BEAK CONSULTANTS LIMITED

GEOLOGY OF THE WARMAN SITE AND ITS RELATIONSHIP TO THE SASKATOON LOW COLLAPSE STRUCTURE

Report 0041-002 November 23, 1979

E. A. Christiansen Consulting Ltd.

E. A. Christiansen Consulting Ltd.

CONSULTING GEOLOGIST

BOX 3087
SASKATOON, SASKATCHEWAN, CANADA
S7K 3S9

PHONE 374-6700

November 23, 1979

Beak Consultants Limited
6870 Goreway Drive
Mississauga, Ontario
L4V 1L9

Attention: Dr. Wilson Eedy

Dear Dr. Eedy:

Enclosed is a copy of the "Geology of the Warman Site and its relationship to the Saskatoon Low collapse structure".

If you have any queries, please contact me at your earliest convenience.

Sincerely yours,

E.A. Christiansen

November 28, 1979

Beak Consultants Limited
6870 Goreway Drive
Mississauga, Ontario, Canada
L4V 1L9

Attention: Dr. Wilson Eedy

Dear Dr. Eedy:

On considering Drawing 0037-002-01 for display purposes, I noticed I had emphasized the area projected above the bedrock surface when I should have emphasized the Saskatoon Low collapse area.

Enclosed are four copies of this Drawing which I suggest you use as a replacement for the ones in the reports which were sent yesterday.

Sincerely yours,

E.A. Christiansen

Februaey 29, 1980

Beak Consultants Limited
6870 Goreway Drive
Mississauga, Ontario
L4V 1L9

Attention: Dr. Wilson Eedy

Dear Dr. Eedy:

I am presently investigating the geology of a region including the Warman site and anticipate further condulting work and research which will include this site.

I request permission to add the four deep testhole logs to my data bank for use in my present study and for future use in consulting and research.

I would appreciate your consideration of this request.

Sincerely yours,

E.A. Christiansen

Beak Consultants Limited

Montreal
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6870 Goreway Drive
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4 March 1980

Dr. E.A. Christiansen
P.O. Box 3087
Saskatoon, Saskatchewan
S7K 3S9

Reference: T-3578

Dear Earl:

I have forwarded your request to use the deep testhole logs to Eldorado. The report was presented to the panel and thus the data should be public but it is their money so they should have the final say.

I'll let you know as soon as I have an answer.

Yours sincerely

BEAK CONSULTANTS LIMITED

Wilson

Wilson Eedy, Ph.D.
Director Environmental Services

/es

ELDORADO
ELDORADO NUCLEAR LIMITED
Refining Division

89 Walton Street, Port Hope, Ontario, Canada L1A 1N4
(416) 885-4564 Telex 06-981425

11 March 1980

Dr. E. A. Christiansen,
E. A. Christiansen Consulting Limited,
Consulting Geologist,
Box 3087,
SASKATOON, Saskatchewan, Canada.
S7K 3S9

Dear Dr. Christiansen:

Re: Geology Data for Eldorado Refinery Site
near Warman

Dr. Wilson Eedy of Beak Consultants forwarded your request to add the four deep testhole logs from the site to your data bank. Eldorado has no objection to your using these data in your consulting and research work. I would, however, request that you do not embark on any visits to the site without first consulting Mr. Gordon Burton in our Saskatoon office: any activity on the site is liable to misinterpretation at the present time.

Sincerely,

A. F. Roake, P. Eng.,
Project Manager,
Saskatchewan Refinery.

AFR/sam

Eldorado Resources Limited
Fuel Services
One Eldorado Place
Port Hope, Ont. Canada L1A 3A1
(416) 885-4511 Telex: 069-81272

eldorado

December 19, 1984

Dr. E. A. Christiansen
c/o Dr. E. A. Christiansen Consulting Ltd.
P.O. Box 3087
Saskatoon, Saskatchewan
S7K 3S9

Dear Dr. Christiansen:

Several weeks ago, we received a request from Mr. B. Schreiner of the Saskatchewan Research Council. This request concerned written authorization to release testhole logs which you have collected from the former Warman uranium refinery site. Please feel free to release this information or any other geological/hydrogeological data which you have relating to the Warman site to SRC.

For your information, Mr. Andy Roake, who was your contact on the Warman project, has left Eldorado, initially to pursue an MBA at Harvard and subsequently to pursue a career out on the West Coast; hence I am writing to you on behalf of Eldorado.

Yours truly,
ELDORADO RESOURCES LIMITED

J. P. Jarrell
Manager
Licensing and Waste Management

:jc

cc: Mr. B. T. Schreiner, SRC

1220F

Logs released to SRC
(Testholes 1-4) 14/01/~~84~~ 85

SUMMARY

The proposed Warman refinery Site is underlain in descending order by:

(1) 4 feet (1m) of soft, stony till of the Battleford Formation;

(2) 14 feet (4m) of hard, jointed, weathered till and 6 feet (2m) of gray unweathered till of the Floral Formation;

(3) 86 feet (26m) of gray, clayey, massive Upper Till of the Sutherland Group;

(4) 104 feet (32m) of sandy, pebbly, more calcareous Middle Till of the Sutherland Group which contains a gravel lens and a 1-foot sand bed in the upper part of the unit;

(5) 160 feet (49m) of fine to course sand interbedded with silt which comprises the Tyner Valley Aquifer;

(6) 12 feet (4m) of chert and quartzite gravel; and

(7) 728 feet (222m) of gray, silty clay and calcareous shale of the Lea Park Formation and Upper Colorado Group. Except for the chert and quartzite gravel, all of the units are present in all four Warman testholes.

The proposed Warman refinery site has not collapsed since the deposition of the Second White Speckled Shale about 85 million years ago. The youngest and nearest collapse took place during the beginning of glaciation about 2 to 3 million years ago. Future collapses are likely to be restricted to the Saskatoon Low or around the periphery of the structure.

LIMITATIONS

The Eldorado Nuclear Limited (ENL) geological logs, which are based on cutting samples and electric logs, and the Saskatchewan Research Council geological logs, which are based on cores, cutting samples, and electric logs, are believed to represent the geology at a specific site at the time studied. The Family Farm Improvement Branch (FFIB) logs include an electric log and a driller's log of the cutting samples which makes this information less reliable. The oil and mining company information is in the form of electric logs only and was used primarily for identifying the bedrock deposits and the bedrock surface topography.

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 contacts between geological 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 available geological models that best fit the geological information available at the time the cross sections were drawn. These lines do not necessarily represent actual contacts between geological units nor do they necessarily imply the nature of these units is the same as at the sites where the information was obtained. The degree of confidence of such geological interpretations depends on the quality and quantity of information and on the complexity of the geology.

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1. INTRODUCTION

1.1 Objective

The objectives of this study were set forth in Project Proposal 0041-001 by E.A. Christiansen Consulting Ltd., October 24, 1979 and confirmed by Beak Consultants Limited on October 31, 1979. They include the following:

(1) to drill and electric log a testhole to the top of the Lower Colorado Group using the base of the Second White Speckled Shale as a marker bed;

(2) to draw a structural contour map on top of the Lea Park Formation and Upper Colorado Group;

(3) to draw cross sections relating the proposed Warman refinery site to the collapse structures in the Saskatoon Low; and

(4) to write a report relating the geology of the proposed Warman refinery site (hereafter called Warman Site) to the collapse structures in the Saskatoon Low.

1.2 Location

The Warman Site is about 3 miles (10 km) southeast of Warman or about 13 miles (43 km) northeast of Saskatoon (Drawing 0041-002-01, in back).

1.3 Previous Work

A geology and groundwater map was published for the Warman area by Christiansen (1967a). This map shows the geology and bedrock surface topography, cross sections, and groundwater resources. In a folio on the "Physical environment of Saskatoon", Christiansen (1970) and Meneley (1970) dealt with the geology and groundwater respectively of this area.

Papers on "Collapse structures near Saskatoon" (Christiansen, 1967b) and "Pleistocene stratigraphy of the Saskatoon area" (Christiansen, 1968a) form the basis for the discussion of these subjects. Geological and geophysical logs from the Saskatchewan Research Council (SRC); from private companies through Riley's Datashare International, Calgary; from the Family Farm Improvement Branch (FFIB), Regina; and from Eldorado Nuclear Limited (ENL) provided the subsurface information.

1.4 Present Study

In order to determine the exact nature of the geologic structure at the Warman Site, a testhole (ENL Warman No. 4) was drilled to the Lower Colorado Group (Drawing 0041-002-05, in back) penetrating the base of the Second White Speckled Shale marker bed (Drawing 0041-002-01; 02, Testhole 16; Fig. 1).

From the geological and geophysical logs mentioned above, a structural map of the top of the Lea Park Formation and Upper Colorado Group was prepared to show the structural relationship of the Warman Site to the collapse structures in the Saskatoon Low (Drawing 0041-002-01, in back). Three cross sections (Drawings 0041-002,02,03,04) were constructed by taping matte positive logs directly on cross section paper to show the stratigraphy and structure of the Warman Site and its relationship to the Saskatoon Low. Many of the SRC logs and the ENL Warman No.4 log include carbonate curves which are an inportant criterion for separating tills in the Warman area and in Saskatchewan generally.

A

B

Figure 1. ENL Warman No. 4 Testhole. (A) ENL Warman No. 4 Testhole site and (B) sand and till cuttings obtained from testhole.

2. BEDROCK STRATIGRAPHY

2.1 Regional Bedrock Stratigraphy

The bedrock deposits in the Warman-Saskatoon region include the Lea Park Formation and Upper Colorado Group, Judith River Formation, and Bearpaw Formation (Drawings 0041-002-02-04) which rest on the Lower Colorado Group (Drawings 0041-002-02,05). For further information on the regional bedrock stratigraphy, the reader is referred to consulting Report 0013-002 (E.A. Christiansen Consulting Ltd., 1978).

2.2 Bedrock stratigraphy at the Warman Site

The Lea Park Formation and Upper Colorado Group is the bedrock at the Warman Site (Drawing 0041-002-02,05). The base of the Second White Speckled Shale, which is used as a structural marker bed throughout the Prairies, forms the contact between this bedrock and the underlying Lower Colorado Group. The Judith River and Bearpaw Formations, which occur elsewhere in the Saskatoon area (Drawings 0041-002-02-04), have been eroded from the Warman Site.

