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Earth Physics Branch
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1 Observatory Crescent
Ottawa Canada
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Geothermal Service of Canada

Service géothermique du Canada

FINAL WELL REPORT, U OF R REGINA 3-8-17-19 (W. 2nd Mer.) SASKATCHEWAN GEOTHERMAL FEASIBILITY PROJECT AT REGINA, PHASE I

L.W. Vigrass, Energy Research Unit, University of Regina

Earth Physics Branch Open File Number 79-9

Ottawa, Canada, 1979

36 pp. and 1 figure

Price/Prix: $17.00

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ABSTRACT

The University of Regina 3-8-17-19 well is intended to be the water source well for the Geothermal Feasibility Project at Regina, a mission-oriented undertaking with aims of testing the practicality of producing low-grade geothermal waters in the western Canadian sedimentary basin and demonstrating their use for space heating at the University of Regina. Objectives of the well are to evaluate water production rates, to determine water chemistry, and to investigate subsurface temperature distribution. The well was drilled to a depth of 2215 m and is currently standing cased to 2034 m with 175 m of Winnipeg and Deadwood Formations and 6 m of Precambrian Basement open below the casing shoe.

Cores, well cuttings, drill stem tests and logs indicate that the Winnipeg-Deadwood sandstones have good reservoir properties.

The Winnipeg-Deadwood waters contain 10 to 12 percent solids, mostly sodium chloride.

Rock temperatures are uncertain because measurements were made when the thermal regime was upset by drilling. Our best estimate of bottom hole temperature is 70°C and we expect a stabilized surface temperature of 65°C for water produced at 100 m^3/h.

The geothermal situation at Regina is regarded as encouraging for establishment of a Geothermal Demonstration Project.

Résumé

Le puit 3-8-17-19 de l'Université de Régina à été considéré comme source d'eau pour le projet de réalization géothermique à Régina. L'entreprise a comme but d'obtenir des résultats d'évaluation pratiques pour la production d'eau géothermique à basse temperature dans le basin sédimentaire de l'ouest canadien et de démontrer l'utilité du chauffage d'immeubles à l'université de Régina. Les objectifs du puit sont d'évaluer les taux de production d'eau, de déterminer sa composition et d'examiner la distribution de température souterraine. Le puit a été foré à une profondeur de 2215 m et tubé jusqu'à 2034 m avec 175 m des formations Winnipeg et Deadwood et 6 m de roche de base Précambrienne ouvert sous le sabot de cuvelage. Les eaux du Winnipeg Deadwood contiennent de 10 à 12 pourcent de matière solide, en grande partie du chlorure de sodium.

La température des roches est incertaine parce qu'elle a été mesuré lorsque le régime thermal était remué par le forage. Notre meilleur estimé de la température du fond du puit est de 70°C et nous anticipons une température de surface stabilisée à 65°C pour un débit d'eau de 100 m^3/h.

La situation géothermique à Régina semble encourageante pour l'établissement d'un projet de démonstration géothermique.

FINAL WELL REPORT

U of R Regina 3-8-17-19

(W. 2nd. Mer.)

Saskatchewan

FINAL WELL REPORT

U of R Regina 3-8-17-19

(W. 2nd. Mer.)

Saskatchewan

TABLE OF CONTENTS

LIST OF TABLES

FINAL WELL REPORT

U of R Regina 3-8-17-19

(W. 2nd. Mer.)

Saskatchewan

ABSTRACT

The University of Regina 3-8-17-19 well is intended to be the water source well for the Geothermal Feasibility Project at Regina, a mission-oriented undertaking with aims of testing the practicality of producing low-grade geothermal waters in the western Canadian sedimentary basin and demonstrating their use for space heating at the University of Regina. Objectives of the well are to evaluate water production rates, to determine water chemistry, and to investigate subsurface temperature distribution. The well was drilled to a depth of 2215 m and is currently standing cased to 2034 m with 175 m of Winnipeg and Deadwood Formations and 6 m of Precambrian Basement open below the casing shoe.

Cores, well cuttings, drill stem tests and logs indicate that the Winnipeg-Deadwood sandstones have good reservoir properties. We expect that with continuous pumping at 2,400 m^3/d, the water level would be drawn down to 124 m below ground level after 250 days and to 131 m below ground level after 7 years. If correct, these drawdowns would indicate a power requirement for water production of 66 kW, about 2 percent of the 3.5 MW of heat energy available if the water is cooled to 35°C.

The Winnipeg-Deadwood waters contain 10 to 12 percent solids, mostly sodium chloride. The Winnipeg waters contain at least 2 to 3 litres of hydrogen sulphide per cubic metre. Water chemistry does not appear un-

favourable except for possible problems with the dissolved H_2S.

Rock temperatures are uncertain because measurements were made when the thermal regime was upset by drilling. Our best estimate of bottom hole temperature is 70°C and we expect a stabilized surface temperature of 65°C for water produced at 100 m^3/h.

The geothermal situation at Regina is encouraging for establishment of a Geothermal Demonstration Project. The well will be completed with a slotted liner across the producing zones. Prior to drilling the disposal well, pump testing will be conducted for as long a time as is practical considering problems of water disposal (estimated 6 to 10 hours). Chemistry of the water will be investigated further, especially regarding amount of H_2S and other dissolved gases, and corrosion studies will be initiated. We plan to measure temperatures in the well during the ensuing year as thermal equilibrium is re-established. Attention should be directed toward usage of the water and the design of a demonstration package.

FINAL WELL REPORT

U of R Regina 3-8-17-19

(W. 2nd. Mer.)

Saskatchewan

INTRODUCTION

The Geothermal Feasibility Project at Regina is a mission-oriented undertaking with the aims of testing the practicality of producing low-grade geothermal waters from depth in the western Canada sedimentary basin and of demonstrating the use of the water for space heating at the University of Regina. The U of R Regina 3-8-17-19 well was drilled as part of Phase I of this project. Primary objectives in drilling and completing the well are to evaluate the lower Paleozoic section at Regina for water production rates, to determine the water chemistry, and to investigate temperature distribution in the well.

This final well report concerns drilling and casing of the well and presents some preliminary results arising from drilling, coring, testing, and logging of the well. Purpose of the report is to provide a summary of the work done to date, present a summary of the results, and to present those conclusions it is possible to make at this time. An inventory of well data (but not the bulk of the data itself) is included. The report is one of a series that will assess the applicability in Canada of low-enthalpy geothermal waters (such as occur at Regina) as an energy source.

The Regina 3-8-17-19 well is situated on the University of Regina Campus within the city of Regina. On site operations (other than survey and lease preparation) were begun with rig move-in on December 18, 1978, and were completed with rig move-out on February 10, 1979. Elapsed time from spud to rig release was 41.3 days. The well was drilled and casing run with an oilfield drilling rig. Coring, testing, logging, cementing, and other well procedures were conducted in conformance with oilfield practice.

Winter weather was severe during much of the period of drilling of the well. The mean daily temperature during January, 1979, was -22.0°C compared to a normal of -17.3°C. The mean daily minimum temperature was -27.2°C (normal -22.6°C). The mean average daily wind speed was 17.6 km/h compared to normal of 22.5 km/h. The wind chill factor from December 28 to February 7 on several occasions attained values of 2200 to 2300 W/m^2 (watts per square metre), described by Environment Canada as bitterly cold to extremely cold. A reference point for 2300 W/m^2 of wind chill is -40°C and 16 km/h: for the average person, exposed areas of the face freeze in less than one minute at 2300 W/m^2 of wind chill. Despite lower than normal precipitation and wind speeds, blizzard conditions with poor road visibility were common in southern Saskatchewan in January and February.

Major questions that we hope are answered by the drilling and evaluation of the Regina 3-8-17-19 well are:

1. Is the geological situation at Regina sufficiently encouraging to continue into Phase II and subsequent steps of the Geothermal Feasibility Project at Regina?

2. What obstacles are we likely to face in developing the Geothermal Feasibility Project?

3. What directions should research take in order to overcome the obstacles and solve the problems that will be encountered in developing low-grade geothermal waters as an economically attractive energy source.?

