OPEN FILE

GEOLOGICAL SURVEY
OTTAWA

GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA

Open File 2422

THE GEOTHERMAL RESOURCES OF SASKATCHEWAN AND S.W. MANITOBA

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada
DSS Contract File No: 069SZ.23283-8-6036

Prepared By:

G.E. Loveseth

Vali Resources Limited
3632 Utah Drive
Calgary, Alberta
T2N 4A7
(403) 265-2568

January 1992

SCIENTIFIC AUTHORITY:

Dr. A.M. Jessop
Geological Survey of Canada

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

ACKNOWLEDGEMENTS

I wish to acknowledge the following firms and individuals for their assistance in the execution of this project:

The Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada, and Dr. A. M. Jessop who supplied the basic heat flow and conductivity data as well as valuable advice.

International Petrodata Ltd. , and Mr. Warren Robertson, who supplied the geological data required for the mapping of the aquifers.

The Canadian Well Logging Society, whose catalogue of water resistivities was used as the basis for the salinity maps.

Drafting Unlimited, and Mr. Larry Chapman, who provided the drafting services and expertise for preparing the base map and drafting the maps.

Miss L. Caroline Wallace, who neatly posted thousands of data points on the maps.

This report is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada nor its ministers, officers, employees or agents makes any warranty in respect of this report or assumes any liability arising out this report.

PREFACE

This report documents the low temperature geothermal resources of Saskatchewan and southwest Manitoba. Presented is a series of 24 maps which comprise a comprehensive inventory of the formation waters of the study area. The maps illustrate the depth, temperature, salinity, and capacity of eleven slices of rock strata in the subsurface of the central plains of Canada.

This report supplies answers to the questions;

where?

how much?

what temperature?

what salinity?

what depth?

to the potential user of low temperature geothermal energy in the study area. This report is written for the lay person, hopefully easily understandable, but users are advised to obtain advice from competent consultants conversant with the oil industry.

Additional copies of this report are available from
G.E. Loveseth, Vali Resources Limited, 3632 Utah Drive,
Calgary, Alberta, T2N 4A7, Telephone (403) 265-2568.

ABSTRACT

This report documents the low temperature geothermal resources of Saskatchewan and southwestern Manitoba by providing an inventory of the formation waters. It is intended to serve as a source of regional information for those planning or contemplating the use of this vast resource. The study makes use of previous workers estimates of the temperature regime which is combined with geological information to produce maps of eleven rock strata units and their enclosed fluids. The parameters mapped are: temperature, salinity, depth, and reservoir capacity.

EXECUTIVE SUMMARY

The sedimentary rocks of Saskatchewan and southwest Manitoba contain large quantities of warm to hot formation water. Waters of similar temperature elsewhere in the world have been used to supply heat for a number of uses. Such utilization is almost unknown in Canada. This study documents the resource by a series of twenty-four maps of the temperature, depth, salinity, and reservoir capacity of eleven strata units in the study area. It is intended to serve as a source of data for a potential user of geothermal energy.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS i

PREFACE iii

ABSTRACT iv

EXECUTIVE SUMMARY v

INTRODUCTION 1

METHOD 4

Depth 6

Temperature 7

Water Salinity 10

Capacity 11

MAP DISCUSSION 13

Lower Cretaceous 13

Jurassic 14

Midale 14

Frobisher 15

Three Forks and Birdbear 15

Duperow 15

Souris River and Dawson Bay 16

Prairie Evaporite, Winnipegosis and Ashern . . . 16

Silurian 17

Ordovician 17

Cambrian 18

Precambrian 18

LIST OF ILLUSTRATIONS

Figure		Page
1.	Mean Annual Soil Temperature	9
2.	Aquifer Temperature and Capacity of Lower Cretaceous Rocks	Enclosed
3.	Aquifer Depth and Water Salinity of Lower Cretaceous Rocks	Enclosed
4.	Aquifer Temperature and Capacity of Jurassic Rocks	Enclosed
5.	Aquifer Depth and Water Salinity of Jurassic Rocks	Enclosed
6.	Aquifer Temperature and Capacity of Midale Rocks	Enclosed
7.	Aquifer Depth and Water Salinity of Midale Rocks	Enclosed
8.	Aquifer Temperature and Capacity of Frobisher Rocks	Enclosed
9.	Aquifer Depth and Water Salinity of Frobisher Rocks	Enclosed
10.	Aquifer Temperature and Capacity of Three Forks & Birdbear Rocks	Enclosed
11.	Aquifer Depth and Water Salinity of Three Forks & Birdbear Rocks	Enclosed
12.	Aquifer Temperature and Capacity of Duperow Rocks	Enclosed