The Lower Colorado Group is composed of dark gray, noncalcareous, clay. The overlying Lea Park Formation and Upper Colorado Group are composed of a lower dark gray, calcareous shale with white specks called the "Second White Speckled Shale". Overlying this shale, is dark gray, noncalcareous (locally calcareous near base), silt and clay (Drawing 0041-002-05).

3. TYNER VALLEY GRAVEL

About 10 feet (3m) of preglacial gravel occurs between the underlying bedrock and overlying glacial deposits beneath the Warman Site (Drawings 0041-002-02,05). These preglacial deposits are composed

of black chert and brown quartzite pebbles which were deposited in the Tyner Valley prior to continental glaciation.

4. GLACIAL STRATIGRAPHY

4.1 Regional Glacial Stratigraphy

The glacial deposits in the Warman-Saskatoon region include the Empress, Sutherland, and Saskatoon Groups (Drawings 0041-002-02-04). For further discussion of these deposits and the geological processes which have affected them, the reader is referred to Report 0013-002 (E.A. Christiansen Consulting Ltd., 1978).

4.2 Glacial Stratigraphy at the Warman Site

4.2.1 Introduction

The glacial deposits at the Warman Site include: the Empress Group, the Middle and Upper Tills of the Sutherland Group (the Lower Till is missing at this site because of nondeposition or subsequent erosion), and the tills of the Floral and Battleford Formations (the Surficial Stratified Drift is missing because of erosion).

4.2.2 Empress Group

The Empress Group (Whitaker and Christiansen, 1972) is composed of 160 feet (49m) of sand with silt interbeds lying between bedrock and till. It now seems more likely that this sand was laid down between the deposition of the Lower and Middle Tills of the Sutherland Group; if so, these deposits should not be called the Empress Group. Until this problem is fully studied, however, these sands will be left in the Empress Group.

4.2.3 Sutherland Group

The Sutherland Group is composed of Lower, Middle, and Upper Tills, the Lower Till of which is missing at the Warman Site and occurs only in downfaulted areas (Drawing 0041-002-02, Testhole 7).

The Middle Till of the Sutherland Group at the Warman Site is composed of 104 feet (32m) of calcareous, sandy, pebbly till, locally with sand and gravel beds (Drawing 0041-002-05). The fact that the gravel between 160 and 165 feet (49 and 50 m) "washed-out" so readily during test drilling suggests this unit is a lens rather than a bed of large areal extent. Whether the sand at the top of the unit has continuity is not known. This sandy unit occurs at the top of this till in all of the four testholes drilled at the Warman locality which suggests that it has considerable continuity.

The Upper Till of the Sutherland Group at the Warman Site is composed of 86 feet (26m) of gray, unweathered till. This till is clayier, has a lower electrical resistance, and has a lower carbonate content than the underlying Middle Till of the Sutherland Group and the overlying tills of the Saskatoon Group (Drawing 0041-002-05).

4.2.4 Saskatoon Group

The Saskatoon Group at the Warman Site is composed of the Floral and Battleford Formations. The Floral Formation is composed of 20 feet (6m) of grayish brown, hard jointed till with yellowish brown staining on the joint surfaces. This till, becomes gray and unweathered in the basal 4 feet (1.2m) of the Formation.

The Battleford Formation is composed of 4 feet (1.2m) of light brownish gray, strongly calcareous, soft till which contains numerous stones in and on the surface of the till.

5. COLLAPSE STRUCTURES

5.1 Previous Work

Christiansen (1967b) concluded the depressional structure in the top of the Lea Park Formation and Upper Colorado Group in the Saskatoon area was caused by collapse as a result of the dissolution of salt from the Devonian Prairie Evaporite Formation. He also inferred that the bedrock surface topography and the thickness of the Surficial Stratified Drift were affected by collapse. Christiansen (1970) related the thickening of the Battleford Formation to collapse and used this model to explain the stratigraphy in a cross section between Saskatoon and Beaver Creek (Christiansen, 1976). Work by Christiansen and Whitaker (1976) has demonstrated that large depressions can also form in bedrock or drift by glacial thrusting (Fig. 2).

5.2 Present Study

The interpretation of the Saskatoon Low collapse structure was updated by redrawing the structural contour map on top of the Lea Park Formation and Upper Colorado Group (Drawing 0041-002-01). The point elevations on this surface were taken either from the actual contacts between the Lea Park Formation and Upper Colorado Group and the Judith River Formation or from the projection of this contact down from a Bearpaw Sand or the top of the Judith River Formation or up from the base of the Second White Speckled Shale. These projected intervals were taken from the closest log exhibiting one of these intervals.

During a test drilling program in 1976, the greatest thickness of Surficial Stratified Drift encountered to that date (264 feet, 80m) was penetrated near the southern boundary of the Saskatoon Low where only 80 feet (24m) of collapse has taken place (Drawings 0041-002-01; 03, Testhole 24). It is concluded, therefore, that depressions in the

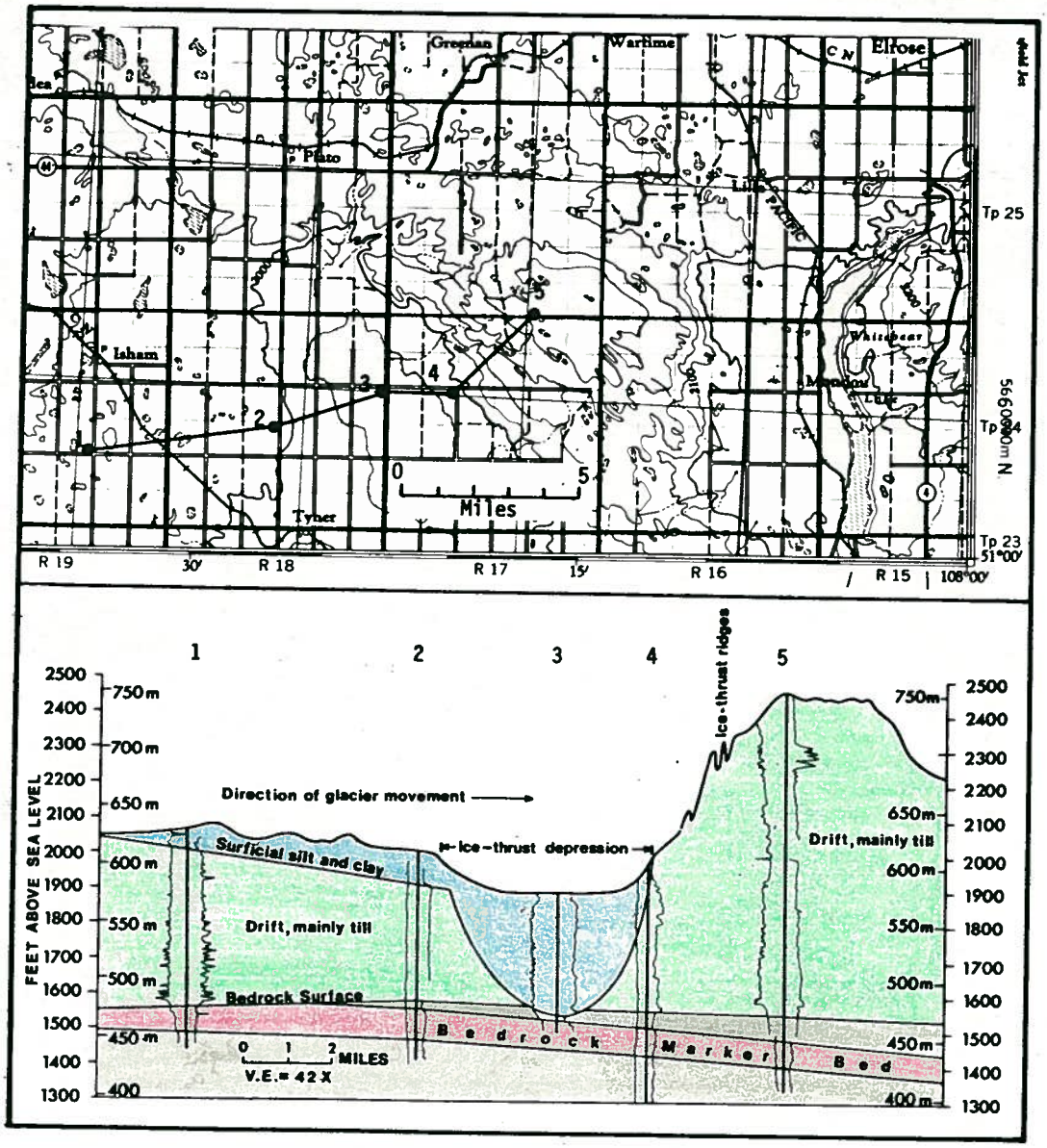


Figure 2. Ice-thrust depression east of Tyner, Saskatchewan. From Christiansen and Whitaker (1976).

bedrock surface and thickening of the Battleford Formation and Surficial Stratified Drift can be explained by glacial erosion as well as by collapse.

South of Floral (Drawing 0041-002-04, Testhole 31), 436 feet (233m) of soft, gray till, believed to be Battleford Formation, rests directly on collapsed bedrock. The absence of older tills of the Sutherland Group in this structure suggests that glacial erosion took place. Whether such erosion took place after collapse or was focused by the collapse is not known. If it is assumed that both collapse and erosion took place at about the same time, then collapse in this area may have taken place about 20,000 to 12,000 years ago (Christiansen 1968b, 1979).

Circular sloughs occur south and east of Floral (Drawing 0041-002-01, S.27,34,T.35, R.4; S.4,T.36,R.4) and resemble Crater Lake which formed by collapse because of the dissolution of salt from the Devonian Prairie Evaporite Formation (Christiansen, 1971; Gendzwill and Hajnal, 1971). Whether these sloughs near Floral were formed because of the dissolution of salt or the melting of ice-blocks is not known.

Test drilling and coring during the last 10 years in collapsed areas has revealed few if any disturbed sediments. The hypothesis that the collapse is accomodated by stretching of the beds rather than by faulting as shown in Drawings 0041-002-02-04 may be more tenable.

5.3 Age of Collapse in the Saskatoon Low

Drawing 0041-002-01 indicates the collapse took place after the deposition of the Lea Park Formation and Upper Colorado Group, and Drawings 0041-002-02-04 indicate that collapse took place after the deposition of the Bearpaw Formation.

The restriction of till of the Sutherland Group to collapse areas (Drawings 0041-002-02, Testhole 7; 03, Testhole 20; Christiansen, 1976, Testhole 3,4) suggests collapse took place during the deposition of these tills which probably took place during the advent of continental glaciation 2 to 3 million years ago (Gary *et al.* 1974).