Phase I of the Geothermal Feasibility Project at Regina is funded by a $655,000 contribution to the University of Regina from the Earth Physics Branch of Energy, Mines and Resources Canada. The contribution was made under authority of Dr. Kenneth Whitham, Director General of the Earth Physics Branch. Additionally, under the authority of Deputy Minister Robert Moncur, a contribution of $30,000 was received from Saskatchewan Department of Mineral Resources to pay for the drilling supervision performed by Saskoil. Additional costs connected with Phase I have been paid by the University of Regina.

ACKNOWLEDGMENTS

The author expresses his gratitude to the people who expedited the drilling and casing of the well, frequently under unpleasant conditions:

The well was drilled under contract by the Mustang #1 rig. Throughout the operation, the crew performed in a workmanlike manner under difficult conditions, ably directed by toolpusher Victor Ludwig.

Drilling supervision was performed on behalf of the University of Regina by Saskatchewan Oil and Gas Corporation. I gratefully acknowledge the proficient direction and the hard work performed by Blake Koeckeritz. I appreciate also the diligent efforts on our behalf of Gerry Czapp, Don Watt and of General Manager Bob Craig. The good work of Bob Shirkie, wellsite geologist (D.L. Surjik and Associates Ltd.), is greatly appreciated.

In addition to the drilling contractor, a long list of service companies and suppliers contributed to the success of the well. Special thanks are tendered to Arne Matiisen and Computalog Service Ltd., responsible for a special donation of $10,000 toward evaluation of the well. The efforts of Stan Blackstock, (coring), Art Wrubleski (power tongs), and Victor Young (testing) are appreciated. The competent advice of Prairie Mud Services is gratefully acknowledged. The efforts of personnel of Dowell of Canada are appreciated. The good work done by the other contractors and subcontractors is gratefully acknowledged.

Thanks are tendered to Dr. Alan Jessop, scientific authority and field representative for the Earth Physics Branch of Energy, Mines and Resources Canada.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

1. The U of R Regina 3-8-17-19 well was drilled to a total depth of 2215 m. It is now standing cased with 178 mm (7 inch) casing set at 2034 m. The open hole below casing shoe comprises 175 m of Winnipeg and Deadwood Formations and 6 m of Precambrian Basement.

2. The strata penetrated at the well match closely the geological prognosis in terms of structural positions and thicknesses.

3. Rock temperature in the well is uncertain because the thermal regime was still upset by drilling when the last temperature determinations were made. It is expected that the bottom hole temperature is about 70°C. If this temperature is correct, the average downhole temperature of water from the Winnipeg and Deadwood is expected to be about 68°C because it will be produced from an average depth of 2135 m.

4. From core analysis, drill stem tests and logs the reservoir quality of Winnipeg sandstone is fair to good and the quality of the Deadwood sandstones are good to very good. Contrary to the prognosis the most effective reservoir is in the Deadwood Formation (80.9 m with average permeability of 331 md. for total transmissivity of 26,750 md.-m) rather than the Winnipeg Formation (30.2 m with average core permeability of 128 md. for total transmissivity of 3,870 md-m.

5. As predicted, the natural water head for the Winnipeg (11 to 15 m below ground level) is higher than for the basal Deadwood (74 m below ground level).

6. Acceptable water production rates from the open Winnipeg-Deadwood should be attainable with reasonable pumping drawdowns. It is expected that during pumping tests with a continuous production of 1363 m^3/day (250 USGPM) for six hours the water level will be drawn down to +503 m elev. (73 m below ground level). At 2,400 m^3/d (440 USGPM) it is expected that the pumping level will be drawn down to +452 m (124 m below ground level) after 250 days of continuous production and will be drawn down to +445 m (131 m depth) after 7 years.

7. If these drawdowns are valid, the pumping power required at 60% overall efficiency is 66 kW.

8. The Winnipeg-Deadwood waters contain 10 to 12 percent dissolved solids by weight. Composition of major ions is similar to our predictions with sodium plus chloride accounting for 95 percent of the dissolved solids.

9. Contrary to the prognosis, dissolved H_2S is present, especially in the Winnipeg waters. Determination of the level present was not very successful but there appears to be at least 2 to 3 litres of H_2S gas (S.T.P.) per cubic metre of water.

10. On newly-caught surface samples, the waters are slightly alkaline (PH7.2 to 7.9) and slightly reducing. Very minor dissolved oxygen was present but probably resulted from contamination.

11. Determination of the volume of dissolved gas was not satisfactory but there appears to be at least 85 to 130 ml/l at atmospheric pressure. At a water production rate of 2,400 m^3/day, at least 267 m^3/d (9,500 ft^3/d) of gas (S.T.P.) would be expected. Indications are that this gas is about 95% nitrogen, up to 2.7% hydrogen sulphide, as much as 4.0 % hydrocarbon

gases (mostly methane), and up to 0.65 % helium. Carbon dioxide levels were extremely low when the samples were analyzed (0.04 percent).

12. Toxic metals, boron, and silicon levels are low.

CONCLUSIONS

1. Stabilized surface temperature of water produced at 100 m^3/hr. is expected to be about 65°C. This compares favourably with low-grade geothermal facilities in France that utilize water at 50°C to 60°C.

2. It is expected that the well should be capable of yielding 100 m^3/hr. with a pumping drawdown after seven years to 131 m below the surface.

3. Power requirements for pumping the production well are anticipated to be 66 kW, about 1.9 percent of the 3.5 MW available if the heat can be removed to the 35°C level before re-injection.

4. Water chemistry does not appear unfavourable except for possible problems with low levels of hydrogen sulphide in the Winnipeg Formation waters.

5. The geological situation at Regina is sufficiently encouraging for establishment of a Geothermal Demonstration Project that work should be continued.

RECOMMENDATIONS

1. Prior to drilling of the disposal well the Regina 3-8-17-19 should be tested on pump for as long as practical bearing in mind that the water will have to be hauled to underground or other disposal areas. Additional completion is required.

2. Chemistry of the Winnipeg-Deadwood waters should be investigated further, especially regarding the amount of hydrogen sulphide and other gases present. The significance of the water chemistry to precipitation and corrosion should be the subject of additional study.

3. Temperature regime at the Regina 3-8-17-19 well should be examined as the well approaches thermal equilibrium. At least three temperature surveys should be run during the year following pump testing of the well.

4. More attention should be devoted to how the geothermal waters are to be used and in preliminary design of the heating system for a demonstration package.

SYNOPSIS OF WORK DONE

1. Drilled 762 mm hole with Western Caissons auger rig and installed 10 m of 508 mm conductor pipe (20 inch culvert) by cementing around the outside with Ready Mix concrete.
2. Moved on rig and rigged up.
3. Drilled pilot hole and reamed and drilled with 349 mm bit to 227.6 m.
4. Ran 20 joints of 273 mm casing, landed at 227.60 m. Cemented with 300 sacks of cement. When truck broke down, displaced cement with no returns.
5. After waiting on cement, recemented top portion of hole with 200 sacks.
6. Drilled 222 mm hole to 1986 m.
7. Cut Core #1 from 1986.6 - 2001.8 m.
8. Reamed and drilled 222 mm hole to 2045.0 m.
9. Cut Core #2 from 2045.0 - 2063.0 m.
10. Reamed and drilled 222 mm hole to 2067 m.
11. Ran DST #1 (2042 - 2067 m).
12. Cut Core #3 from 2067.0 - 2085.0 m.
13. Reamed and drilled 222 mm hole to 2088 m.
14. Ran DST #2 (2067 - 2088 m)
15. Drilled 222 mm hole to 2095 m.
16. Cut Core #4 from 2095.4 - 2104.8 m.
17. Reamed and drilled to 2202 m.
18. Cut Core #5 from 2202.1 - 2211.6 m.
19. Reamed and drilled 222 mm hole to 2214 m (F.T.D.)
20. Ran DST #3 (2190 - 2214)
21. Ran the following Computalog logs: Dual Induction-Radially Focussed Log, Borehole Compensated - Sonic-Gamma Ray-Caliper Log with total Time Integration, Compensated Density-Sidewall Neutron-Analyzed

Porosity Log with Gamma Ray and Dual Calipers, Temperature Log (Plus the following computed logs: Continuous Crossplot Laserlog and Hole Volume-Annular Volume Integration).

22. Ran DST #4 (2152 - 2183 m).

23. Ran 193 joints of 178 mm casing, landed at 2033.46 m. Cemented through float collar with 890 sacks, no returns. Cemented through stage collar #1 at 628 m with 550 sacks; returns to surface. Stage collar #2 at 217 m opened and cement displaced with water followed by diesel fuel to fill annulus.