13. Aquifer Depth and Water Salinity of
Duperow Rocks . . . . . Enclosed
14. Aquifer Temperature and Capacity of
Souris River & Dawson Bay Rocks . . . . . Enclosed
15. Aquifer Depth and Water Salinity of
Souris River & Dawson Bay Rocks . . . . . Enclosed
16. Aquifer Temperature and Capacity of
Prairie Evaporite, Winnipegosis and Ashern . Enclosed
17. Aquifer Depth and Water Salinity of
Prairie Evaporite, Winnipegosis and Ashern . Enclosed
18. Aquifer Temperature and Capacity of
Silurian Rocks . . . . . Enclosed
19. Aquifer Depth and Water Salinity of
Silurian Rocks . . . . . Enclosed
20. Aquifer Temperature and Capacity of
Ordovician Rocks . . . . . Enclosed
21. Aquifer Depth and Water Salinity of
Ordovician Rocks . . . . . Enclosed
22. Aquifer Temperature and Capacity of
Cambrian Rocks . . . . . Enclosed
23. Aquifer Depth of Cambrian Rocks . . . . . Enclosed
24. Depth and Temperature of
Precambrian Surface . . . . . Enclosed

LIST OF TABLES

Table Page

1 Formation Names of Prominent Aquifers 5

Introduction

Huge quantities of warm to hot water lies entrapped in the sedimentary rocks of Saskatchewan and southwestern Manitoba. Elsewhere in the world, similar waters have been used to supply heat for buildings, fish farms, swimming pools, and greenhouses. Utilization of the resource is not new, it has been in use for over a century. In Canada, however, the use of this resource is almost nil, indeed the resource and its potential use is almost unknown except to a few devotees. Almost everyone in Canada thinks of geysers and steam when geothermal energy is mentioned but Lienau et al (1988) identify 67,170 sites using geothermal energy in the U.S.A. the vast majority of which use low to moderate temperature water. It is estimated that these so-called direct use applications supply the energy equivalent of 4,500,000 barrels of oil per year (Lienau et al (1988)). The actual size of the resource in the sedimentary rocks of the Canadian plains is enormous. This report presents an inventory of the resource in Saskatchewan and southwest Manitoba.

There exists a vast bank of subsurface data which has been amassed as the result of oil and gas exploration and development. There are over 40,000 wells drilled in the study area. Previous workers have used parts of this data bank to estimate the characteristics of the temperature regime in the study area. This study extends their work to produce a suite of maps that will allow a possible user of geothermal energy to assess the potential of the formation waters of Saskatchewan and southwest Manitoba. This study integrates geological information with the temperature regime of previous authors and is basically an inventory of the formation waters of the two provinces. It is intended to answer the questions,

where?,

how much?,

what temperature?,

what salinity?, and

what depth?

for the waters of Saskatchewan and southwest Manitoba. These questions are of primary importance to anyone contemplating the use of geothermal energy.

A total of twenty-four maps were made illustrating the temperature, depth, water salinity and qualitative capacity of eleven groups of rock strata as well as the maximum temperature and depth to be expected at the base of the sedimentary sequence. The groups of rocks were selected to correlate with the groups mapped in Alberta last year (Loveseth and Pfeffer (1988)), where equivalent strata exist (Table 1).

METHOD

The sedimentary basin of western Canada has been divided into thirteen slices of strata based on the age of the deposited rocks as shown in Table 1. In Alberta, ten of the slices have geothermal potential and were mapped in Loveseth and Pfeffer (1988). In Saskatchewan and southwest Manitoba, there are eleven slices with geothermal potential, and these have been mapped in this report. Note that because of the distribution of aquifers, the slices selected for mapping are not identical in the Alberta study and this one. Four parameters were mapped for each rock strata unit. These parameters are: depth to the top of the unit, temperature at the top of the unit, capacity of the rocks in the unit, and salinity of the water enclosed in the unit. The maps are at a scale of 1:1,000,000 and adjoin the Alberta maps of Loveseth and Pfeffer (1988) . To save bulk, each physical map presents two parameters for the unit in question. Since temperature and depth are closely related their contours are sub-parallel and were therefore placed on separate map sheets to avoid possible confusion. The mapped pairs are:

(1) Temperature and Capacity and

(2) Depth and Salinity.