Whether collapse took place in the Saskatoon Low since the glacier retreated is not known. The depressions in the bedrock surface (Christiansen, 1967b) and those in which the Battleford Formation was deposited (Christiansen, 1970) and the Surficial Stratified Drift was deposited (Christiansen, 1967b) can be explained by glacial erosion as well as collapse. Further work is required before the youngest collapse in the Saskatoon Low can be dated.

5.4 Warman Site

According to ENL Warman No.4 Testhole (Drawings 0041-002-01,02 Testhole 16), the Warman Site has not collapsed since the deposition of the Second White Speckled Shale which was deposited about 85 million years ago (Obradovich and Cobban, 1975 through W.G.E. Caldwell, 1977, personal communication). The nearest and youngest collapse to the Warman Site,encountered to date,is believed to have taken place either during the deposition of the Lower Till of the Sutherland Group or during the interval between the deposition of Lower and Middle Tills of the Sutherland Group (Drawing 0041-002-02, Testhole 7). This is the oldest known till in Saskatchewan and probably dates the beginning of continental glaciation which is thought to have begun 2 to 3 million years ago (Gary *et al.* 1974).

Although the date of future collapses cannot be forecasted, it is likely that this process will be restricted to the Saskatoon Low and to the periphery of this structure.

6. GEOLOGIC HISTORY OF THE WARMAN-SASKATOON AREA

6.1 Introduction

The geologic history is based on Cross section AA' between Warman and Saskatoon (Drawing 0041-002-02) and is shown in 6 phases (Fig.3).

6.2 Phase 1.

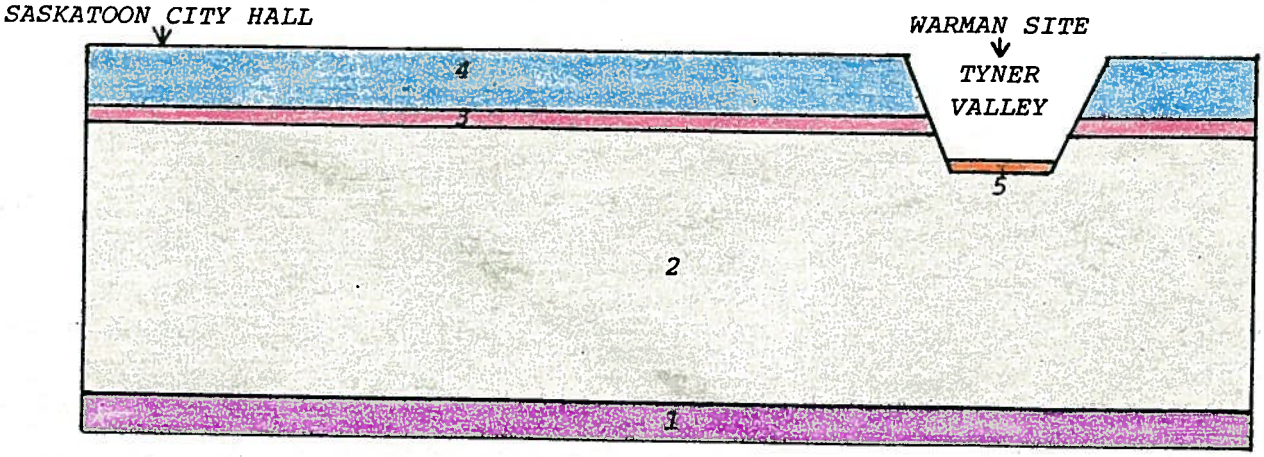
During late Cretaceous, the study-area was covered by shallow seas into which rivers from the Cordillera emptied to form sandy deltas. These deltas shifted eastward as the sea levels fell and westward as the sea levels rose. The Judith River Formation and the sandy member in the Bearpaw Formation represent such deltaic deposits, whereas the Lower and Upper Colorado Groups, the Lea Park Formation, and the clayier parts of the Bearpaw Formation were deposited eastward from such deltas. The Cretaceous Period came to a close about 64 million years ago (Obradovich and Cobban, 1975).

During Phase 1, the Tyner Valley eroded through the Bearpaw and Judith River Formations into the Lea Park Formation and Upper Colorado Group, and preglacial gravel (Tyner Valley Gravel) was deposited on the valley floor.

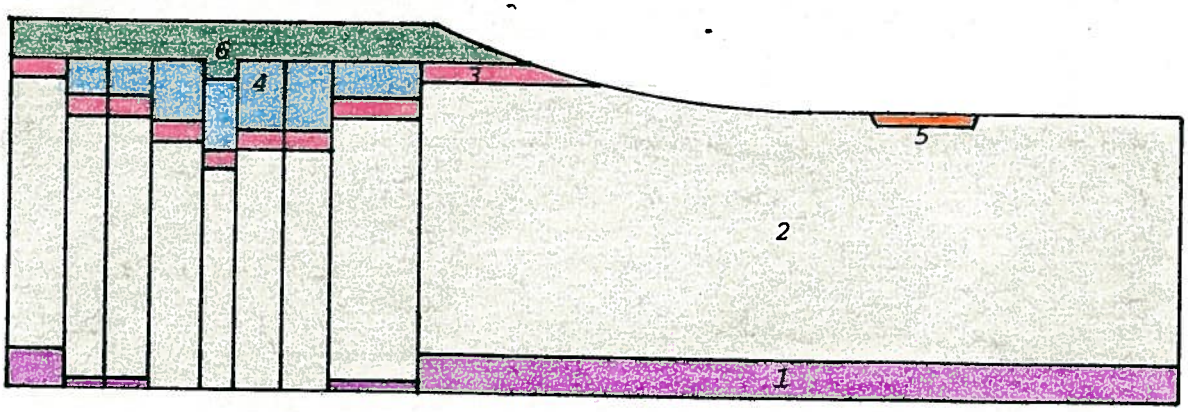
6.3 Phase 2.

Between Phases 1 and 2, the City of Saskatoon area collapsed up to 400 feet (122m), about 100 feet (30m) of which took place either during the deposition of the Lower Till of the Sutherland Group or during the interval between the deposition of the Lower and Middle Tills of the Sutherland Group.

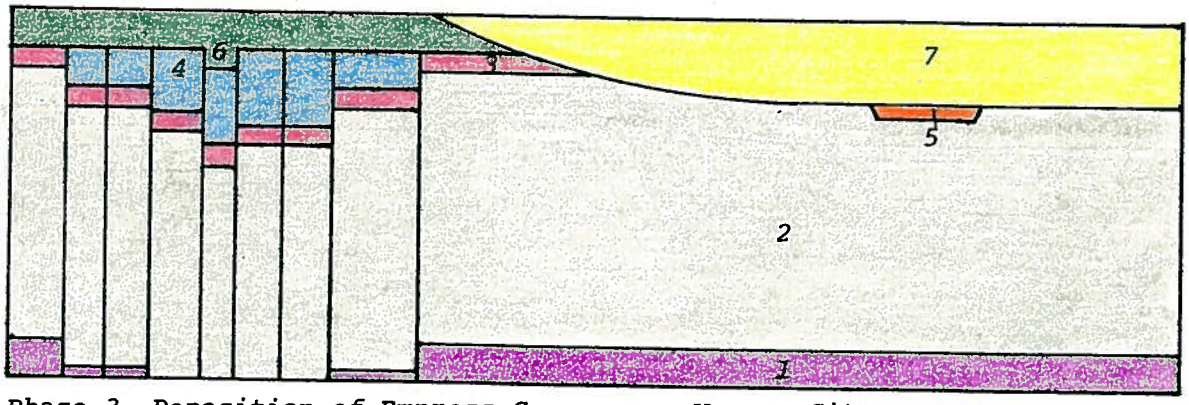
During Phase 2, the Tyner Valley, except for the gravel on the valley floor, was removed by glacial erosion, and the Lower Till of the Sutherland Group was deposited in the Saskatoon area.



Phase 1. Tyner Valley eroded into bedrock prior to glaciation.



Phase 2. Erosion of Tyner Valley and deposition of Lower Till of the Sutherland Group on collapsed or collapsing bedrock in the Saskatoon area.



Phase 3. Deposition of Empress Group over Warman Site.
(1) Lower Colorado Group, (2) Lea Park Formation and Upper Colorado Group, (3) Judith River Formation, (4) Bearpaw Formation, (5) Tyner Valley Gravel, (6) Lower Till of Sutherland Group, (7) Empress Group, (8) Middle Till of Sutherland Group, (9) Upper Till of Sutherland Group, (10) Floral and Battleford Formations, and (11) Surficial Stratified Drift.

Figure 3. Geological history of Warman-Saskatoon area.