24. Moved out rig.

25. Following samples were sent for analysis:

    a) To Chemical and Geological Laboratories Ltd:

        i) Cores for full diameter analysis
        ii) Core samples for permeability to water, X-ray diffraction, and wet sieve analyses.
        iii) Bottom hole samplers (DST 1, 2, 3) for gas and fluid analysis.
        iv) Drill stem test recoveries and mud for routine water analysis and heavy metals.

    b) To Dr. M.S. King, University of Saskatchewan:

        i) 20 core samples
        ii) One set of washed well cuttings sent <u>via</u> Department of Mineral Resources Subsurface Laboratory

    c) To Geochemical Laboratory, University of Regina:

        i) Water samples from DST's for pH, eH, dissolved oxygen.
        ii) Basement sample for whole rock analyses and preparation of thin section.
        iii) Water samples for determination of Na, K and heavy metals.

MAIN RESULTS

REPORT OF WELLSITE GEOLOGIST

Following is the report prepared by geologist Robert L. Shirkie at the wellsite.

WELL DATA SHEET

Well:	U OF R REGINA 3-8-17-19	Lsd.: 3		Sec.: 8		Tp.: 17		Rge.: 19	W. 2

CLASSIFICATION: RESEARCH

Coord.

PROSPECT:

Grd. 576 m

F.T.D. 2214 m

DR'G CT'R: MUSTANG DRILLING

K.B. 581 m

P.B.D.

OPERATOR: UNIVERSITY OF REGINA, ENERGY RESEARCH UNIT

Spudded DECEMBER 28, 1978

PARTICIPANTS:

Rig Release FEBRUARY 7, 1979

On Prod.

Abandoned

GEOLOGICAL MARKERS

Formation	Marker	Sample	E-Log	Elev.
Cretaceous	1st W Specks	530	530	+ 51
	2nd W Specks	560	545	+ 36
	Viking	680	652	- 71
	Mannville	710	703	- 122
Jurassic	Vanguard	801	790	- 209
	Shaunavon Ls	858	848	- 267
	Gravelbourg	876	874	- 293
	Watrous Anhy	933	937	- 356
	Red Beds	963	960	- 379
Mississippian				
	Souris Valley	993	989	- 408
	Bakken	1095	1097	- 516
Devonian	Big Valley	1109	1104	- 523
	Torquay	1124	1119	- 538
	Birdbear	1167	1164	- 583
	Duperow	1205	1204	- 623
	Souris River	1382	1377	- 796
	Davidson Salt	1455	1454	- 873
	1st Red Bed	1526	1526	- 945
	Dawson Bay	1542	1538	- 957
	2nd Red Bed	1581	1581	-1000
	Prairie Evap	1587	1585	-1005
	Winnipegosis	1699	1698	-1117
	Ashern	1751	1751	-1170
Silurian	Interlake	1763	1763	-1182
Ordovician	Stonewall	1885	1885	-1304
	Stony Mtn	1913	1914	-1333
	Herald	1944	1950	-1369
	Yeoman	1965	1968	-1387
	Winnipeg	2034	2034	-1453
	Winnipeg Sd	2044	2045	-1464
Cambrian	Deadwood	2082	2083	-1502
PreCambrian	Basement	2208	2209	-1628
F.T.D.		2214	2215	-1634

Logs

Logs:	Interval	Date
Dual Ind.	228.5-2214.5	Feb. 3/79
Density/Neutron Porosity	228.5-2214	Feb. 4/79
BHC Sonic GR	228.5-2214	Feb. 4/79
Temperature	228.5-2214	Feb. 4/79
MicroLaterolog Caliper	2138-2212	Feb. 4/79

CASING(S)

Surface Casing: 273 mm at 228.5 m

Production Casing: Ran 7" to Top of Winnipeg Sand;

Cemented to Surface

Perf. Interval	Shots	Treatment

CORES

Formation or Member	No.	Interval	Rec.
Yeoman	1	1986-2002	16
Winnipeg Sand	2	2045-2063.4	18.
Winnipeg/Deadwood	3	2067-2085	18.
Deadwood	4	2095.4-2104.8	9
Deadwood/PreCambrian			
	5	2202.1-2211.1	9

WELL DATA SHEET
(Cont'd)

WELL: U OF R REGINA 3-8-17-19 Lsd. 3 - 8 - 17 - 19 W2M

TESTS

NO.	FORMATION	INTERVAL	DURATION-MIN. I.S.I.	V.O.	F.S.I.	PRESSURE—P.S.I. I.S.I.	F.S.I.	I.H.P.	F.H.P.	I.F.P.	F.F.P.	RESULTS
1	Winnipeg Sd	2042-2067	40	40	60	21.255	21.431					Preflow: SAB
		Preflow	3					25.789				Valve Open: SAB 35"
									25.602			dying in 40"
										18.871		Rec. 1975 m:
											21.174	200m muddy s.w.
												1775m salt water
												1234 ppm (10.7
												Temp. 51.7°C
2	Winnipeg	2067-2088	30	30	60	21522	21557	25493	25493	20547	2152[illegible]	
		Preflow	3			20031						SAB Preflow
												VO Strong blow decr
												to nil in 20"
												Rec. 2034 msw
												(183,000 ppm)
												Temp: 40.99° C
3	Deadwood	2190-2214	30	30	60	221896						Preflow: Strong Bl
		Preflow	5				221896					VO:Strong Blow decr
						194238		274508				after 20" to weak
									271739			Temp: Mud 53° C
										201603		Flow 45°C
											213203	Thermometer
												66.7°C
												Salinity:
												107,700 ppm
												Rec. 2017 m salt wa

COMPLETION OR ABANDONMENT SUMMARY

4	Deadwood	2152-2183	Flow 34"	IH 27410	IF 21353	Misrun
				FH 27281	FF 21996	Tool did not shut
						after Preflow

Recovered 2090 msw; Pipe filled in
indicating very good permeability.
Final Flow pressure should be close
Shut In Pressure. Salinity 100,000
Density 1090 kg/

Ran 7" Casing to Top of Winnipeg Sand; Cemented to Surface; Winnipeg and Deadwood Formatio
left open

SAMPLE DISPOSITION

Two sets washed and dried samples to University of Regina
One set bags to Department of Mineral Resources, Province of Saskatchewan
One set bags to Geological Survey of Canada

