

SASKATCHEWAN WATER CORPORATION

GEOLOGY OF THE MAIN CANALS
IN THE OUTLOOK AREA

REPORT 0101-001

26/10/84

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October 26, 1984

Saskatchewan Water Corporation
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Attention: Mr. Lloyd Barteski

Dear Mr. Barteski:

Enclosed are five copies of Report 0101-001 on the "Geology of the main canals in the Outlook area", as requested by Dr. W.A. Meneley. The report was critically read by Dr. Meneley and his suggested additions and changes have been included. Dr. Meneley wishes to have a copy of the report which I thought should come from you rather than directly from me.

I found the investigation both interesting and informative and look forward to working with you again sometime.

Sincerely yours,

E.A. Christiansen

SUMMARY

The base of exploration for geological framework investigations is the Lea Park Formation, whereas the base of exploration for canal seepage studies ranges from 20 to 60 feet below the present surface. This shallower base of exploration is in silt and clay beneath the upper sand of the Judith River Formation, in the Bearpaw Formation under the Saskatoon Group, and in the Sutherland Group.

Seepage from canals may occur through bedrock sands, deltaic sands, intertill and intratill sands and gravels, and through joints. Comminution of jointed till or bedrock by glacial thrusting may provide permeability barriers to canal seepage.

In studying canal seepage, it is recommended to drill at least one testhole to the base of exploration as defined above and in the cross sections. This information may permit the investigator to raise the base of exploration for the remainder of the study.

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1. INTRODUCTION

1.1 Terms of Reference and Objective

E. A. Christiansen Consulting Ltd. was commissioned by the Saskatchewan Water Corporation (SWC) to provide geological information along WMI, MI, and SSEWS canals which would serve as a stratigraphic framework for detailed investigations of the seepage areas along the canals. During the test drilling program, two additional testholes were requested north of Outlook to provide the geological framework for salinity problems.

More specifically E. A. Christiansen Consulting Ltd. was commissioned to:

1. approve the location of all testholes and supervise the drilling, sampling, sample descriptions, electrical logging, and abandonment of each testhole;
2. compile geological and other relevant information on the original electric logs;
3. compile longitudinal and cross sections for each canal studied;
4. supervise auger test drilling;
5. train SWC staff to carry out rotary drilling and augering programs.

1.2 Location

The locations of the WMI, MI, and SSEWS canals are shown in Drawing 0101-001-01 which is herein called the Outlook area. Longitudinal sections A-A' B-B' and D-D' and cross sections C-C' and E-E' are also shown in this drawing. The location of this drawing is shown in Figure 1.

1.3 Previous Work

The geology and hydrogeology of the proposed Conquest reservoir site was evaluated by Meneley and Christiansen (1970), and the geology and groundwater resources of the Outlook area were investigated regionally by Christiansen and Meneley (1971). The surficial geology of the study-area was investigated by Scott (1971).

In addition to these more regional studies, a "Canal leakage investigation" along the SSEWS canal between the Broderick and Brightwater reservoirs was conducted by Clifton Associates Ltd. (1983).

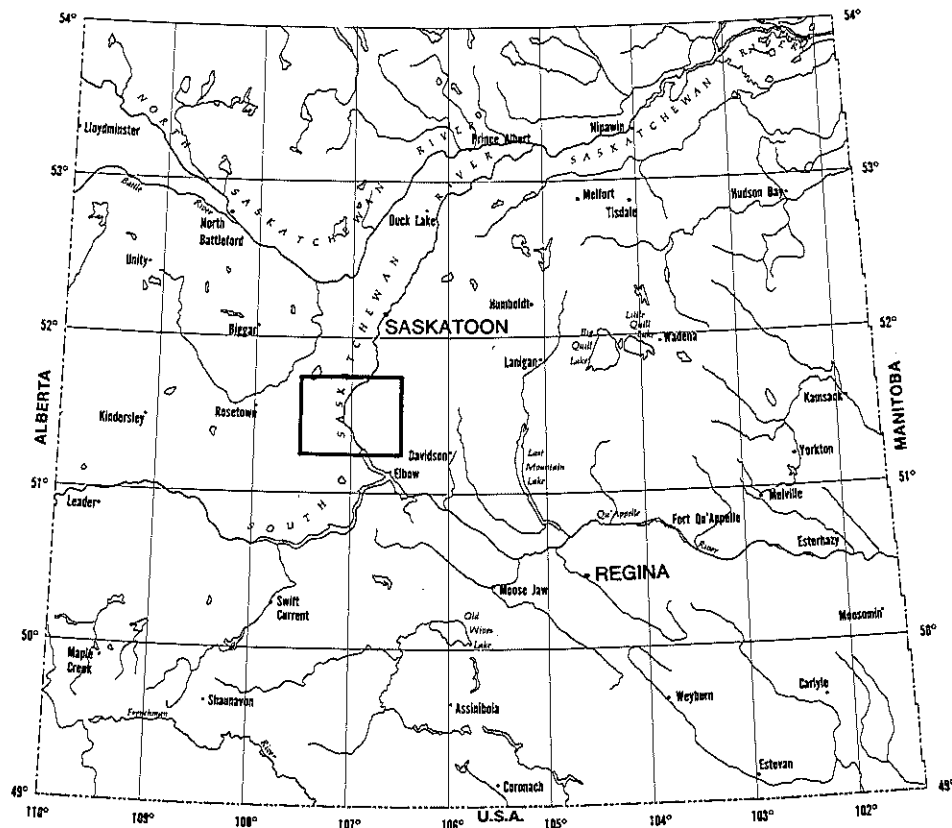


Figure 1. Location of Outlook area.

Papers on collapse structures (Christiansen, 1967, 1971; Gendzwill and Hajnal, 1971), Pleistocene stratigraphy (Christiansen 1968 a,b), and the history of deglaciation (Christiansen, 1979) are the bases for discussions on these subjects.

1.4 Present Study

This study is based on information from the Saskatchewan Research Council, Family Farm Improvement Branch, and on 17 rotary testholes and 4 augerholes which were drilled, sampled, and electric logged for the purpose of this investigation.

Samples from the 17 testholes and 4 augerholes were described and interpreted (Appendices 1,2). The samples were described with the aid of hydrochloric acid to test for carbonates, a Munsell Color Chart, and a hand lens. Tills were submitted for total carbonate and mechanical analyses to characterize and differentiate them (Appendices 3,4).

1.5 Acknowledgements

Messrs. L. Barteski and C.A. Rogal assisted with the auger drilling program, and Mr. Rogal assisted with the rotary test drilling program.

2. GEOLOGY

2.1 Introduction

The bedrock and glacial deposits in ascending order include the Lea Park Formation and Upper Colorado Group, Judith River and Bearpaw Formations, and Empress, Sutherland, and Saskatoon Groups (Fig. 2).

2.2 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 Group is about 1,000 feet thick in the study-area, and the upper one half is composed of gray, noncalcareous, nonmarine silt and clay which becomes

ERA	PER.	EPOCH	SOUTHERN ALBERTA	NORTHEASTERN MONTANA	SOUTHERN SASKATCHEWAN	NORTHWESTERN NORTH DAKOTA	SOUTHWESTERN MANITOBA
CENOZOIC	QUAT.	PLEISTOCENE	GLACIAL DRIFT	GLACIAL DRIFT	GLACIAL DRIFT	GLACIAL DRIFT	GLACIAL DRIFT
	TERTIARY	PLIOCENE		FLAXVILLE	EMPRESS		
		MIOCENE			WOOD MOUNTAIN		
		OLIGOCENE			CYPRESS HILLS	WHITE RIVER	
		Eocene			SWIFT CURRENT CREEK	GOLDEN VALLEY	
		PALEOCENE		SENTINEL BUTTE		SENTINEL BUTTE	
			PORCUPINE HILLS	TONGUE RIVER		TONGUE RIVER	
				LEBO	RAVENS CRAG		
			WILLOW CREEK	TULLOCK		LUDLOW	TURTLE MOUNTAIN
						CANNONBALL	
MESOZOIC	CRETACEOUS	UPPER	BATTLE (KNEE HILLS)	HELL CREEK	FRENCHMAN	HELL CREEK	
			WHITEMUD	COLGATE	BATTLE WHITEMUD	COLGATE	BOISSEvain
			ST. MARY RIVER	FOX HILLS	EASTEND	FOX HILLS	
			BLOOD RESERVE				
			BEARPAW	BEARPAW	BEARPAW		
			JUDITH RIVER (BELLY RIVER)	JUDITH RIVER	JUDITH RIVER	PIERRE	RIDING MOUNTAIN
			CLAGGETT (PAKOWKI)	CLAGGETT	LEA PARK		

A

PERIOD	EPOCH	GROUP	STRATIGRAPHIC UNITS	
QUATERNARY	RECENT	SASKATOON	Surficial Stratified Drift	Alluvium
	PLEISTOCENE		Battleford Formation	Glacial Lake Sediments
			Floral Formation	
		SUTHERLAND	Upper Till	
			Middle Till	
			Lower Till	
		EMPRESS		
			?	
	TERTIARY			

B

Figure 2. Correlation charts of: (A) Upper Cretaceous and Tertiary formations in southern Saskatchewan and adjacent areas. From Whitaker et al. (1978) and (B) Quaternary deposits.

slightly sandy as the overlying Judith River Formation is approached. The top of the Lea Park Formation and Upper Colorado Group was the base of exploration for the geological investigation in the study-area.

2.3 Judith River Formation

The Judith River Formation is composed of 150-190 feet of gray, noncalcareous, carbonaceous sand, silt, and clay with thin coal seams (Drawings 0101-001-02-06). In Testhole 17 (Drawings 0101-001-01,05), the Judith River Formation was penetrated by the canal. In testhole 8 (Drawings 0101-001-01,03), on the other hand, the top of the Judith River Formation is 950 feet below the present surface.

Testholes 16, 17 and 21 in the vicinity of Section 18, Township 30, Range 5 (Drawing 0101-001-01) show that the Judith River Formation dips about 150 feet per mile to the SSW or about 2 degrees. This explains the presence of Bearpaw "shale" beneath drift at testhole 16 and the disappearance of the Judith River "sandstone" north of testhole 17.

The Judith River Formation is a nonmarine, deltaic deposit which extends eastward into marine sediments (Fig.3).

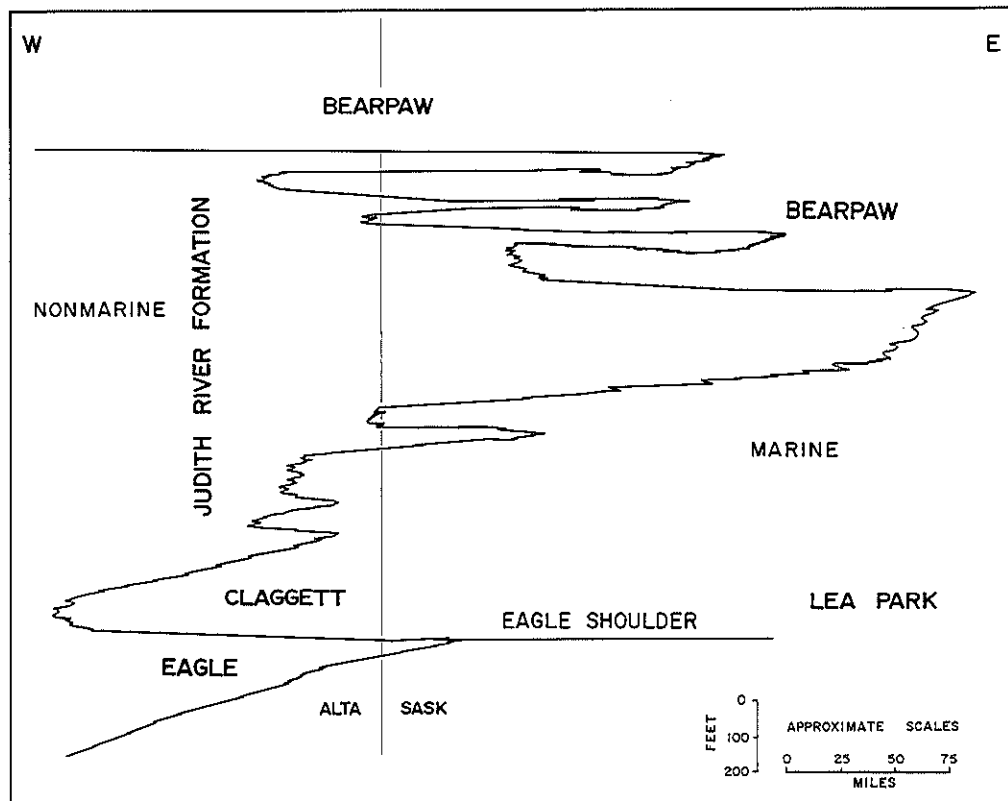


Figure 3. Schematic cross section of intertonging nonmarine sand and silt and marine silt and clay in the Canadian Great Plains. From McLean (1971).

2.4 Bearpaw Formation

The Bearpaw Formation is composed of gray, noncalcareous, marine silt and clay with a 50-foot marine sand bed believed to be the Ardkenneth Member (Drawings 0101-001-02 03,05). The Bearpaw Formation is preserved only in down-faulted blocks where it escaped both fluvial and glacial erosion.

2.5 Empress Group

The Empress Group, which was named by Whitaker and Christiansen (1972), is composed of gravel, sand, silt, and till lying between bedrock and till (Drawings 0101-001-02,03,04,06). Chert and quartzite gravel in testhole 9 (Drawing 0101-001-03) suggests a preglacial valley, whereas the abundance of granite gravel in testhole 19 (Drawing 0101-001-06) suggests a glacial valley.

2.6 Sutherland Group

The Sutherland Group, which was named by Christiansen (1968a), has a lower electrical resistance and a lower carbonate and higher clay content than the Saskatoon

Group. The mean carbonate content of tills in the Sutherland Group is 15.5 ± 3.8 mL CO₂ per gram, whereas the overlying tills of the Saskatoon Group have a mean carbonate content of 20.6 ± 5.2 mL CO₂ per gram (Appendix 3). The more clayey Sutherland Group tills have a mean sand, silt, and clay content of $37 \pm 2\%$, $32 \pm 3\%$, and $31 \pm 2\%$, whereas the Saskatoon Group has a mean sand, silt, and clay content of $53 \pm 5\%$, $26 \pm 2\%$, and $21 \pm 5\%$ on an untreated basis (Appendix 4). The contact between the Sutherland and Saskatoon Group is distinct where the upper part of the Sutherland Group is weathered. This weathering zone is commonly olive in color and contains joints with yellowish-brown staining and gypsum veinlets.

The Sutherland Group is composed of Lower, Middle, and Upper tills (Drawing 0101-001-02,03). The mean carbonate contents of the Lower, Middle, and Upper tills are 14.6 ± 4.1 , 17.5 ± 2.6 , and 11.8 ± 2.9 mL CO₂ per gram (Appendix 3). Sample descriptions suggest that the Middle till is more sandy than the Lower and Upper tills. Recent, unpublished work has shown that the Upper till is a separate stratigraphic unit rather than a "partly leached" zone as described by Christiansen (1968a).

2.7 Saskatoon Group

The Saskatoon Group, which was named by Christiansen (1968a), is composed in ascending order at Floral, (Christiansen, 1968a) and Battleford formations (Christiansen, 1968b) and Surficial Stratified Drift. The scale of the cross sections (Drawings 0101-001-02-06), for the most part, does not permit separation of these units.

The Floral Formation is composed mainly of till, sand, and silt. The upper part of the formation is commonly weathered to grayish-brown color with yellowish-brown iron oxide and black manganese oxide stainings on well-developed joint surfaces.

The Battleford Formation, which is commonly less than 10 feet thick, is composed mainly of soft, unjointed, and unstained till. In some localities, the formation is composed also of a harder, lower till which commonly contains comminuted weathered till from the underlying Floral Formation. Commonly only the upper softer till, which is generally 5 to 10 feet thick, represents the Battleford Formation. The harder, lower till is interpreted as a "lodgment till", whereas the softer, upper till is considered to be an "ablation till" released during the melting of the glacier.

The upper contact with the overlying Surficial Stratified Drift is commonly gradational with a mixed zone of till and stratified drift separating the two units.

2.8 Surficial Stratified Drift

Most of the Surficial Stratified Drift in the study-area is glacio-lacustrine, eolian, and alluvial in origin. The glacial lake sediments grade from a lower lacustrine silt and clay unit to an upper deltaic sand and silt (Drawing 0101-001-06). The fining downward in texture suggests these sediments are inwash derived from the extraglacial South Saskatchewan River.

Eolian sand covers a buried soil developed on glacial lake deposits in testhole 20 (Drawing 0101-001-06, Appendix 2). These sands have encroached from the dune area to the east. A few feet of silty, very-fine sand covers the deltaic deposits in the vicinity of testhole 19 (Drawing 0101-001-06). These deposits are believed to be loess derived mainly from the South Saskatchewan River valley. Cliff-top eolian deposits along the top of the valley attest to the presence of eolian activity in the area.

Alluvial sand and silt have been deposited in the South Saskatchewan River valley during and since the last deglaciation. At the Outlook Bridge (Drawing 0101-001-01, testhole 24), the alluvium is composed of 118 feet of sand and silt (testhole 24, Appendices 1,2). This testhole is the basis for showing alluvium in Drawing 0101-001-06.

