were deposited.

In conclusion, Cross sections C'C" and JJ' (Drawing 0016-003-07,16; Fig.7) suggest that collapse took place during the deposition of the Empress and Sutherland Groups. This was followed by erosion of these Groups

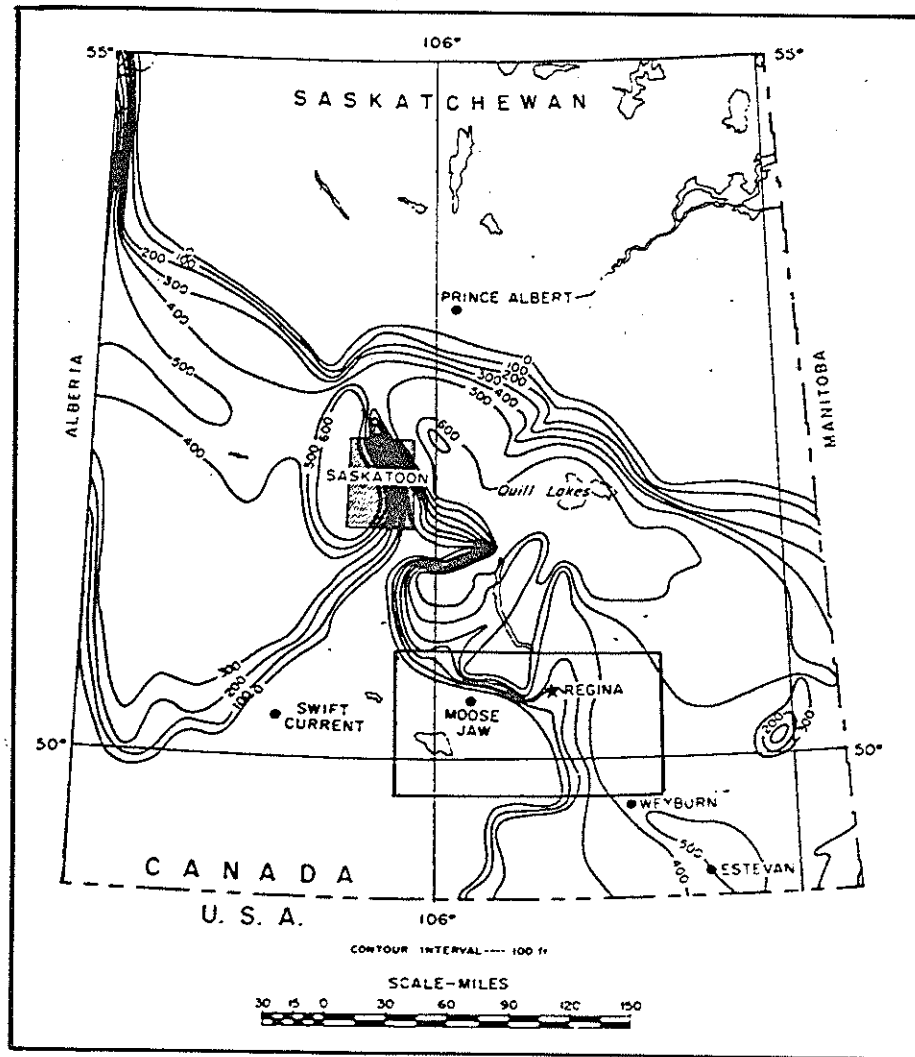


Figure 11. Thickness of salt in the Devonian, Elk Point Group. From Pearson (1963).

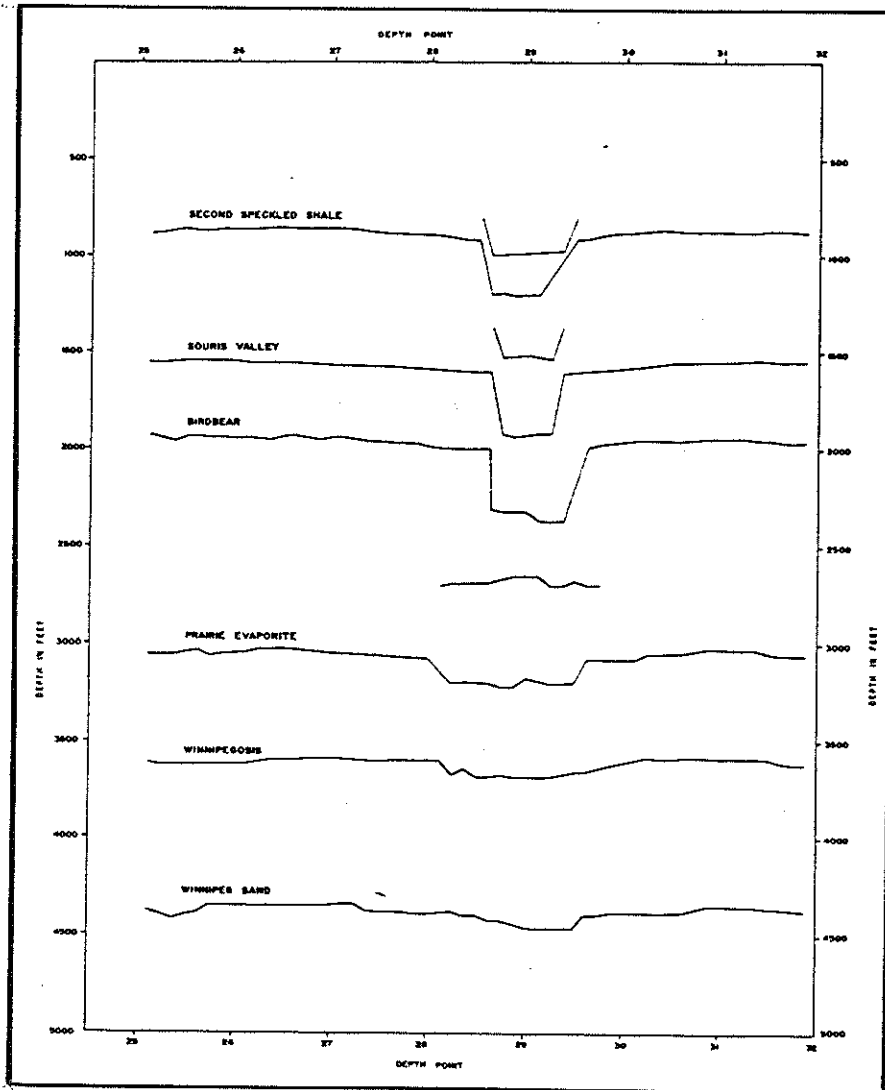


Figure 12. Seismic cross section of the Crater Lake structure which formed as the result of removal of salt from the Devonian, Elk Point, Prairie Evaporite Formation. From Gendzwil and Hajnal (1971).

of deposits by the glacier that deposited the Lower Floral Till (Drawings 0016-003-07, Log 81; 16, Log 249). This, in turn, was followed by further collapse (Drawing 0016-003-16, logs 250, 251) and deposition of the Interglacial Sediments in the glacially modified, collapsed depression. There is no evidence, however, to suggest that collapse has taken place since the deposition of the Interglacial Sediments.

5.4 Collapse Caused by Melting Ice

The contact between the Surficial Stratified Drift and the underlying Battleford Formation is gradational and is commonly represented by a 1 to 2-foot (.3-.6 m) zone of mixed till and silt and clay. In addition, where the Surficial Stratified Drift is sufficiently thick, its sediment exhibits faults and brecciated and slickensided surfaces (Fig. 13) and hummocky topography.

The deglaciation model provides a very plausible explanation for these observations. As the glacier retreated downslope to the north, glacial Lake Regina was dammed by the retreating glacier (Chapter 7). As the glacier diminished by downmelting, the glacial lake waters inundated the stagnant ice which extended along the margin of the glacier. From these waters, silts and clays were deposited on the stagnant ice. As the stagnant ice melted, englacial material was released from the glacier to mix with the lake sediments resulting in a mixed contact zone between these two deposits. As the ice continued to melt, the lake sediments and englacial material would slump and slide forming faults and brecciated and slickensided zones. Finally, as remnant blocks of ice melted, kettles would form by collapse of the overlying sediments to form a hummocky surface.



Figure 13. Slickensided surfaces in collapsed Surficial Stratified Drift in the city of Saskatoon. Notice the smooth, polished, slickensided surface below the jagged sediment and the irregular structures in the right part of the photograph which were formed by collapse of the deposit when the underlying stagnant ice melted. Such structures can also be anticipated in the Regina-Moose Jaw region.

6. GEOLOGICAL HISTORY

6.1 Cretaceous Period

During the Cretaceous Period, the Regina-Moose Jaw region was covered by shallow seas into which rivers from the Cordillera emptied to form deltas which regressed eastward as the sea levels fell and transgressed westward as the sea levels rose. The sandy Judith River Formation and the Outlook and Ardkeneth Members of the Bearpaw Formations (Fig.2) represent such deltaic deposits, whereas the clayier Lower Colorado Group, Lea Park Formation and Upper Colorado Group, and the Bearpaw Formation were deposited in the shallow seas eastward from these deltas. The Cretaceous sediments were deposited from about 94 million to 64 million years ago (Obradovich and Cobban, 1975).

6.2 Tertiary Period

During the Tertiary Period from about 64 million to 3 million years ago, the Regina-Moose Jaw region received nonmarine clay, silt, sand, and gravel from streams originating in the rapidly rising Cordillera to the west. These streams formed alluvial and lacustrine plains of brown silt and clay, olive sand, and chert and quartzite gravels. This was probably the origin of the brown silts and chert gravels in the Empress Group in the Regina-Moose Jaw region.

6.3 Quaternary Period

6.3.1 Introduction

The Quaternary Period covers about the last three million years of the earth's history and is composed of the Pleistocene and Recent Epochs.

6.3.2 Pleistocene Epoch

As the first continental glacier advanced southwestward across southern

Saskatchewan, it eroded the Cretaceous and Tertiary bedrock deposits and diverted the northeast flowing preglacial Swift Current river into the Hatfield Valley which drained northwestward along the glacial margin (Fig. 3). Although the Lower Till of the Sutherland Group was deposited during this first glaciation in the Saskatoon region, till of this age has not been encountered in the Regina-Moose Jaw region. The Upper Till of the Sutherland Group, which is believed to be the only till of this Group in the Regina-Moose Jaw region, was deposited during the second glaciation. The presence of a well-developed weathered zone in the upper part of the Sutherland Group suggests that a long weathering interval existed between the deposition of this Group and the overlying Floral Formation.

The presence of Interglacial Sediments in the middle of the Floral Formation suggests that the Floral Formation was deposited during two glaciations. The Lower Floral Sand and Gravel and the overlying Lower Till of the Floral Formation were deposited during the third glaciation, and the Upper Floral Sand and Gravel and the overlying Upper Till of the Floral Formation were deposited during the fourth glaciation. The presence of the thick Interglacial Sediments between these Lower and Upper Tills of the Floral Formation suggest that a long interglacial interval took place between the deposition of these two tills.

The Battleford Formation was deposited during the fifth and last glaciation which took place about 20,000 years ago (Christiansen, 1968a). On the basis of radiocarbon dates, the interval between the deposition of the Floral and Battleford Formation is more than 20,000 years (Westgate *et al.* 1977).

This fifth and last glacier started to retreat from the Cypress Hills about 17,000 years ago (Christiansen, 1979) and retreated across the Regina-Moose Jaw region between about 15,500 and 13,500 years ago. Details of the last deglaciation in the Regina-Moose Jaw region will be discussed in the next Chapter.