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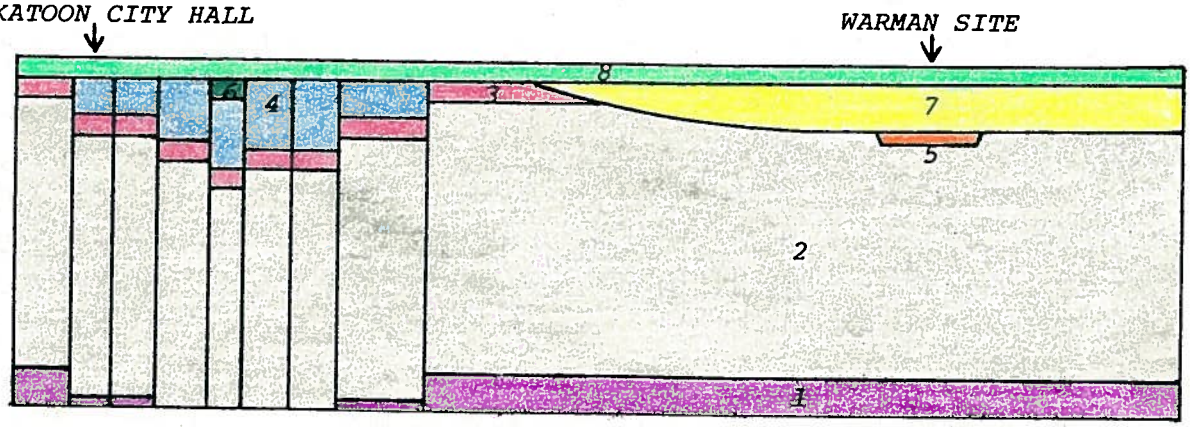
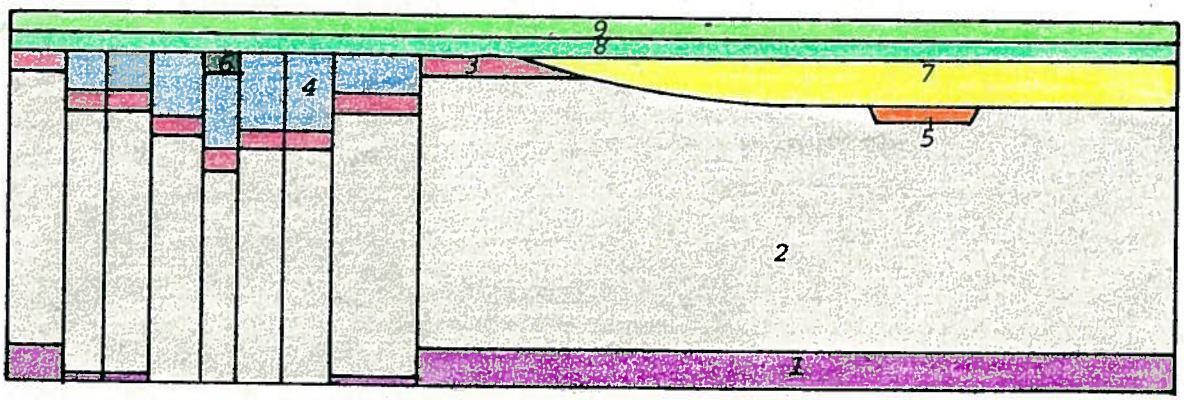
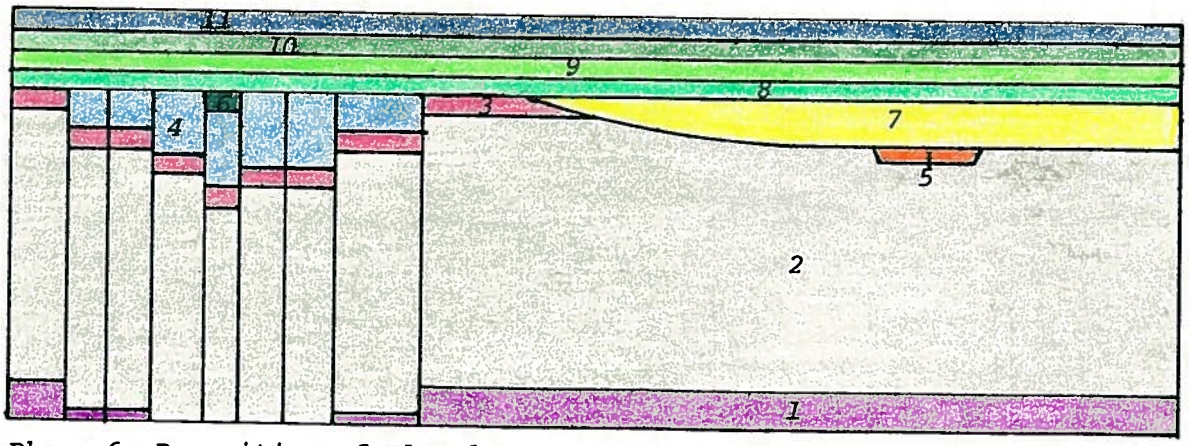


Phase 4. Erosion of Lower Till and deposition of Middle Till of Sutherland Group.



Phase 5. Deposition of Upper Till of the Sutherland Group.



Phase 6. Deposition of Floral and Battleford Formations and Surficial Stratified Drift.

(1) Lower Colorado Group, (2) Lea Park Formation and Upper Colorado Group, (3) Judith River Formation, (4) Bearpaw Formation, (5) Tyner Valley Gravel, (6) Lower Till of Sutherland Group, (7) Empress Group, (8) Middle Till of Sutherland Group, (9) Upper Till of Sutherland Group, (10) Floral and Battleford Formations, and (11) Surficial Stratified Drift.

Figure 3. Geological history of Warman-Saskatoon area.

6.4 Phase 3.

During Phase 3, the Empress Group sands and interbedded silts were deposited in the glacially eroded depression at the Warman Site. These sands and silts were derived from the melting glacier which deposited the Lower Till of the Sutherland Group.

6.5 Phase 4.

During Phase 4, most of the Lower Till of the Sutherland Group and part of the Empress Group was removed by glacial erosion prior to deposition of the Middle Till of the Sutherland Group. This Middle Till is the oldest till at the Warman Site.

6.6 Phase 5.

During Phase 5, the Upper Till of the Sutherland Group was deposited throughout the area. Whether the Middle and Upper Tills represent separate glaciations or re-advances of the same glacier that deposited the Lower Till is not known.

6.7 Phase 6.

Between Phases 5 and 6, the surface of the Upper Till of the Sutherland Group was subjected to weathering during which the upper part of the till became oxidized. During Phase 6, the Floral and Battleford Formations were deposited on the glacially eroded Upper Till of the Sutherland Group at the Warman Site. During this erosion, the entire weathered zone, which developed between Phases 5 and 6, was removed by glacial erosion at this site.

During the interglacial interval between the deposition of the Floral and Battleford Formations, the upper part of the Floral Formation was oxidized and jointed, and iron oxide was deposited on the joint surfaces. These joints are shrinkage cracks formed during drying of the till above the water table.

The last glacier, which deposited the Battleford Formation, advanced across the Warman Site about 20,000 years ago and was retreating from the site about 12,000 years ago. During this retreat, glacial Lake Saskatchewan (Fig.4) shrank as the glacier retreated. Lake sands, silts, and clays were deposited and later removed from the Warman Site by stream erosion during the drainage of Lake Saskatchewan. The valleys near the Warman Site were formed during this time (Fig. 4, Phase 4). The Warman Site has been essentially unaffected geologically since the drainage of Lake Saskatchewan about 12,000 years ago.

7. CONCLUSIONS

In decending order, the Warman Site is underlain by: (1) 4 feet (1m) of soft stony till of the Battleford Formation; (2) 20 feet (6m) of till of the Floral Formation, the upper 14 feet (4m) of which is oxidized and highly jointed; (3) 86 feet (26m) of gray, clayey Upper Till of the Sutherland Group; (4) 104 feet (32m) of sandy, pebbly, Middle Till of the Sutherland Group, the uppermost sandy bed of which may be fairly extensive areally;(5) 160 feet (49) of fine to coarse sand interbedded with silt comprising the Tyner Valley Aquifer; (6) 12 feet (4m) of chert and quartzite gravel; and (7) 728 feet (222m) of gray silty clay of the Lea Park Formation and Upper Colorado Group.

The Warman Site has not collapsed since the deposition of the Second White Speckled Shale about 85 million years ago. The

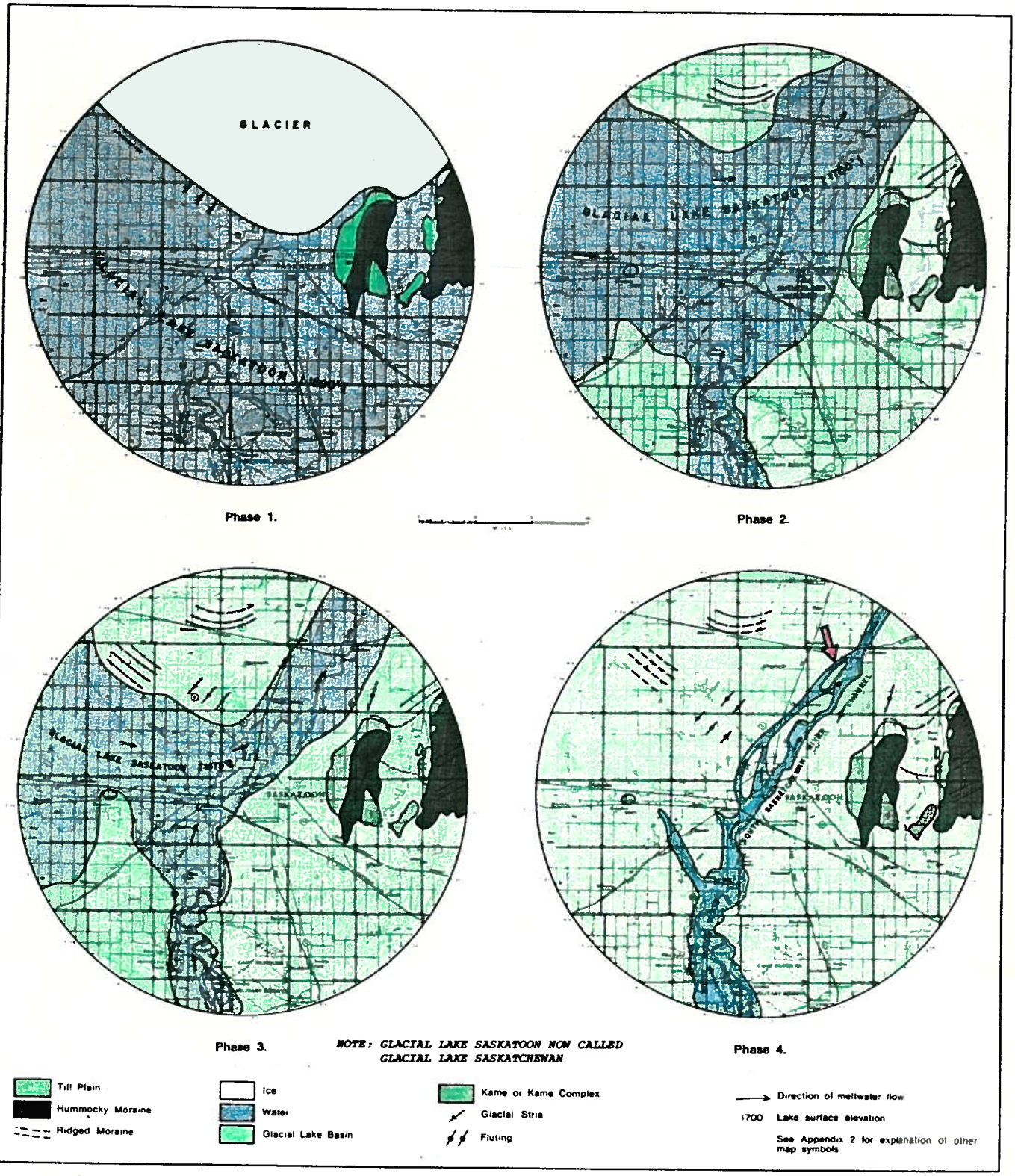


Figure 4. History of deglaciation in the Warman-Saskatoon area. From Christiansen (1970).

youngest and nearest collapse took place during the advent of glaciation which is thought to be 2 to 3 million years ago. Future collapses are likely to be restricted to the Saskatoon Low or around the periphery of the structure.