3. GEOLOGICAL PROCESSES

3.1 Introduction

Collapse, glacial thrusting, regressive offlap and transgressive onlap are the most important geological processes that were operative in the study-area.

3.2 Collapse

Christiansen (1967) showed that the bedrock deposits south of Saskatoon were collapsed to form the "Saskatoon Low". Christiansen (1971) demonstrated that Crater Lake lies in a collapse structure, and Gendzwill and Hajnal (1971) showed that the collapse was the result of dissolution of salt (Fig. 4). The effect of this dissolution of

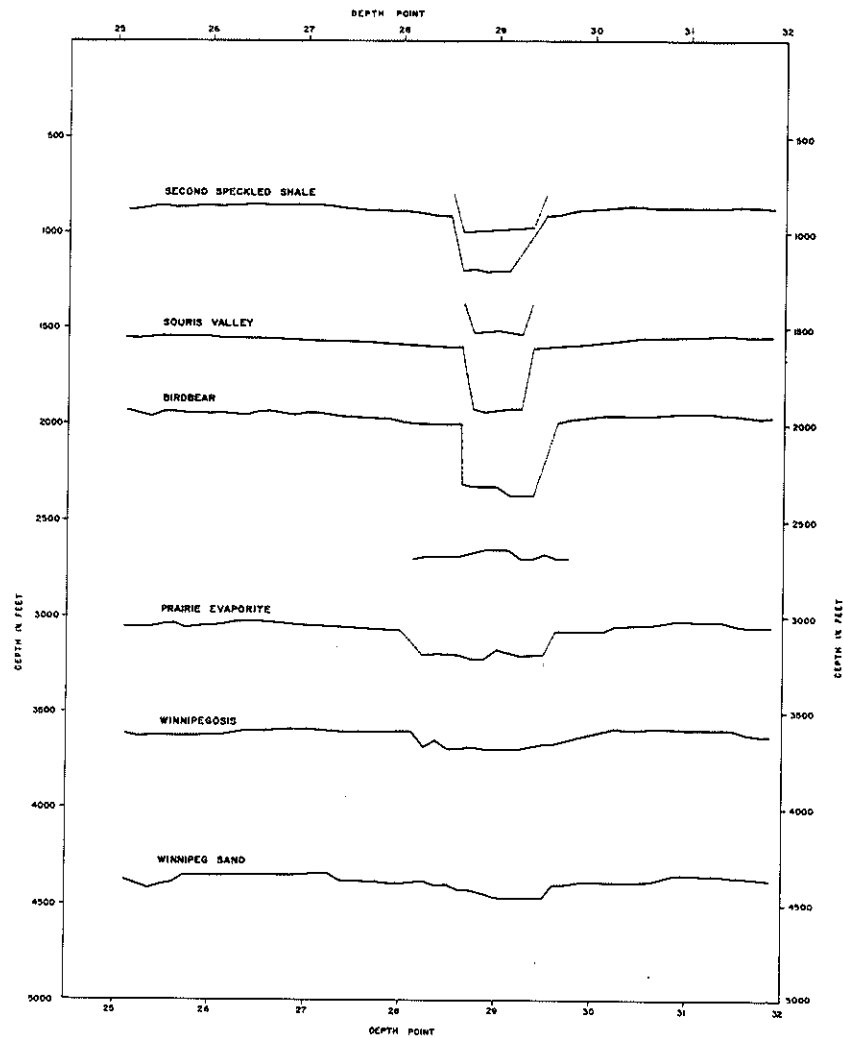


Figure 4. Seismic cross section of Crater Lake structure formed by dissolution of Devonian Prairie Evaporite salt. From Gendwill and Hajnal (1971).

Devonian, Prairie Evaporite salt is shown in Figure 5. From this thickness map, it appears that the entire Devonian salt section is present at testholes 17 and 18 (Drawing 0101-001-05), for example, and appears to be entirely absent at testhole 9 (Drawing 0101-001-03). Whether the beds in the structure have continuity as shown or have been offset by gravity faulting is uncertain. Recent, unpublished work by Gendzwill (personal communication) suggests that some beds have not been offset.

3.3 Glacial Thrusting

Glacial thrusting occurred near the margin of the glacier where drift and/or bedrock were eroded from the ice-thrust depression and carried upward along diverging flowlines (Fig. 6). This glacial thrusting model explains the upward-facing, concave surfaces shown in (Drawings 0101-001-02,03,06). The brecciated bedrock in testhole 16 (Drawing 0101-001-05) and the fractured and slickensided bedrock in testhole 20 (Drawing 0101-001-06) are attributed to glacial thrusting.

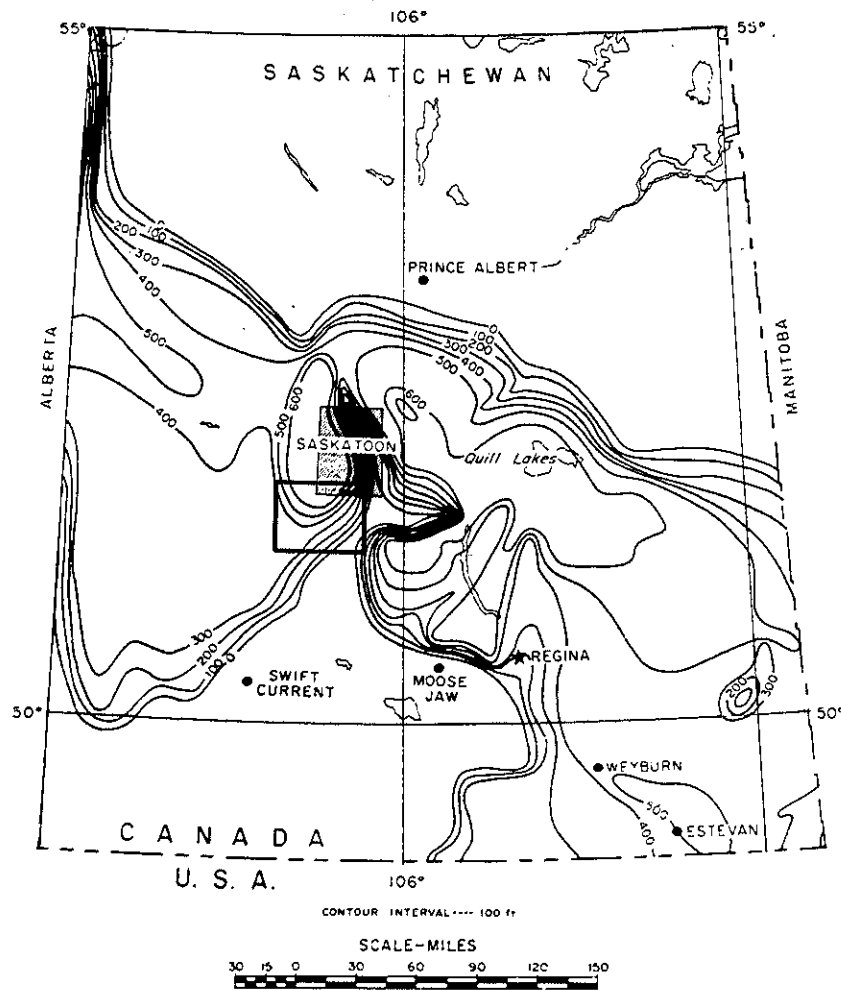


Figure 5. Thickness of Devonian Prairie Evaporite salt. From Pearson (1963).

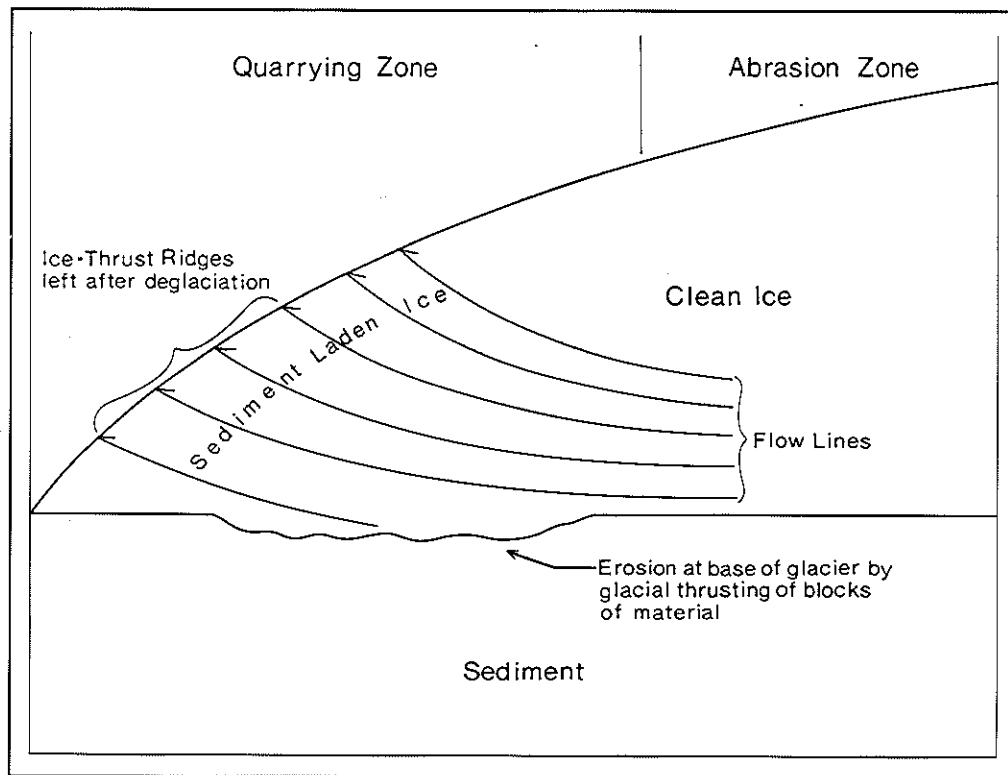


Figure 6. Schematic diagram showing the process of glacial thrusting. From Christiansen and Whitaker (1976).

During the augering program, comminuted Floral Formation was observed in the lodgement till of the Battleford Formation, and comminuted, oxidized bedrock was observed over jointed and stained Bearpaw Formation (testhole 16, Drawing 0101-001-05). In the latter example, this comminuted bedrock may act as a permeability barrier to seepage. These comminuted sediments are interpreted as ice-thrust deposits formed at the base of ice by glacier shearing.

3.4 Regressive Offlap and Transgressive Onlap

Where the South Saskatchewan River entered Lake Saskatchewan near Outlook, deltaic sands were deposited with finer-grained silts and clays being deposited farther north into the lake. As the glacier retreated, the lake level fell and the shoreline receded causing the delta to prograde with the receding shoreline. As the delta prograded, deltaic sands were deposited on lacustrine silts and clays forming an upward coarsening sequence by the process of regressive offlap.

If the lake level should rise in response to a glacial re-advance, and this is known to have occurred further north, the shoreline would transgress shoreward, and newly

deposited deltaic sand would be laid down on previously deposited deltaic sediments. This process is called transgressive onlap which results in sediments becoming coarser grained with depth.

4. GEOLOGICAL HISTORY

4.1 Cretaceous Period

During late Cretaceous (Upper Cretaceous, Fig. 2A), the Outlook area was covered by shallow seas into which rivers from the Cordilleran emptied forming retrograding and prograding deltas as the sea levels rose and fell. The Judith River Formation represents such nonmarine, deltaic deposits, whereas the clayier Lea Park and Bearpaw Formations were deposited in shallow seas eastward beyond the deltas (Fig. 3). The marine Ardkeneth Member was formed by a prograding delta during the deposition of the Bearpaw Formation. According to Obradovich and Cobban (1975), late Cretaceous extended from 94 to 64 million years ago.

4.2 Tertiary Period

During the Tertiary Period from 69 to 3 million years ago, the Outlook area presumably received nonmarine gravel, sand, silt, and clay from streams originating in the rapidly rising Cordillera to the west. These streams formed alluvial plains of chert and quartzite gravel and brown sand, silt, and clay, the remnants of which are called Swift Current Creek, Cypress Hills, and Wood Mountain formations (Fig. 2A). Most of these sediments were removed from the Outlook area by fluvial and glacial erosion. The chert and quartzite gravels in testhole 9 (Drawing 0101-001-03) were derived presumably from one of these formation by fluvial erosion.

4.3 Quaternary Period

The Quaternary Period covers the last two to three million years of the earth's history and is composed of the Pleistocene and Recent Epochs. In late Tertiary or early Quaternary, the previously mentioned alluvial plains in the Outlook area were dissected by the Tyner Valley (Drawing 0101-001-01). The valley containing the chert and quartzite gravels at testhole 9 (Drawings 0101-001-03) is believed to be a tributary of the Tyner Valley.

As the continental glaciers advanced southwestward through the Outlook area, they eroded the Upper Cretaceous and Tertiary deposits leaving only remnants of the latter and diverted the drainage from the northeast to the southwest. Weathered zones in the upper parts of the Lower, Middle, and Upper tills suggest that the Sutherland Group was deposited during three separate, distinct glaciations. Although only one till appears to be present in the Floral Formation of the study-area, two and possibly three are present in the Saskatoon area.

The Floral and Battleford formations are separated by another interglacial interval that commenced more than 38,000 years ago and ended about 20,000 years ago when the last glacier advance across the study-area.

During the last deglaciation, the ice retreat across the Outlook area between about 14,000 and 1200 years ago (Figs. 7,8,9). About 14,000 years ago (Fig. 7), the Outlook area started to appear from beneath the glacier. Lake Saskatchewan drained through the Whitebear, South Saskatchewan, and Thunder spillways into Lake Regina.

Between 14,000 and 12,500 years ago the Anerley Spillway drained water from Lake Saskatchewan into the South Saskatchewan Spillway which in turn drained into the

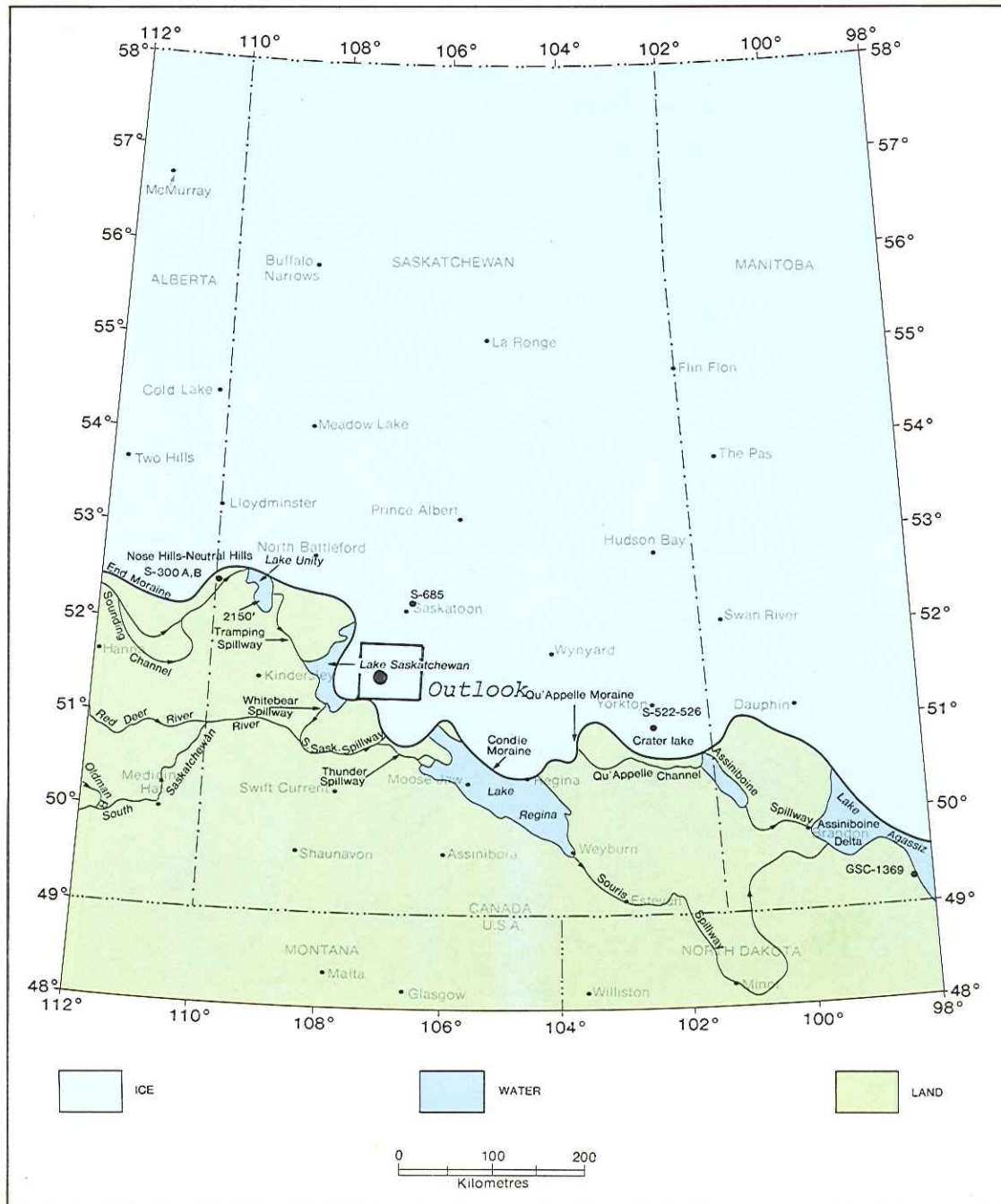


Figure 7. History of deglaciation about 14,000 years ago.
From Christiansen (1979).