6.3.3 Recent Epoch

The Qu'Appelle Alluvium has been and is being deposited during the Recent Epoch. Early in this Epoch and, to a lesser extent, more recently, the deltaic sands in the Regina-Moose Jaw region have been reworked by wind into dunes. Except for gully erosion, spring sapping, landslides, and alluviation in the Qu'Appelle Valley, few changes have taken place in the landscape during the Recent Epoch.

7. HISTORY OF DEGLACIATION

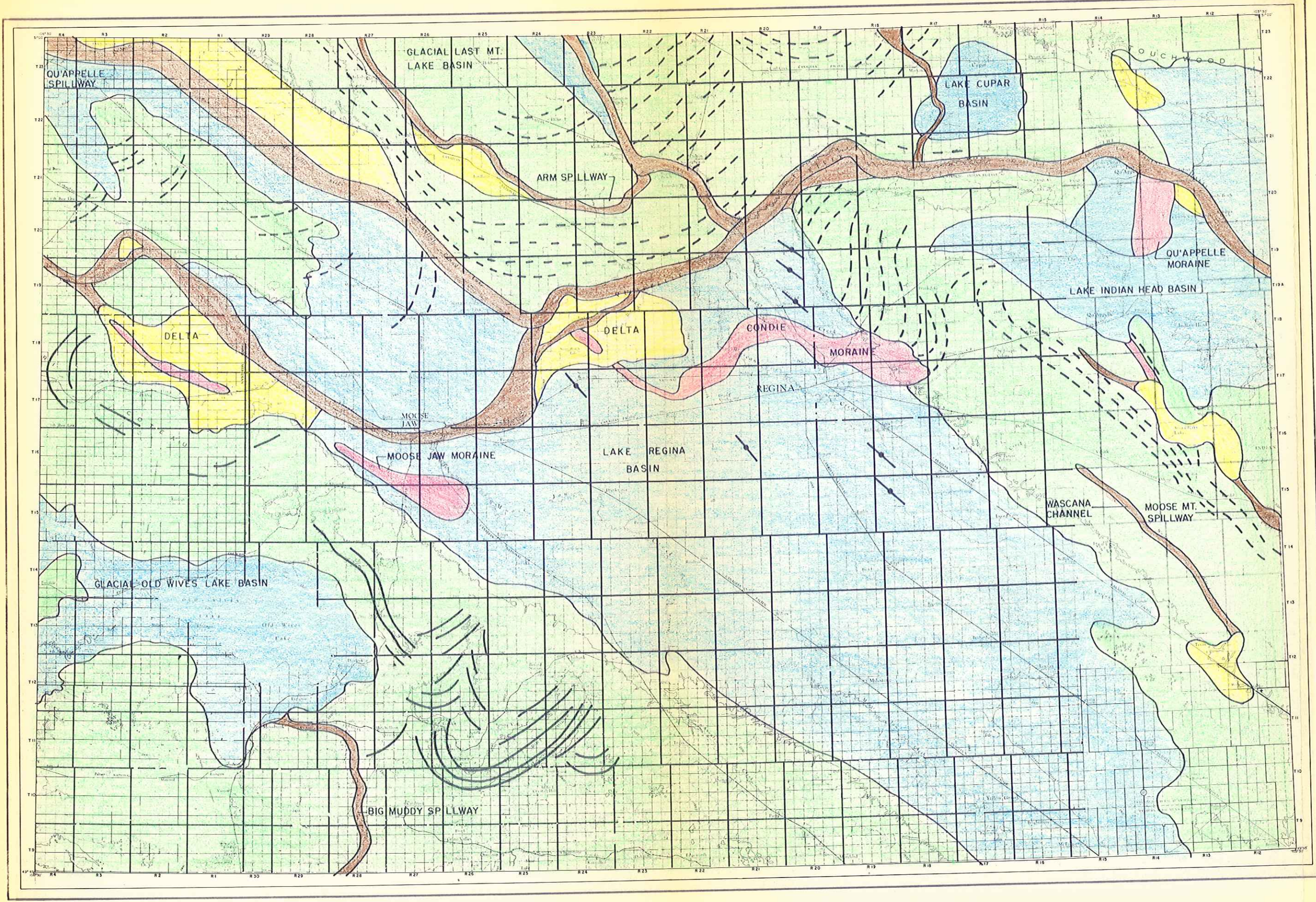
7.1 Introduction

Most features of the landscape and most surficial sediments in the Regina-Moose Jaw region, particularly the Surficial Stratified Drift, owe their origin to the last deglaciation. Figure 14 shows the main geo-environments in the Regina-Moose Jaw region. Seven Phases were sketched to show the origin and history of these environments. The compilation of the history of deglaciation of southern Saskatchewan and adjacent areas (Christiansen, 1979) forms the framework for the history of deglaciation of the Regina-Moose Jaw region.

The geo-environmental map (Fig. 14) is based on geological reports (Christiansen 1956, 1960, 1961; Parizek, 1964; Whitaker, 1965), on a soil map by Head (1979), and on a study of air-photo mosaics during the compilation of the history of deglaciation of southern Saskatchewan and adjacent areas (Christiansen, 1979).

7.2 Phase 1 of the History of Deglaciation

During Phase 1 (Fig. 15), The Dirt Hills Moraine and other ice-thrust moraines were formed on the Missouri Coteau by glacial overthrusting. Glacial Old Wives Lake was impounded between these moraines and the uplands to the south and drained through the Big Muddy Spillway and the Missouri River (Fig. 16).



- EXP
- MORaine - Mainly ti
lacustrine silt and cl
 - END MORaine - Ric
Moraine is covered wi
 - THRUST MORaine -
composed of till and
 - RIDGED MORaine -
high.
 - FLUTINGS - Straight
in till covered with cl
 - GLACIAL LAKE BA
or absent near margi
 - FLUVIAL PLAINS -
silt, and gravel.
 - GLACIAL CHANNEL
and bedrock.

0

Figure 14 - Geo-environmental

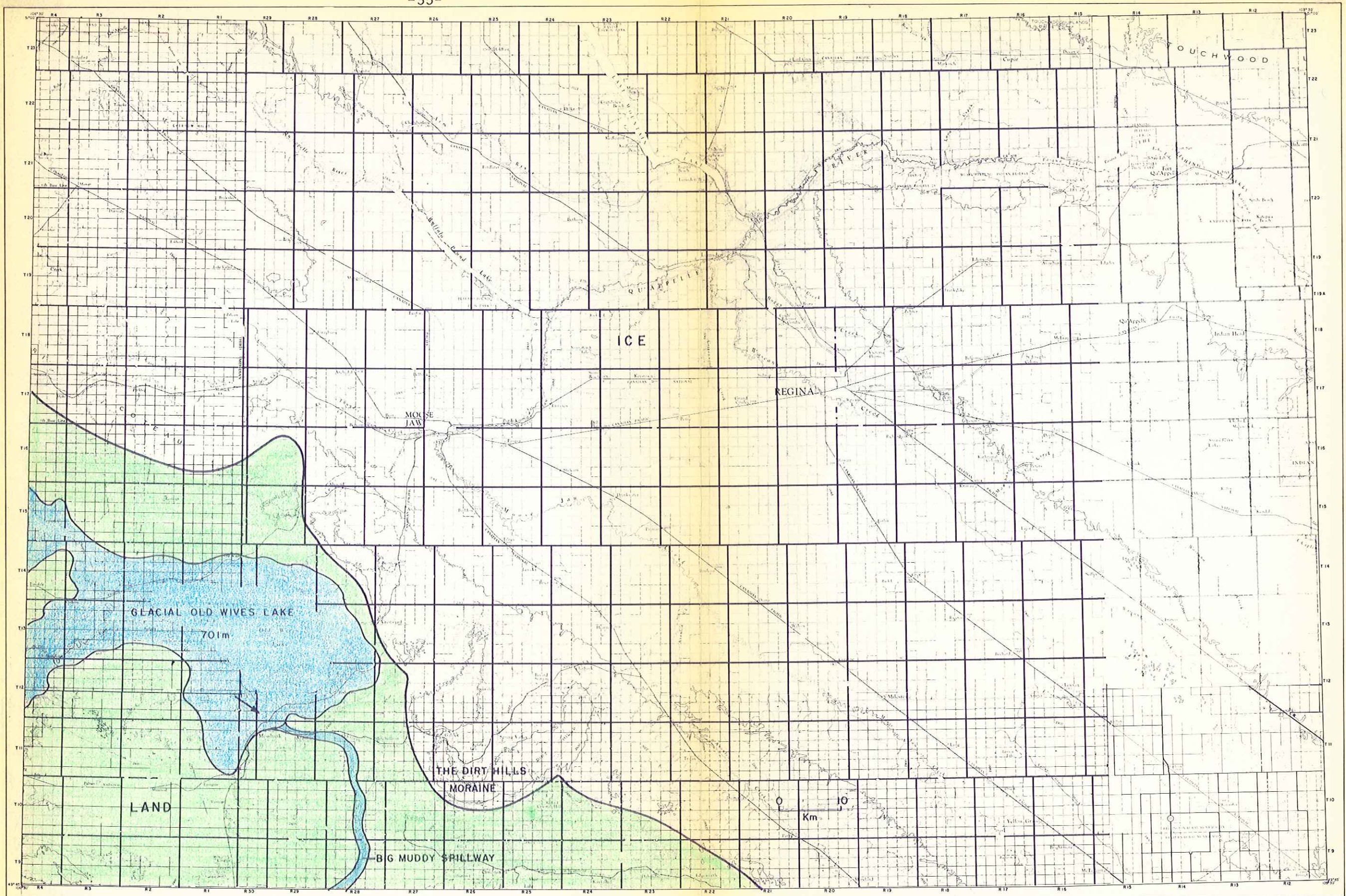


Figure 15. - Phase I of the history of deglaciation of the Regina-Moose Jaw Region.