8. LITERATURE CITED

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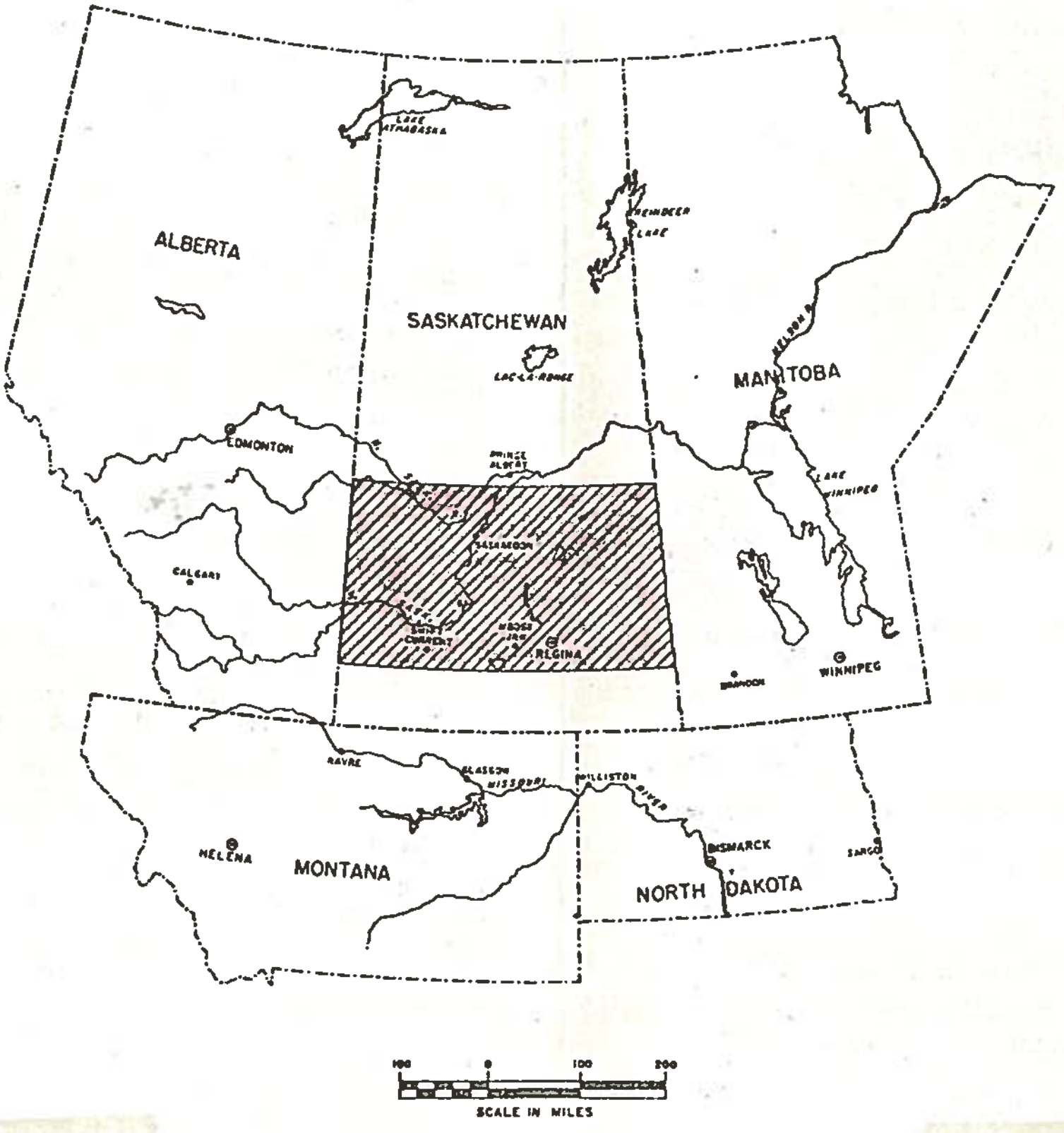
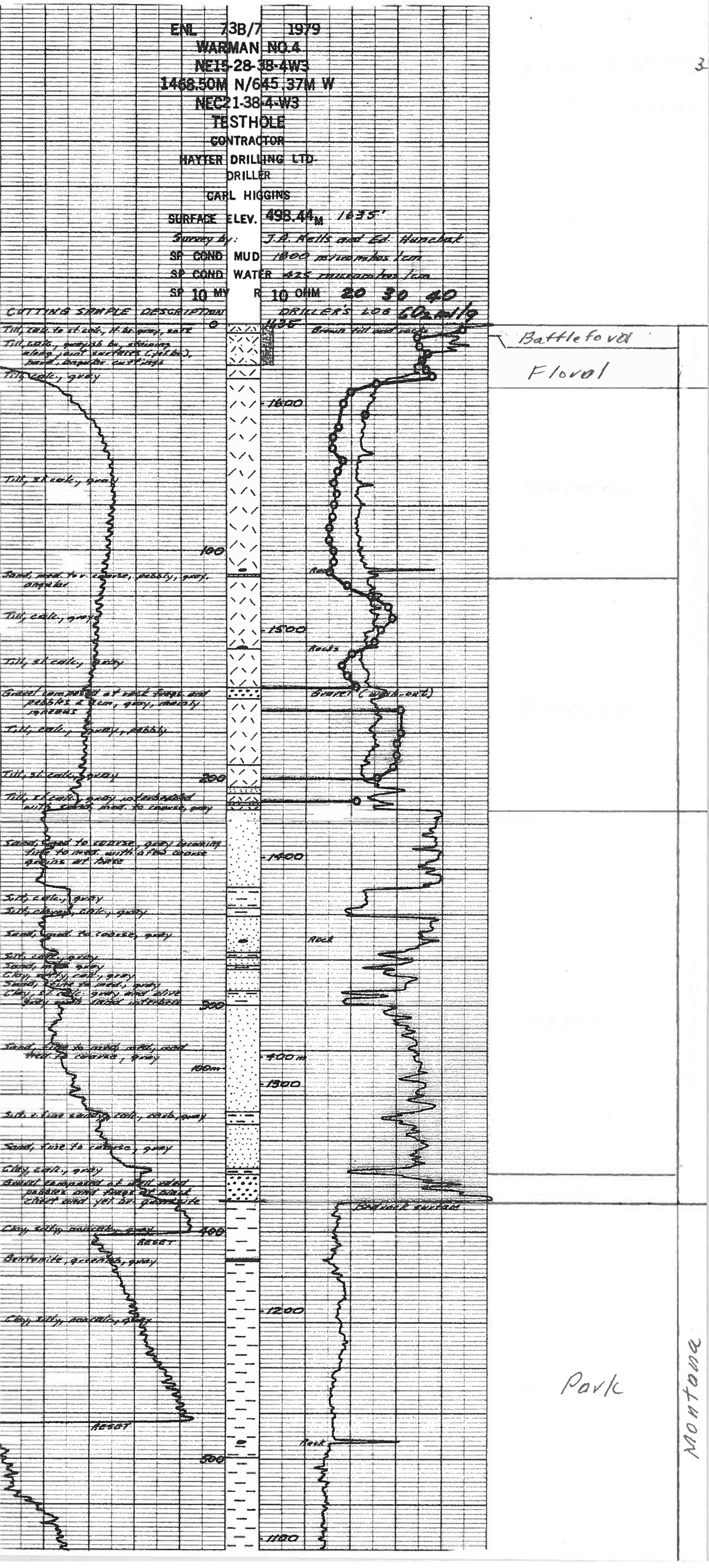
APPENDIX 1. NAME AND LOCATION OF LOGS

Log No.	Name	Location
1	SRC Cory	NE16-27-36-6-W3
2	SRC Saskatoon	NW1-32-36-5-W3
3	SRC Saskatoon City Hall	SE3-33-36-5-W3
4	SRC Saskatoon	NE5-34-36-5-W3
5	SRC Saskatoon	SW11-34-36-5-W3
6	HDC Sutherland	SE3-2-37-5-W3
7	SRC Sutherland	SW12-1-37-5-W3
8	SRC Forestry Farm	SW7-12-37-5-W3
9	SRC Sutherland	SW5-13-37-5-W3
10	SRC Saskatoon	NW14-14-37-5-W3
11	ICL Rochdale	4-26-37-5-W3
12	SRC Clarks Crossing	SE9-26-37-5-W3
13	BA Warman	16-16-38-5-W3
14	FFIB D.H. Brown	NW2-23-38-5-W3
15	ENL Warman No.2	4-28-38-4-W3
16	ENL Warman No.4	NE15-28-38-4-W3
17	Winsal Osler	3-28-39-4-W3
18	NRC Neuhorst	SE1-1-40-5-W3
19	SRC Pike Lake	SE3-18-34-6-W3
20	SRC Pike Lake	SW1-17-34-6-W3
21	SRC Pike Lake	SW4-15-34-6-W3
22	SRC Valley Park	SE1-24-33-6-W3
23	NRC-SRC Whitecap	SE14-15-33-5-W3
24	SRC Camp Dundurn	NE11-24-33-5-W3
25	NRC-SRC Dundurn	NE15-21-33-4-W3
26	NRC-SRC Strehlow	SW4-5-34-3-W3
27	SRC Floral	SE4-2-35-4-W3
28	SRC Clavet	NW4-11-35-4-W3
29	SRC Clavet	NW13-11-35-4-W3
30	SRC Duro	NE16-22-35-4-W3
31	SRC Martins Slough 02	NE16-27-35-4-W3

Log No.	Name	Location
32	MIDAS No.1	4-2-36-4-W3
33	X-PLORE-IT Floral	NE8-3-36-4-W3
34	SRC Floral	NE16-10-36-4-W3
35	MIDAS STH	SW4-14-36-4-W3
36	SRC Floral	SW5-13-36-4-W3
37	MIDAS STH	NE16-12-36-4-W3
38	PCA Saskatoon No.11	3-18-36-3-W3

KEY MAP


ALBERTA
SASKATCHEWAN
MANITOBA
EDMONTON
CALGARY
REGINA
WINNIPEG
HAVRE
HELENA
MONTANA
BISMARCK
NORTH DAKOTA
100 0 100 200
SCALE IN MILES