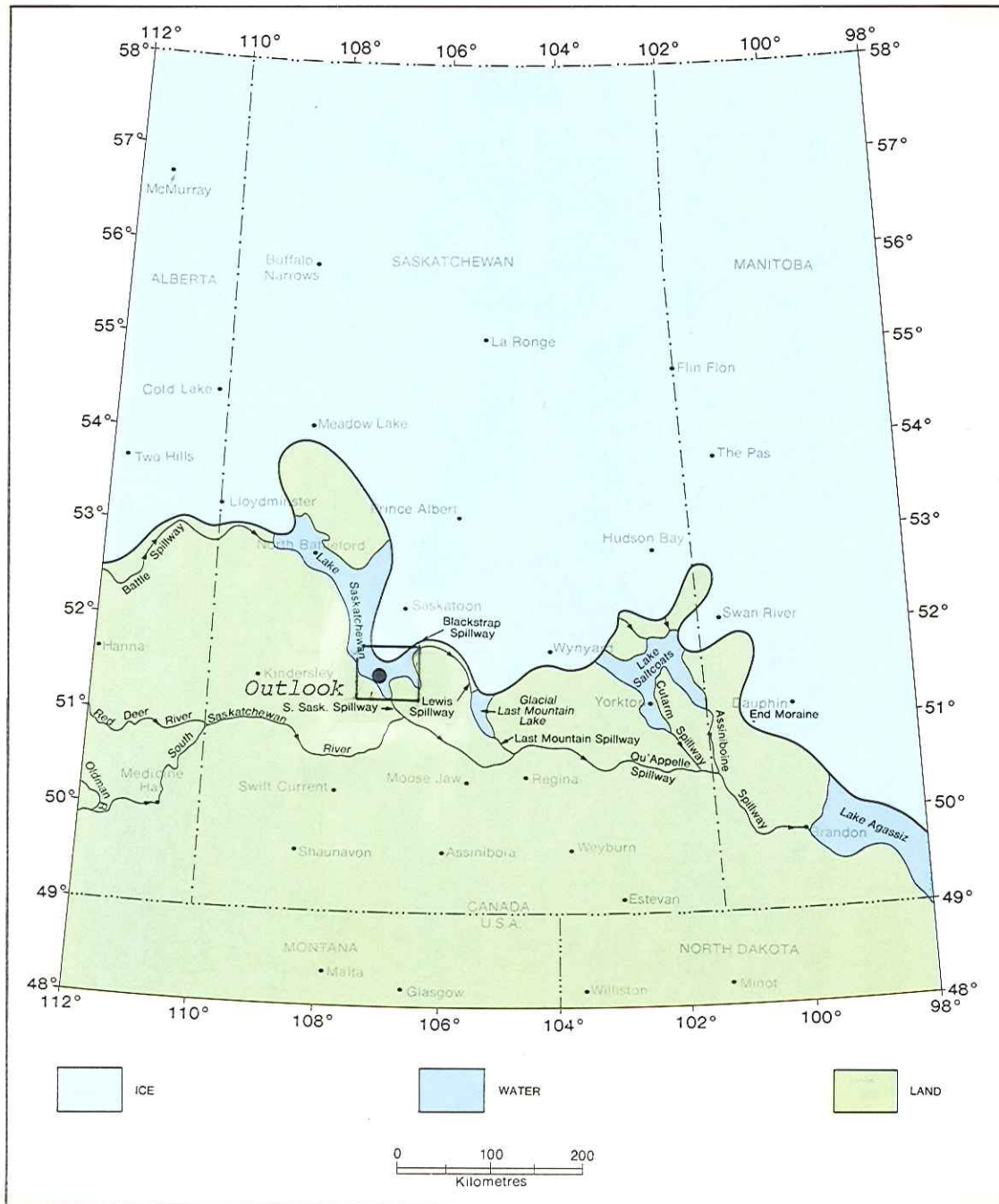


Figure 8. History of deglaciation about 12,500 years ago.
From Christiansen (1979).

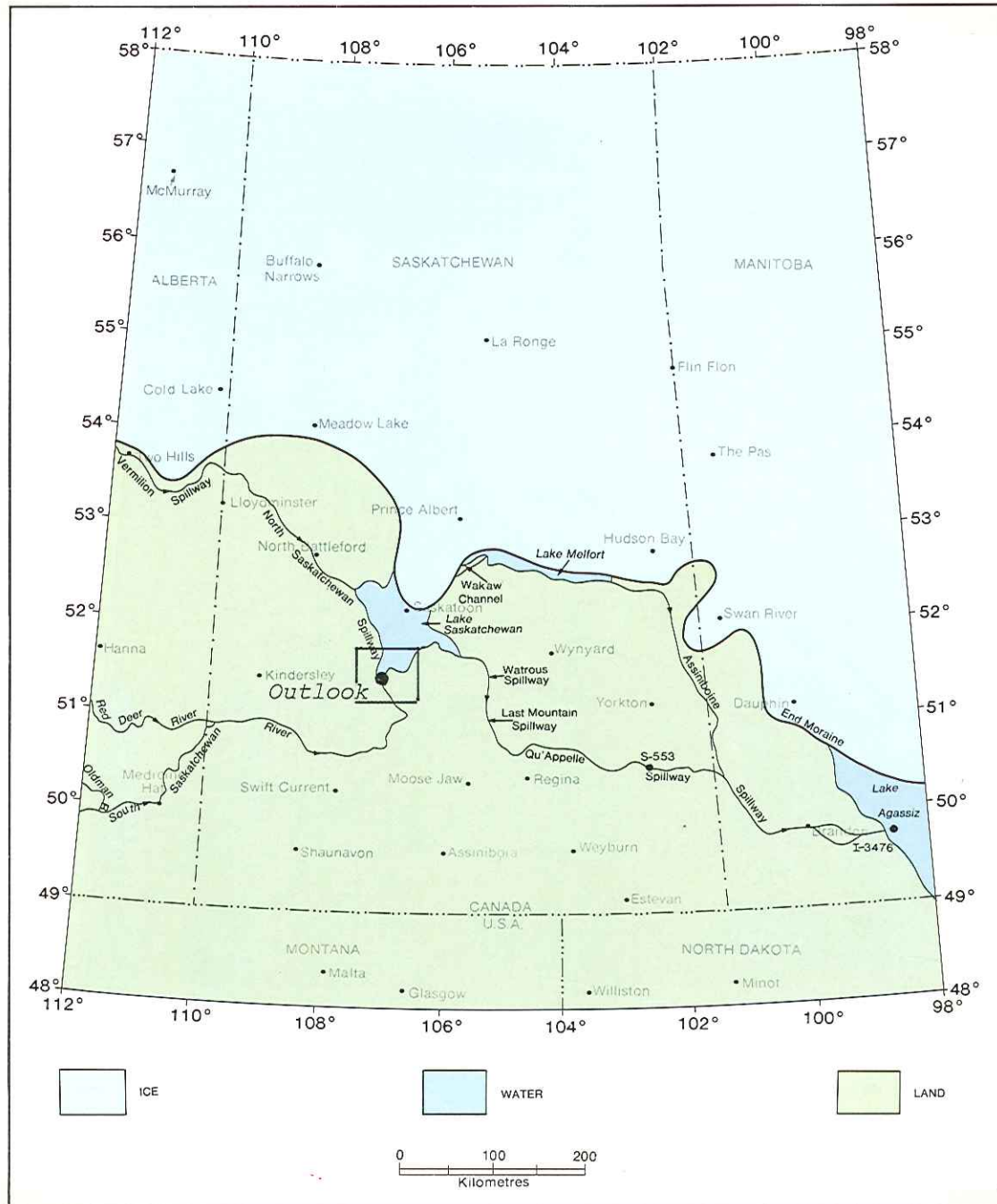


Figure 9. History of deglaciation about 12,000 years ago.
From Christiansen (1979).

Qu'Appelle Spillway. The gravel deposits south of Coteau Bay, which were used during the construction of the Gardiner Dam, are believed to have formed at this time.

About 12,500 years ago (Fig. 8), Lake Saskatchewan drained through the South Saskatchewan Spillway into the Qu'Appelle Spillway and through the Blackstrap Spillway, glacial Last Mountain Lake, and the Last Mountain Spillway into the Qu'Appelle Spillway.

Between 12,500 and 12,000 years ago, the flow in the South Saskatchewan River valley was reversed. Instead of flowing southeastward as in Figure 8, it flowed northwestward into Lake Saskatchewan at Outlook (Fig. 9). It was at this time that the deltaic sands and silts were deposited in the vicinity of Outlook (Drawing 0101-001-06). Between 12,000 and 11,500 years ago, Lake Saskatchewan receded from the Outlook area. Except for continued downcutting by the South Saskatchewan River in response to a lower base level of erosion as a result of glacier retreat, the effect of glaciation in the Outlook area was over.

The North Saskatchewan River and presumably the South Saskatchewan River began the process of aggradation about 11,000 years ago (Christiansen, 1983). Since that time the South and North Saskatchewan River valleys have received up to 120' of alluvial sands and silts.

After the drainage of Lake Saskatchewan, deltaic sands were reworked into parabolic dunes, which for the most part, are now stabilized. Such eolian activity placed a cover-sand over a soil developed on clays laid down in Lake Saskatchewan at testhole 20 (Drawing 0101-001-06). In addition to dunes, cliff-top loess was deposited adjacent to the South Saskatchewan River valley.

During the formation of the South Saskatchewan River valley, retrogressive landslides started to form when the bedrock clays were penetrated. Work on the Denholm landslide (Christiansen, 1983) would suggest that the landslides in the Outlook area may be still moving. Except for gullying, spring sapping, mass wastage, loessial activity, and some sedimentation in depressions, few changes have taken place in the landscape during the Recent Epoch.

5. SEEPAGE MODELS

5.1 Introduction

Seepage from canals may occur through bedrock sands, deltaic sands, intertill and intratill sands and gravel, and through joints.

5.2 Bedrock Sands

In the northern part of the Outlook area, sands of the Judith River Formation occur in the upper 20 feet. At testhole 17 (Drawing 0101-001-05), these sands were penetrated during the excavation of the canal. It is conceivable that sands of the Ardkenneth Member may be present near enough to the surface to also become a seepage path.

5.3 Deltaic Sands

Soils north of Outlook in the vicinity of testhole 19 (Drawing 0101-001-06) are developed in less than three feet of eolian silty sand overlying medium to very coarse grained deltaic sand. Because local relief is low,

infiltration of irrigation water causes the water table to rise sufficiently close to the surface in places to form saline soils.

5.4 Intertill and Intratill Sands and Gravels

Sands and gravels are known to occur between the Floral and Battleford tills and within the Floral Formation. Where such deposits of sands and gravels occur, continuity over extensive areas should be contemplated. Locally, within the Floral and Battleford formations, ice-thrust lenses of sands and gravels are also known to occur. Where such deposits of sands and gravels form seepage paths from the canal, leakage can be anticipated.

5.5 Joints

Joints occur in weathered tills of the Floral Formation and Sutherland Group and in the upper part of the Bearpaw Formation in testholes 16 and 21 (Drawing 0101-001-01). Whether these joints extend through the unoxidized tills and Bearpaw Formation is not known. It is known, however, that joints in the weathered zone are sufficiently open to receive precipitates of iron and manganese oxides and veinlets of gypsum. It is generally conceded that

vertical permeability is enhanced by joints, but there is less certainty about the effect of joints on horizontal permeability. If joints enhance horizontal permeability, they could be the most important conductor of seepage because of their almost continuous occurrence. Detailed geotechnical or hydrogeological studies, however, will be required to resolve this problem.

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Appendix 1. Index of Geologic Logs.

No.	Name	Location
1	FFIB J. D. Forsberg	NE-16-32-26-07-W3
2	FFIB Roy Lee	SE-04-07-27-07-W3
3	SWC Conquest WM1-84-RH-02	NW-06-04-28-08-W3
4	SWC Conquest WM1-84-RH-01	SW-10-17-28-08-W3
5	SWC Conquest WM1-84-RH-03	SE-12-20-28-08-W3
6	SWC Conquest WM1-84-RH-05	NE-01-02-29-09-W3
7	SSRIP Conquest No. 2	SW-03-18-30-09-W3
8	SRC Cutbank	SE-01-06-27-06-W3
9	SWC Outlook M1-84-RH-04	NW-14-13-27-07-W3
10	SWC Outlook M1-84-RH-03	NW-04-02-28-07-W3
11	SWC Outlook M1-84-RH-02	SE-15-28-28-07-W3
12	SWC Outlook M1-84-RH-01	SE-04-16-29-07-W3
13	SWC Outlook M1-84-RH-05	SE-09-29-28-07-W3
14	SWC Outlook M1-84-RH-06	NW-13-26-28-07-W3
15	Rankin Glenside	NW-10-17-29-06-W3
16	SWC Broderick SSEWS-84-RH-03	NW-13-07-30-05-W3
17	SWC Broderick SSEWS-84-RH-01	SW-01-19-30-05-W3
18	SWC Broderick SSEWS-84-RH-04	SE-02-31-30-04-W3
19	SWC Outlook SSRID-84-RH-02	NE-14-03-30-08-W3
20	SWC Outlook SSRID-84-RH-01	NW-13-06-30-07-W3
21	SWC Broderick SSEWS-84-RH-02	SW-04-17-30-05-W3
22	SWC Conquest WM1-84-RH-04	NE-12-16-28-08-W3
23	SSRIP Conquest No. 49	NW-15-12-30-09-W3
24	SDH Outlook	SW-03-16-29-08-W3

Appendix 2. Geological Logs.

1

01 Reckin Drilling

CONTRACTOR'S TELEPHONE NUMBER 306544-2428 OR R CONTRACTOR'S ADDRESS Box 263

OWNER'S NAME Harley OWNER'S ADDRESS SOG REC

03 D. Eonsberg

OWNER'S TELEPHONE NUMBER 306243-14270 OR R OWNER'S ADDRESS Box 128

TEST - C.I. MUNICIPAL LAND LOCATION NE32-26-7-W3 RURAL VARIETY (R) OR LOCAL IMPROVEMENT DISTRICT (LID) OR INDIAN RESERVATION (IR) 255

DATE TESTHOLE COMPLETED 22/08/75

LOGS OPERATORS NAME Alvin Reckin DATE TESTHOLE LOGGED 22/08/75

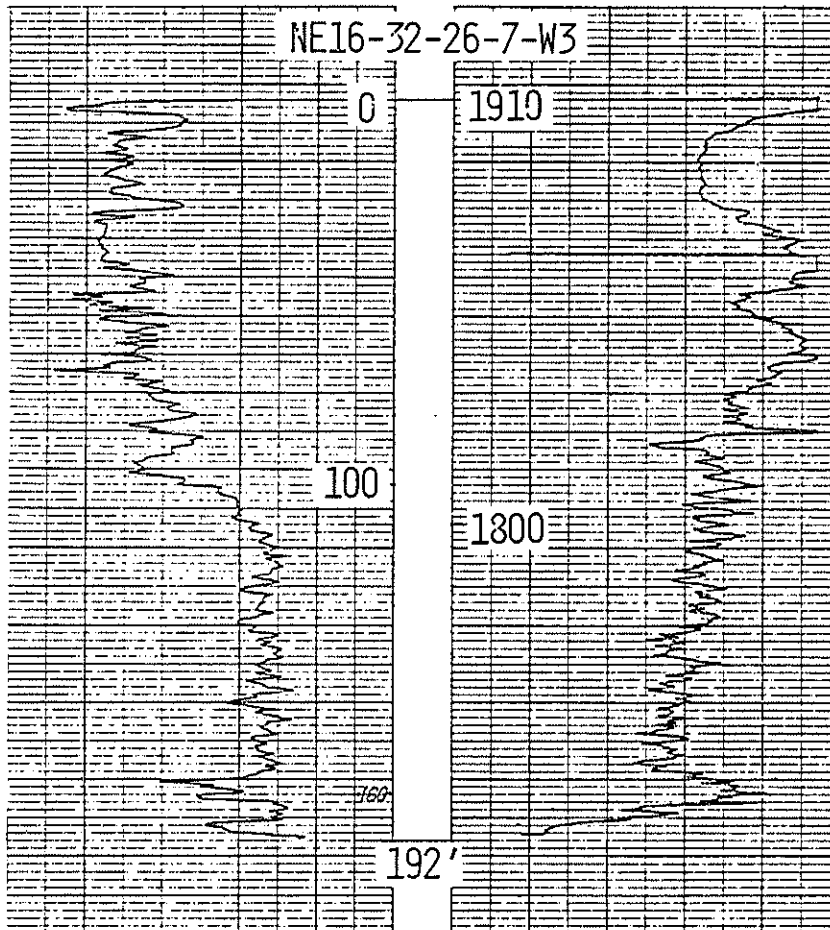
TRADE NAME OF LOGGER Wideo

TYPE OR MODEL OF LOGGER YALD

SERIAL NO. OF LOGGER 90 ACCREDITATION DATE 18/8/73

SINGLE-POINT RESISTANCE 10 OHMS/INCH

LOG SCALES 10 millivolts/mch



TESTHOLE MUNICIPAL LAND LOCATION			DATE TESTHOLE COMPLETED
NE32-26-7-W3			22/8/75
DEPTH	TO	DRILLER'S LOG AND PROPOSED RECORD	
0	80	Till, gray, aspage, wet	
80	83	Clay, blue	
83	84	Sand, medium, wet	
84	120	Clay & shale, blue	
120	195	Bedrock mixture	
No well recorded.			