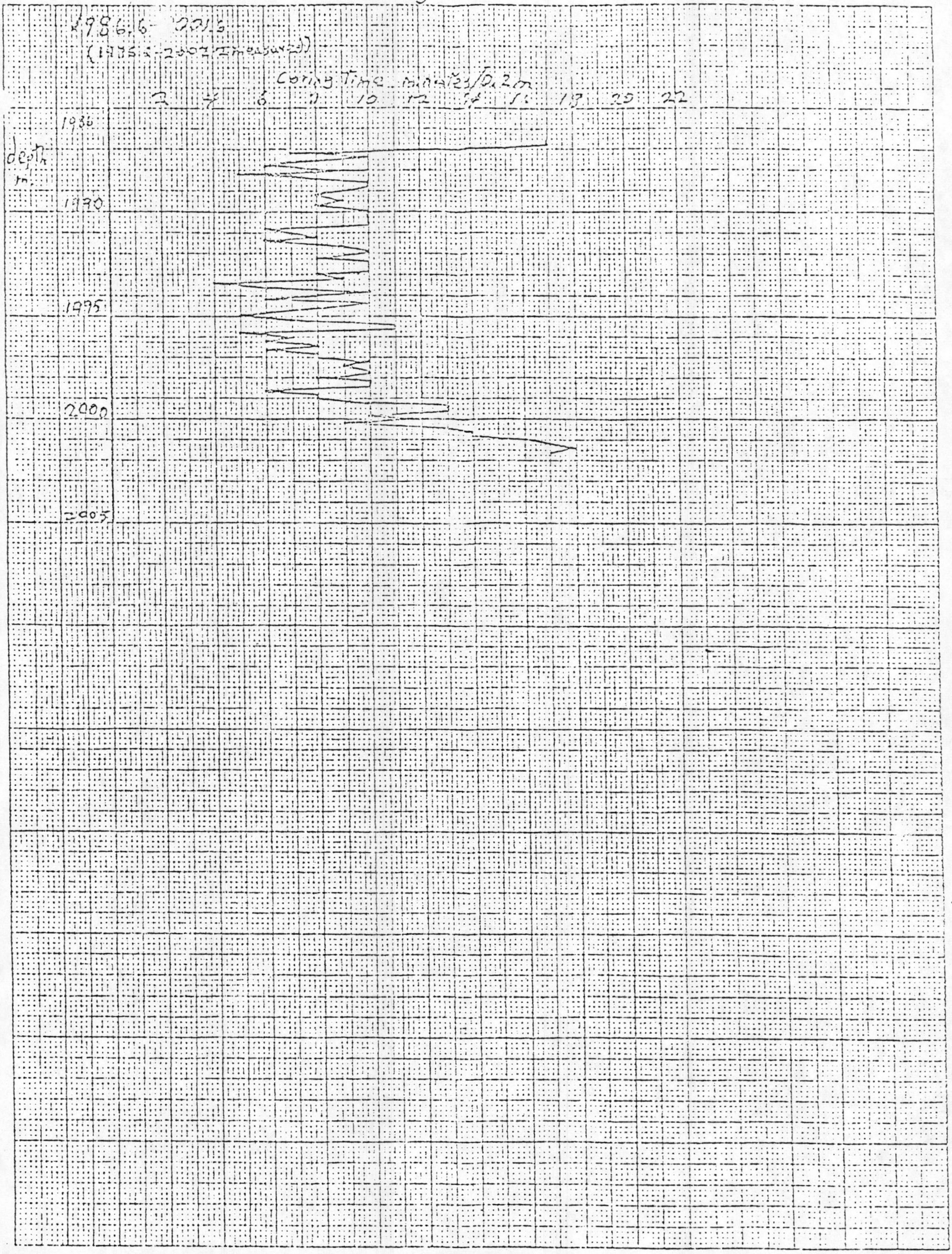
UNIVERSITY OF REGINA 3-8-17-19
Lsd. 3 - 8 - 17 - 19 W2M

CORE DESCRIPTION

CORE No. 1 1986.6 - 2002.2

1986.6 - 88.3	Limestone - dolomitic, light grey and tan mottled (grey, dense, tan, fair intercrystalline porosity); occasional pinpoint vugs, occasional small anhydrite crystals (band of light brown stain with orange fluorescence 1987.5 m)
1988.3 - 1994.25	Limestone - dolomitic, light grey mottled with dense medium grey Dolomite, microcrystalline to fine crystalline with fair intercrystalline porosity. Occasional anhydrite crystals 0.5 - 2 cm vugs common, often associated with skeletal material; pinpoint vugs common under mike 10X; good filtercake was present on porous limestone of this section when removed from core barrel. Porosity - fair to good.
1994.25 - 1996.0	Limey Dolomite - light grey microcrystalline mottled with medium grey microcrystalline dolomite as above; very few vugs over 0.5 cm; occasional pinpoint vug; porosity - poor - sli filter cake build-up.
1996.0 - 1999.0	Limestone - light grey to light tan, microcrystalline to cryptocrystalline, mottled w/Dolomite - cryptocrystalline, light grey, tight, occasional pinpoint vugs and fine crystal lined fracture, occasional fossil coral brachiopod, stylolites common, occasional black bitumen fleck. Anhydrite crystals common; section generally tight.
1999 - 2000.5	Limestone - light grey, mottled with light tan, crypto-crystalline to microcrystalline, stylolitic and occasional argillaceous flecks, dense, tight. White and brown anhydrite crystals common up to 4 mm.
2000.5 - 2002.2	Limestone - light tan to tan, crypto-microcrystalline, occasional anhydrite occasional stylolite, mottled with slightly darker dolomitic limestone. Tight.

core#1 U of R Regina 3-8-17-19 w2 KB: 581m



UNIVERSITY OF REGINA 3-8-17-19
Lsd. 3 - 8 - 17 - 19 W2M

CORE DESCRIPTION

Core No. 2 — 2045 - 2063.4

2045 - 2046.5	Siltstone - medium grey, argillaceous, medium quartz sand grains common, mottled with quartz sandstone (burrows). Siltstone is tight, often pyritic. Sandstone is fairly well cemented with white clay; fair porosity, occasional short fracture.
2046.5 - 2048.5	Sandstone - fine to medium grained, fairly well sorted white quartz sand mottled with grey-brown argillaceous, slightly pyritic sand; cement slightly calcareous, generally quite friable. Good porosity (mottling is result of burrowing).
2048.5 - 2048.9	Light grey quartz sandstone, fine grained, well sorted, occasional pyrite stringer, brittle, well cemented with wilica -- good porosity.
2048.9 - 2051	Quartz sandstone - fine to medium grained, minor medium grained, light grey to brown, argillaceous, mottled with clean white quartz sandstone (50/50) argillaceous is slightly pyritic, friable, good porosity (becoming more argillaceous 2049.6 - 51 m --poor - fair porosity).
2051.0 - 2053.3	White quartz sandstone - very fine to fine grained, fractured about 51.5 m, friable, very good porosity trace pyrite (slightly more pyritic 52.2 - 52.4) cross bedding at 2053.
2053.3 - 2054.0	Sandstone - as above, black pyritic freckles common, occasional stylolite? of pyrite, well packed, poorly cemented with silica - good porosity; crossbedding 53.75 - 54 m; occasional small holes.
2054.0 - 2056.75	Sandstone - white, very fine to fine grained, occasional medium sized quartz grain, occasional argillaceous laminae, good porosity, some crossbedding.
2056.75 - 2059.75	Sandstone - white - medium to coarse grained, silty, slightly argillaceous; matrix - light green, fair porosity (fine sand lens 57.8 - 57.9).

.. 2

CORE DESCRIPTION (continued)

2059.75 - 2061.5	Quartz Sandstone - white, fine grained, occasional medium-sized grains, friable, good porosity.
2061.5 - 2063.55	Sandstone - quartz white, fine to medium grained, slightly argillaceous, slightly pyritic, friable, good porosity, fair to good permeability.