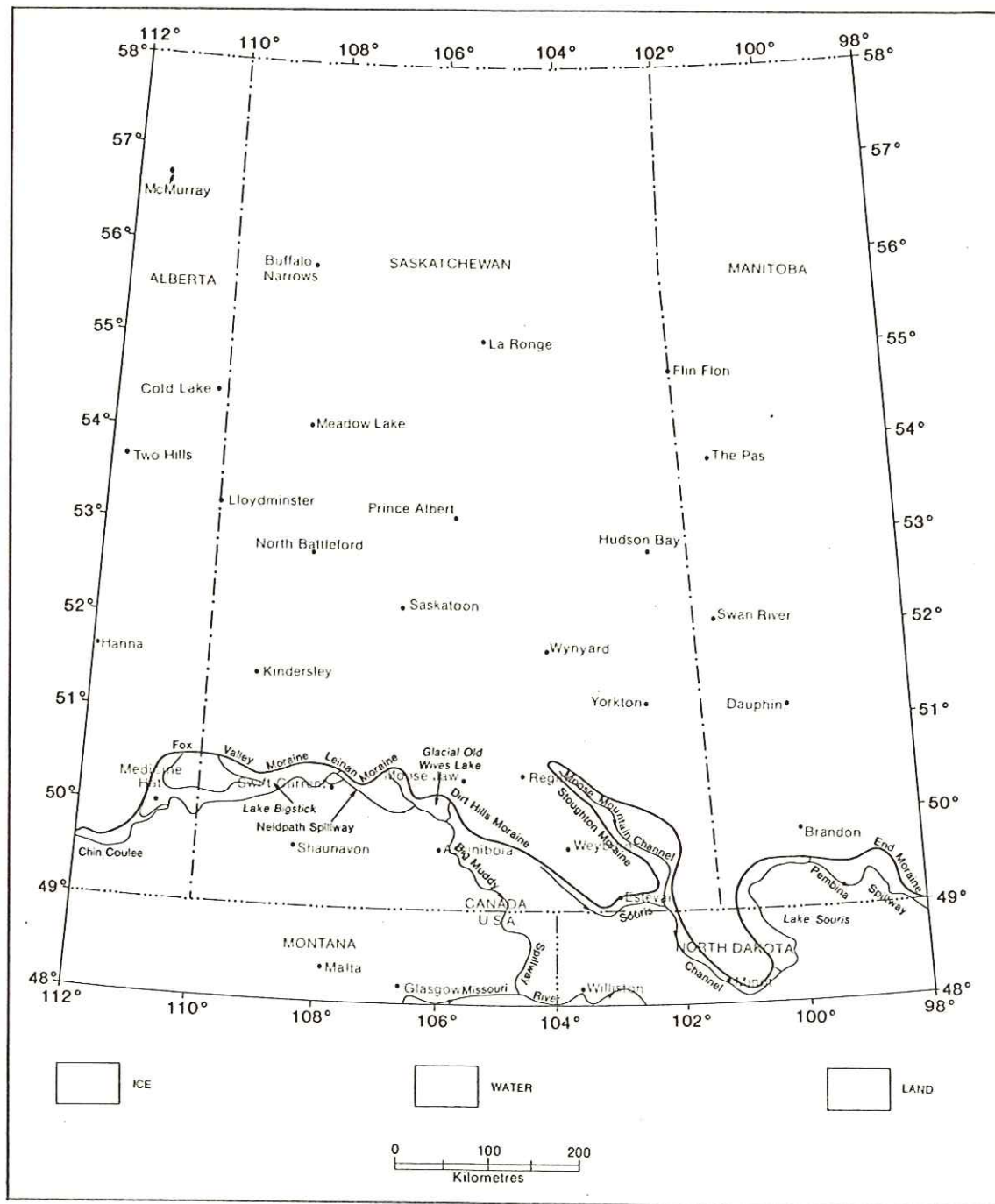


Figure 16. Phase 3 of the history of deglaciation of southern Saskatchewan and adjacent areas about 15,500 years ago. From Christiansen (1979). This Phase is correlative with Phase 1 and is slightly older than Phase 2 of the history of deglaciation of the Regina-Moose Jaw region.

7.3 Phase 2 of the History of Deglaciation

During Phase 2 (Fig. 17), the glacier stood at the foot of the Missouri Coteau Escarpment, and the ice margin formed a major re-entrant in the eastern part of the region. This re-entrant is the northwestern extension of the Moose Mountain Upland.

Meltwater and extraglacial water drained through the Chaplin Spillway, Glacial Old Wives Lake, and the Big Muddy, and Missouri Spillways (Fig. 16). Lake Indian Head, which was impounded between the glacier and the Moose Mountain Upland, drained through the Moose Mountain (Fig. 17) and Souris Channels, Lake Souris, and the Pembina Spillway into Lake Agassiz (Fig. 16).

7.4 Phase 3 of the History of Deglaciation

Between Phases 2 and 3 (Figs. 17, 18), the Chaplin Spillway was abandoned and Glacial Old Wives Lake became Old Wives Lake much as it is today.

Meltwater and extraglacial water drained through the ice-marginal Thunder Spillway into Lake Regina (Fig. 18) which, in turn, drained through the Souris Spillway, Lake Souris, and the Pembina Spillway into Lake Agassiz. The Moose Jaw Moraine (Drawing 0016-003-22) was formed as a ridge of sand and gravel in the ice-walled lower reaches of the Thunder Spillway between active ice to the north and stagnant ice to the south (Fig. 18) and as a delta in the northwestern part of Lake Regina. Meltwater from the northeastern margin of the lobe, which occupied the Regina Plain, flowed along the ice margin through the Wascana Channel into Lake Regina.

Glacial Lake Indian Head expanded greatly between Phase 2 and 3 (Fig. 17, 18). As lower ground was uncovered by the melting glacier, the lake level fell from 2200 feet (671 m) during Phase 2 to 2100 feet (640 m) during Phase 3. Lake Indian Head drained through the Hillesden

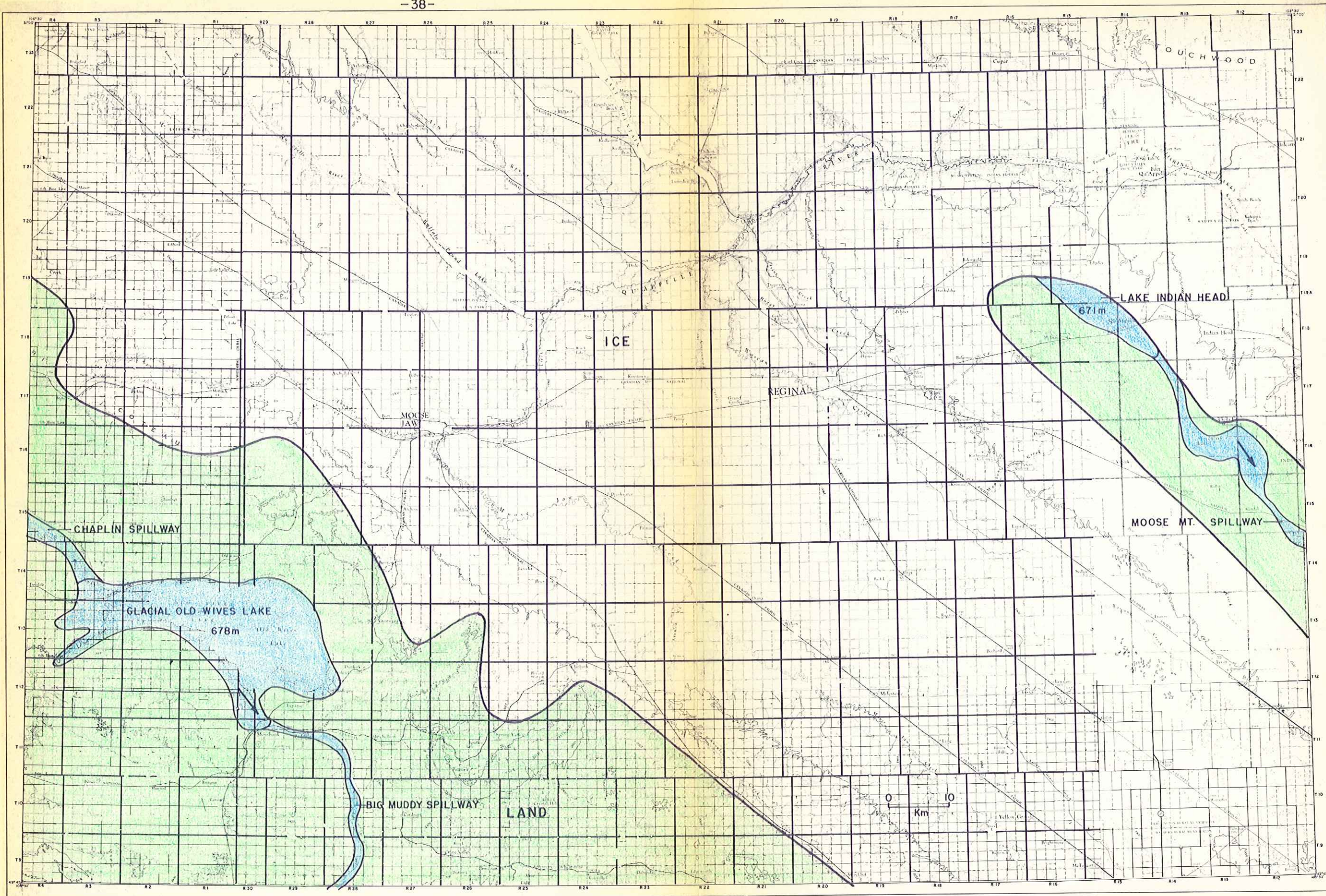


Figure 17. - Phase 2 of the history of deglaciation of the Regina-Moose Jaw Region.

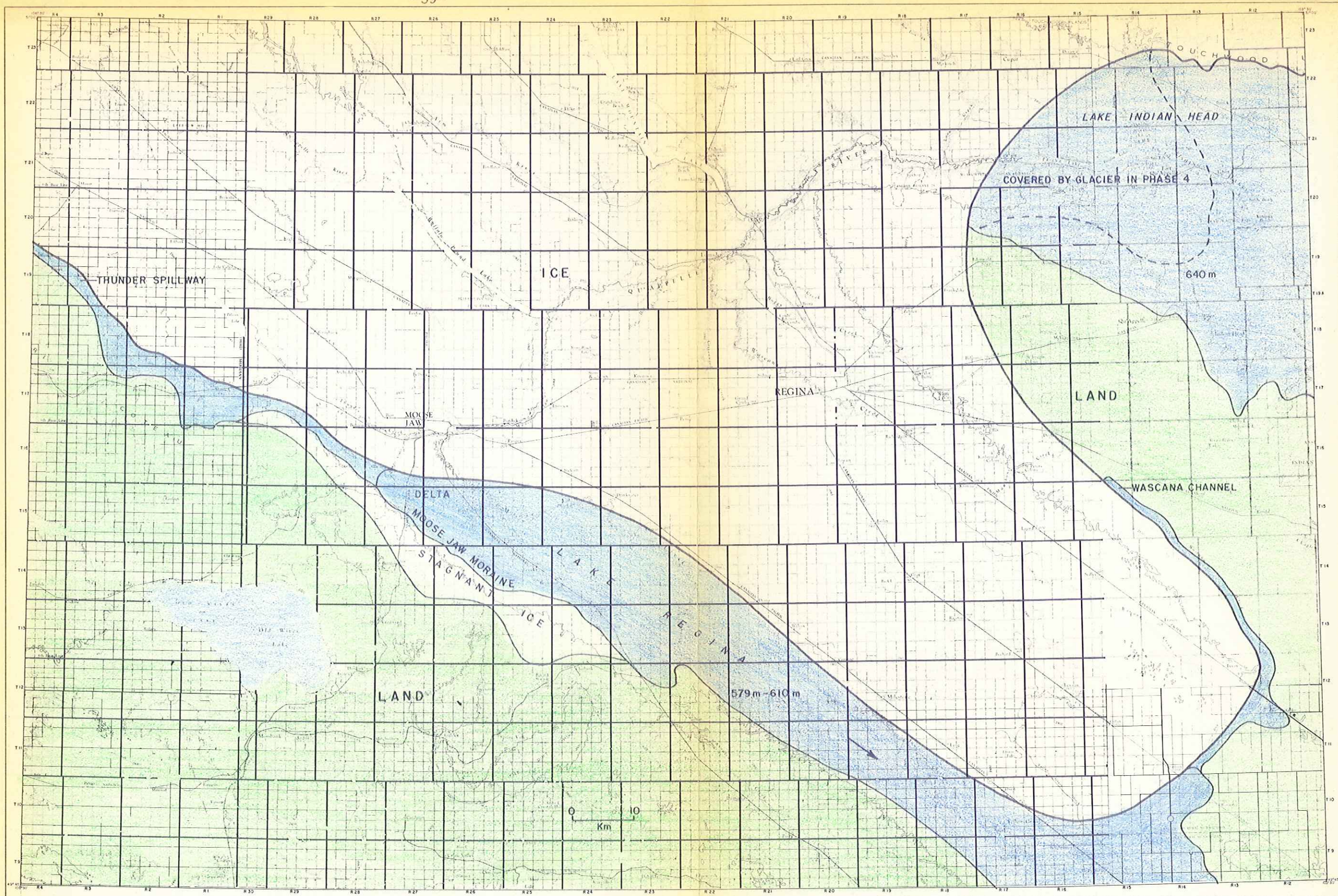


Figure 18. - Phase 3 of the history of deglaciation of the Regina-Moose Jaw Region.