2

72-01

ELECTRIC LOG

TEST DRILLING ASSISTANCE PROGRAM

FAMILY FARM IMPROVEMENT BRANCH
SASKATCHEWAN DEPARTMENT OF AGRICULTURE
1318 WINNIPEG STREET, REGINA, S.S. S4T 0B5

ACQUISITION NO. 0000

GROUP NO. 0000

DRILLING CONTRACTOR: COMPANY NAME 01 HAYTER DRILLING LTD.

CONTRACTOR'S TELEPHONE NUMBER 02 306 9461 OR R1

CONTRACTOR'S ADDRESS BOX 404

SIGNATURE: NAME AND DATE MATROUS SOX 4/10

OWNER'S NAME 03 ROY, J.E.

OWNER'S TELEPHONE NUMBER 04 306 2431 OR R1

OWNER'S ADDRESS MACROBIE SQ. 250

TESTHOLE: MUNICIPAL LAND LOCATION 05 S.W. 7-27-7-13 RURAL NUMBER 283 DISTRICT NO. 283 INDIAN RESERVATION (R1)

DRILLER'S NAME 06 ROY, J.E. DATE TESTHOLE COMPLETED 14/04/82

LOGGING OPERATOR'S NAME 07 ROY, J.E. DATE TESTHOLE LOGGED 14/04/82

CONDUCTIVITY: DRILLING FLUID 08 250 CONDUCTIVITY: DRILLING WATER 900

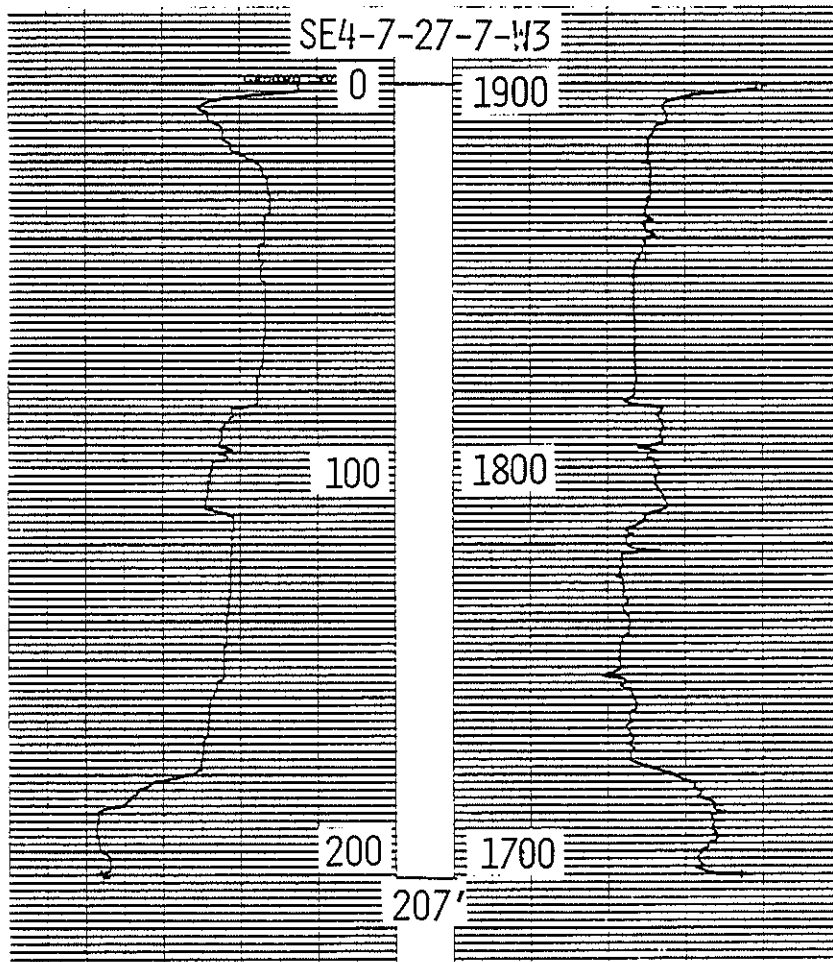
DEPTH: DRILLED 09 207' DEPTH: LOGGED 207'

BIT DIAMETER 10 4.37 TRADE NAME OF LOGGER WLOGO

SPONTANEOUS POTENTIAL 11 1.0 TYPE OR MODEL OF LOGGER 1200

SINGLE-POINT RESISTANCE 13 24 SERIAL NO. OF LOGGER 14 171051/174

LOG SCALES 15 1.0 JAMES J. JONES



2

TESTHOLE MUNICIPAL LAND LOCATION			DATE TESTHOLE COMPLETED
SWOT-27 - 07-W3			15/04/82
DEPTH m	DEPTH ft	TESTHOLE LOG AND PROCEDURE RECORD	
0	1	GRAVEL	
1	4.9	TILL, brown	
4.9	8.4	TILL, gray	
8.4	11.0	SILT, gray	
11.0	12.1	SHALE	
12.1	12.2	CONCRETION	
12.2	17.8	SHALE	
17.8	18.5	SAND, silty	
18.5	20.0	SAND, clean	
20.0	20.1	SAND, interbedded	
20.1	22.7	CONCRETION	
Well description:			
Screenless casing: dia 5", length 19.0'			
Screen dia 4", length 0', net 20.0'			
Well bottom 20.1'			
Static water level 16.5'			
Pump test - 4hr at 316pm			
Recommended 316pm from 19.5'			
100%			

3

SWC 720/6 1984
CONQUEST WM1-84-RH-02
NW-06-04-28-08-W3
13:355600E/5692200N
TESTHOLE

1623' E. AND 95' S. OF EL/4C-5-28-8-W3

SURFACE ELEV. 1894 FT

SURVEY

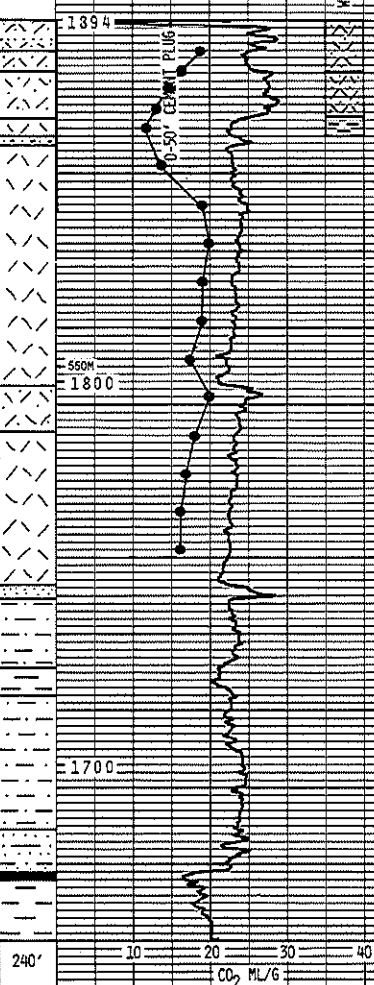
SP COND MUD 625 MICROSEIMENS/CM AT 25° C

SP COND WATER 475 MICROSEIMENS/CM AT 25° C

SP 10 MV R 10 OHMS

CUTTING SAMPLE DESCRIPTION

0-
TILL, SANDY, ST. CALC., LT. BR. GR.
TILL, CALC., BR., UNSTAINED, SOFT
TILL, SANDY, CALC. GR. BR., VEL. BR. STAINS, HARD
TILL, SL. CALC., DK. GR. BR.
SAND AND GRAVEL (E-LOG)
20M
TILL, SL. CALC., GR.-DK. GR.
100M
TILL, CALC., OL. GR.
40M
TILL, SL. CALC., GR.-DK. GR.
200M
SAND (E-LOG)
SILT, SANDY, CALC., CARB., LT. GR.+ DK. GR.
CLAY, SILTY, CALC., CARB., LT. GR.+ DK. GR.
SILT, ST. CALC., CARB., GR.+ DK. GR.
SAND AND SILT, ST. CALC., GR.+ OL. GR.
BENTONITE, NONCALC., LT. GR.+ DK. GR., + OL. GR.
CLAY, NONCALC., GR.



SASKATOON GROUP

UPPER TILL

MIDDLE TILL

LOWER TILL

EMPRESS GROUP

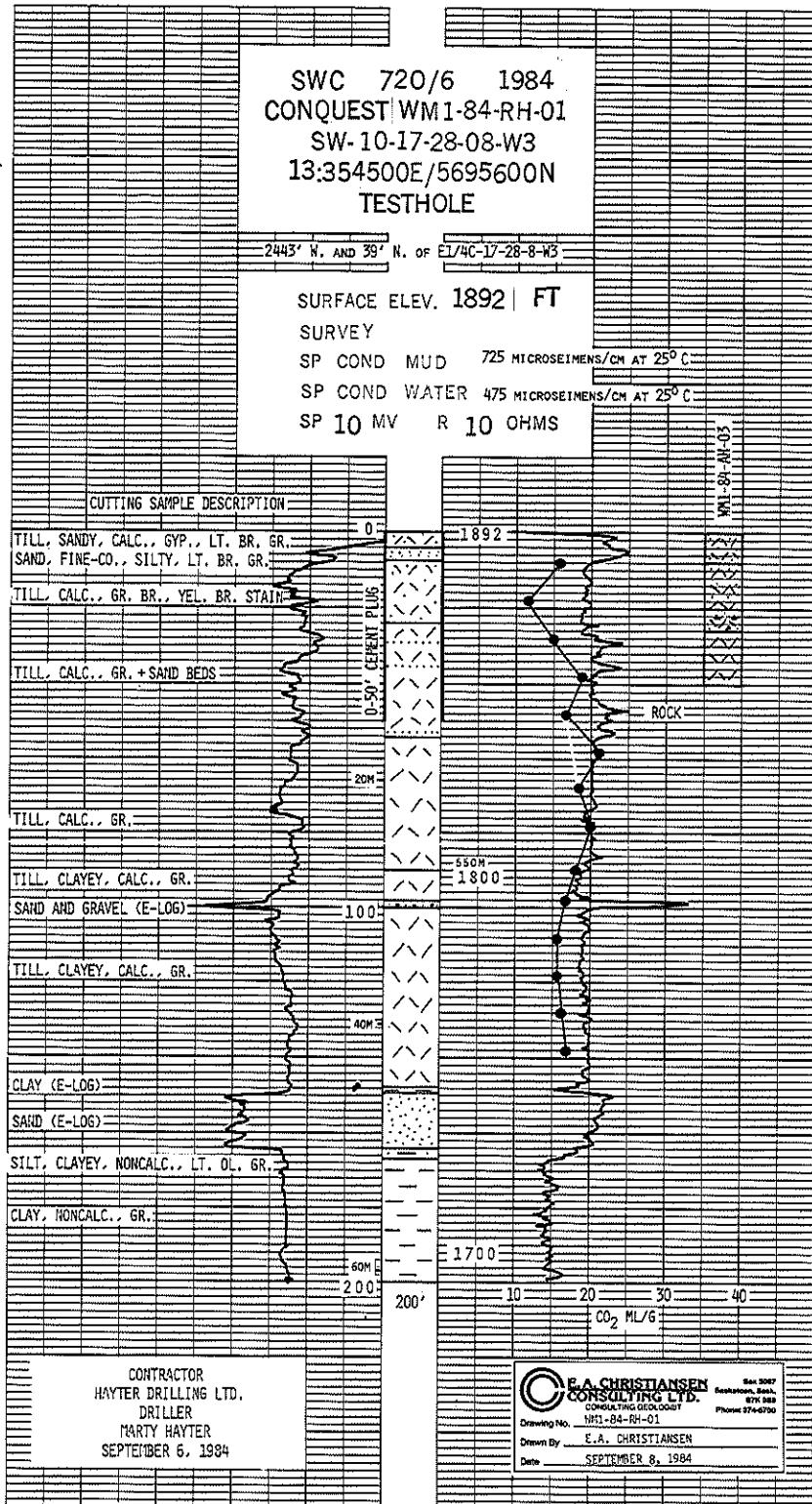
BEARPAW FORMATION

CONTRACTOR
HAYTER DRILLING LTD.
DRILLER
MARTY HAYTER
SEPTEMBER 5, 1984

E. A. CHRISTIANSEN
CONSULTING LTD.
CORPORATE GEOLOGIST
Drawing No. WM1-84-RH-02
Drawn By E. A. CHRISTIANSEN
Date SEPTEMBER 8, 1984
Box 2087
Saskatoon, Sask.
S7N 3B8
Phone 274-4700