TABLE 1

	ALBERTA			SASKATCHEWAN	
ROCK UNIT AGE	MAP UNIT NAME	FORMATION AQUIFER NAMES		MAP UNIT NAME	FORMATION AQUIFER NAMES
		SOUTHERN ALBERTA	NORTHERN ALBERTA		
Lower Cretaceous	Lower Cretaceous	Viking,Mannville, Blairmore,Glauconitic, Ellerslie	Paddy,Cadotte,Notikewin, Bluesky,Gething, Cadomin	Lower Cretaceous	Viking,Mannville
Jurassic				Jurassic	Success,Roseray, Shaunovan
Triassic	Triassic		Baldonnel,Halfway, Montney		
Permo-Penn	Permo-Penn		Belloy		
Mississippian	Turner Valley-Debolt	Turner Valley	Debolt,Elkton	Midale	Charles,Midale
	Shunda-Pekisko-Banff	Shunda-Pekisko	Clark's Member	Frobisher	Mission Canyon, Frobisher, Alida,Tilston
Devonian	Wabamun-Winterburn	Wabamun,Stettler	Winterburn, Nisku	Three Forks & Birdbear	Three Forks, Birdbear,Nisku
	Woodbend	Leduc, Cooking Lake	Grosmont,Leduc	Duperow	Duperow
	Beaverhill Lake	Moberley,Calmut	Swan Hills,Slave Point	Souris River & Dawson Bay	Souris River & Dawson Bay
	Elk Point	Winnipegosis	Gilwood,Sulphur Point Bistcho,Keg River,Zama, Presqu'ile,Rainbow	Prairie Evaporite, Winnipegosis & Ashern	Winnipegosis
Silurian				Silurian	Interlake,Stonewall
Ordovician				Ordovician	Stony Mountain, Red River,Winnipeg
Cambrian	Cambrian-Granite Wash	Pika,Basal Sand	Granite Wash	Cambrian	Deadwood

GEOTHERMAL RESOURCES
OF
SASKATCHEWAN &
S.W.MANITOBA

FORMATION NAMES
OF
PROMINENT AQUIFERS

Depth

The depth to the top of each slice and, in the case of the Paleozoic units, the distance of the unit from the Post - Paleozoic unconformity were derived from a retrieval of geological tops from the well data file maintained by International Petrodata Ltd. All the wells in the study area were searched and the information was retrieved for the deepest well in each township. As is to be expected, the best data coverage is in the shallower beds. All of the units mapped, however, had enough depth and thickness information to permit the making of meaningful maps.

The maps show the sum of the subsurface structure of the various units and the surface topography. Some features are common to all maps. The influence of the bowl shaped Williston Basin is readily seen along the south border of the maps. The influence of the Sweetgrass Arch is to be seen coming up to the north and east from the extreme southwest corner of the mapped area. Topographic highs are also obvious especially on the shallower maps where the control is denser. The Cypress Hills are prominently shown in the southwest corner of the maps. Also to be seen are the Turtle Mountain and Moose Mountain topographic features.

Temperature

The basic temperature and gradient data came from two sources. Jones and Majorowicz, (1985) supplied gradient data both above and below the pre-Cretaceous unconformity as well as the temperature at the unconformity for the area of Saskatchewan adjacent to Alberta. Since these data were uncorrected for the disturbance of the temperature by the borehole, the data were corrected using the algorithm given in that source. The second source of basic temperature and gradient data is Majorowicz et al (1986), where information on heat flow and conductivities is available for the whole study area. Since these data are inconvenient to use in that form, they were converted to gradients by a graphical method and merged with the first source. In general, the agreement was reasonably good. For the top of the Lower Cretaceous and Jurassic slices and the top of the Paleozoic, the temperature at the top of the slice was estimated by graphically multiplying the Mesozoic gradient (Grad 1) times the depth to the top of the unit in question and adding the surface temperature. The surface temperature was estimated from Environment Canada (1984), and is shown as Figure 1.