Spillway which was abandoned in favor of a lower upper arm of the Pipestone Spillway (Christiansen, 1960, p. 38), and the Lake Indian Head level fell to about 2000 feet (610 m).

7.5 Phase 4 of the History of Deglaciation

Between Phases 3 and 4 (Figs. 18,19), the ice retreated north of the Qu'Appelle Valley to the east of the Regina-Moose Jaw region causing Lake Indian Head to disappear. Whether the glacier retreated north of the Qu'Appelle Valley in the Regina-Moose Jaw region is not known; however, it is believed to have retreated north of the position shown in Phase 4 (Fig. 19). After this retreat the glacier re-advanced to the position shown in Figure 19. Meltwater and extraglacial water entered Lake Regina from the Thunder Spillway and built a delta north of Mortlach (T.17, R.1; Drawing 0016-003-23). Lake Regina overflowed through the Souris Spillway into Lake Agassiz (Fig. 20).

During Phase 4 (Fig. 19), the Condie Moraine ridge of sand and gravel (Drawing 0016-003-22, Fig. 7) was deposited along the glacier margin, and the silt apron of the Moraine was deposited southward into Lake Regina. After the formation of the Condie Moraine, the glacier re-advanced slightly and covered most of the morainal ridge of sand and gravel with a thin veneer of till (Drawing 0016-003-22). As the glacier margin retreated from the position shown in Phase 4 (Fig.19), Lake Regina silts and clays were deposited on the Condie Moraine(Fig.7).

During Phase 4 (Fig. 19), the Qu'Appelle Channel drained the glacier which stood at the Qu'Appelle Moraine in the northeastern part of the Regina-Moose Jaw region.

7.6 Phase 5 of the History of Deglaciation

During Phase 5 (Fig. 21), the glacier stood along the northern boundary of the Qu'Appelle Valley which permitted the level of Lake

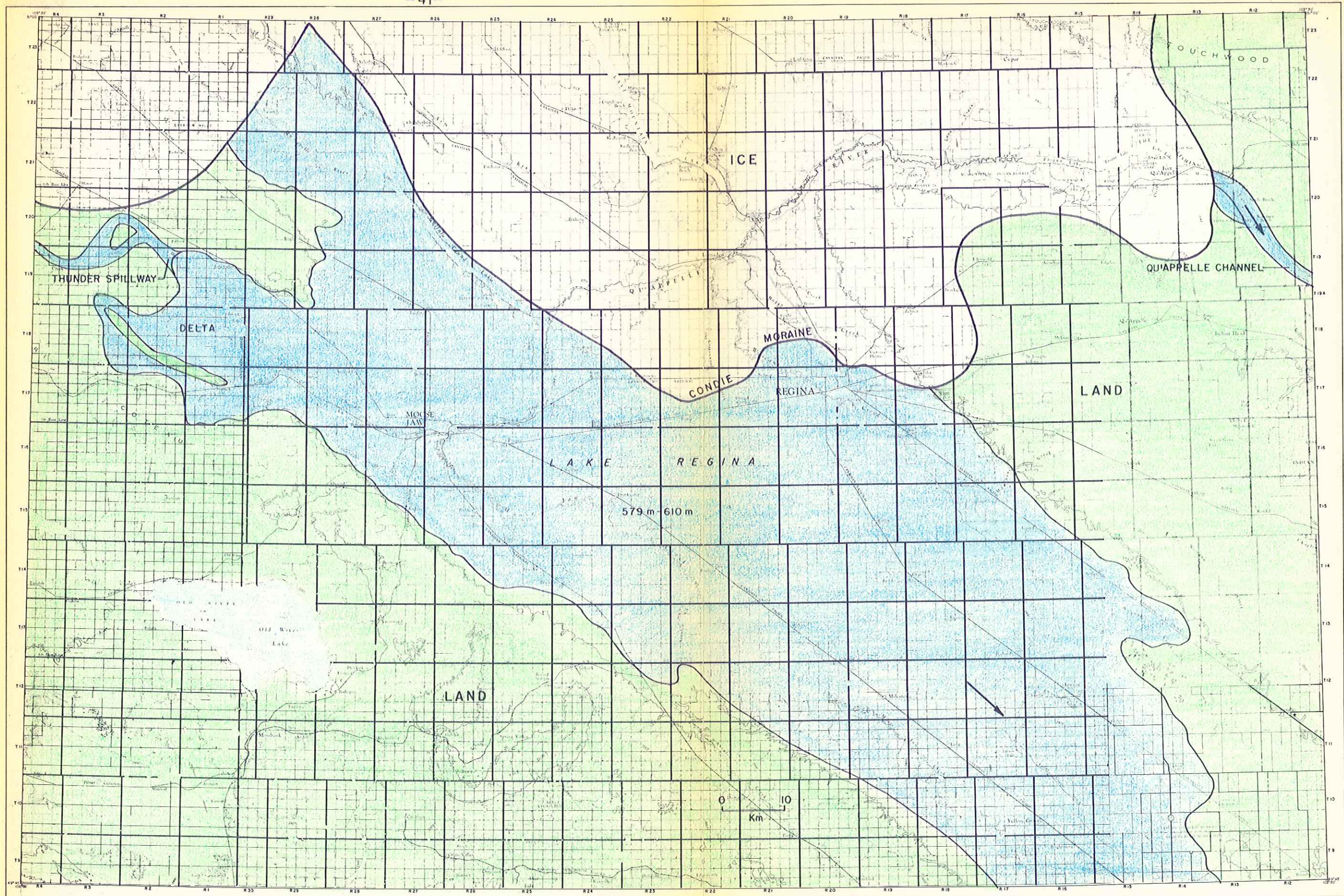


Figure 19. - Phase 4 of the history of deglaciation of the Regina-Moose Jaw Region.

E. A. Christiansen Consulting Ltd.

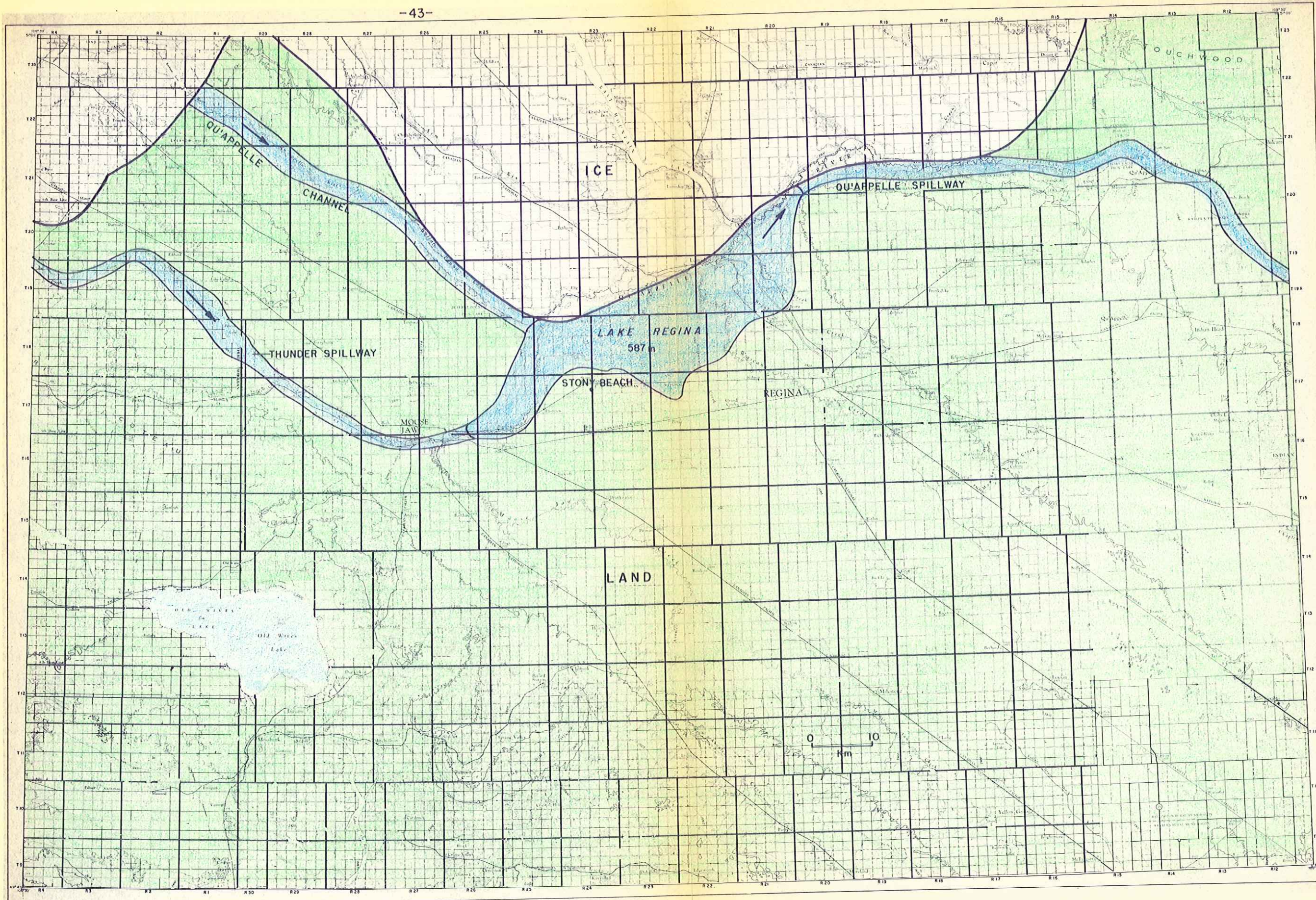


Figure 21. - Phase 5 of the history of deglaciation of the Regina-Moose Jaw Region.

Regina to fall from 2000 feet (610 m) to about 1925 feet (587 m) in Phase 5.

Where the Thunder Spillway entered Lake Regina a delta was built north of Stony Beach. Lake Regina drained through the Qu'Appelle and Assiniboine Spillways into Lake Agassiz (Fig. 22). The upper part of the Qu'Appelle Valley started to develop at this time as a melt-water channel.

7.7 Phase 6 of the History of Deglaciation

During Phase 6 (Fig. 23), meltwater and extraglacial water from the South Saskatchewan River flowed through the Qu'Appelle and Assiniboine Spillways into Lake Agassiz (Fig. 22). Lake Cupar drained into the Qu'Appelle Valley through the Loon Spillways and the Last Mountain Channel came into existence during this phase.

7.8 Phase 7 of the History of Deglaciation

During Phase 7 (Fig.24), the ice-marginal Arm Spillway drained into the Qu'Appelle Spillway via the Last Mountain Spillway. The Loon Channel drained meltwater from the glacier margin into the Qu'Appelle Spillway. The meltwater and extraglacial South Saskatchewan River continued to drain through the Qu'Appelle and Assiniboine Spillways into Lake Agassiz during this phase(Fig. 22).