E. A. Christiansen Consulting Ltd.

4



SASKATOON GROUP

UPPER TILL

MIDDLE TILL

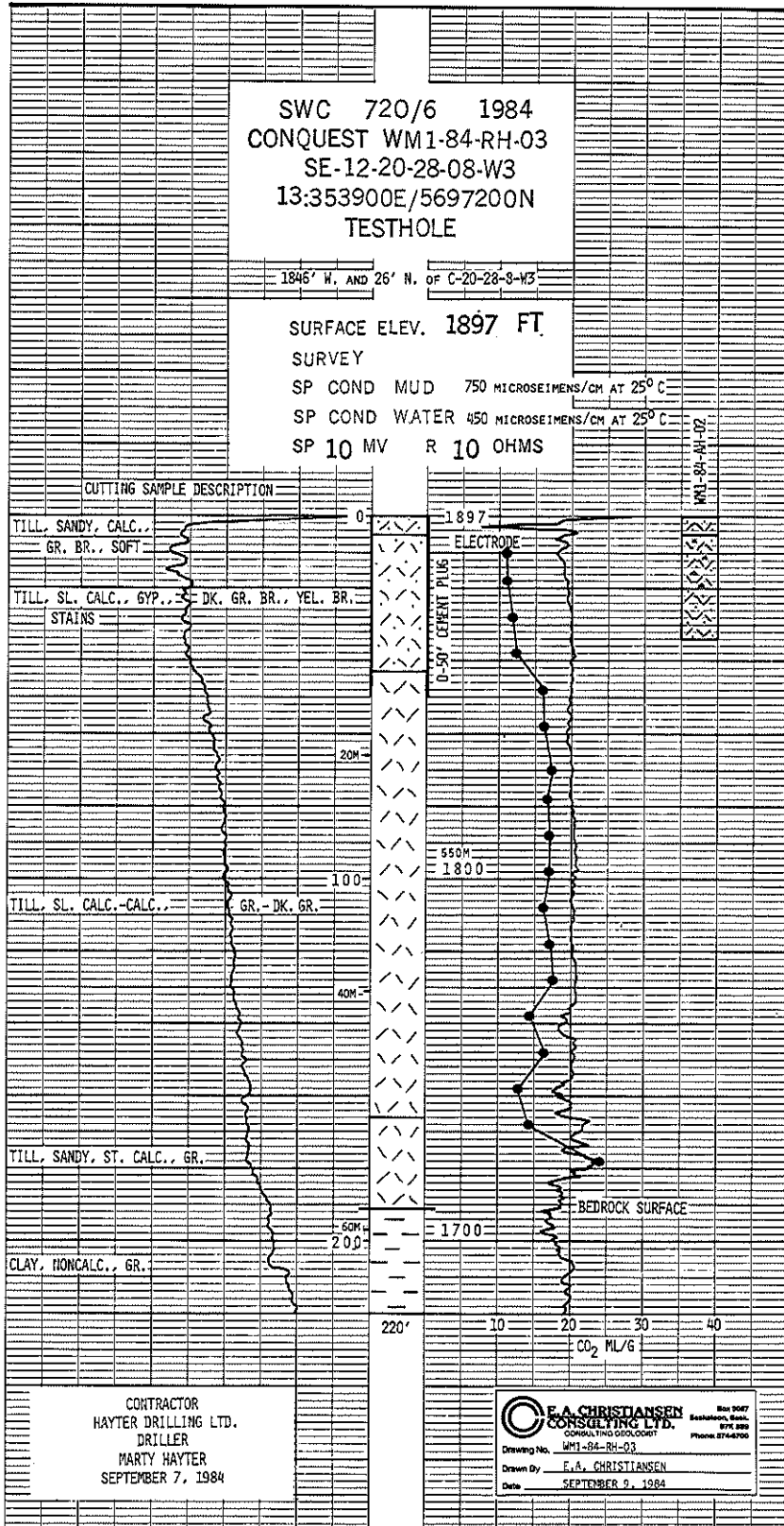
LOWER TILL

EMPRESS GROUP

BEARPAW FORMATION

E. A. Christiansen Consulting Ltd.

5



SASKATOON GROUP

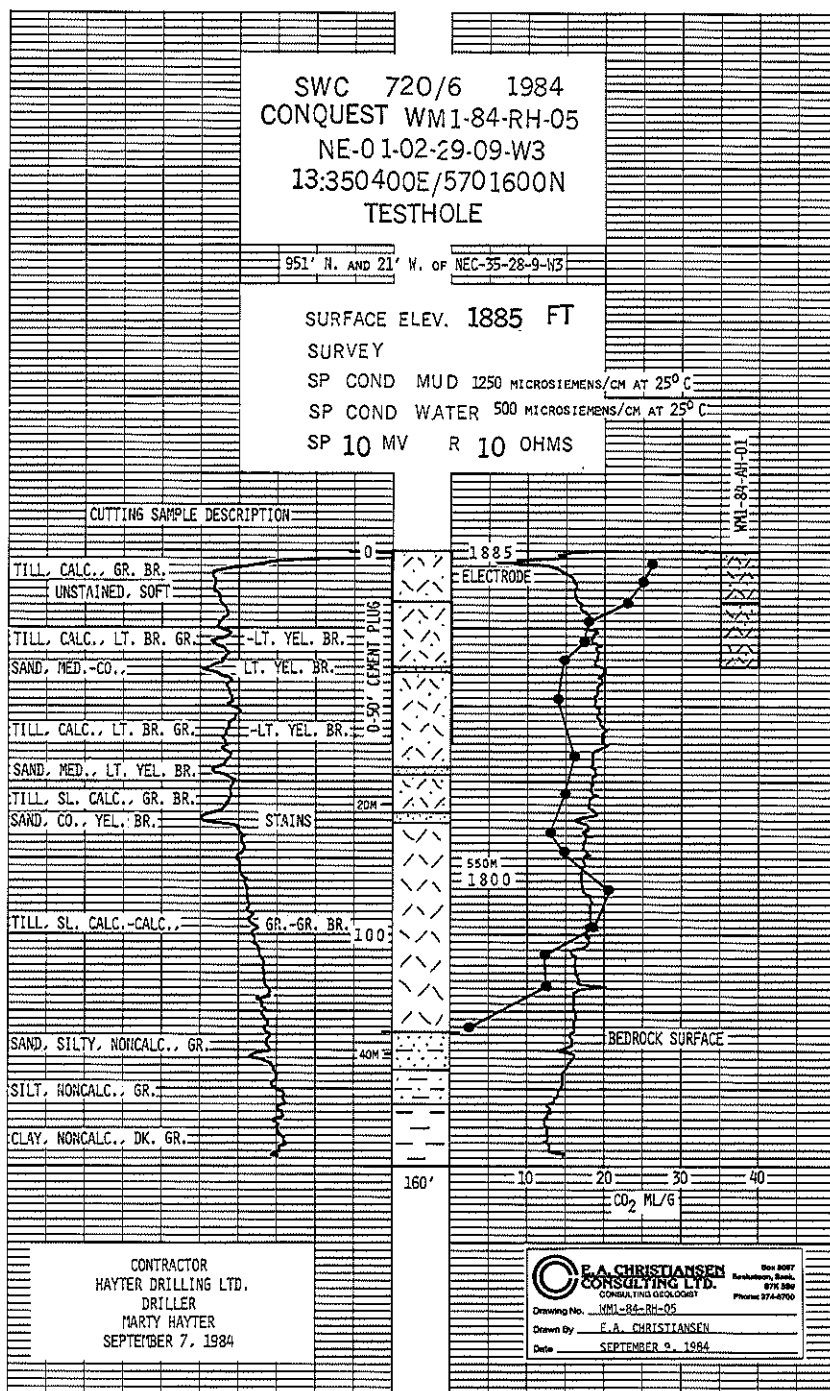
UPPER TILL

MIDDLE TILL

BEARPAW FORMATION

SUTHERLAND GROUP

6



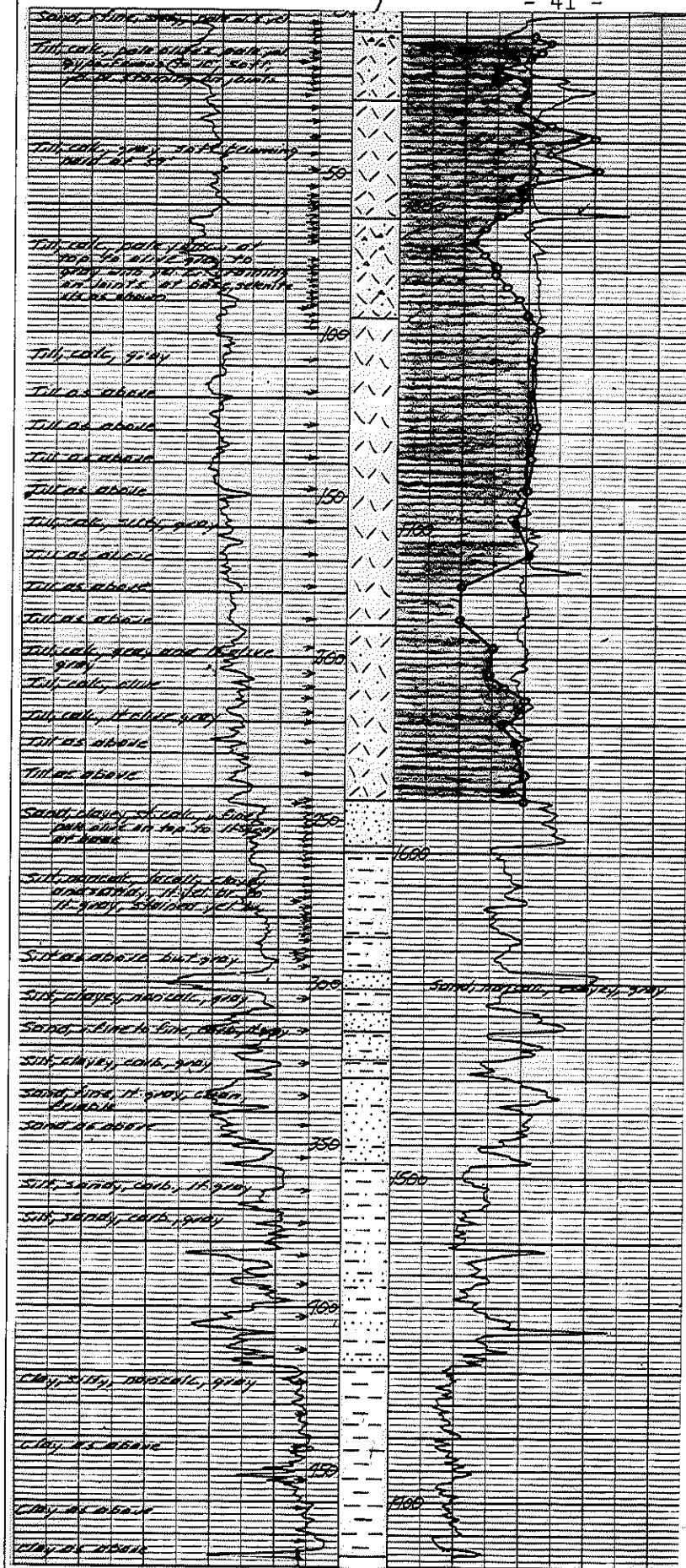
SASKATOON GROUP

MIDDLE TILL

LOWER TILL

BEARPAW FORMATION

SUTHERLAND GROUP



72011ESSRIP1970

CONQUEST NO. 2

SW3-13-30-9-W3

TEST HOLE

HAYTER DRILLING CO

D. HAYES

DRILLERS C.HIGGINS

M. TAYLOR

SURFACE ELEV. 1860 ft

ELEV FROM TOP MAP 1 ET C 1

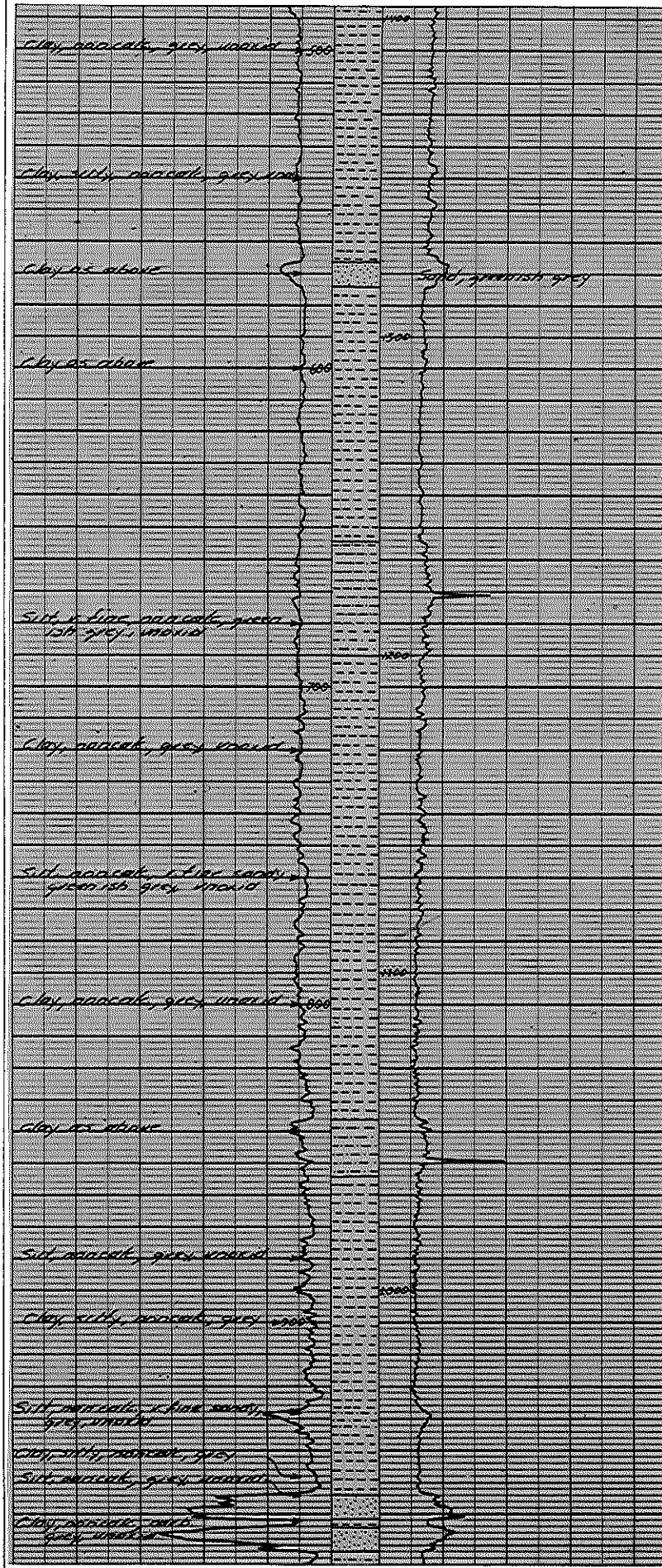
SP COND MUD 900 micrometers

SP COND WATER 420 CO₂

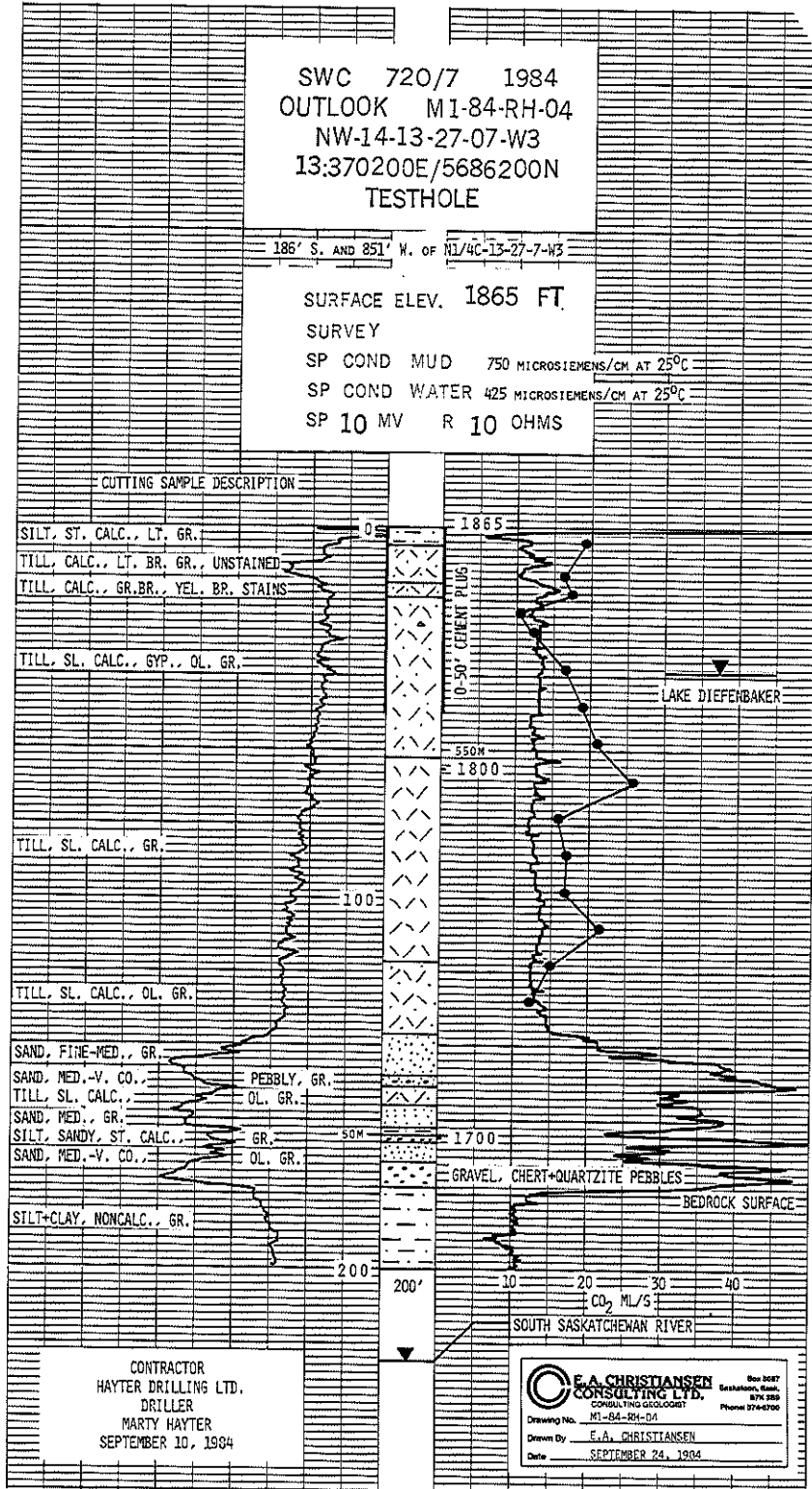
SP 10 MY R 10 CHMS