For the Paleozoic units, the temperature at the top was estimated by multiplying the Paleozoic gradient (Grad 2) by the distance from the top of the Paleozoic and adding the temperature previously calculated for the Paleozoic temperature using the Mesozoic gradient. These calculations were also done graphically. The resulting contours were merged with the data from Jones and Majorowicz (1985). These contours were then adjusted with the sparse high quality data available, namely the Regina geothermal well and the Dodsland water source well documented in Jessop (1989). Since this method of temperature estimating (sometimes referred to as the blanket approach) is sensitive to the depth of the rocks, the effect of topography may be seen on many of the maps.

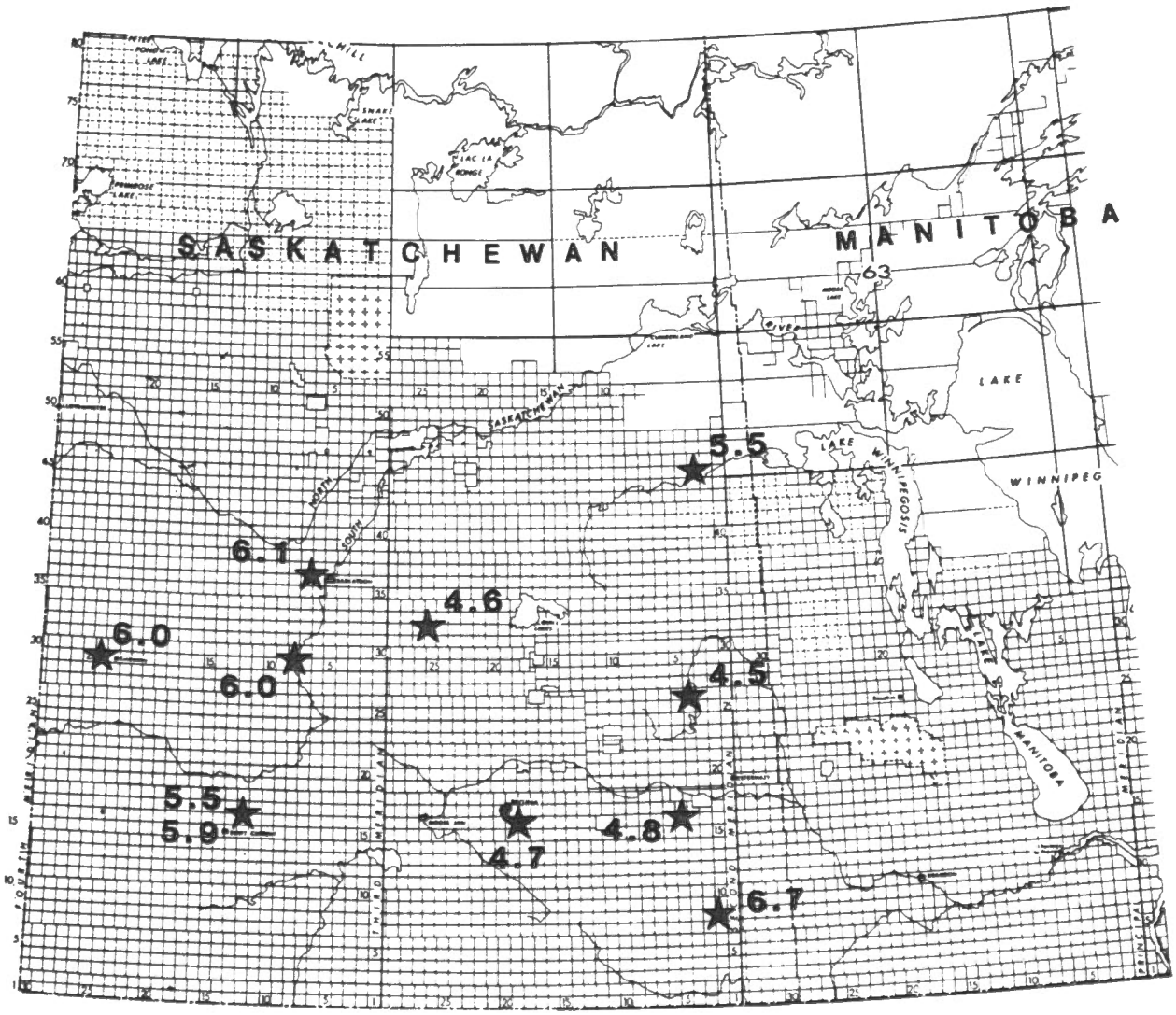
FIGURE 1

GEOTHERMAL RESOURCES OF SASKATCHEWAN & S.W. MANITOBA

MEAN ANNUAL SOIL TEMPERATURE

DEGREES CELSIUS
AT 150cm DEPTH

1951-1980



Water Salinity

The salinity of the formation water was determined by utilizing the catalogue of Formation Water Resistivities of Canada published by the Canadian Well Logging Society. The information on resistivities was converted from resistivity to an equivalent total dissolved solids expressed in terms of sodium chloride concentration. It is not possible to map the salinity and water type more definitively given the regional scale of the maps and the grouping of the aquifers. More detail is available and the user who requires it is advised to seek professional guidance on a site specific basis.

The data are reliable and show cohesive patterns of salinity. Of particular interest is an area near the American border (49° North) and along the Third Meridian (106° West) where a tongue of fresh water is seen in all formations with sufficient data.

The Cambrian does not have enough salinity data to map. The waters contained in Cambrian are almost certainly very highly saline everywhere and may approach saturation in many places. There is some indication that the lowest Cambrian salinity is in the area described above where tongues of fresh waters are seen in all the younger formations.

Capacity

The capacity of the rock units is a measure of the amount of formation water they contain. The basis of the maps is the net porous rock figure expressed as the thickness in meters of porous rocks interpreted from logs by International Petrodata Ltd. This number is retrieved from their file for the deepest well in each township that completely penetrates the rock unit in question. These numbers show considerable scatter. They have been contoured in a qualitative fashion on the maps. The maps show three grades of capacity:

(1) Excellent to Good, Continuous. The user can be assured that good quality reservoir is present.

(2) Good to Fair, Fairly Continuous. The user should check local well data to determine the exact quality of aquifer at his site.

(3) Poor, Discontinuous. The user must rely on site specific data to determine whether an aquifer is present and its quality.