UNIVERSITY OF REGINA 3-8-17-19
Lsd. 3 - 8 - 17 - 19 W2M

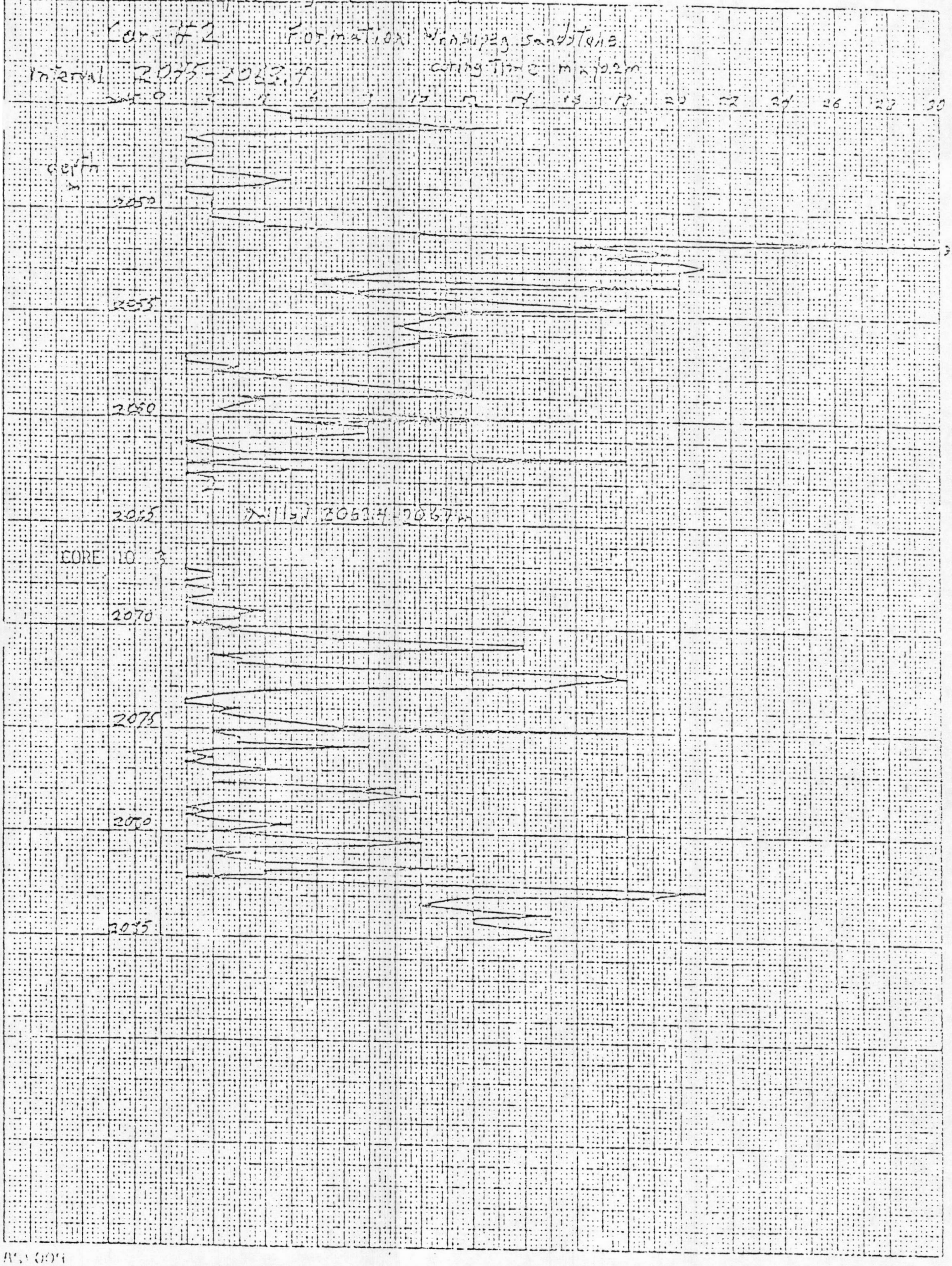
CORE DESCRIPTION

K.B. 581

Core No. 3	Winnipeg Sandstone	Cut 2067 - 2085, Recovered 100%

2067.0 - 2068.75	Sandstone - medium grey, medium grained quartz, pyritic nodules up to 1 mm in diameter, well cemented - calcareous cement, fair porosity.
2068.75 - 2071.3	Sandstone - white to light grey, medium to fine grained, fairly friable, occasional pyrite nodule, calcareous cement, good porosity.
2071.3 - 2074.9	Sandstone - light grey to white, medium to minor coarse grained, fairly well sorted, occasional argillaceous, pyritic stringer, calcareous cement, friable, good to excellent porosity; mud invaded.
2074.9 - 2075.8	Sandstone - medium grey, medium grained argillaceous, pyritic, poor to fair porosity burrows filled with light grey clean sand, calcareous cement, fair porosity
2075.8 - 2077.6	Sandstone - white, pale green, medium to fine grained, fair porosity, occasional coarse stringer, white to green kaolin matrix, occasional pyrite crystal between grains.
2077.6 - 2078.6	Siltstone - grey green, argillaceous, tight, poor porosity burrowed.
2078.6 - 2079.5	Sandstone - very fine grained, minor medium grained, light green, clay matrix, fair to good porosity, pyrite nodules.
2079.5 - 2080.0	Shale - pale green, silty, burrowed w/burrows filled with fine white sandstone, occasional pyrite stringer.
2080.0 - 2080.6	Sandstone - white, fine to medium grained, white clay matrix, well indurated, fair porosity, occasional pyrite nodule, green clay clast.
2080.6 - 2081.5	As above - clay matrix pale green, poor to fair porosity.
2081.5 - 2082.4	Sandstone - white;light grey; pale green, medium to coarse grained, fairly well sorted, very friable, good to excellent porosity.
2082.4 - 2085.0	Banded Siltstone/Shale - green to pale green, micaceous, glauconitic, chloritic, pyritic, occasionally sandy.

U of R Regina 3-8-17-19W2



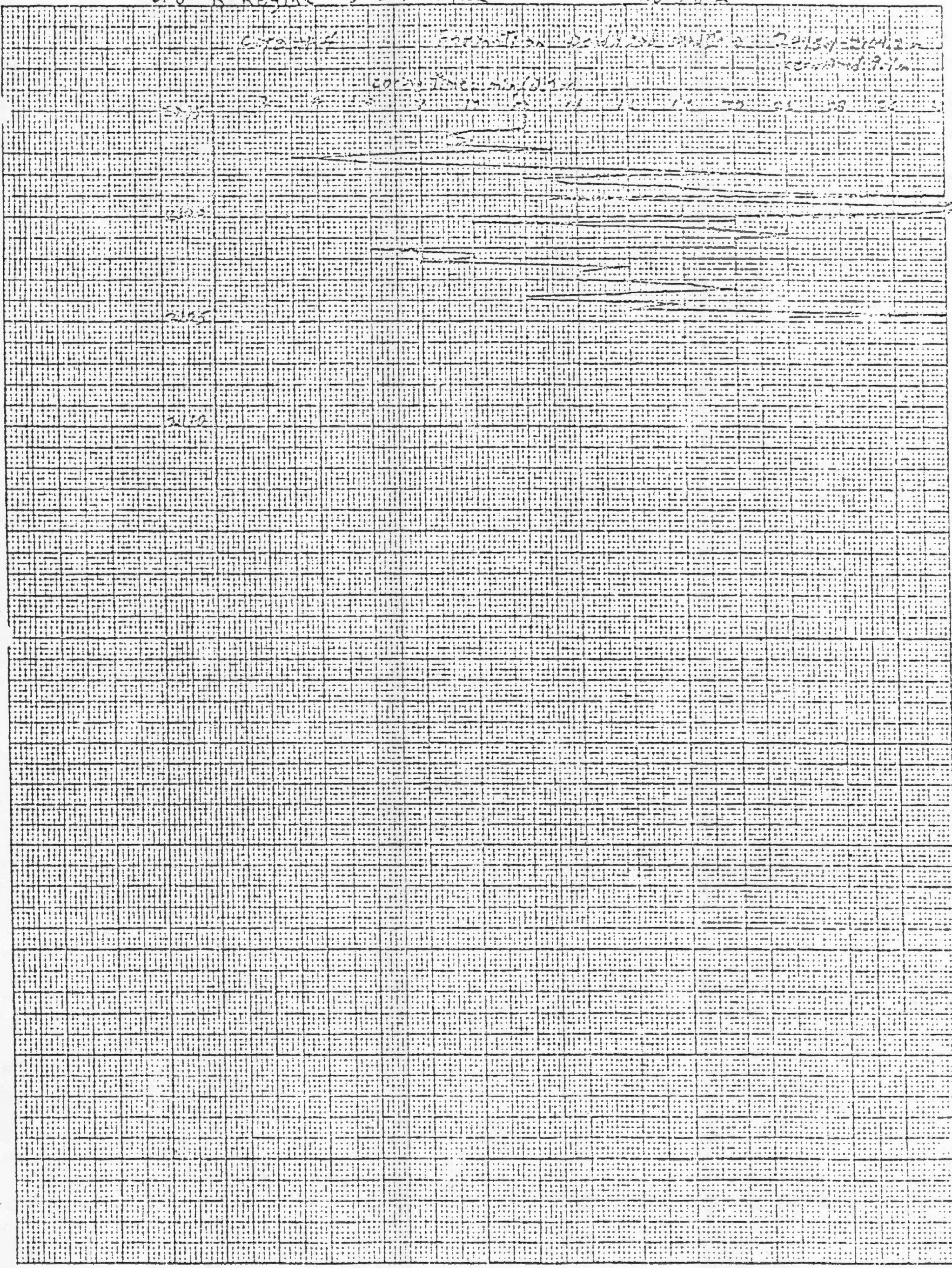
UNIVERSITY OF REGINA 3-8-17-19
Lsd. 3 - 8 - 17 - 19 W2M

CORE DESCRIPTION

CORE NO. 4	Deadwood Formation	2095.4 - 2104.8 m	(9.4 m)

2095.4 - 2096.25	Quartz Sandstone - fine to medium grained, occasionally coarse (poorly sorted) well cemented (sli calcareous cement)bioturbated argillaceous stringers common, poor to fair porosity.
2096.25 - 2099.2	Sandstone - quartz, light grey, fine to medium grained, well cemented, poor porosity, thin filter cake on surface of best porosity. Argillaceous stringers and thin bands of argillaceous, sandy siltstone, tight, pyrite crystals common in argillaceous portions, occasional burrows.
2099.2 - 2100.8	Sandstone - medium grained. Fairly well cemented, grading to very well cemented, tight in bands about 8 cm thick usually with a thin stylolitic argillaceous stringer at base, porosity varies from good to tight below 2100. This banding is not so regular.
2100.8 - 2103.4	Quartz Sandstone - medium grained, occasionally coarse, fairly friable, good porosity, very little argillaceous material, minor (15%) well cemented, tight sandstone lenses.
2103.4 - 2104.8	Quartz Sandstone - medium to coarse grained, very well cemented, poor porosity, occasional band fair porosity (fairly well cemented) trace argillaceous material.