8. GEOTECHNOLOGY

8.1 Introduction

This discussion will be restricted to the application of geology to geotechnology and does not include any engineering aspects, such as strength of material. Although this subject is mainly the responsibility of the consultant responsible for Part B, it is felt that those geotechnical aspects that are mainly geological in nature should be

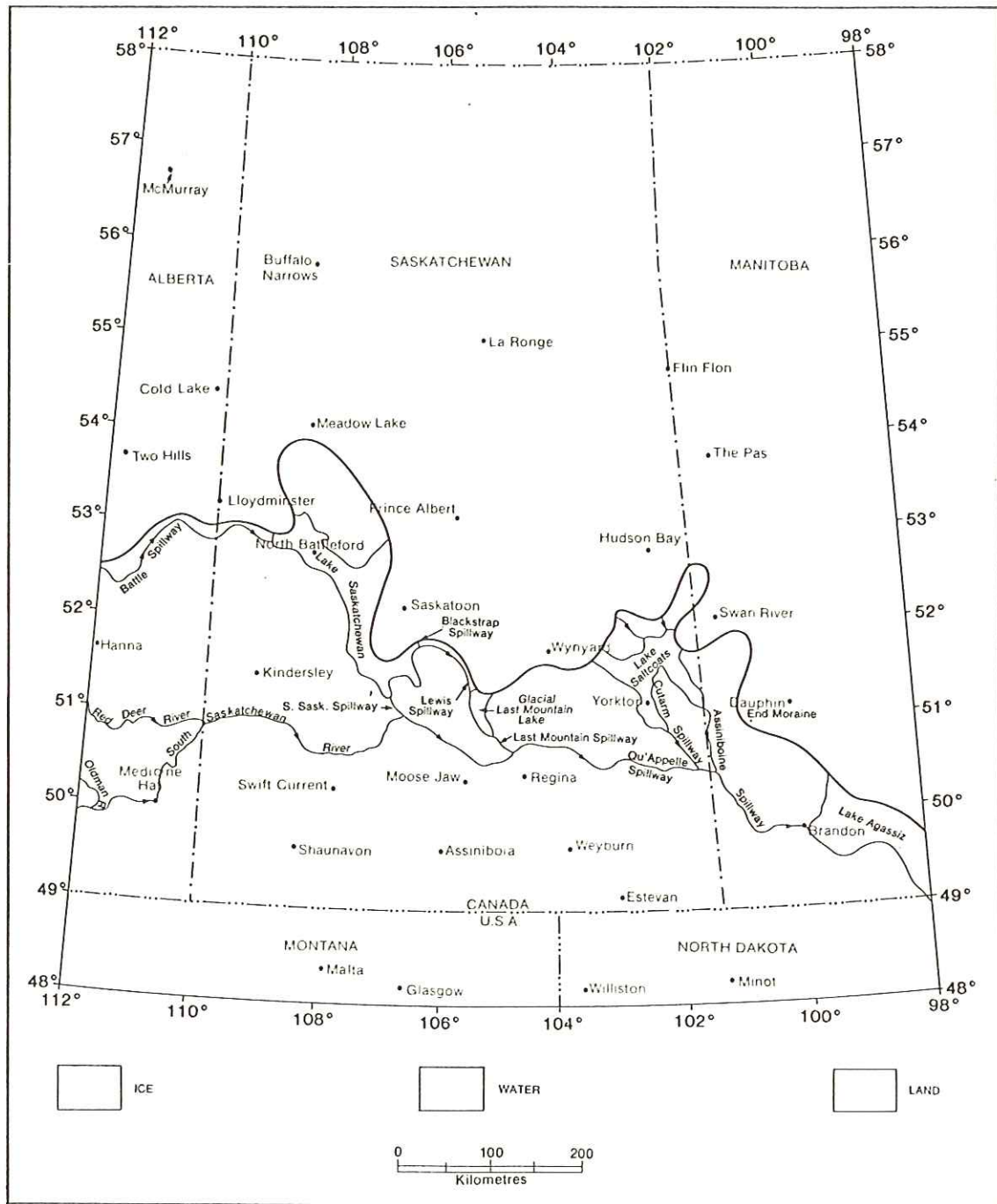


Figure 22. Phase 5 of the history of deglaciation of southern Saskatchewan and adjacent areas about 12,500 years ago. From Christiansen (1979). This Phase is younger than Phases 5,6, and 7 of the Regina-Moose Jaw regions (Fig. 21,23,24).

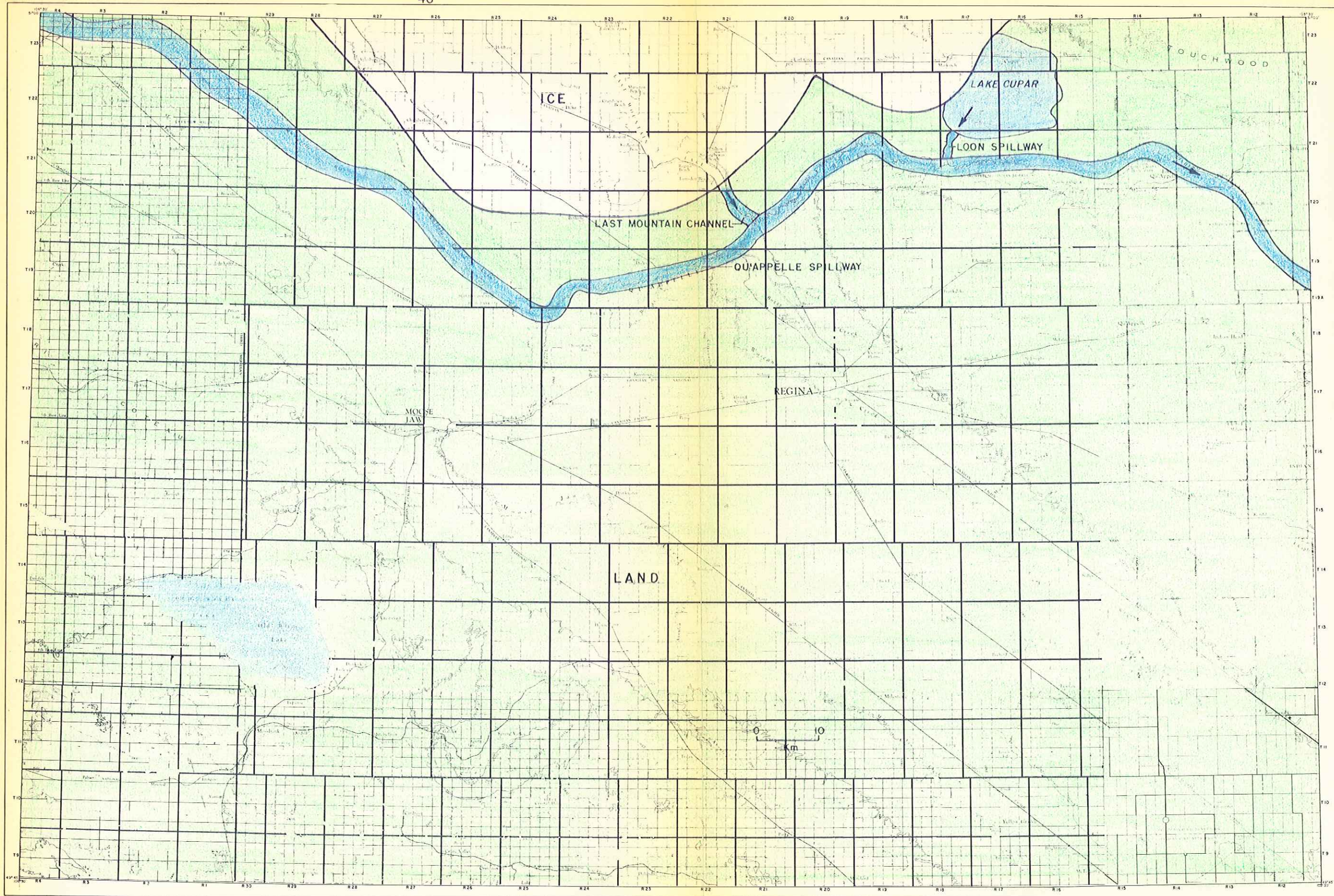


Figure 23. - Phase C of the history of deglaciation of the Regina-Moose Jaw Region.

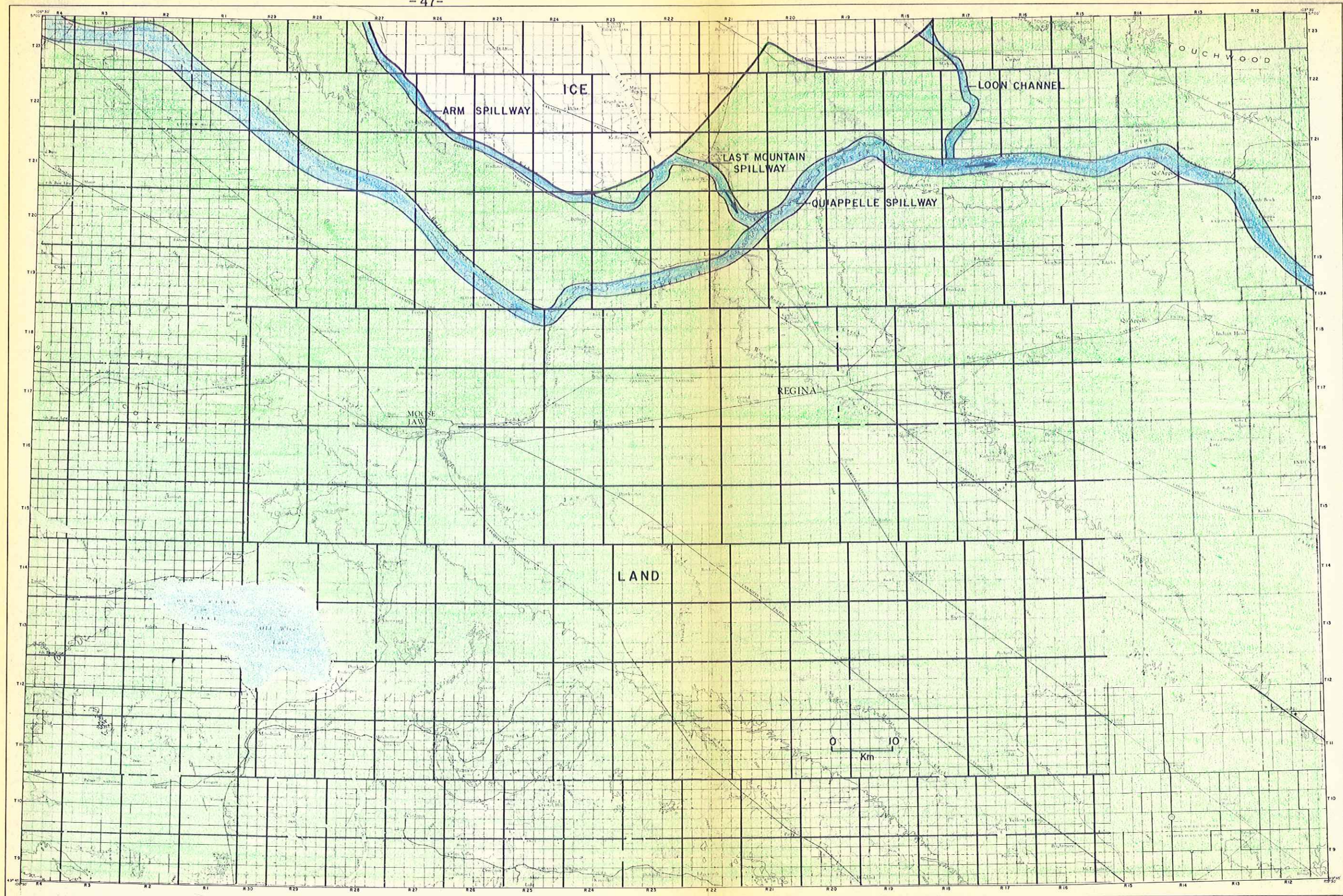


Figure 24. - Phase 7 of the history of deglaciation of the Regina-Moose Jaw Region

discussed in this report.