An attempt was made to present this aspect of the rocks as a series of maps of the transmissivity of the units which might be a better index of their usefulness as a geothermal source. Unfortunately, the variability of the rocks precludes mapping that parameter on the regional scale used. It should be remembered that the deliverability of any borehole is a function of not only the transmissivity and porosity of the rocks but also dependent upon many features of the mechanical equipment of the well. The size of the tubing, the size of the pump, the number of perforations, the depth of the well are all important factors influencing the deliverability of the well. In addition, the undisturbed pressure of the aquifer is important.

Map Discussion

Lower Cretaceous

The lower Cretaceous group of rock strata are everywhere cooler than what is usually considered the temperature threshold for low temperature direct use applications (50°C). They have been mapped here because much of southwestern Saskatchewan is underlain by a series of lower Cretaceous artesian aquifers. The artesian pressure systems considerably reduce the pumping expense normally associated with subsurface waters and therefore makes these cooler waters of interest. The use of lower Cretaceous waters as input to heat pumps appears to be particularly attractive.

For many years, artesian waters were used to supply "The Natatorium" at Moose Jaw. Mechanical problems with the source well caused the demise of the project several years ago. At the present, resumption of the project is being actively pursued.

Jurassic

Jurassic rocks west of the Third Meridian (106° west) generally contain good reservoirs. This is the area where Jurassic rocks house important quantities of oil and gas. The waters in these strata are quite fresh. Temperature is expected to be low for geothermal purposes. On the depth map, one can see the north facing scarp of the Cypress Hills and the gentler south facing slope. Because of the method of calculating the temperature, these topographic features also show up in the temperature map.

Midale

Midale rocks are restricted to the extreme south of Saskatchewan in the deep part of the Williston Basin. They host most of the oil and gas of southeastern Saskatchewan. The contained waters are mostly above the 50°C threshold but are rather salty since the Midale rocks are preserved east of the area of incursion of fresh water. Because of facies change the west boundary of Midale preservation is interpretative, but the north erosional edge is clear.

Frobisher

Frobisher rocks are widely distributed across Saskatchewan and Manitoba. They achieve temperatures in excess of 60°C. The area of best development of reservoir is mostly east of the fresh water area but there is an area of particular interest near the U.S. border just west of the Third meridian where warm (55°C) fresh water and excellent reservoir are predicted to co-exist.