ENL 73B/7 1979
WARMAN NO.4
NE15-28-38-4W3
1468.50M N/645.37M W
NEC21-38-4-W3
TESTHOLE
CONTRACTOR
HAYTER DRILLING LTD.
DRILLER
CARL HIGGINS
SURFACE ELEV. 498.44M 1635'
SP COND MUD
SP COND WATER
SP 10 MV
R 10 OHM
20 30 40
CUTTING SAMPLE DESCRIPTION
DRILLER'S LOG
Till, calc., grey
Till, sl. calc., grey
Till, calc., grey
Till, sl. calc., grey
Sand, fine to coarse, grey
Clay, calc., grey
Bentonite, greenish, gray
0
100
200
300
100m
400
500
1600
1500
1400
1300
1200
1100
400m
Rock
Battleford
Floral
Park
Montana

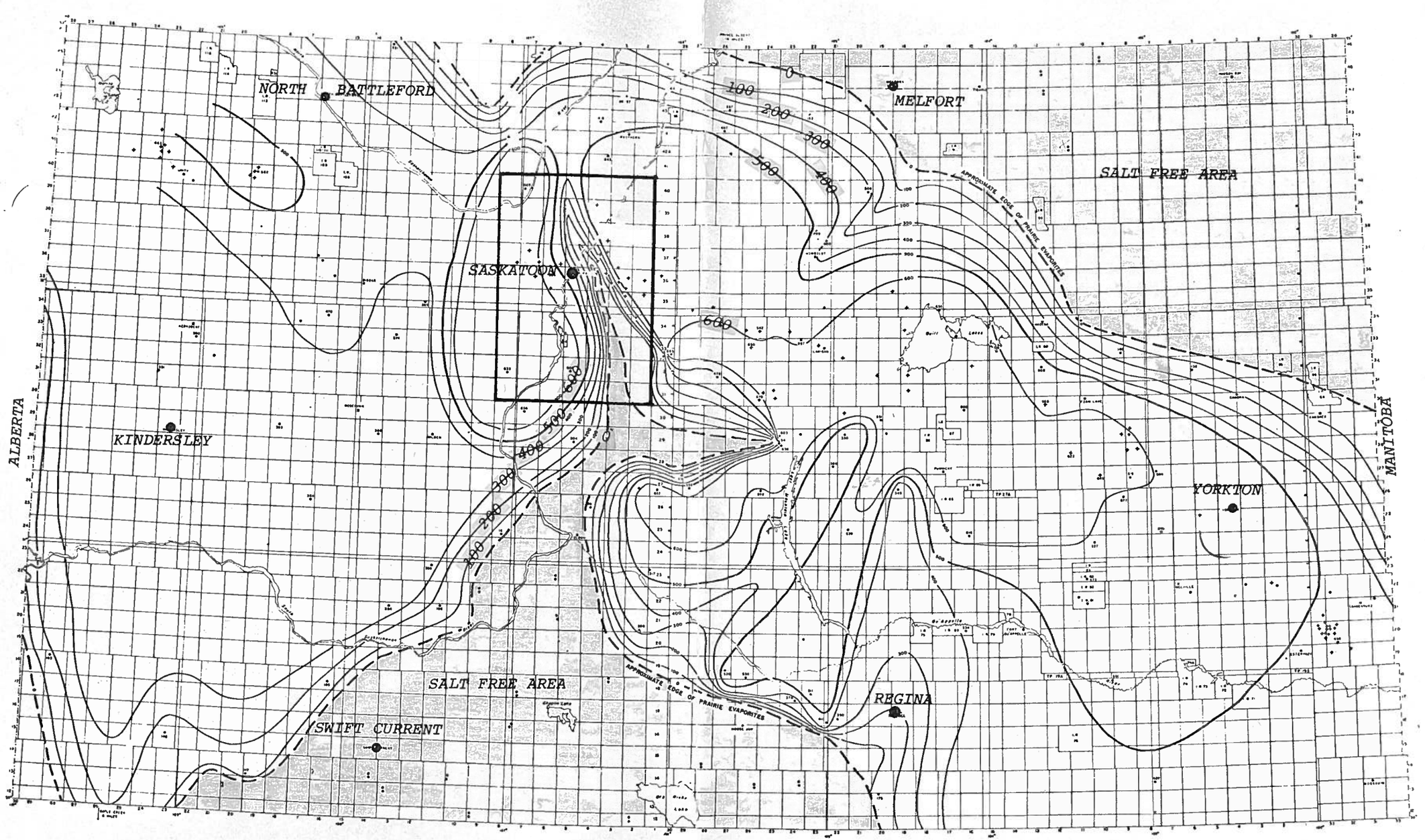


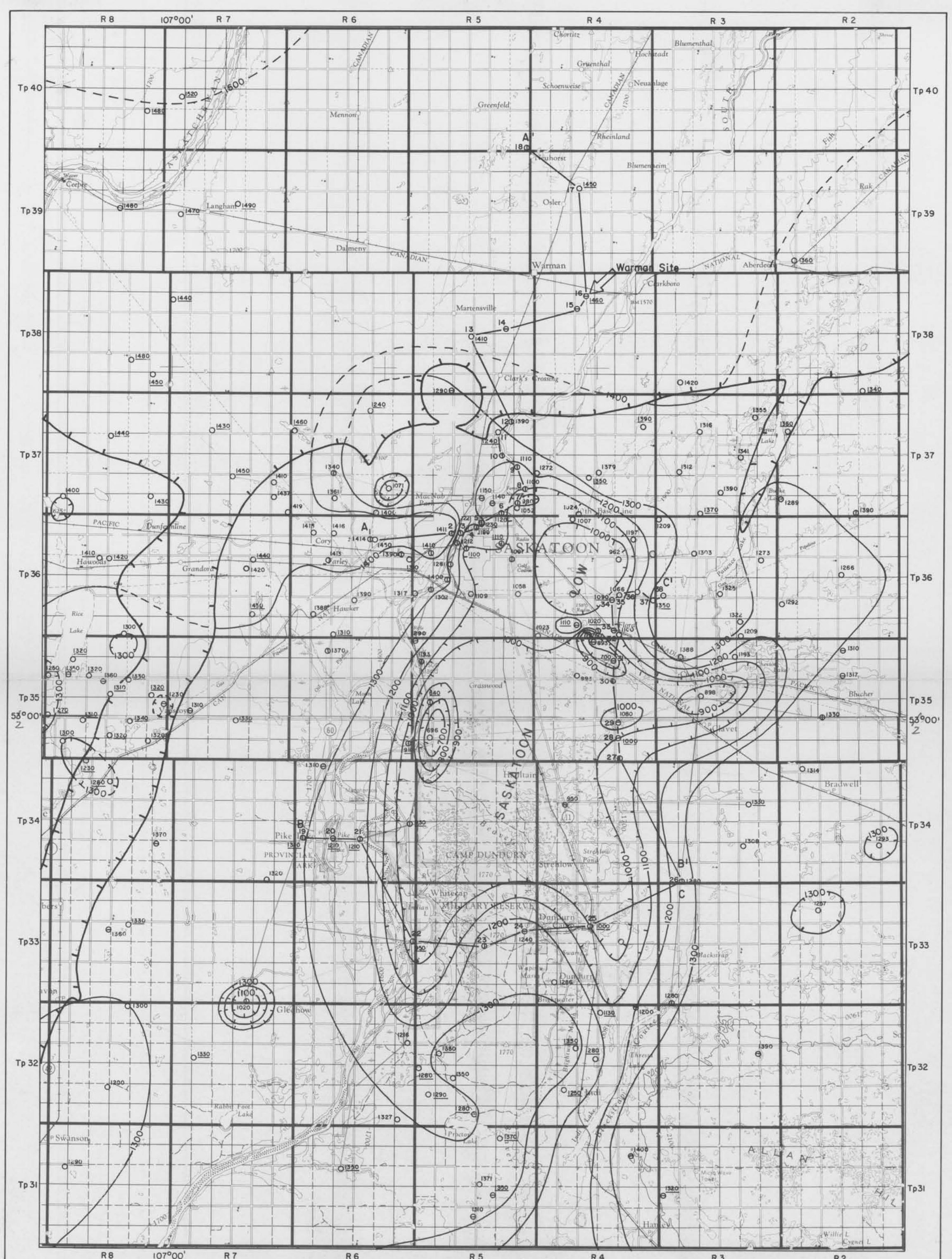
FIGURE 3

ISOPACH MAP

OF THE

PRAIRIE EVAPORITES

LOCATION OF DRAWING 0041-002-01.



- Electric logs, cutting samples, and cores
- Electric logs and cutting samples
- Electric logs
- Augerhole logs