E. A. Christiansen Consulting Ltd.

LOG 8



9



SASKATOON GROUP

UPPER TILL

MIDDLE TILL

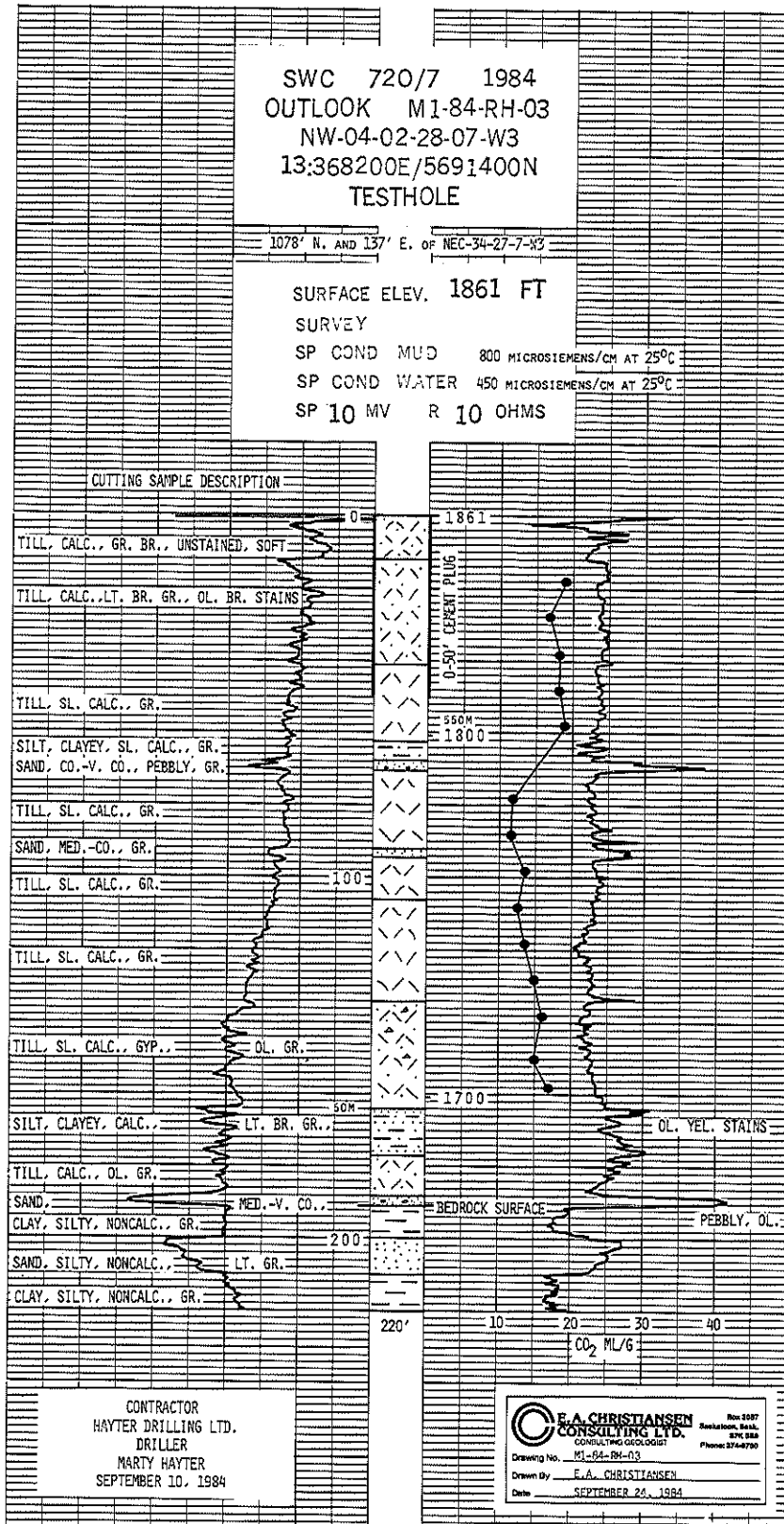
LOWER TILL

EMPRESS GROUP

BEARPAW FORMATION

E. A. Christiansen Consulting Ltd.

10



SASKATOON GROUP

UPPER TILL

MIDDLE TILL

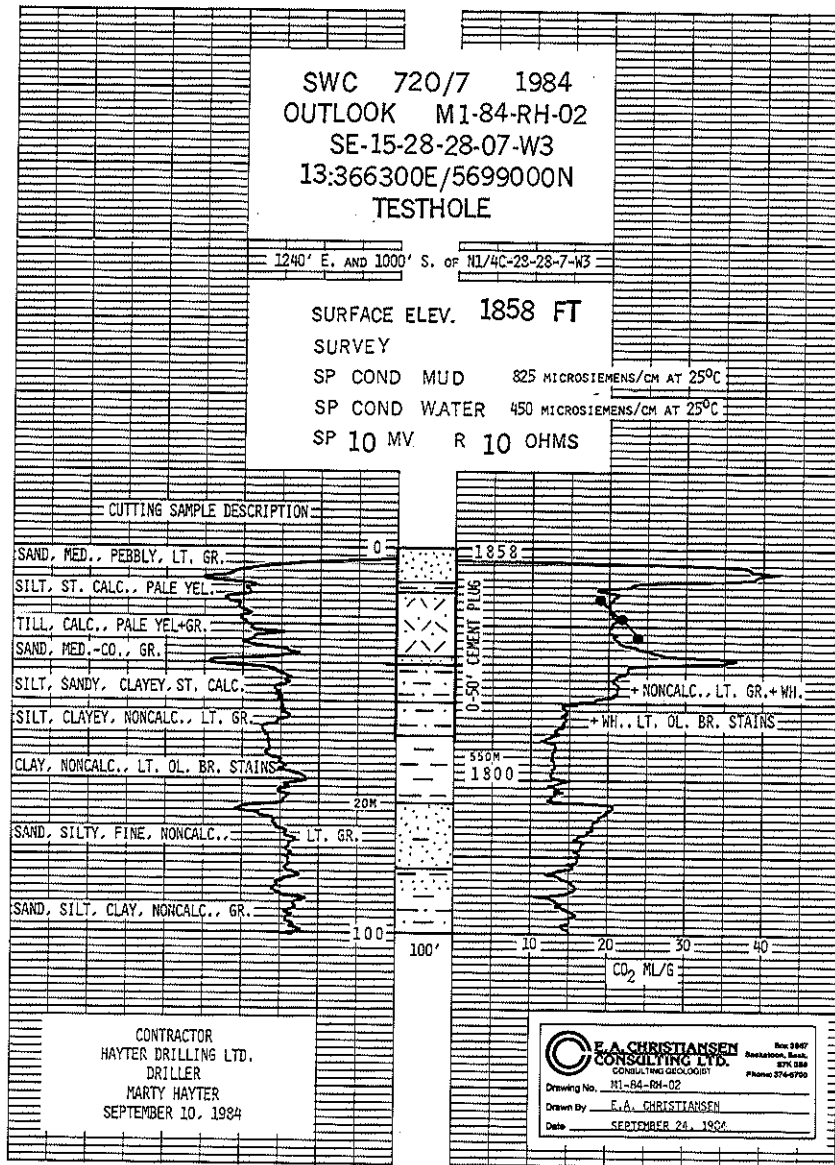
EMPRESS GROUP

BEARPAW FORMATION

JUDITH RIVER FORMATION

SUTHERLAND GROUP

11



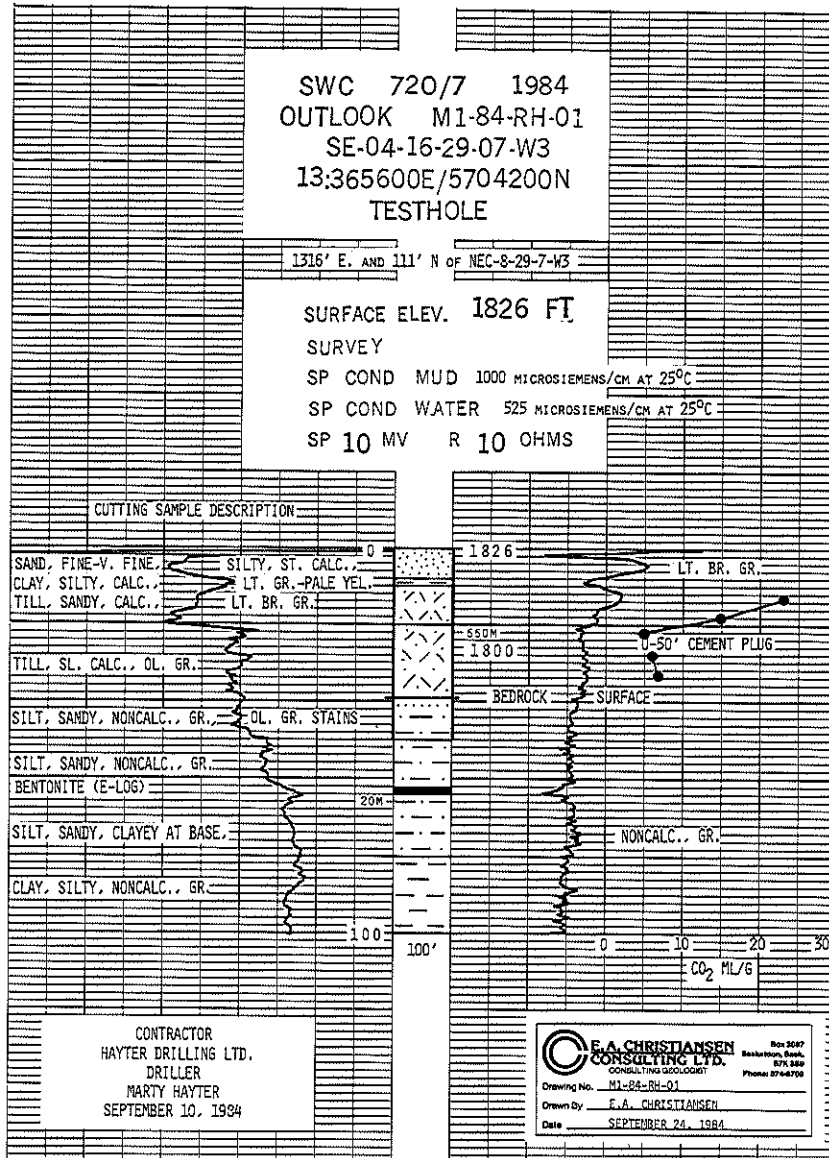
SASKATOON GROUP

EMPRESS GROUP

BEARPAW FORMATION

JUDITH RIVER FORMATION

12

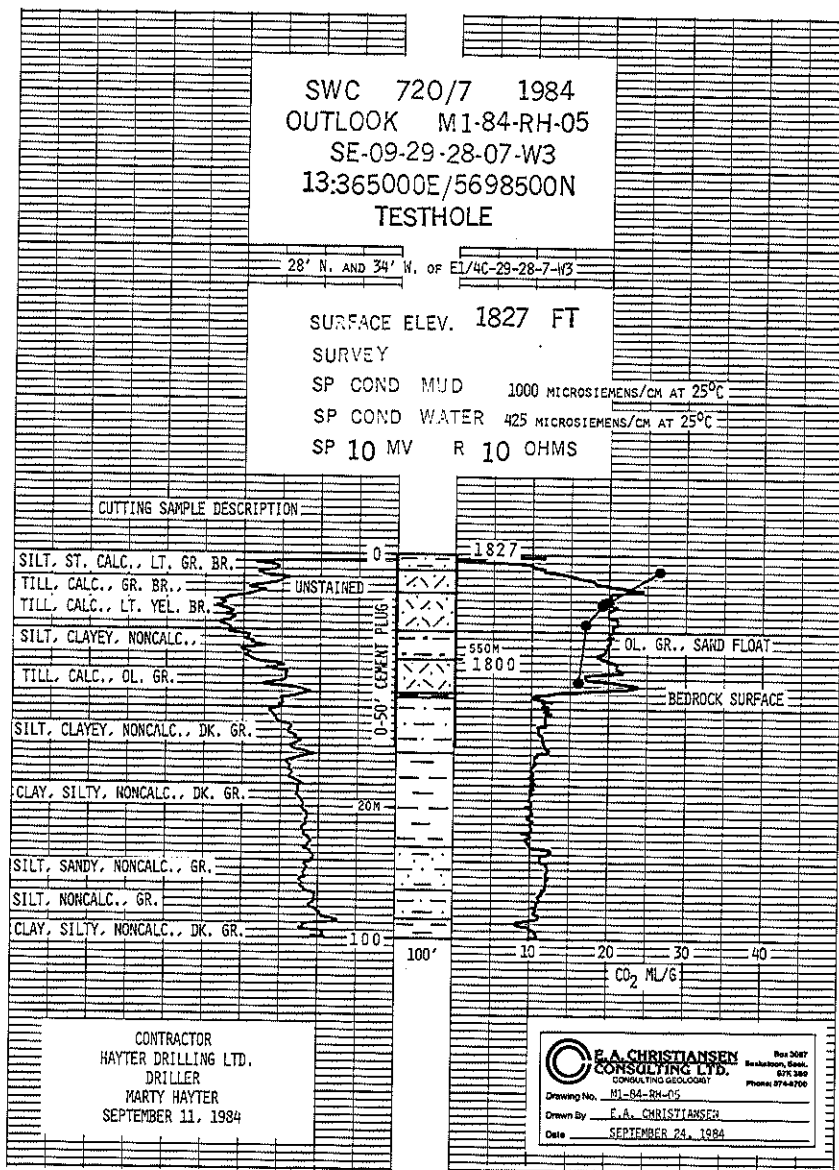


SASKATOON GROUP

SUTHERLAND GROUP

JUDITH RIVER FORMATION

13

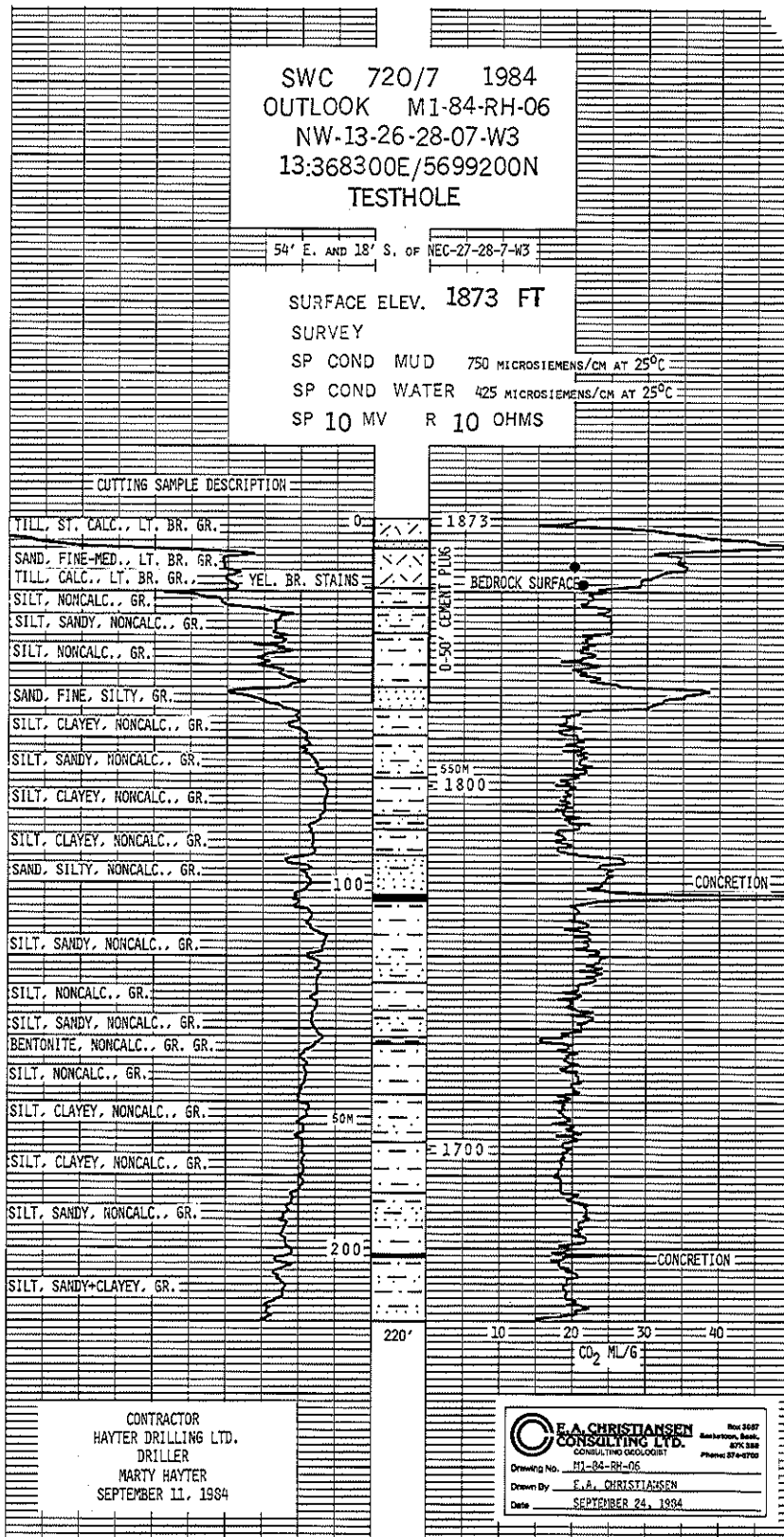


SASKATOON GROUP

BEARPAW FORMATION

JUDITH RIVER FORMATION

14



SASKATOON
GROUP

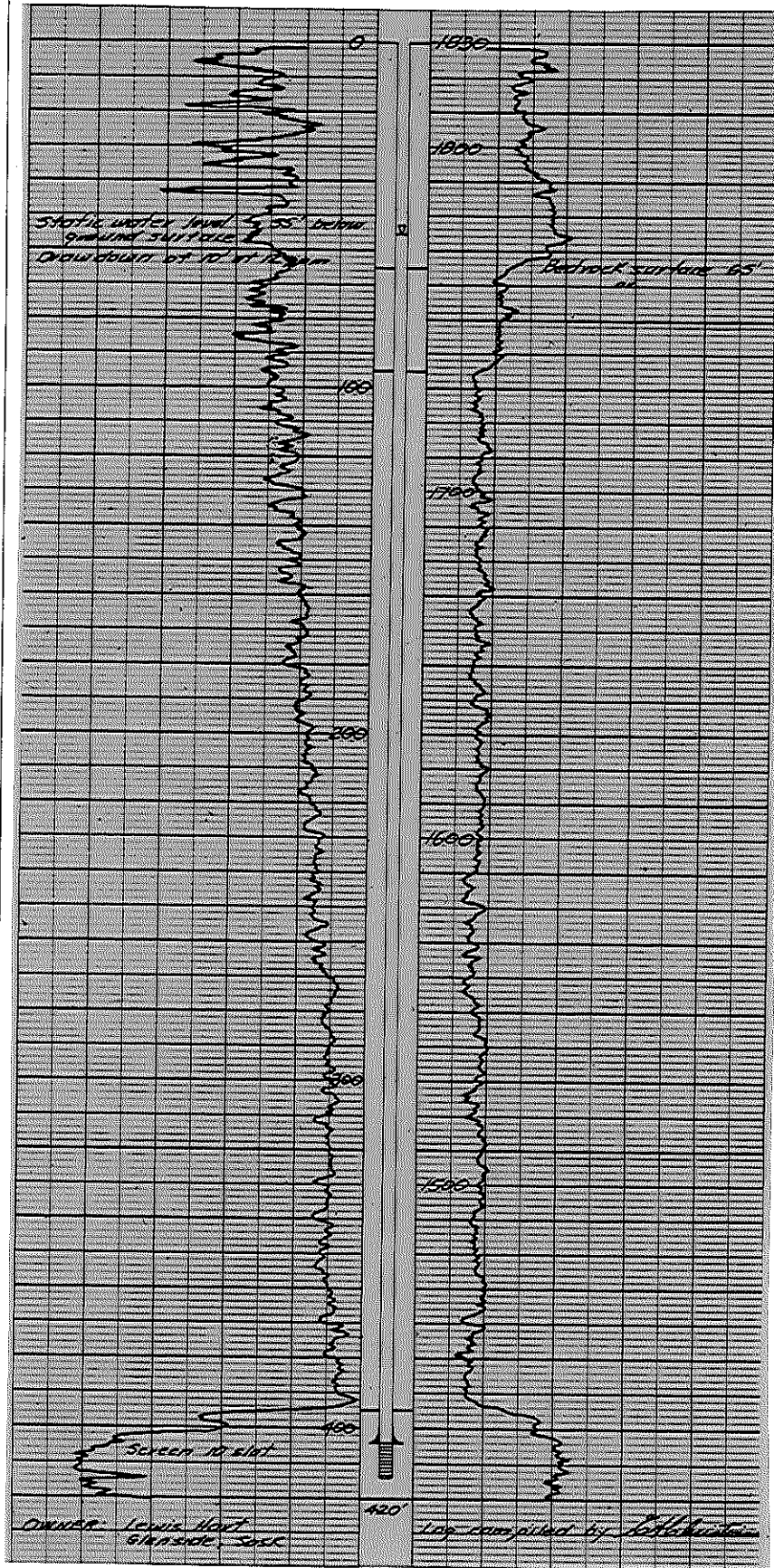
TILL AND SAND

DISTURBED BEDROCK?