Three Forks and Birdbear

The group of rocks mapped as Three Forks and Birdbear generally contain only poor discontinuous reservoir development. They are reasonably continuous in Manitoba where the temperature is of interest but the salinity is very high.

Duperow

Duperow strata in the center of the Williston Basin are fair reservoir rocks but along the margins thick porous zones are everywhere developed even though the unit contains much anhydrite. Temperatures range up to 70°C at the top of the unit, and fresh water may be found in the Gravelbourg area.

Souris River and Dawson Bay

Rocks in the Souris River and Dawson Bay map unit are shelf margin carbonates with considerable anhydrite and even some halite in local areas. Porous developments are variable from a regional viewpoint but certain areas have good to excellent reservoir characteristics. Again a tongue of fresh water is seen in the south but appears to be slightly farther west than in the upper map units.

Prairie Evaporite, Winnipegosis and Ashern

This unit contains the major halite deposits of the study area but still encases some fair reservoirs. The reservoirs are found in the Winnipegosis carbonate sequence. This sequence is largely dolomitized and contains a large number of reefs. Usually these reefs are porous and would serve as good water sources but the porosity may be salt plugged. The water in the areas where the best reservoirs may be expected is usually highly saline.

Silurian

Silurian rocks cover most of the study area with the exception of the extreme western edge where they are missing due to erosion. The best reservoirs are in the Melville area where the temperatures are quite high but where the salinity is very high. Silurian rocks are largely lithographic dolomites but fragmental limestones are abundant and there are frequent beds of anhydrite in certain places. Dolomitization of the fragmental limestones gives rise to the porous rocks.

Ordovician

The Ordovician maps include both the siliclastic Winnipeg formation and the carbonate Red River Formation. The Winnipeg consists of up to 60 metres of porous sand centred on the Regina area and makes up the bulk of the reservoir shown in Figure 20. The Winnipeg is an excellent reservoir but the enclosed water is very salty. The overlying Red River consists of two main sequences. The lower unit is a fragmental limestone variably dolomitized while the the upper unit is a sequence of dolomites and anhydrites.

Cambrian

Rocks of Cambrian age in Saskatchewan and Manitoba are referred to as the Deadwood formation. The Deadwood is a sand - shale sequence which contains excellent reservoirs. It is deep and therefore hot by the standards of the Western Canada basin. The number of wells which test this formation is rather limited, and there are not enough analyses available to map the salinity of the water. One well, at Dodsland, is used as a water source well for an oilfield waterflood. This well is reported to be capable of producing 40,000 barrels per day. The water is very salty and is mixed with fresher water from the Lower Cretaceous to prevent salt from precipitating as the water cools at surface.

Precambrian

Figure 24 shows the depth and expected temperature at the top of the Precambrian which is the base of the sedimentary rocks. Of course, no reservoirs are to be expected below this point. The map is included for the sake of completeness and shows the maximum temperature and maximum depth of geothermal interest.

REFERENCES

Environment Canada, (1984), Canadian Climate Normals, Volume 9, Soil Temperature, Lake Evaporation, Days With .../ Blowing Snow, Hail, Fog, Smoke or Haze, Frost.

Jessop, A.M., (1989), Accuracy of Temperature Data in Basins, Pure and Applied Geophysics, in press.

Jessop, A.M., and Vigrass, L.W., (1989), Geothermal Measurements in a Deep Well at Regina, Saskatchewan, Journal of Volcanology and Geothermal Research, v. 37, p. 151 - 166.

Jones, F.W., and Majorowicz, J.A., (1985), A Study of the Geothermal Environment of the Western Canadian Sedimentary Basin, (DSS Contract OSG84-00073).

Lienau, P.J., Culver, G., and Lund, J.W., (1988), Geothermal Direct Use Developments in the United States, Geo-Heat Center, Oregon Institute of Technology, (U.S.Department of Energy, Contract No. DE-FG07-87ID 12693)

Loveseth, G.E., and Pfeffer, B.J., (1988), Geothermal Resources of the Alberta Plains, (DSS Contract 48SZ 23283-7-6132)

Majorowicz, J.A., Jones, F.W., and Jessop, A.M., (1986), Geothermics of the Williston Basin in relation to Hydrodynamics and Hydrocarbon Occurrences, Geophysics, v. 51, No. 3, p. 767 - 779.

Struyk, C.J. , (1987), Editor, Formation Water Resistivities of Canada, Canadian Well Logging Society Publication.