E. A. Christiansen Consulting Ltd.

0 5 10 Miles

0 5 10 Kilometres

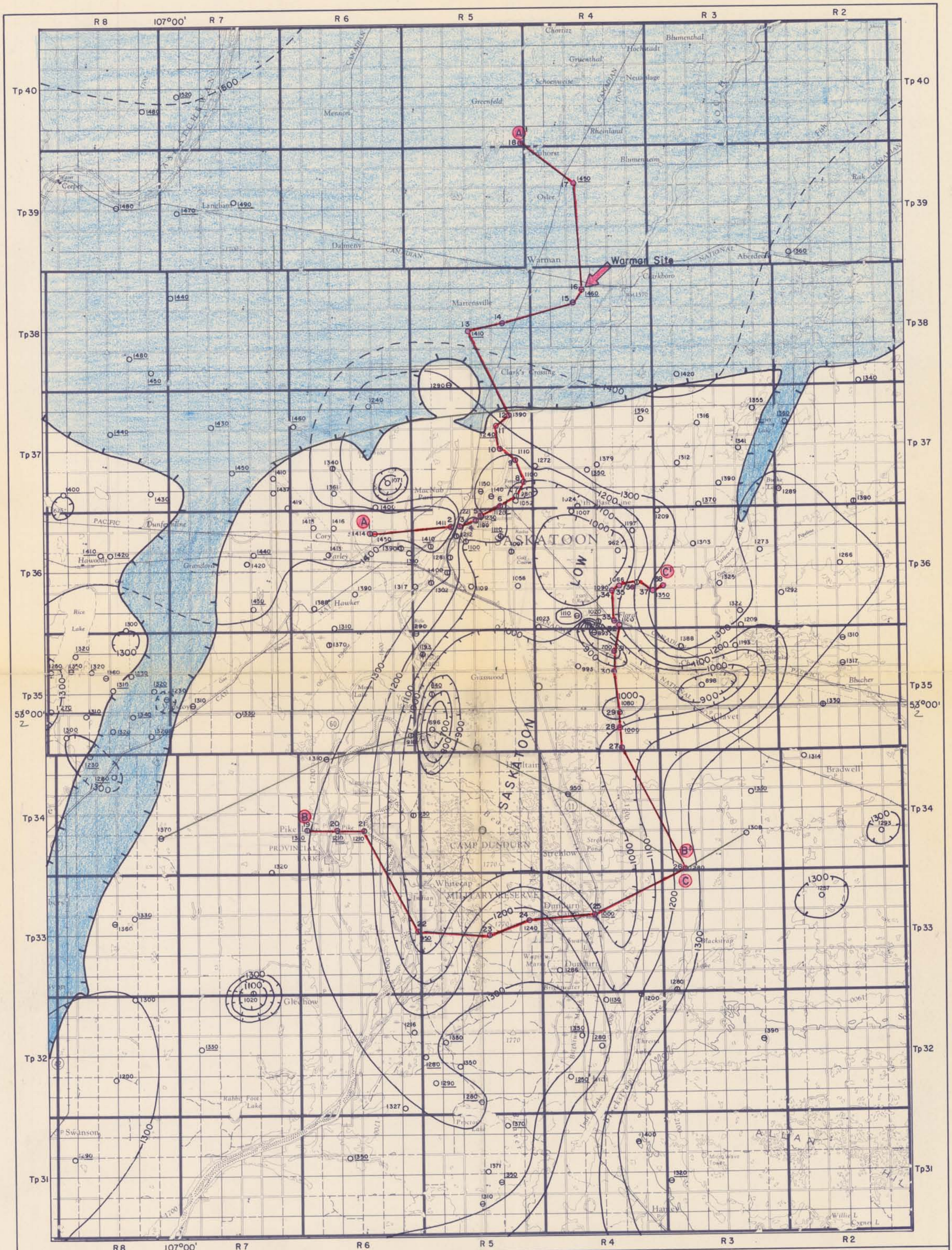
Contour interval, 100 feet

Top of Lea Park Formation and Upper Colorado Group projected above bedrock surface.

1230 Data points projected from marked beds.

Base map by Energy, Mines and Resources, Ottawa

Drawing 0041-002-01. Structural contour map of the top of the Lea Park Formation and Upper Colorado Group in feet above sea level, Contour interval is 100 feet.



- Electric logs, cutting samples, and cores
- Electric logs and cutting samples
- Electric logs
- Augerhole logs

E. A. Christiansen Consulting Ltd.

0 5 10 Miles

0 5 10 Kilometres

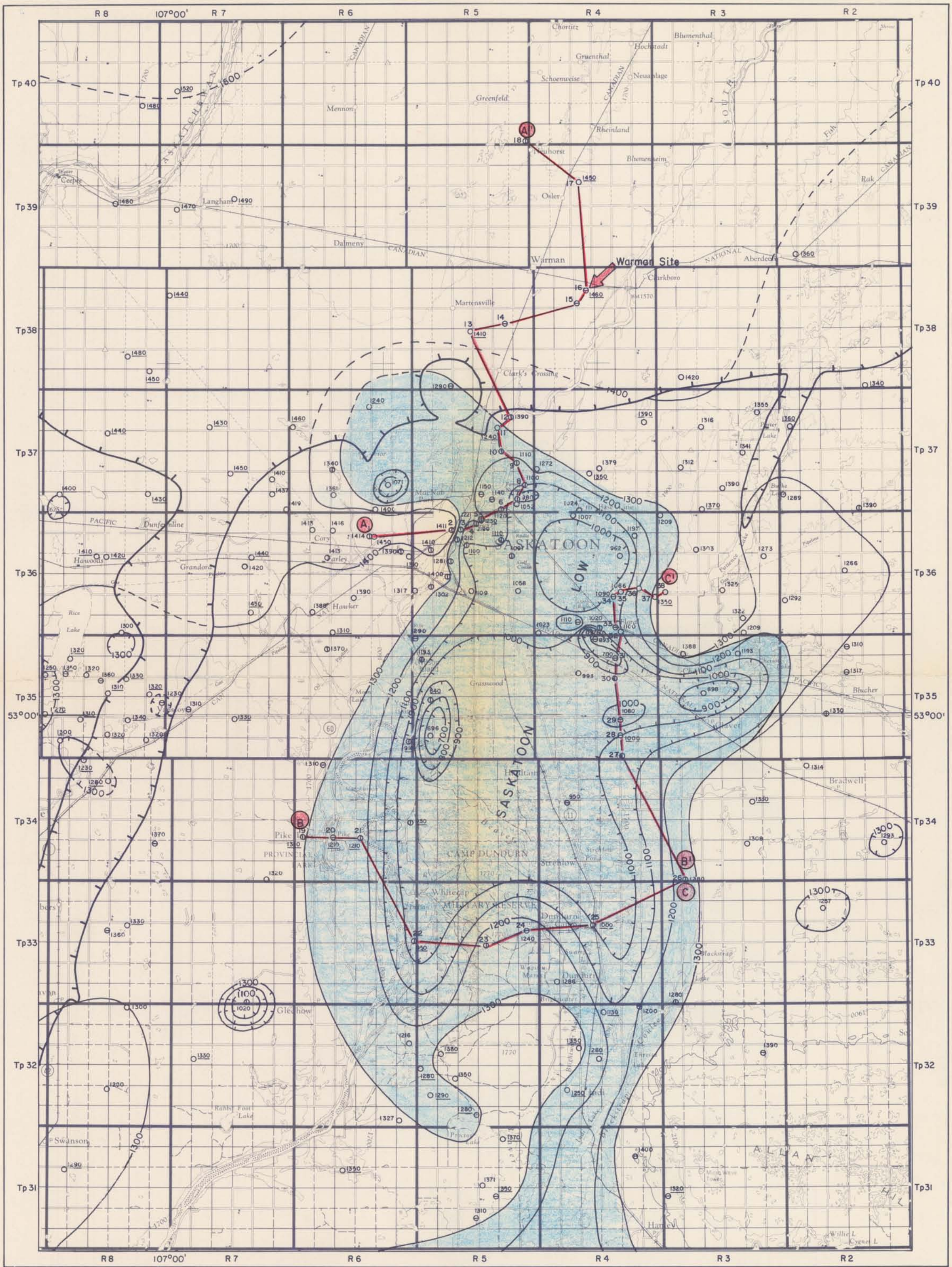
Contour interval, 100 feet

Top of Lea Park Formation and Upper Colorado Group projected above bedrock surface.

1230 Data points projected from marked beds.

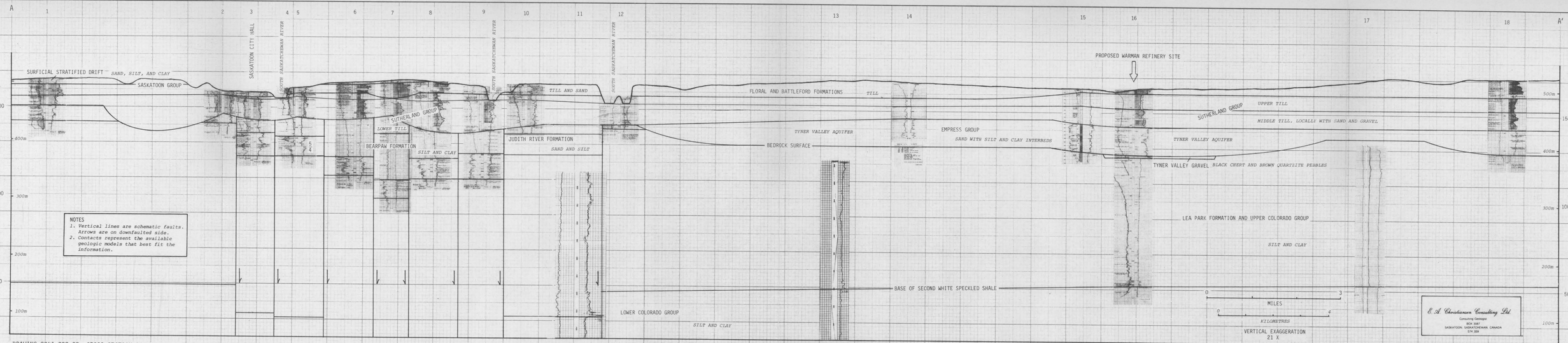
Base map by Energy, Mines and Resources, Ottawa

Drawing 0041-002-01. Structural contour map of the top of the Lea Park Formation and Upper Colorado Group in feet above sea level, Contour interval is 100 feet.



E. A. Christiansen Consulting Ltd.

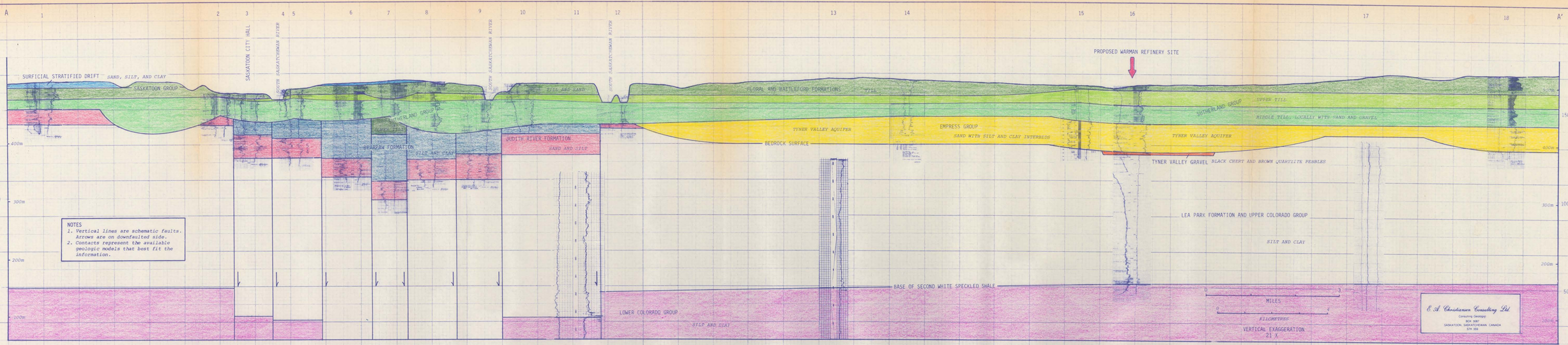
Drawing 0041-002-01. Structural contour map of the top of the Lea Park Formation and Upper Colorado Group in feet above sea level, Contour interval is 100 feet.