U of R Regina 3-8-17-19W2 KB: 581m



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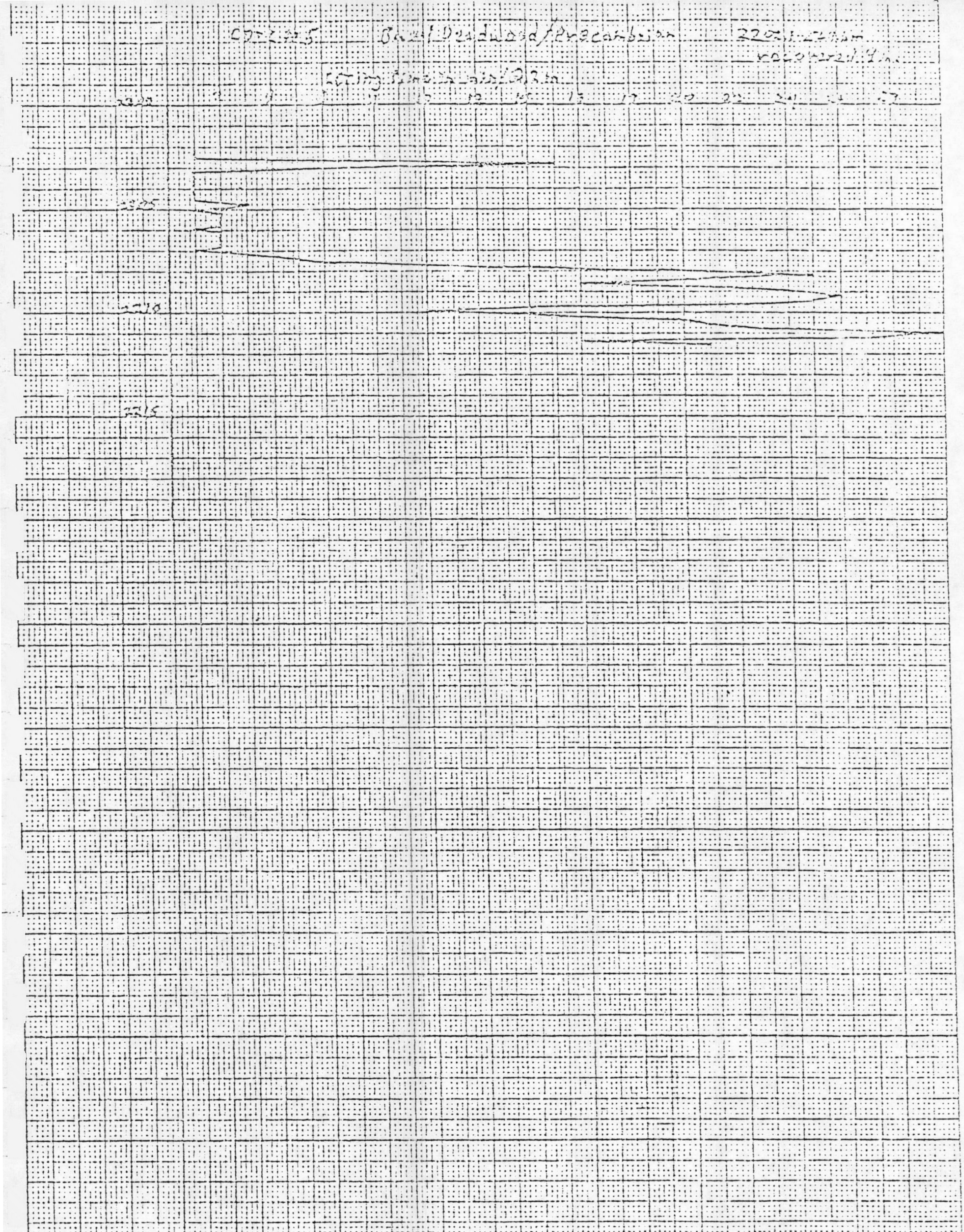
UNIVERSITY OF REGINA 3-8-17-19
Lsd. 3 - 8 - 17 - 19 W2M

CORE DESCRIPTION

CORE No. 5	Deadwood/Precambrian	2202.1 - 2211.1	9 m.

2202.1 - 2202.5	Sandstone - medium to coarse, grey - green, kaolin matrix, friable, occasional pebble up to 1 cm diam. Quartz sandstone, minor orthoclase grains in coarse beds, fair to good porosity.
2202.5 - 2203.0	Sandstone - fine grained with coarse stringers, good porosity, well indurated, quartz, minor feldspar, trace biotite, silica cement.
2203.0 - 2205.4	Sandstone - medium to coarse, grey to green, cross-bedded, good porosity, matrix is kaolin with very fine sand.
2205.4 - 2205.8	Sandstone - medium, minor coarse, clean with occasional argillaceous stringer, very friable, light grey, very good porosity.
2205.8 - 2208.0	Sandstone - light grey - green, cross bedded, occasional argillaceous stringer, quartz, minor feldspar (pebbles up to 2 cm common). Kaolin matrix, very good porosity.
2208.0 - 2211.1	PreCambrian - Coarse grained biotite rich - granite.


Base Deadwood/Precambrian

SUMMARY OF MAIN RESULTS

Geological Markers: Comparison to Prognosis

Depth below K.B. and elevation of the main geological markers are given in the wellsite geologist's report. Table 1 compares the actual results to the predicted results.

TABLE 1

Depths to Major Marker Horizons-Comparison of Actual Depths to Geological Prognosis (Pre-Drill Estimates)

	Depth Below Kelly Bushing (m)	
	Prognosis	Actual (Sonic Log)
Second White Specks	541	545
Mannville	726	703
Shaunavon Ls.	860	848
Souris Valley	1000	989
Birdbear	1175	1164
Souris River	1389	1377
Dawson Bay	1541	1538
Prairie Salt	1587	1586
Winnipegosis	1694	1698
Ashern	1744	1751
Red River	1950	1950
Winnipeg	2029	2034
Deadwood	2079	2083
Basement	2217	2209

Above the top of the Prairie Salt, the well generally came in somewhat higher than expected (a maximum of 23 m on the Mannville top). Below the top of the salt, the markers were generally encountered 4 to 7 m lower than expected except for the Red River (at predicted depth) and the Basement (8 m higher than expected).

Depth predictions for the Devonian and lower Paleozoic were remarkably close. Considering that the well is in or near areas of salt solution and the sparsity of subsurface control, this must be regarded to some degree as fortuitous.

Reservoirs (Aquifers) Below the Ashern

The well was drilled primarily to evaluate the lower Paleozoic section for water production rates, water chemistry and temperature. The prime geothermal targets were the Winnipeg and Deadwood sandstones and a secondary, more uncertain target was the Interlake carbonate section. Other reservoirs below the Prairie Salt were to be evaluated by logging and, if warranted, by coring and testing.

Geothermal gradient and temperatures - Problems associated with determining true earth temperatures during drilling of a well, or soon thereafter, are well known. It is possible that these problems were aggravated at the Regina 3-8-17-19 well because of the extreme cooling effect of the cold mud and of the very cold drill string going into the borehole on "trips to bottom". It should also be noted that we tested much thicker intervals (21 m to 31 m) of permeable reservoir than is generally the case in petroleum exploration : this resulted in short DST flowing times (20 to 35 minutes) probably insufficient to bring downhole thermometers and temperature recorders with their relatively long response time up to the temperature of the fluid being produced into the hole. It is felt intuitively that problems of inconsistent, unreliable and indifferent temperature determinations are widespread and common in the wells that are drilled during petroleum exploration and development.