BEARPAW FORMATION

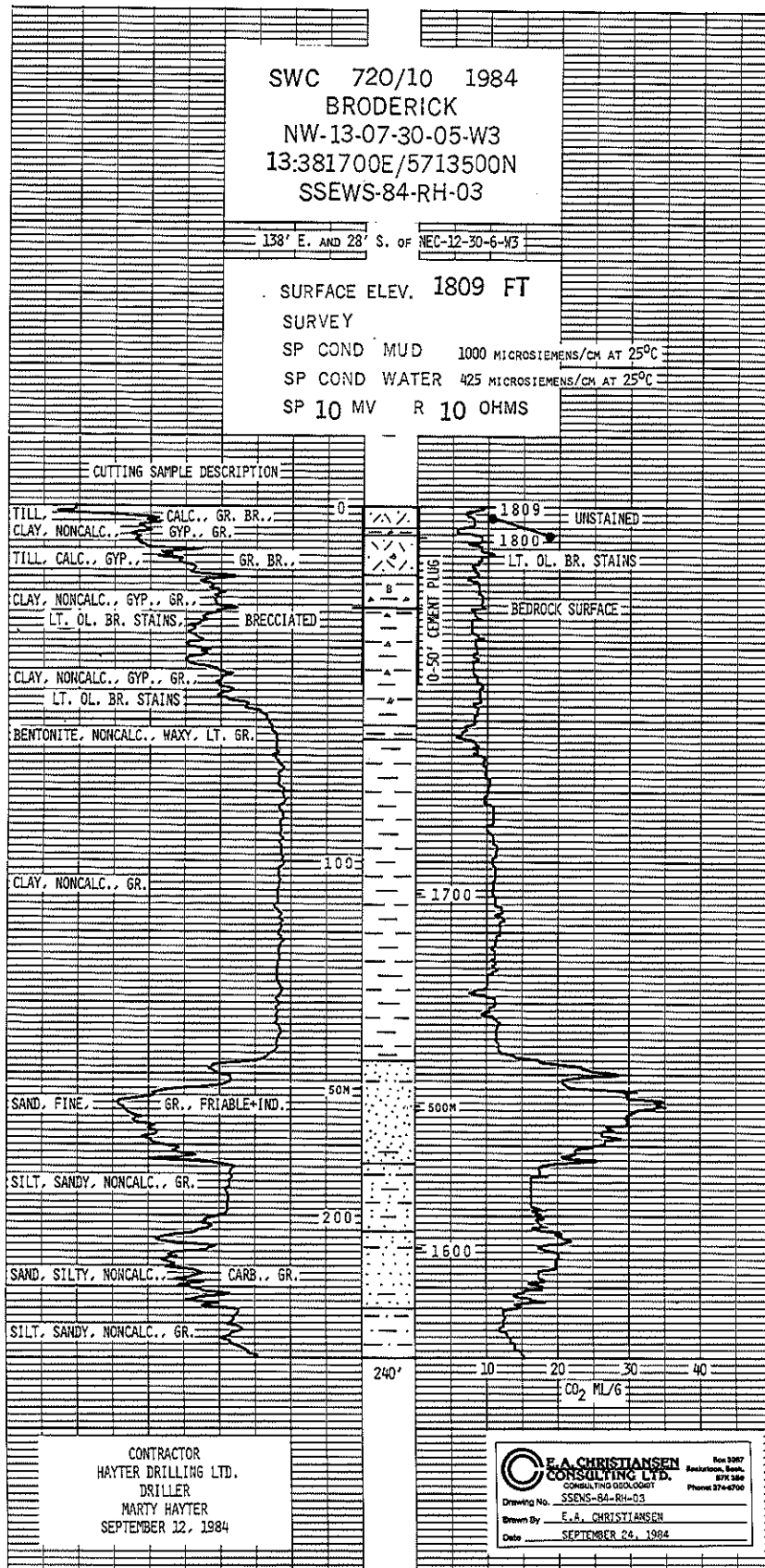
JUDITH RIVER FORMATION

15



RANKIN	720/7	1973
GLENSIDE		
NW10-17-29-6-W3		
TESTHOLE WELL		
RANKIN DRILLING		
DRILLER: A. RANKIN		
SURFACE ELEV.	1830	FT
ELEV. FROM	1010	MEAN 25' CT
SP COND MUD		
SP COND WATER		
SP 10 MV	R 10	OHMS