8.2 Groundwater Geology

8.2.1 Introduction

Groundwater information in the Regina-Moose Jaw region was obtained from Christiansen (1971a,b), Lissey (1962), Meneley (1975); Meneley and Christiansen (1975), and Whitaker (1967;1970;1974a,b).

8.2.2 Base of Groundwater Exploration

The base of groundwater exploration is the depth below which it is considered to be uneconomic to explore for groundwater because of the higher costs of water, insufficient permeability, and/or because the water is considered to be too highly mineralized for the intended use ($>4,000$ ppm TDS). The base of groundwater exploration is shown in the cross sections (Drawing 0016-003-02-18).

8.2.3 Groundwater Occurrence

In the Regina-Moose Jaw region, groundwater occurs in the Judith River Formation, the Outlook and Ardkeneth Members of the Bearpaw Formation (Drawings 0016-003-01,02, for example), and in the Empress sand and gravel (Drawing 0016-003-19), Lower Floral Sand and Gravel (Drawing 0016-003-20), Upper Floral Sand and Gravel (Drawing 0016-003-21), sands and gravels in the Condie and Moose Jaw Moraines (Drawing 0016-003-22), and in Surficial Sand and Gravel (Drawing 0016-003-23). Aquifer names appear (Drawing 0016-003-19) if they were previously named (Hatfield Valley Aquifer) or if there is sufficient information to warrant naming them (Swift Current Valley Aquifer).

8.3 Slope Instability

8.3.1 Introduction

Slope instability in the Regina-Moose Jaw region is expressed mainly as landslides and spring sapping or as combinations of these processes. Landslides are facilitated by structural weakness caused by brecciation and slickensiding and by bentonitic zones in the Bearpaw Formation.

8.3.2 Landslides

In the Regina-Moose Jaw regions, landslides occur where the Qu'Appelle Valley and its tributaries have cut into silts and clays of the Bearpaw Formation and where slopes are developed in surficial silts and clays, particularly the Regina clay (Sauer, 1975). Although most old landslides along the Qu'Appelle Valley are apparently stable because of the thick Qu'Appelle Alluvium, many of these and those in the tributary valleys are moving in response to human activity or down-cutting of the tributary streams. If the toe of such apparently stable landslides are excavated or the top is loaded, the movement will be activated (Fig. 25). In 1960, for example, a landslide took place in the Qu'Appelle Valley east of Lumsden when the toe of a stable landslide was excavated during the construction of Highway 20. After 19 years, this landslide is still active.

8.3.3 Spring Sapping

Spring sapping (piping) is the removal of subsurface material from a valley side by the discharge of groundwater causing the springhead to retreat. Spring sapping has occurred where the Lower and Upper Floral Sands and Gravels (Drawings 0016-003-20,21) and Surficial Sand and Gravel discharge into valleys, particularly the Qu'Appelle Valley.

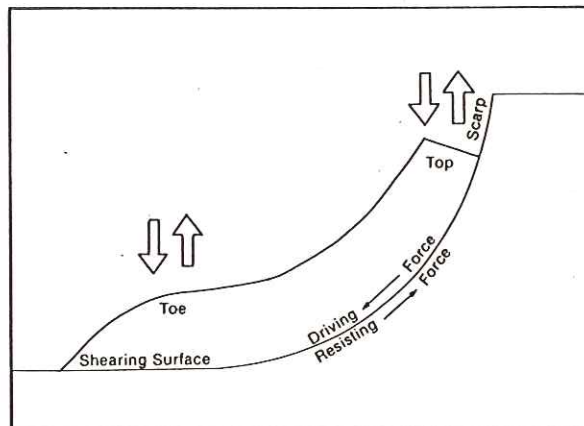


Figure 25. Diagrammatic cross section of a landslide. Arrows pointing upward signify excavation, and arrows pointing downward signify loading. If the toe is loaded and/or the top is excavated (blue arrows) the slide becomes more stable. If, on the other hand, the landslide is excavated and/or loaded as shown by the red arrows, the landslide becomes less stable. From Christiansen *et al.* (1979).

Most of the short, well-developed gullies, which are at right angles to the Qu'Appelle Valley in The Fishing Lakes area, for example, have been attributed to spring sapping during the formation of the valley (Christiasen *et al.* 1977, p. 46-49).

8.3.4 Brecciation and Slickensiding

Brecciation and slickensiding form where there is differential movement (faulting) within or between sediments. Such movement will take place along plains of least shear resistance such as along bentonitic beds. A breccia is a deposit composed of angular pieces of material in a fine-grained groundmass or matrix. Slickensides, which greatly decrease the shear strength of material, are formed by glacial thrusting (Fig. 8,10), in landslides, and during collapse of super-glacial deposits (Fig. 13).

8.4 Tills

Under excess moisture conditions, the Battleford Formation is difficult to work with earth moving equipment, whereas older tills, particularly the jointed Floral Formation, can be excavated below the water table (Sauer, 1974).

8.5 Gravel

Outwash and inwash are the two main occurrences of gravel in the Regina-Moose Jaw region. Outwash gravels are derived from the melting glacier and grade from proglacial blankets to ice-contact wedges. Inwash gravels are deposited in the apex of deltas which formed where extra-glacial and meltwater channels entered glacial lakes. The outwash gravels are generally less well sorted and are composed of more deleterious material (schists, shales, concretions) than inwash gravels. The gravel in the Condie Moraine is an example of outwash, whereas the gravel in the delta west of Mortlach is an example of inwash.

According to Sauer (1974), most of the surficial gravel has been located, and many of these deposits have been depleted, particularly near urban areas. Intertill gravel in the Upper Floral Sand and Gravel is a potential source of gravel in the Regina-Moose Jaw region (Drawings 0016-003-16, Log 241, for example).

8.6 Boulder Pavements

Boulder pavements (Fig. 6) occur between the Floral and Battleford Formations in the Regina-Moose Jaw region (along Highway 6, SW17-20-19-W2, for example). The frequency of spacing of these boulders ranges from a hundred metres or more to a few centimetres (Sauer, 1974). Excavating through boulder pavements can be very difficult and expensive, and driven piling or sheet piling can be severely damaged by these boulders. Where boulder pavements are exhumed by erosion, however, they are an excellent source of riprap.

8.7 Expansible Clays

Christiansen (1960, p.32) showed that montmorillonite is the dominant clay mineral in the till and bedrock in the Regina-Moose Jaw region and, presumably, is more dominant in the lacustrine clays. Because montmorillonite has the capacity to orient water between its molecular plates, it undergoes large volume changes causing deterioration of buildings and roads.

Expansible clays, on the other hand, provide the surface soil with the capacity to store water which is available to plants but which will not drain under the influence of gravity.

8.8 Stratigraphic Control of Subsurface Drainage

Water percolates vertically downward through the less permeable sediments (till, silt, clay) and flows horizontally through the more

permeable sand and gravel to the discharge areas. For example, water percolates downward through the Lake Indian Head clay and Battleford and Floral Formations and moves laterally through the Echo Lake Gravel (Lower Floral Sand and Gravel) and Qu'Appelle Alluvium into Katepwa Lake (Christiansen *et al.* 1977, p. 48).

Water also persolates downward through Surficial Sand and Gravel (Drawing 0016-003-23) and moves laterally along the base of the sand and gravel deposits to springheads where the water returns to the surface (Christiansen *et al.* 1977, p. 59).

8.9 Waste Disposal Sites

If we accept that development should cause only a minimum impact on the environment, then it follows that industrial polluters and waste disposal sites should be placed in areas where the geological deposits are the least permeable. Bedrock silt and clay, till, and surficial silt and clay are the least permeable sediments in the Regina-Moose Jaw region, and ideally, waste disposal sites and industrial polluters should be in areas where only these sediments occur. Such polluters, for example, should not be placed on the Regina Aquifer nor on the Condie Moraine which recharges this aquifer.

9. RECOMMENDATION FOR FURTHER STUDIES

9.1 Introduction

In Part A(h) of the Terms of Reference, it is required to indicate where more detailed investigations would be desirable and/or essential to make positive recommendations regarding the suitability of certain lands in the region being allotted for certain uses.

Minimum impact of the environment must be the goal of any development. To attain such a goal, the physical environment (land-geology, water-hydrology, air-meteorology) must be defined and, subsequently, monitored to determine the impact of the development.

To provide the proper geological documentation for determining the minimum impact of a particular development, a regional geological framework is required which, because of the time constraints, must be based on available information. In addition to this regional compilation of existing information, a more detailed investigation of the area to be influenced by the development must be undertaken. This present report on the geology of the Regina-Moose Jaw region provides such a regional geological framework.

The more detailed study requires test drilling and field investigations on a scale of at least 1:50,000 with testholes at one-mile centers. Because such studies must be done prior to development, their results will form a geological framework for future site investigations and assessment of groundwater, etc.

9.2 Recommendations

To provide a more detailed geological framework, testholes drilled 50 feet (15 m) into bedrock and electric logs are required at one-mile

centers for the cities of Regina and Moose Jaw and their immediately adjoining areas (Regina , T.16-18, R.17-21; Moose Jaw , T.15-18, R.25-27).

At least one testhole and electric log is recommended in each hamlet, village, and town in the Regina-Moose Jaw region. If satellite communities are anticipated, test drilling at one-mile centers is recommended before final selection of a site is made.

If such a more detailed geological framework is available and if site investigations are conducted within this framework, environmental impact on the region will be minimized.

10. LITERATURE CITED

- Caldwell, W.G.E. 1968. The late Cretaceous Bearpaw Formation in the South Saskatchewan River Valley. Saskatchewan Research Council, Geology Division, Report 8.
- Christiansen, E.A. 1956. Glacial geology of the Moose Mountain area, Saskatchewan Department of Mineral Resources, Report 21.
- Christiansen, E.A. 1960. Geology and ground-water resources of the Qu'Appelle area, Saskatchewan Research Council, Geology Division, Report 1.
- Christiansen, E.A. 1961. Geology and Ground-water resources of the Regina area, Saskatchewan Research Council, Geology Division, Report 2.
- Christiansen, E.A. 1967. Collapse structures near Saskatoon, Saskatchewan, Canada. Canadian Journal of Earth Sciences, v.4, p. 757-767.
- Christiansen, E.A. 1968a. A thin till in west-central Saskatchewan, Canada. Canadian Journal of Earth Sciences, v.5, p. 329-336.
- Christiansen, E.A. 1968b. Pleistocene stratigraphy of the Saskatoon area, Saskatchewan, Canada. Canadian Journal of Earth Sciences, v.5, p. 1167-1173.
- Christiansen, E.A. 1971a. Geology and groundwater resources of the Melville area (62k,L), Saskatchewan. Saskatchewan Research Council, Geology Division, Map 12.
- Christiansen, E.A. 1971b. Geology and groundwater resources of the Regina area (72I), Saskatchewan. Saskatchewan Research Council, Geology Division, Map 13.
- Christiansen, E.A. 1971c. Geology of the Crater Lake collapse structure in southeastern Saskatchewan. Canadian Journal of Earth Sciences, v.8, p. 1505-1513.
- Christiansen, E.A. 1972. Cross section of drift and bedrock between Condie and Craven, Saskatchewan. Saskatchewan Research Council, Geology Division, Cross section 1.
- Christiansen, E.A. 1979. The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas. Canadian Journal of Earth Sciences (in press).