Drillstem test results and water temperatures

DST #1 (Winnipeg) 2042-2067 m (Mean depth of reservoir 2054 m). 1975 m of water recovered in approximately 35 minutes. Temperature recorder mud 42.9°C; water 53.1°C; Max. reading thermometer (in bullnose) 51.7°C.

DST #2 (Winnipeg) 2067-2088 m (Mean depth of reservoir 2075 m). 2034 m of water in approximately 20 minutes. Recorder # 1 at 2069 m 41.0°C; Recorder #2 (DMR) at 2069 m 56.8°C.

DST #3 (Basal Deadwood) 2190-2214 (Mean depth of reservoir 2199 m) 2017 m of salt water in about 20 minutes. Recorder #1 indicates mud temperature of 42.7°C, water temperature of 54.1°C. Maximum thermometer 66.7°C.

DST #4 (Deadwood) 2152-2183 m (Mean depth of reservoir 2168 m) 2040 m of salt water in about 20 minutes. Recorder #1 at 2154 m 54.0°C Recorder #2 (DMR) at 2165? indicates mud temperature of 53.6°C, water flow temp. of 57.5°C. Maximum reading thermometer 62.0°C.

The results are inconsistent and unreliable. It is unlikely that the thermometers reached an equilibrium temperature with the water flowing past them and the waters may have been cooled considerably in the formation around the borehole prior to the tests. The maximum reading thermometer on DST #3 suggests a bottom hole temperature of at least 66.7°C, not inconsistent with a true earth temperature of 70°C.

Mud temperatures. These were obtained on three drill stem tests and four logging runs as shown in Table 2.

TABLE 2

Mud Temperatures on Tests and Logging Runs

Source	Depth (m)	Temperature (°C)	Elapsed Hours After Circulation
DST 1	2046	42.9	7.7
DST 2	2069	48.3	7.3
DST 3	2192	42.7	9.8
DST 4	2165 ?	53.6	9.5
DIRFL	2215	53.0	6.5
BHCSL	2215	56	17.0
CDL-SNPL	2215	58	26.0
TEMP L	2212	60.9 (Recorder)	35.0
TEMP L	2212	57.8 (Max. Therm.)	35.0

The rate of temperature recovery suggests an earth temperature at 2215 m depth that does not exceed 70°C.

The regional geological study (Vigrass, Kent and Leibel, 1978) suggested a geothermal gradient in the Paleozoic section at Regina of 29°C/km (0.0158°F/ft.). We do not have new information that would substantiate or contradict this value.

Winnipeg sandstone reservoir - Preliminary results on the Winnipeg reservoir are compared to predicted properties (Vigrass, Kent and Leibel, 1978) in Table 3.

TABLE 3

Comparison of Predicted and Actual Properties of Winnipeg Sandstone

(Results Preliminary)

	Predicted	Observed (Preliminary)
Net Reservoir (Thickness)	33.5m (110 ft.)	30.2 m
Porosity (Ave.)	0.175	0.157 (core)
Porosity x Thickness	5.86 m	4.74 m
Permeability (Ave.)	1,000. md	128 md (core) 462 md (DST's)
Transmissivity	33,500 md- m	3,870 md- m (core) 13,900 md- m (DST's)
Pressure (-1463m)	21,480 kPa	21,470 kPa (DST #1) 21,300 kPa (DST #2)
Total Dissolved Solids (ppm)	150,000 ppm	125,000 mg/l (DST #1) 108,000 mg/l (DST #2)
S.G. of Water (25°C)	1.103	1.082 (DST #1) 1.074 (DST #2)
Natural Water Head (Elev.)	+ 525 m	+ 565 m (DST #1) + 561 m (DST #2)
(Depth Below Ground)	51 m	11 m (DST #1) 15 m (DST #2)
Temp. (at 2,063 m)	71°C	66°C ?

Most of the 38 m of Winnipeg sandstone was cored. Only sandstone with core permeability (horizontal permeability K_{MAX}) above 9.5 md. and core porosity above 0.09 is included as net effective reservoir.

The average porosity for the effective reservoir is derived from the full-diameter helium porosimeter determinations for Core #2 (upper Winnipeg) and Core #3 (lower Winnipeg). Average porosity for Core #2 is 0.158 and for Core #3 is 0.157.

The average permeability (core) of 128 md. is derived from full-diameter air permeabilities measured in a horizontal direction (K_{MAX}) after toluene extraction. Average core permeability for the upper Winnipeg (Core #2) is 104 md. and for the lower Winnipeg (Core #3) is 171 md.

The average permeability of 462 md. derived from DST's 1 and 2 is considerably larger than the average core permeability. Both tests, but especially DST #2 (lower Winnipeg) show excellent flow properties with no sign of reservoir depletion or formation damage. The upper Winnipeg Test (DST #1) suggests an average permeability ranging from 223 md. (Petco, corrected for net pay thickness) to 168 md (Vigrass). The lower Winnipeg Test (DST #2) suggests a permeability range (Vigrass) from 1,970 md to 985 md. (In deriving the average DST permeability for the Winnipeg reservoir, I have used the lower end of the range in each case).

In our preliminary study, I recommend that we use the core permeability (128 md.) and core transmissivity (3,866 md - m) because these are the safest values in calculating the maximum drawdown.

Deadwood reservoir - Preliminary results on the Deadwood reservoir sandstones are compared to predicted properties (Vigrass, Kent and Leibel, 1978) in Table 4.

TABLE 4

Comparison of Predicted and Actual Properties of Deadwood Sandstones (Results Preliminary)

	Predicted	Observed (Preliminary)
Net Reservoir (Thickness)	79.2m (260 ft.)	80.9 m
Porosity (Ave.)	0.120	0.147
Porosity x Thickness	9.50 m	11.90 m
Permeability (Ave.)	150. md	331. md
Transmissivity	11,900 md- m	26,750 md- m
Pressure (of Basal Deadwood at -1585)	21,800 kPa	22,000 kPa (DST #3)
Total Dissolved Solids	150,000 ppm	112,000 mg/l (DST #3)
		127,000 mg/l (DST #4)
S.G. of Water (25°C)	1.103	1.076 (DST #3)
		1.081 (DST #4)
Natural Head (Basal Deadwood, Elev.)	+ 430 m	+ 502 m
(Depth below ground)	146 m	74 m
Temp. (at 2156 m)	74°C	68°C

For analysis at the Regina 3-8-17-19 well, the Deadwood has been divided into four divisions at the following depths below K.B. (m):

Upper Deadwood	2,083 - 2,110	(27 m)
Middle Deadwood	2,110 - 2,152	(42 m)
Lower Deadwood	2,152 - 2,195	(43 m)
Basal Deadwood	2,195 - 2,209	(14 m)

Only the Basal Deadwood has been both cored and tested. The cores and logs show 11.3 m of effective sandstone with average porosity of 0.173

and average permeability of 404 md (K_{MAX}). DST #3 substantiates the permeability with permeabilities calculated from the test ranging from 184 md. (Petco) to 413 md. (Vigrass).

The Lower Deadwood was not cored but was tested by DST #4, a partial misrun. Log interpretation indicates 29 m of net effective sandstone in this interval and suggests a porosity similar to the Basal Deadwood. The sandstone is assigned a similar permeability to the basal Deadwwod of 400 md. This permeability is substantiated by a high flow rate during DST #4 (Q = 820 m^3/day) from 19 m of effective sandstone. This compares to flow rate, Q, of 500 m^3/day from 14.3 m of net pay for DST #3.

The middle Deadwood was neither cored nor tested but porosity logs suggest properties intermediate between the Lower and the Upper Deadwood. It has been assigned a net pay of 27 m, average porosity of 0.142, and average permeability of 300 md.

The Upper Deadwood was cored but not tested. Using a permeability cutoff of 9.5 md. and a porosity cutoff of 0.075, the zone has 13.6 m of effective sandstone, average porosity of 0.112 and average permeability of 183 md.

Summary of Section Open Below Casing Shoe - The Winnipeg-Deadwood sandstones have combined porosity-thickness estimated at 16.64 m and transmissivity estimated at 30,670 md- m.

Calculation of the expected drawdown for the section is complicated. There appear to be at least three separate pressure systems and there are probably five. Assuming the transmissibility is distributed as described above, a stepwise drop in pressure from the Winnipeg to the basal Deadwood, average density of pumping water of 1.073, storage coefficient of 4 x 10^{-5}, absolute viscosity of 0.475 centipoise, and well bore radius of 0.111 m, we have calculated the drawdowns at pumping rates of 1363 m^3/day and at 2,400 m^3/day (Table 5).