16



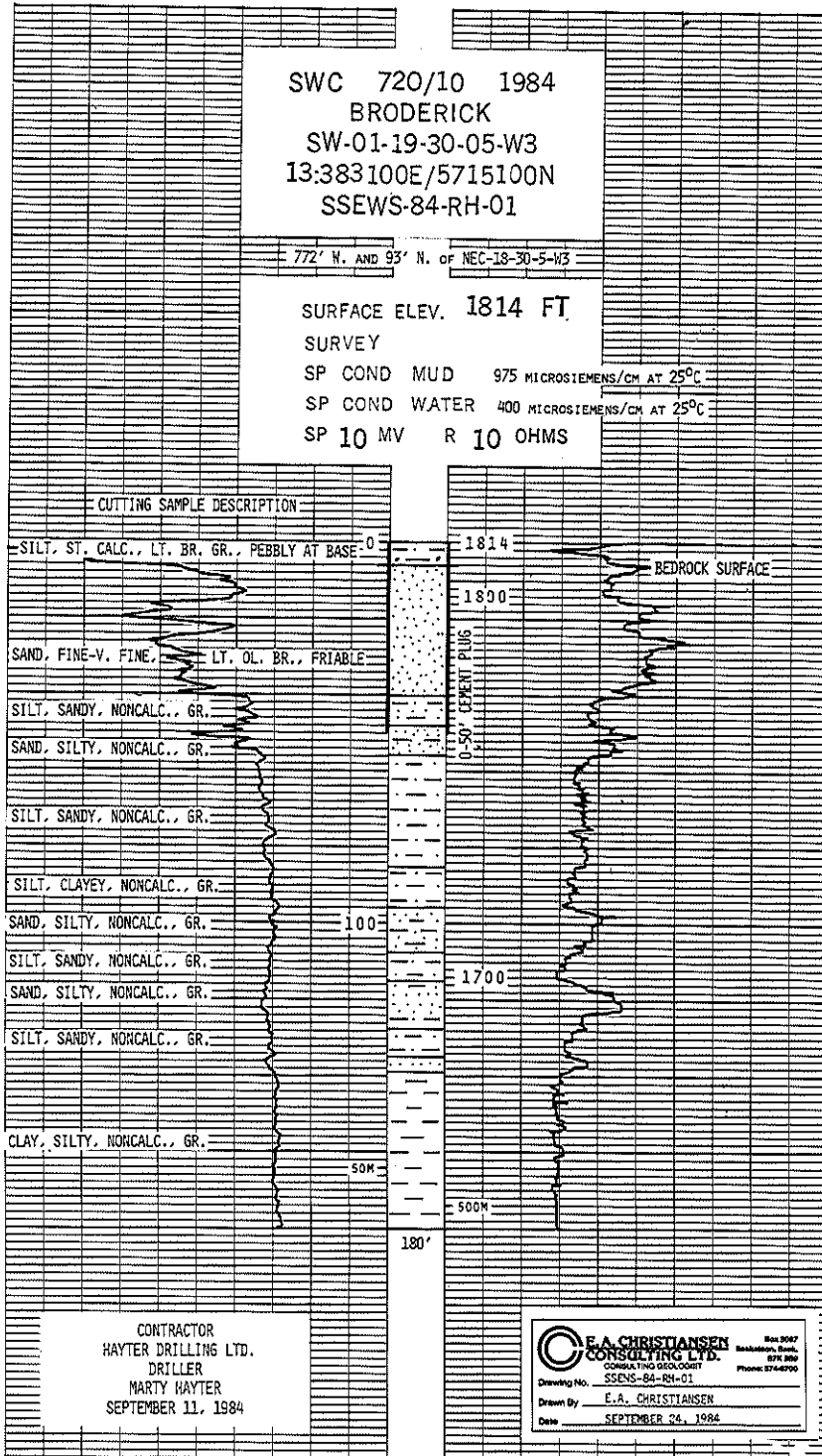
SASKATOON GROUP

BEARPAW FORMATION

JUDITH RIVER FORMATION

E. A. Christiansen Consulting Ltd.

17

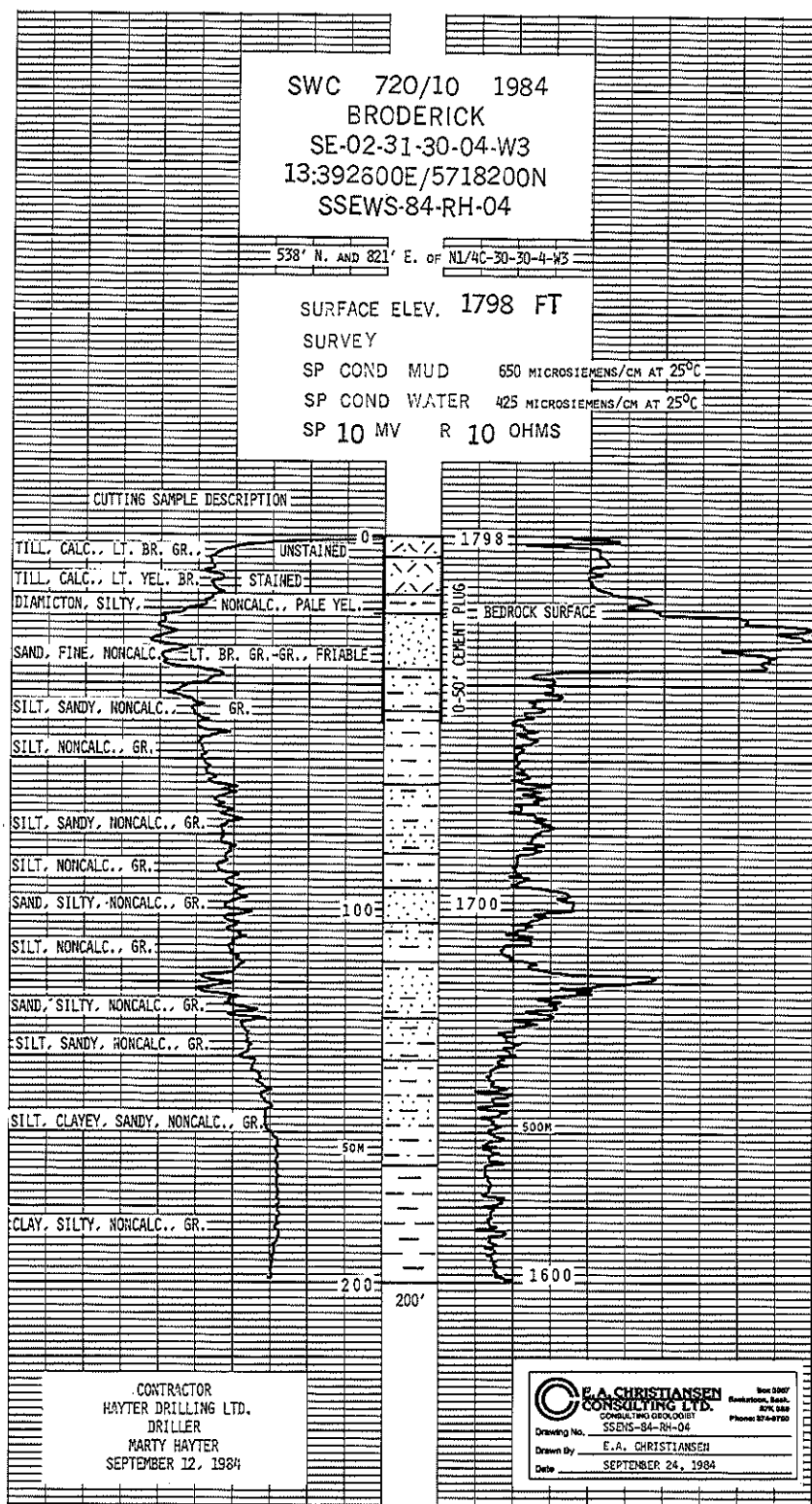


SASKATOON GROUP

JUDITH RIVER FORMATION

LEA PARK FORMATION

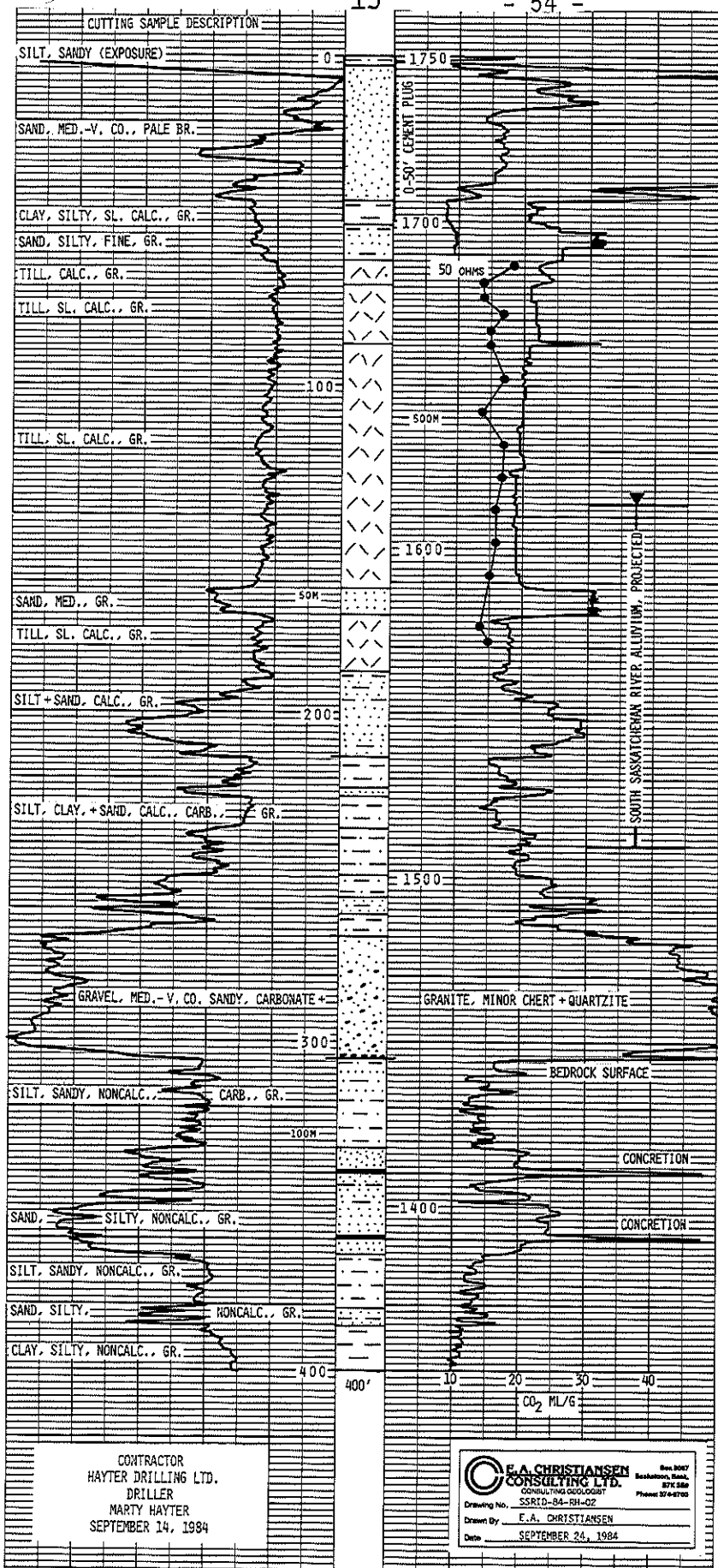
18



SASKATOON GROUP

JUDITH RIVER FORMATION

LEA PARK FORMATION



SASKATCHEWAN GROUP

DELTAIC SAND

LACUSTRINE CLAY

SAND

TILL

SUTHERLAND GROUP

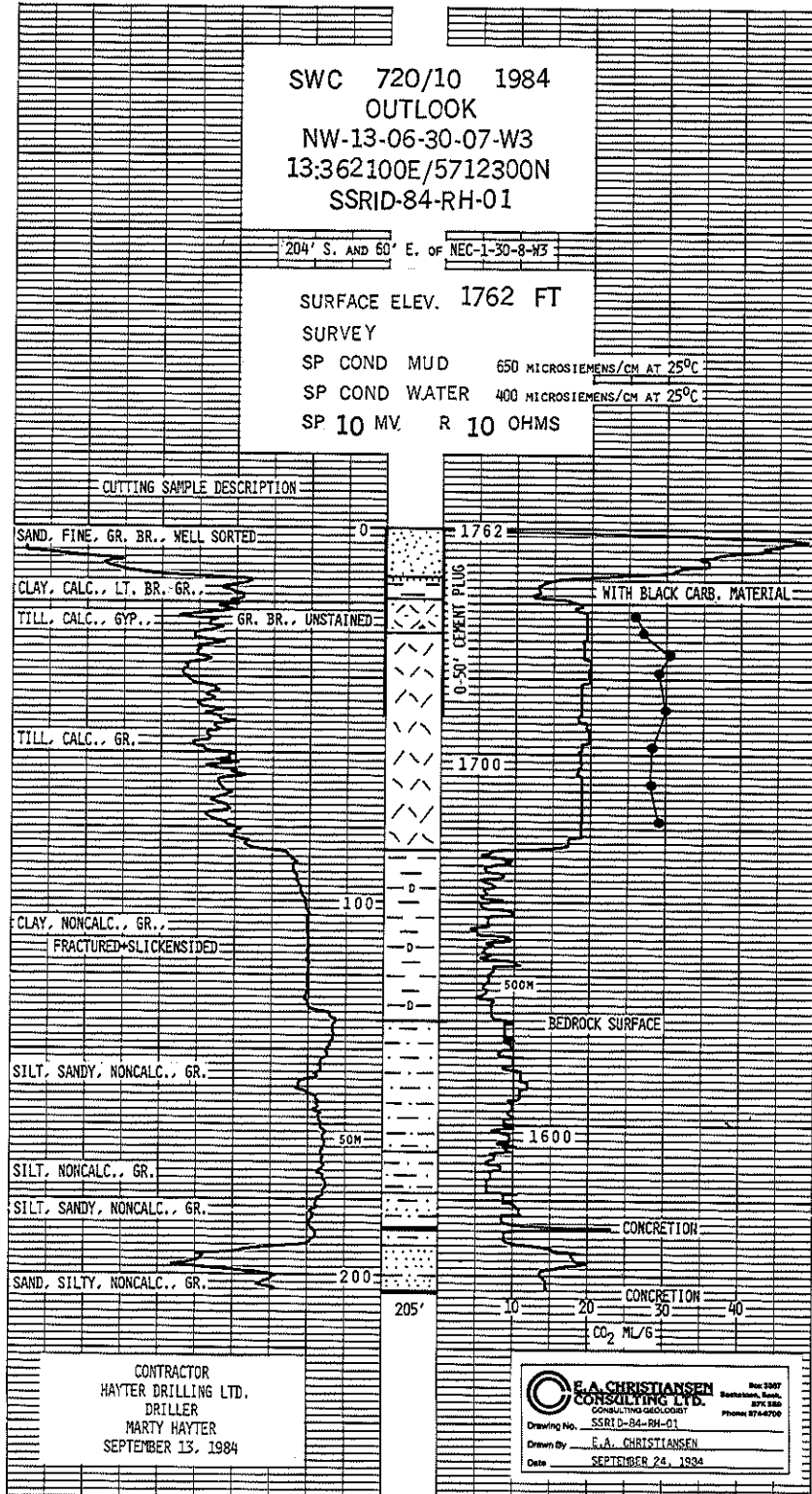
EMPRESS GROUP

JUDITH RIVER FORMATION

LEA PARK FORMATION

E. A. Christiansen Consulting Ltd.

20



SASKATOON GROUP	EOLIAN SAND
	BURIED SOIL
	LACUSTRINE CLAY
	TILL
DISTURBED BEDROCK	EMPRESS GROUP, INFERRED
	BEARPAW FORMATION
JUDITH RIVER FORMATION	

LOG 21

SWC 720/10 1984
BRODERICK
SW-04-17-30-05-W3
13:383300E/5713500N
SSEWS-84-RH-02

174' E. AND 108' N. OF REC-7-30-5-W3

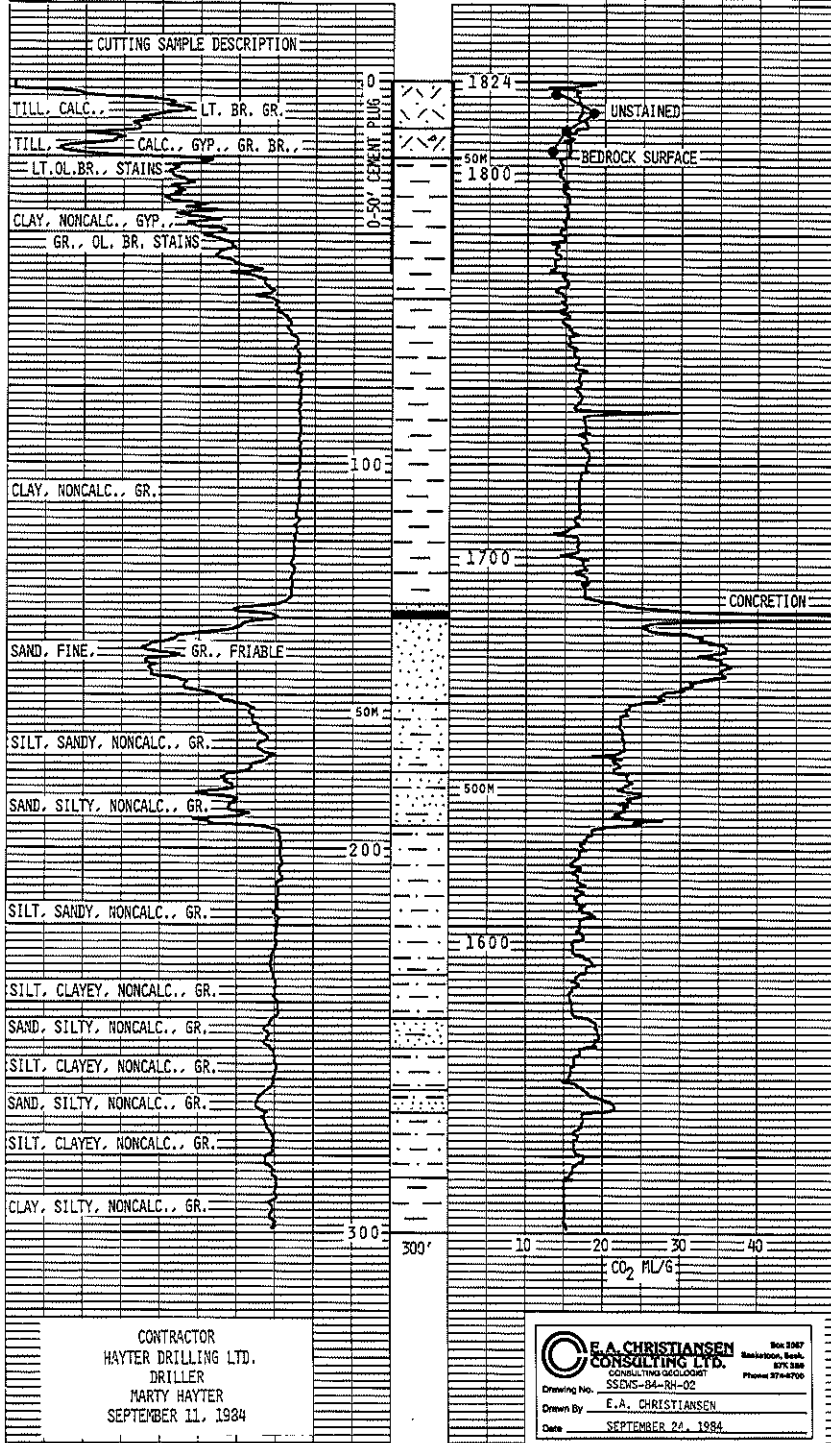
SURFACE ELEV. 1824 FT

SURVEY

SP COND MUD 1000 MICROSIEMENS/CM AT 25°C

SP COND WATER 450 MICROSIEMENS/CM AT 25°C

SP 10 MV R 10 OHMS



SASKATOON GROUP

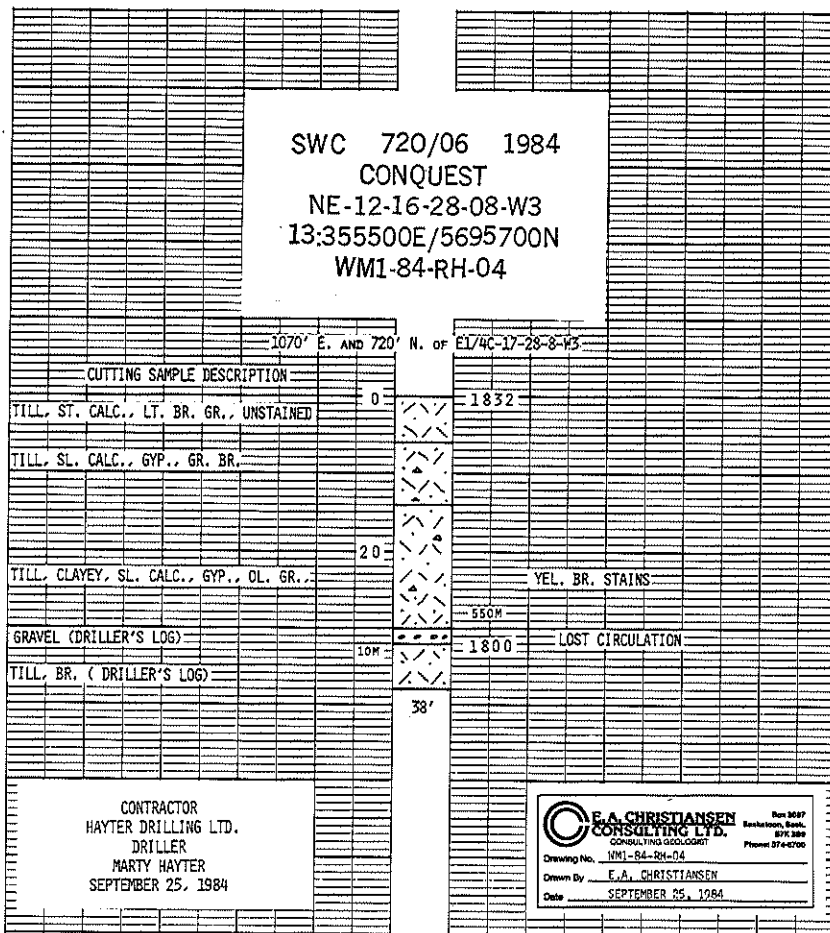
BEARPAW FORMATION

JUDITH RIVER FORMATION

LEA PARK FORMATION

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SASKATOON GROUP

SUTHERLAND GROUP

Appendix 3. Total Carbonate Analyses.

Testhole	Depth feet	% inorg. carbon	mL CO ₂ /gram	Testhole	Depth feet	% inorg. carbon	mL CO ₂ /gram
WM1-84-RH-01	5- 10	0.85	15.7	WM1-84-RH-03	135-140	0.79	14.6
	15- 20	0.64	11.8		145-150	0.88	16.3
	25- 30	0.80	14.8		155-160	0.70	13.0
	35- 40	1.00	18.5		165-170	0.78	14.4
	45- 50	0.91	16.8		175-180	1.27	23.5
	55- 60	1.12	20.7	WM1-84-RH-05	0- 5	1.43	26.5
	65- 70	0.97	17.9		5- 10	1.36	25.1
	75- 80	1.10	20.4		10- 15	1.25	23.1
	85- 90	0.98	18.1		15- 20	0.96	17.8
	95-100	0.90	16.7		20- 25	0.94	17.4
	105-110	0.83	15.4		25- 30	0.80	14.8
	115-120	0.84	15.5		35- 40	0.77	14.2
	125-130	0.89	16.5		50- 55	0.88	16.3
	135-140	0.91	16.8		60- 65	0.81	15.0
WM1-84-RH-02	5- 10	0.99	18.3		70- 75	0.70	13.0
	10- 15	0.88	16.3		75- 80	0.82	15.2
	15- 20	0.83	15.4		85- 90	1.11	20.5
	20- 25	0.71	13.1		95-100	1.00	18.5
	25- 30	0.65	12.0		100-105	0.68	12.5
	35- 40	0.75	13.9		110-115	0.66	12.2
	45- 50	1.05	19.4		120-125	0.14	2.6
	55- 60	1.08	20.0	M1-84-RH-01	10- 15	1.25	23.1
	65- 70	1.04	19.2		15- 20	0.83	15.4
	75- 80	1.02	18.9		20- 25	0.29	4.6
	85- 90	0.94	17.4		25- 30	0.30	5.6
	95-100	1.08	20.0	M1-84-RH-02	30- 35	0.40	7.4
	105-110	0.97	17.9		10- 15	1.01	18.7
	115-120	0.90	16.7		15- 20	1.20	22.2
	125-130	0.85	15.7	M1-84-RH-03	20- 25	1.28	23.7
	135-140	0.85	15.7		5- 10	1.36	25.1
WM1-84-RH-03	5- 10	0.57	10.5		15- 20	1.05	19.4
	15- 20	0.60	11.1		25- 30	0.94	17.4
	25- 30	0.63	11.7		35- 40	0.96	17.8
	35- 40	0.68	12.6		45- 50	0.96	17.8
	45- 50	0.86	15.9		55- 60	1.00	18.5
	55- 60	0.86	15.9		65- 70	0.73	13.5
	65- 70	0.93	17.2		75- 80	0.67	12.4
	75- 80	0.90	16.7		85- 90	0.62	11.5
	85- 90	0.92	17.0		95-100	0.75	13.9
	95-100	0.92	17.0		105-110	0.71	13.1
	105-110	0.86	15.9		115-120	0.74	13.7
	115-120	0.91	16.8		125-130	0.79	14.6
	125-130	0.95	17.6		135-140	0.85	15.7

Testhole	Depth feet	% inorg. carbon	mL CO ₂ /gram ²	Testhole	Depth feet	% inorg. carbon	mL CO ₂ /gram ²
M1-84-RH-03	145-150	0.80	14.8	SSRIP-84-RH-01	20- 25	1.40	25.9
	155-160	0.94	17.4		25- 30	1.44	26.6
M1-84-RH-04	5- 10	1.05	19.4		30- 35	1.65	30.5
	10- 15	0.93	17.2		35- 40	1.55	28.7
	15- 20	0.95	17.6		45- 50	1.60	29.6
	20- 25	0.57	10.5		55- 60	1.49	27.6
	25- 30	0.68	12.6		65- 70	1.52	28.1
	35- 40	0.93	17.2		75- 80	1.59	29.4
	45- 50	1.04	19.2	SSRIP-84-RH-02	60- 65	0.98	18.1
	55- 60	1.12	20.7		65- 70	0.75	13.9
	65- 70	1.42	26.3		70- 75	0.77	14.2
	75- 80	0.87	16.1		75- 80	0.90	16.7
	85- 90	0.90	16.7		80- 85	0.82	15.2
	95-100	0.90	16.7		85- 90	0.81	15.0
	105-110	1.17	21.6		95-100	0.93	17.2
	115-120	0.79	14.6		105-110	0.76	14.1
	125-130	0.67	12.4		115-120	0.94	17.4
M1-84-RH-05	5- 10	1.48	27.4		125-130	0.92	17.0
	10- 15	1.01	18.7		135-140	0.88	16.3
	15- 20	0.90	16.7		145-150	0.87	16.1
	20- 25	1.08	20.0		155-160	0.83	15.4
	25- 30	0.30	5.6		170-175	0.76	14.1
	30- 35	0.85	15.7		175-180	0.83	15.4
M1-84-RH-06	10- 15	1.08	20.0				
	15- 20	1.13	20.9				
SSEWS-84-RH-02	0- 5	0.74	13.7				
	5- 10	0.97	17.9				
	10- 15	0.79	14.6				
	15- 20	0.72	13.3				
SSEWS-84-RH-03	0- 5	0.58	10.7				
	10- 15	0.98	18.1				

Appendix 4. Mechanical Analyses.

Borehole	Depth feet	Carbonate + Organic free			Original Sediment		
		% Sand	% Silt	% Clay	% Sand	% Silt	% Clay
WMI-84-AH-01	7	54.3	23.6	22.1	51.3	27.0	21.7
	27	38.6	31.1	30.3	37.3	33.3	29.4
WMI-84-AH-02	3	51.0	24.6	24.4	50.1	24.7	25.2
	15	38.5	26.5	35.0	38.3	28.6	33.1
WMI-84-AH-03	5-7	52.3	25.3	22.4	53.3	26.3	20.4
	15	41.6	27.1	31.3	40.4	30.3	29.3
WMI-84-AH-04	9	46.2	26.4	27.4	47.7	28.1	24.2
	19	63.5	22.6	13.9	61.7	24.6	13.7
WMI-84-RH-02	40-45	36.3	28.5	35.2	38.2	30.4	31.4
WMI-84-RH-05	80-85	32.0	34.0	34.0	34.0	35.7	30.3