- Christiansen, E.A., Acton, D.F., Long, R.J., Meneley, W.A., Sauer, E.K. 1977. Fort Qu'Appelle Geolog. Saskatchewan Culture and Youth, Saskatchewan Museum of Natural History, Interpretive Report 2.
- Christiansen, E.A. and Whitaker, S.H. 1976. Glacial thrusting of drift and bedrock. *In* Glacial Till. *Edited by* R.F. Legget. Royal Society of Canada, Special Publication 12, p. 121-230.
- Gendzwil, D.J. and Hajnal, Z. 1971. Seismic investigation of the Crater Lake structures in southeastern Saskatchewan. *Canadian Journal of Earth Sciences*, v.8, p. 1514-1524.
- Head, W.K. 1979. Soil resources of the Regina-Moose Jaw region, Saskatchewan Institute of Pedology, Publication M48, Project A-6, Saskatchewan Municipal Affairs Regional Studies Program.
- Lissey, A. 1962. Ground-water resources of the Regina area, Saskatchewan. City of Regina, City Engineering Department, Hydrology Division, Report 1.
- McLean, J.R. 1971, Stratigraphy of the Upper Cretaceous Judith River Formation in the Canadian Great Plains. Saskatchewan Research Council, Geology Division, Report 11.
- Meneley, W.A. 1975. Moose Jaw effluent irrigation study. Saskatchewan Research Council, Geology Division, Preliminary Report 7 of 10.
- Meneley, W.A. and Christiansen, E.A. 1975. Hydrology of the Regina area. Saskatchewan Research Council, Geology Division. Preliminary Report 9 of 10.
- Obradovich, J.D. and Cobban, W.A. 1975. A time-scale for the late Cretaceous of the Western Interior of North America. *In* The Cretaceous System in the Western Interior of North America. *Edited by* W.G.E. Caldwell. The Geological Association of Canada, Special Paper 13, p.36.
- Parizek, R.R. 1964. Geology of the Willow Bunch Lake area (72H), Saskatchewan. Saskatchewan Research Council, Geology Division, Report 4.
- Pearson, W.J. 1963. Salt deposits of Canada. Northern Ohio Geological Society Symposium on salt, p. 196-239.
- Sauer, E.K. 1974. Geotechnical implications of Pleistocene deposits in southern Saskatchewan. *Canadian Geotechnical Journal* v.11, p.359-373.

- Sauer, E.K. 1975. Urban fringe development and slope instability in southern Saskatchewan. Canadian Geotechnical Journal, v. 12, p. 106-118.
- Westgate, J.A. Christiansen, E.A. and Boellstorff, J.D. 1977. Wascana Creek Ash (Middle Pleistocene) in southern Saskatchewan: characterization, source fission track age, palaeomagnetism and stratigraphic significance. Canadian Journal of Earth Sciences, v. 14, p. 357-374.
- Whitaker, S.H. 1965. Geology of the Wood Mountain area (72G), Saskatchewan. Unpublished Ph.D. Thesis, University of Illinois, Urbana, Illinois.
- Whitaker, S.H. 1967. Geology and groundwater resources of the Wood Mountain area (72G), Saskatchewan. Saskatchewan Research Council, Geology Division, Map 5.
- Whitaker, S.H. 1970. Geology and groundwater resources of the Swift Current area (72J), Saskatchewan. Saskatchewan Research Council, Geology Division, Map 11.
- Whitaker, S.H. 1974a. Geology and groundwater resources of the Willow Bunch area (72H), Saskatchewan. Saskatchewan Research Council, Geology Division. Map 20.
- Whitaker, S.H. 1974b. Geology and groundwater resources of the Weyburn area (62E,F), Saskatchewan. Saskatchewan Research Council, Geology Division, Map 21.
- Whitaker, S.H. and Christiansen, E.A. 1972. The Empress Group in southern Saskatchewan. Canadian Journal of Earth Sciences, v. 9, p. 353-360.

Appendix 1. Name and Location of Logs

Log No.	Name	Location
1	HB Bridgeford	12-2-22-4-W3
2	FFIB Stanley Cave	14-34-21-3-W3
3	SRC Eyebrow	NW13-36-21-3-W3
4	FFIB Larry Smith	NE8-17-21-29-W2
5	SRC Keeler	SW4-21-21-28-W2
6	Can.Ex. Findlater	2-29-21-27-W2
7	DTRR Lovering Lakes	NE11-1-22-27-W2
8	FFIB Chris Hager	SW4-9-22-26-W2
9	FFIB Ray Barber	NE16-15-22-26-W2
10	SRC Holdfast	NE16-31-22-25-W2
11	SRC Holdfast	SW1-1-23-25-W2
12	SRC Dilke	SE8-17-22-24-W2
13	SRC Dilke	SW5-15-22-24-W2
14	SRC Dilke	SE1-15-22-24-W2
15	SRC Dilke	SE1-12-22-24-W2
16	FFIB Cyril Flavel	SW8-24-22-23-W2
17	SRC Silton	NW7-17-22-22-W2
18	FFIB James Fisher	13-24-22-22-W2
19	Sohio Gibbs	16-29-22-21-W2
20	FFIB Victor VanMeir	SE1-9-23-20-W2
21	Sohio Earl Gray	9-10-23-20-W2
22	TW Southey Cr.	4-29-22-18-W2
23	FFIB Dan Schuster	NW16-23-22-18-W2
24	FFIB Gerald Gebhardt	12-9-22-17-W2
25	TW Ft.Qu'Appelle #6	8-6-22-16-W2
26	B.A. Qu'Appelle Hornung	2-4-22-15-W2
27	DTRR Echo Lake No. 5	SW5-29-21-14-W2
28	DTRR Echo Lake No. 4	NW4-36-21-14-W2
29	FFIB John Leigh	NE5-30-21-13-W2
30	FFIB L. Onrait	SE2-20-21-12-W2
31	CDR Patrick	4-28-21-12-W2
32	FFIB Donald Powell	SW2-19-21-11-W2
33	FFIB Harold Hammer	NW5-18-19-4-W3
34	FFIB Larry Drake	NW7-22-19-3-W3
35	FFIB Fred Beck	NE16-5-19-1-W3

Log No.	Name	Location
36	D.O.B. Rowletta	9-36-18-1-W3
37	FFIB Frank Mercer	SE8-35-18-29-W2
38	SRC Marquis	NE8-16-19-27-W2
39	Dillman Marquis	4-14-19-27-W2
40	SRC Buffalo Pound Lake	NE4-9-19-25-W2
41	SRC Rocky Lake	SW5-7-19-23-W2
42	SRC Qu'Appelle Valley	SW8-13-19-24-W2
43	Sohio Disley	15-12-20-23-W2
44	FFIB Wm. G. Kistner	NW3-6-20-22-W2
45	IMP Lumsden	11-11-20-22-W2
46	SRC Craven	SE9-23-20-21-W2
47	SRC Craven	NW16-14-20-21-W2
48	SRC Craven	NE1-13-20-21-W2
49	SRC Craven	NE8-7-20-20-W2
50	FFIB Vern Harvey	SE3-3-20-20-W2
51	DOE Regina 507	NE14-31-19-19-W2
52	FFIB Norman Boswell	4-10-20-19-W2
53	DOE Regina 510	NW13-32-19-18-W2
54	Reality Read	14-9-20-18-W2
55	SRC Edenwold	SW5-9-20-17-W2
56	TW Avonhurst	1-38-19-16-W2
57	Dillman Indian Head	6-32-19-13-W2
58	SRC Katepwa Beach 06	NW13-34-19-13-W2
59	SIP Mission Lake	NW5-1-20-13-W2
60	SRC Katepwa Beach 05	SW13-32-19-12-W2
61	SRC Katepwa Beach 03	SW4-9-20-12-W2
62	SRC Katepwa Beach 02	NW7-9-20-12-W2
63	SRC Katepwa Beach 01	NW4-15-20-12-W2
64	EPD Abernethy	SW12-6-20-11-W2
65	SRC Secretan	SE16-27-17-4-W3
66	TW Parkbeg	11-14-17-3-W3
67	FFIB Albert Cole	SE16-6-17-2-W2
68	Penzoil Mortlach	4-12-17-1-W3
69	PanAm Caron	10-10-17-29-W2
70	FFIB Barry Clement	13-9-17-28-W2

Log No.	Name	Location
71	SRC Moose Jaw	NE9-34-16-27-W2
72	SRC Moose Jaw	NW13-20-16-26-W2
73	DOE Baildon 16	NW12-22-16-26-W2
74	DOE Baildon 3	NW15-19-16-25-W2
75	UOHL Pasqua	11-30-16-24-W2
76	Standard Water Well #1	12-11-17-24-W2
77	Kalium Stony Beach #7	6-30-17-23-W2
78	DOE Regina 521	NW13-34-17-22-W2
79	DOE Regina 520	NW13-32-17-21-W2
80	DOE Regina 505	NW13-35-17-21-W2
81	DOE Regina 503	NE16-31-17-20-W2
82	DOE Regina 517	NW15-34-17-20-W2
83	DOE Regina 516	SE1-1-18-20-W2
84	Co-op Regina	1-5-18-19-W2
85	DOE Regina 514	NW1-5-18-19-W2
86	DOE Regina 509	SE16-33-17-19-W2
87	DOE Regina 508	SE13-25-17-19-W2
88	Hall Kearney	SW 13-30-17-18-W2
89	Pilot Butte	NW15-33-17-18-W2
90	SDL Pilot Butte	SE1-3-18-18-W2
91	FFIB Nyles Coulin	1-5-18-17-W2
92	FFIB Jack Kuntz	NW9-31-17-16-W2
93	Solie McLean	SW5-27-17-16-W2
94	FFIB John Laturnas	NE16-8-17-15-W2
95	Agro. Agro Nurd	10-9-17-15-W2
96	FFIB Leonard Pelzer	SE1-11-17-15-W2
97	FFIB Alex Kattler	NE1-7-17-13-W2
98	FFIB Jack Serson	SE10-26-17-12-W2
99	SRC Sintaluta	NE8-6-18-11-W2
100	SRC Courval	NE16-31-13-2-W3
101	Shell Old Wives	16-11-14-30-W2
102	SRC Old Wives	NE16-13-14-30-W2
103	SRC Old Wives	SE1-16-14-29-W2
104	Sohio South Buttress	2-11-14-28-W2
105	FFIB Wayne Hall	SW2-15-14-27-W2

Log. No.	Name	Location
106	SRC Leakville	SE1-15-14-26-W2
107	FFIB Dale Johnston	NE16-7-14-25-W2
108	Sohio Briercrest	14-11-14-24-W2
109	Sohio Corehole No. 12	SE1-6-14-21-W2
110	Sohio Corehole No. 11	SE1-5-14-21-W2
111	Sohio Corehole No. 10	SE1-4-14-21-W2
112	Sinclair Diana	4-2-14-21-W2
113	Sohio Corehole No. 14	SE1-2-14-21-W2
114	Sohio Corehole No. 15	NW13-31-13-20-W2
115	Sohio Corehole No. 16	NW13-32-13-20-W2
116	IMP Wilcox	15&16-32-13-20-W2
117	Sohio Corehole No. 17	NW13-33-13-20-W2
118	Sohio Corehole No. 18	SW4-3-14-20-W2
119	Sohio Corehole No. 19	SW4-2-14-20-W2
120	SRC Gray	NE1-4-14-19-W2
121	FFIB Brock Burwell	NW13-5-14-18-W2
122	SRC Riceton	SE3-18-14-17-W2
123	B.A. Normandin	14-11-14-16-W2
124	FFIB George Mitchell	NW7-30-13-14-W2
125	B.A. Francis	8-29-13-14-W2
126	FFIB Anton Meyer	NE9-25-13-13-W2
127	FFIB Tony Lang	NE13-33-13-12-W2
128	B.A. Kendal	12-12-14-12-W2
129	SRC Coppen	SW4-7-12-4-W3
130	SRC Palmer #2	NE16-19-11-3-W3
131	FFIB Ruth Cohrke	NE15-7-11-2-W3
132	SRC Ettington	SW12-10-11-1-W3
133	Socony Ardill S.T.F. 7	4-17-11-29-W2
134	Socony Ardill S.T.H. 4	SW4-14-11-29-W2
135	Socony S.T.H. 9	SE1-20-11-28-W2
136	Socony Mossbank	12-27-11-28-W2
137	FFIB Richard Chant	SE13-6-12-27-W2
138	HB Gallilee	8-2-12-27-W2
139	SRC Spring Valley	SE4-6-12-25-W2
140	Socony Claybank	11-9-12-24-W2