DRAWING 0041-002-02. CROSS SECTION AA'.

SEE DRAWING 0041-002-01 FOR LOCATION OF CROSS SECTION

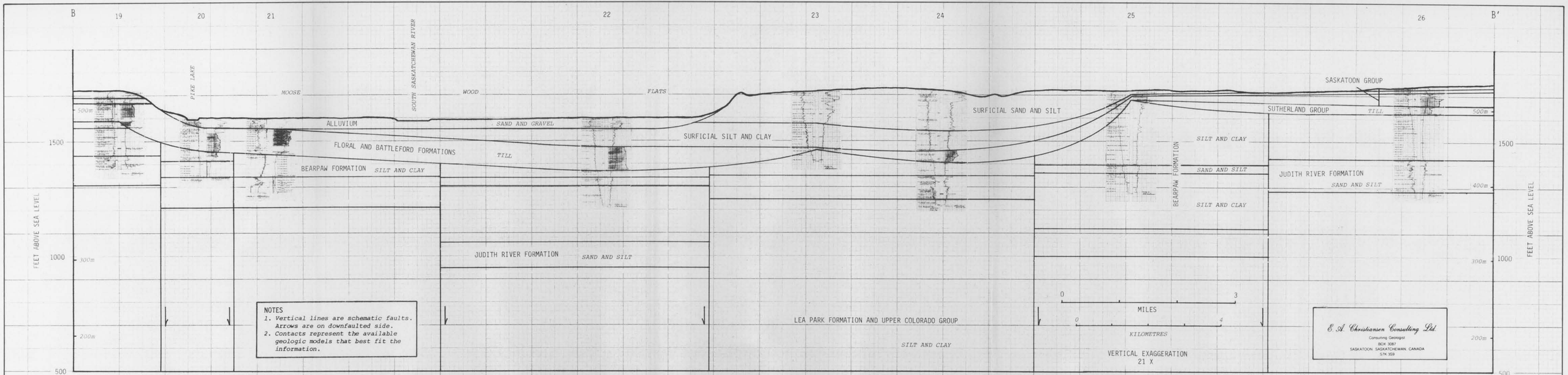
15 - SEE APPENDIX 1 FOR NAME AND LOCATION OF TESTHOLES



DRAWING 0041-002-02. CROSS SECTION AA'.

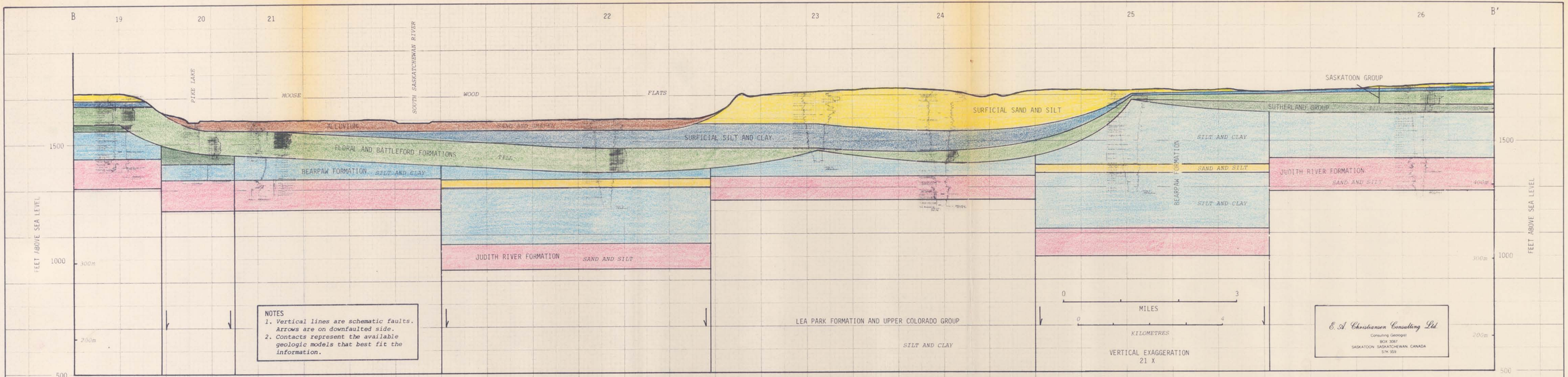
SEE DRAWING 0041-002-01 FOR LOCATION OF CROSS SECTION

15 - SEE APPENDIX 1 FOR NAME AND LOCATION OF TESTHOLES



DRAWING 0041-002-03, CROSS SECTION BB'.

SEE DRAWING 0041-002-01 FOR LOCATION OF CROSS SECTION
20 - SEE APPENDIX 1 FOR NAME AND LOCATION OF TESTHOLES

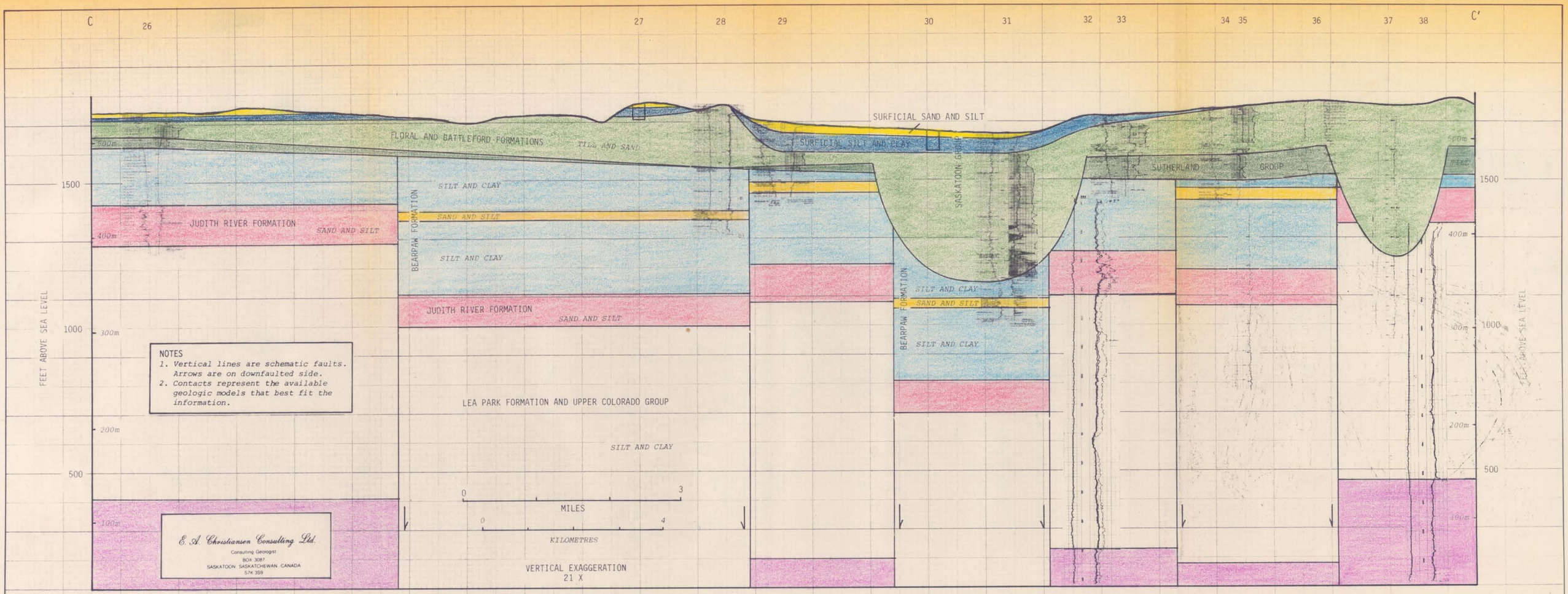


NOTES
1. *Vertical lines are schematic faults. Arrows are on downfaulted side.*
2. *Contacts represent the available geologic models that best fit the information.*

E.A. Christiansen Consulting Ltd.
Consulting Geologist
BOX 3087
SASKATOON, SASKATCHEWAN, CANADA
S7K 3S9

DRAWING 0041-002-03, CROSS SECTION BB'.

SEE DRAWING 0041-002-01 FOR LOCATION OF CROSS SECTION
20 - SEE APPENDIX 1 FOR NAME AND LOCATION OF TESTHOLES



DRAWING 0041-002-04, CROSS SECTION CC'.

SEE DRAWING 0041-002-01 FOR LOCATION OF CROSS SECTION
30 - SEE APPENDIX 1 FOR NAME AND LOCATION OF TESTHOLES

ENL 73B/7 1979

WARMAN NO.4

NE15-28-38-4W3

1468.50M N/645.37M W

NEC21-38-4-W3

TESTHOLE

CONTRACTOR

HAYTER DRILLING LTD.

DRILLER

CARL HIGGINS

SURFACE ELEV. 498.44M 1635'

Survey by: J.A. Halls and Ed. Hunchak

SP COND MUD 1800 micromhos/cm

SP COND WATER 425 micromhos/cm

SP 10 MV R 10 OHM 20 30 40

CUTTING SAMPLE DESCRIPTION

DRILLER'S LOG CO_2 ml/g

BATTLEFORD FM

FLORAL FM

UPPER TILL GROUP

MIDDLE TILL SUTHERLAND GROUP

EMPRESS GROUP

TYNER VALLEY GRAVEL

LEA PARK FORMATION AND UPPER COLORADO GROUP

LOWER COLORADO GROUP

SAND SILT CLAY
2.1 37.7 60.2
% WHT.

SAND SILT CLAY
2.6 36.5 60.9
% WHT.

1176'

E.A. Christiansen Consulting Ltd.

DRAWING 0041-002-05. ENL WARMAN NO.4 TESTHOLE.

ENL 73B/7 1979
WARMAN NO.4
NE15-28-38-4W3
1468.50M N/645.37M W
NEC21-38-4-W3
TESTHOLE
CONTRACTOR
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CUTTING SAMPLE DESCRIPTION
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BATTLEFORD FM
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UPPER TILL GROUP
MIDDLE TILL
SUTHERLAND GROUP
EMPRESS GROUP
TYNER VALLEY GRAVEL
LEA PARK FORMATION AND UPPER COLORADO GROUP
LOWER COLORADO GROUP
RESET
SAND SILT CLAY
2.1 37.7 60.2
% WHT.
SAND SILT CLAY
2.6 36.5 60.9
% WHT.
E.A. Christiansen Consulting Ltd

DRAWING 0041-002-05. ENL WARMAN NO.4 TESTHOLE.