TABLE 5

Estimated Drawdown (Pumping Level) at Pumping Rates of 1353 m^3/day (250 USGPM) and at 2400 m^3/day.

A. Continuous Pumping Rate 1363 m^3/day (Test Period)

Time From Start	Pumping Level	
Days	Elev. (m)	Depth Grnd. (m)
0.025 (36 min.)	+ 507	69
0.25 (6 hr.)	+ 503	73
2.5	+ 499	77
25	+ 495	81
250	+ 491	85
2500 (6.8 years)	+ 487	89
25,000 (68 years)	+ 483	93

B. Continuous Pumping Rate 2,400 m^3/day

Time From Start	Pumping Level	
Days	Elev. (m)	Depth Grnd. (m)
0.025 (36 min.)	+ 480	96
0.25 (6 hrs.)	+ 473	103
2.5	+ 466	110
25	+ 459	117
250	+ 452	124
2,500 (6.8 years)	+ 445	131
25,000 (68 years)	+ 438	138

If the pumping level is at 135 m below the ground surface, the submersible pump would be set at a depth of 165 to 195 m. At an overall efficiency of 60%, the pumping power required would be 66 kW, approximately 1.9 percent of the power that might be recovered.

Water Chemistry - Predicted water chemistry was as follows:

1. Total dissolved solids are 150,000 ppm

2. The waters are of the Williston Basin type

   a) Sodium and chloride are dominant

   b) Calcium content is about 2,000 ppm and magnesium content is about half as much.

   c) Sulphate is 3,000 to 6,000 ppm.

   d) Bicarbonate is less than 500 ppm

3. It is unlikely that significant H_2S is present.

4. The waters are neutral or slightly alkaline

5. The waters are low in dissolved oxygen

Preliminary examination of the water chemistry shows the following:

1. Total dissolved solids are 108,000 to 127,000 mg/l (101,000 to 117,000 ppm by weight).

2. a) Sodium and chloride constitute 94.8 to 95.0 percent of the total dissolved solids

   b) Calcium is 1,325 to 1,526 mg/l. and magnesium is 313 to 369 mg/l.

   c) Sulphate is 3,679 to 4,350 mg/l.

   d) Bicarbonate is determined at 98 to 409 mg/l.

3. Hydrogen sulphide is present in the water, especially in the water from the upper Winnipeg, but we were not very successful in measuring its concentration (see below).

4. On newly caught waters the pH at room temperature is 7.2 to 7.9 indicating slight alkalinity.

5. Redox potential and dissolved oxygen were measured when the samples were caught at the surface. The waters are slightly reducing (-20 to -95 mv relative to the hydrogen electrode). Determined dissolved oxygen was very low and was probably due to entrainment of air when the samples were caught. It is expected that there is virtually no oxygen in solution in the reservoir.

Bottom hole samplers were run with the drill stem tests with the objectives of catching water at close to reservoir pressure and determining the volume and composition of dissolved gases. A sample was not obtained on DST #4 (Misrun) and the other three downhole samplers were at atmospheric pressure when opened. Oxygen was present (mole fraction 0.0265 to .0345) in the three samples and we have assumed that some of the gas is atmospheric contamination. After correcting for the contamination, the gas : water ratio is fairly constant, ranging from 85 ml/l to 129 ml/l. After correction nitrogen makes up 95 to 97 percent of the gas phase. Hydrogen sulphide was not detected but appeared to have reacted with the container to form hydrogen : restored to hydrogen sulphide, this makes up 2.6 to 2.7 percent of the gas from the Winnipeg drill stem test waters and it is present in volumes of 2.2 to 3.2 litres per cubic metre of water. Helium makes up 0.14 to 0.65 percent of the gas and is present in volumes at least as great as 0.5 to 0.8 litres per cubic metre of water. Hydrocarbon gases occur in trace amounts in all the waters but are most abundant in the basal Deadwood (DST #3) where methane makes up 2.8 percent of the dissolved gas, C_2 to C_4 hydrocarbons account for 0.7 percent, and C_5 to C_9 hydrocarbons make up 0.4 percent of the dissolved gas. Carbon dioxide is present in only trace amounts ranging from 0.03 to 0.05 percent of the dissolved gas.

Toxic metals (As, Se and Hg) are present in the parts per billion range and boron constitutes only 5 to 6 ppm. Silicon, possibly deleterious as a precipitate, ranges from 9 to 24 ppm.

Salts most likely to precipitate on cooling and pressure release are calcium and magnesium carbonates (B.D. Kybett, personal communication). These salts are especially likely to precipitate if the pH is raised by releasing CO_2 or H_2S from solution. The precipitation can be controlled by maintaining carbon dioxide in solution or by lowering the pH of the water.

An unexpected chemical problem may result due to H_2S in the Winnipeg waters. Conceivably this could result in serious corrosion or steel embrittlement problems.

Other reservoirs - Interlake carbonates, a secondary geothermal target, did not have significant effective porosity at the Regina 3-8-17-19 well and were not cored or tested. A core was taken in the Yeoman Member, Red River Formation (1,986.6 - 2,001.8 m) but there was not sufficient good effective porosity to warrant a drill stem test.

INVENTORY OF WELL DATA

Following is a list of the more important data available on the well, on file at the University of Regina. Well completion data, logs, drill stem test reports, and analyses of core, water and gas are also filed with the Saskatchewan Department of Mineral Resources. Logs, reports and analyses will be available through the usual commercial channels for wells drilled under the Oil and Gas Conservation Act and Regulations.

1. PRE-DRILL

i) Survey

ii) Licence

iii) Geological and evaluation program (prognosis)

iv) Summary of expenditures (estimated and actual)

2. DRILLING OPERATIONS

i) Daily drilling reports (Saskoil summary)

ii) Daily drilling reports (tour sheets) of Mustang Drilling Rig No. 1

iii) Charts - Rotation Time/Bits vs. Depth and Drilling Cost vs. Days

iv) Bit record

v) Prairie Mud and Service report (Field tests and mud recapitulation)

vi) Drilling time recorder charts ("Geolograph")

3. GEOLOGICAL AND RESERVOIR ASSESSMENT

i) Report of wellsite geologist (included with this report)

ii) Open-hole mechanical logs by Computalog Services Ltd.

- a) Dual Induction - RFL 228.5 - 2214.5 m
- b) BHC Sonic - GR - Caliper Log with Total Time Integration 228.5 - 2210.8 m
- c) Compensated Density - Sidewall Neutron Analysed Porosity 228.5 - 2214.0 m
- d) Temperature Log 213 - 2211 m
- e) Continuous Crossplot Laserlog 867 - 2215 m
- f) Hole Volume Integration 190 - 936 m

iii) Service company reports for DST 1 to DST 4

iv) Routine full-diameter core analysis (Chem. and Geol. Labs. Limited) on Core #1 to Core #5

v) Liquid (brine) permeabilities on five selected core samples

vi) Sieve analyses of sand (8 samples) and X-ray diffraction analysis of sand and clay fractions (7 rock samples)

vii) Chemical and Geological Laboratories analyses DST 1 to DST 4 including 20 routine oilfield analyses, 20 heavy metal analyses by argon plasma, 4 special analyses (Br, Rb, As, Hg, Se, V, P) by other methods, and 3 dissolved gas (H_2S, CO_2, O_2) analyses

viii) University of Regina Geochemical Laboratory determinations on pH, eH, dissolved oxygen and heavy metals

ix) Gas analyses from down-hole samplers on DST 1 to DST 3

x) Well completion data sheet - Sask. DMR

4. WELL HARDWARE (ENGINEERING REPORTS)

i) Tuboscope inspection report of new 178 mm (7-inch) production casing

ii) Casing tally record for 273 mm (10 3/4-inch) and 178 mm (7-inch) casing strings

REFERENCE

Vigrass, L. W., D. M. Kent, and R. J. Leibel, 1978,

Low-grade geothermal project, geological feasibility study, Regina-Moose Jaw area, Saskatchewan: Open file report, Earth Physics Branch of EMR Canada, Ottawa, 142 p., 29 maps and diagrams.

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