Log No.	Name	Location
141	Socony Claybank S.T.H. 5	SW4-18-12-23-W2
142	FFIB Dave Holland	SE14-7-12-23-W2
143	Socony Corehole No.3	NE16-10-12-23-W2
144	SRC Avonlea	NE16-7-12-22-W2
145	Sohio Corehole No.3	SW2-11-12-22-W2
146	Sohio Avonlea	15-7-12-21-W2
147	Sohio Corehole No.8	SW4-10-12-21-W2
148	Kewanee Milestone	7-4-12-20-W2
149	FFIB A.J. Rennick	NE11-5-12-19-W2
150	SRC Lang	NW5-30-11-18-W2
151	FFIB Werner Ehr	6-22-11-18-W2
152	FFIB Bill Priebe	SE3-18-11-17-W2
153	Wilkinson	SW1-19-10-16-W2
154	SRC Brightmore	SE1-17-10-15-W2
155	SRC Cedoux	SE1-17-10-14-W2
156	H.A. Chapman Talmage	3-12-10-13-W2
157	Texaco Plymouth	1-2-10-12-W2
158	SRC Melaval	NW13-23-9-4-W3
159	SRC Palmer #1	SE1-16-10-3-W3
160	SPC Palmer	10-35-11-3-W3
161	SRC Palmer	NW13-11-12-3-W3
162	Signal Johnston Lake	2-2-13-3-W3
163	SRC Coderre	SW4-2-15-3-W3
164	TW Parkbeg	13-8-15-3-W3
165	SRC Thistledown	SW5-12-16-4-W3
166	SRC Secretan	SE2-27-16-4-W3
167	UOHL Melba	14-36-16-4-W3
168	IMP Secretan	2-27-17-4-W3
169	TW Parkbeg	16-18-18-3-W3
170	TW Parkbeg	10-32-18-3-W3
171	HB Darmody	1-27-20-3-W3
172	FFIB Sid Bryon	NW13-31-22-3-W3
173	SRC Bridgeford	SE7-21-23-3-W3
174	FFIB Kelly Johnson	SE13-20-9-29-W2

Log No.	Name	Location
175	SRC Vantage	NE16-10-10-20-W2
176	Socony Ardill S.T.H. 8	16-20-10-29-W2
177	Socony Ardill S.T.H. 6	SW4-3-11-29-W2
178	Socony Ardill	14-11-11-29-W2
179	Socony Ardill S.T.H. 3	4-28-11-29-W2
180	Socony Ardill S.T.H. 10	13-28-11-29-W2
181	Socony Mossbank S.T.H. 7	NW13-4-12-29-W2
182	Socony Mossbank S.T.H. 5	16-9-12-29-W2
183	Shell Mossbank	10-33-12-29-W2
184	Socony Buttress	8-4-15-28-W2
185	FFIB Arthur Ogle	NE16-10-15-28-W2
186	FFIB Joe McIntrye	14-34-16-29-W2
187	FFIB Len Wegwitz	NW5-24-17-29-W2
188	Socony Marquis	12-28-19-28-W2
189	SRC Marquis	NW4-35-19-28-W2
190	SRC Keeler	NW4-34-20-28-W2
191	Dillman Keeler	4-34-20-28-W2
192	SRC Keeler	NW12-16-21-28-W2
193	GSC Aylesbury	1-35-22-28-W2
194	P.Am Aylesbury	8-23-23-28-W2
195	SRC Ormiston	NE16-24-9-26-W2
196	Socony North Ormiston	3-18-10-25-W2
197	Socony Bliss Lake S.T.H. 1	SE4-18-10-25-W2
198	Socony Bliss Lake S.T.H. 2	SW5-30-10-25-W2
199	SRC Dirt Hills	NE1-10-11-25-W2
200	FFIB S.A. Nestman	SE16-18-13-24-W2
201	Sohio Leakville	4-11-14-26-W2
202	Ceepee Baildon	2-11-15-26-W2
203	DOE Baildon 6	SE15-15-15-26-W2
204	DOE Baildon 12	NE16-22-15-26-W2
205	DOE Baildon 7	NW12-26-15-26-W2
206	DOE Baildon 11	SE14-35-15-26-W2
207	DOE Baildon 30	NE8-2-16-26-W2
208	DOE Baildon 9	SW4-18-16-25-W2
209	FFIB George Fagan	SE10-2-17-26-W2
210	SRC Belbeck	NE16-33-17-26-W2

Log No.	Name	Location
211	Dillman Lindley	14-3-18-26-W2
212	Sohio Findlater #2	9-20-20-25-W2
213	Sohio Findlater	2-4-21-25-W2
214	FFIB Lloyd Hills	SE16-9-21-25-W2
215	U of S Findlater	NE13-32-21-25-W2
216	U of S Dindlater	SE9-6-22-25-W2
217	SRC Holdfast	SW3-18-23-25-W2
218	Hayter Holdfast	1-30-23-25-W2
219	Lobitos Dahinda	2-4-10-23-W2
220	IMP Dahinda #1	10-23-10-23-W2
221	UOHL Dahinda	10-34-10-23-W2
222	Sohio Avonlea	15-20-12-22-W2
223	Texas Pitman	2-1-15-23-W2
224	FFIB John Teichreb	NE16-12-15-23-W2
225	SRC Drinkwater	SE1-15-16-22-W2
226	Sohio South Pense	5-15-16-22-W2
227	SRC Pense	SE1-5-17-22-W2
228	Sohio Pense #1	14-10-17-22-W2
229	FFIB Kenneth Campbell	NW3-2-19-22-W2
230	FFIB Richard Seidlitz	NW2-14-21-23-W2
231	FFIB Aden Wilcox	NE3-3-23-22-W2
232	FFIB Alf Nordal	SE6-15-23-22-W2
233	FFIB Harold Young	3-27-23-22-W2
234	SRC Moreland	SW4-13-9-20-W2
235	Mobil Lang	14-32-10-19-W2
236	FFIB Garry Nicholas	14-18-11-19-W2
237	Kissinger Milestone	9-28-12-19-W2
238	FFIB Barney Galbraith	NE1-16-13-19-W2
239	Amerada "S-A0"	16-4-14-19-W2
240	Socony Estlin #1	1-20-15-19-W2
241	SRC Estlin	NW14-20-15-19-W2
242	FIB Stan Kostron	1-2-16-20-W2
243	SRC Rowatt	NE16-22-16-20-W2
244	SPC Regina	9-27-16-20-W2
245	DOE Regina 524	NW13-34-16-20-W2

Log No.	Name	Location
246	Doe Regina 523	NE9-10-17-20-W2
247	P.Am Regina	16-9-17-20-W2
248	Doe Regina 512	NW1-23-17-20-W2
249	DOE Regina 511	SW12-30-17-19-W2
250	DOE Regina 513	NW4-32-17-19-W2
251	IMP Regina	4-32-17-19-W2
252	DOE Regina 515	SE14-4-18-19-W2
253	DOE Regina 519	SW12-10-18-19-W2
254	DOE Regina 501	SE8-15-18-19-W2
255	Hall Seibel Creek	SE2-24-18-19-W2
256	Hall Zehner	SE4-31-18-18-W2
257	SRC Zehner	NW13-32-18-18-W2
258	SDL Zehner	SE13-22-19-18-W2
259	Hall Qu'Appelle River	SW14-36-20-19-W2
260	FFIB Edward Glass	SE4-10-22-19-W2
261	Socony Bulyea #1	8-30-23-20-W2
262	Champlin Brightmore	11-18-9-16-W2
263	SRC Lewvan	SW4-2-12-17-W2
264	SRC Lewvan	NW13-9-12-16-W2
265	SRC Bechard	NW13-22-12-16-W2
266	SRC Bechard	NW5-7-13-16-W2
267	SRC Bechard	SE1-14-13-17-W2
268	SRC Riceton	NW13-23-13-17-W2
269	B.A. Riceton #1	4-29-13-17-W2
270	SRC Riceton	NE16-30-13-17-W2
271	SRC Riceton	SW13-31-13-17-W2
272	SRC Riceton	NE9-1-14-18-W2
273	SRC Kronau	SW3-26-15-17-W2
274	FFIB David Heisler	SW12-12-16-17-W2
275	Hall Jameson	NW13-36-16-17-W2
276	Chevron Regina East	6-29-18-16-W2
277	FFIB Henry Silzer	SE9-4-19-16-W2
278	Edenwold	SW14-8-19-16-W2
279	FFIB Dale Franbach	SW8-16-20-16-W2
280	FFIB Gerald Sager	SE14-26-20-16-W2

Log No.	Name	Location
281	TW Ft. Qu'Appelle Strat. 8	NE16-32-20-16-W2
282	IOL Muscowpetung	1-9-21-16-W2
283	HDL Cupar	SE9-19-21-16-W2
284	TW Ft. Qu'Appelle Strat. 4	SE8-25-21-17-W2
285	SRC Cupar	NW14-31-22-16-W2
286	FFIB Katalin Tusa	NE16-12-23-17-W2
287	TW Markinch	13-29-23-17-W2
288	Sun N. Weyburn	13-22-9-14-W2
289	Plaza Lillie Glen	1-5-10-14-W2
290	Sun Worcester	7-25-10-14-W2
291	FFIB Robert Kilback	SE16-12-12-14-W2
292	B.A. Tyvan #1	9-11-13-13-W2
293	FFIB Lawrence Sebastian	SW13-18-13-12-W2
294	FFIB Stewart MacDougall	NW6-3-14-13-W2
295	Palmer Manybone	3-16-14-13-W2
296	SRC Wascana Creek	NW4-16-14-13-W2
297	FFIB Karl Van Farber	SE6-33-14-13-W2
298	FFIB John Halzapfel	NE6-10-15-13-W2
299	FFIB Leo D. Reise	SW5-25-15-13-W2
300	Phillips Odessa #1	5-12-16-13-W2
301	B.A. Strawberry Lake	5-29-16-13-W2
302	SRC Qu'Appelle	NE14-16-18-14-W2
303	FFIB H.C.M. McDonald	SE1-8-19-13-W2
304	FFIB K.H. McDonald	NW10-17-19-13-W2
305	FFIB Stanley Sinclair	NE15-13-20-14-W2
306	TW Ft. Qu'Appelle Strat. 1	16-24-20-14-W2
307	DTRR Ft. Qu'Appelle	SW12-30-20-13-W2
308	TW Ft. Qu'Appelle Strat. 2	8-36-20-14-W2
309	DTRR Ft. Qu'Appelle	NE8-1-21-14-W2
310	SRC Ft. Qu'Appelle	NW14-7-21-13-W2
311	SRC Ft. Qu'Appelle	NW11-17-21-13-W2
312	B.A. Qu'Appelle	2-29-32-13-W2
313	FFIB Dave McVicker	SE14-20-22-12-W2
314	FFIB Earl Todd	SW3-13-23-12-W2