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GEOTHERMAL RESOURCES OF THE ALBERTA PLAINS

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PREFACE

This report documents the geothermal resources of the Alberta plains through a series of 21 maps which present the temperature, depth, salinity and capacity of the aquifers within ten vertically contiguous slices of rock strata. There have been some previous site specific inventories of the geothermal resources of the Alberta plains, however, this study is the first comprehensive survey attempted.

Several strategies are proposed whereby the geothermal resources accessed by oil exploration activity could be put on stream at reduced capital cost.

Although this report attempts to present the data in an easily understandable fashion, comprehensible to the lay person, potential users are advised to obtain advice from competent consultants conversant with the oil industry.

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 provides an inventory of the formation waters of the Alberta plains, their temperature, salinity, depth and the reservoir capacity of the enclosing rocks. It is intended to serve as an information source for those contemplating using these waters as a source of geothermal energy. The study makes use of pre-existing temperature and gradient data which is combined with geological information to generate maps of ten rock units and the enclosed fluids. Suggestions on the ways of exploiting the resource are given.

EXECUTIVE SUMMARY

The sedimentary envelope of the Alberta plains ranges in thickness from zero in the northeast corner of the province to nearly 5000 metres along the edge of the disturbed belt in the southwestern corner of the province. Many excellent aquifers are present. Temperature gradients (degrees Celsius per kilometre) range from over 45 to less than 10 and average about 30. No highly anomalous hot spots have identified to date. Water at temperatures suitable for many purposes is readily available. The water generally contains considerable dissolved solids, usually 100,000 ppm or greater.

Due to the fact that waters of geothermal interest are at depth of 1.5 kilometers or more, the capital cost of accessing this energy is very high. This handicap could be overcome by utilizing a wellbore drilled in the course of exploration or production of oil or gas.

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INTRODUCTION

Under the plains of Alberta lie huge quantities of water. This water is warm to hot and represents a vast potential source of energy. The well known Leduc reef, at the time of its discovery, contained about 1,600,000,000 cubic meters of water. Lowering the temperature of that water 10 degrees Celsius would yield enough energy to supply 3400 prairie households with their requirements for 100 years. The Leduc reef contains only a miniscule fraction of the formation waters of Alberta. Elsewhere in the world, notably France, Hungary and the U.S.S.R. similar waters are used to heat buildings. In the western United States there are a large number of projects which use warm waters to supply heat for such things as greenhouses and fish farms. It seems inevitable that the resource will be tapped in Canada at some time in the future.

There exists in Alberta a vast bank of subsurface data which has been amassed as the result of oil and gas exploration and development. Previous workers have used part of the data to estimate the subsurface temperature and gradients. This study combines the results of the previous work with more data to produce a suite of maps that will allow a possible user of geothermal energy to assess the potential at any location on the Alberta plains.

A total of twenty-one maps were generated indicating the temperature, depth, water salinity and qualitative capacity of rock strata from the Lower Cretaceous to the Precambrian surface. Individual aquifers within these groups of rock strata are identified in the accompanying stratigraphic column (Table 1). The lower limit of interest in geothermal water source was deemed to be 50 degrees Celsius and the data was therefore compiled for those portions of each group exceeding that temperature.

TABLE 1

ROCK STRATA UNIT	FORMATION AQUIFER NAMES	
	SOUTHERN ALBERTA	NORTHERN ALBERTA
Lower Cretaceous	Viking,Mannville Blairmore,Glauconitic, Ellerslie	Paddy,Cadotte,Notikewin, Bluesky,Gething, Cadomin
Jurassic	No Aquifers	No Aquifers
Triassic		Baldonnel,Halfway, Montney
Permo Penn		Belloy
Turner Valley-Debolt	Turner Valley	Debolt,Elkton
Shunda-Pekisko-Banff	Shunda,Pekisko	Clark's Member
Wabamun-Winterburn	Wabamun,Stettler	Winterburn,Nisku
Woodbend	Leduc,Cooking Lake	Grosmont,Leduc
Beaverhill Lake	Moberley,Calmut	Swan Hills,Slave Point,
Elk Point	Winnipegosis	Gilwood,Sulpher Point Bistcho,Keg River,Zama, Presqu'ile,Rainbow
Cambrian-Granite Wash	Pika,Basal Sand	Granite Wash

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FORMATION NAMES OF PROMINENT AQUIFERS

METHOD

General

That portion of the sedimentary rocks underlying the plains of Alberta deemed to have geothermal potential was divided into eleven rock strata units as shown in Table 1. The names of those formations in each unit that have sufficient porosity and permeability to qualify them as aquifers are shown in the table. One unit, the Jurassic, has no significant aquifers and was therefore not considered further. The other ten units have one or more aquifers and were mapped on a scale of 1:1000000. Four parameters were mapped for each unit, namely temperature, depth, water salinity and reservoir capacity. Two parameters are presented on each of two maps for each strata unit.

Temperature

The temperature at the top of each rock strata unit has been mapped. Using pre-existing data (Jones et al, 1984, Jones et al, 1985, Jones et al, 1986, Jones et al, 1987), and graphical methods for the calculations. For the most part, the Jones data was accepted as found. However, the depth to the Paleozoic unconformity used by Jones et al was checked against our data. Where temperature anomalies were found to be due to incorrect depths, the data were corrected to reflect the correct depths. This required estimating the surface temperature which was done using data from Environment Canada, 1984. The variation was surprisingly small and the information is shown in Figure 1. The temperature gradients above and below the Paleozoic surface (referred to as Grad 1 and Grad 2 respectively) were accepted but smoothed somewhat in contouring.

A map of the temperature at the Paleozoic Unconformity was the first map produced and was subsequently used to generate the maps for each slice. A map of the interval thickness from the slice to the unconformity was combined with the appropriate gradient to generate a temperature difference map. The temperature difference map was then added or subtracted from the Unconformity temperature map as appropriate to determine the temperature at the top of the slice.

Depth

The depth to the top of each slice and the depth to the top of the Paleozoic surface were derived from a retrieval of geological tops from the well data file maintained by International Petrodata Ltd. These data were used to calculate the interval from the top of the slice to the Unconformity and also the drilling depth to the slice. The information was selected from the deepest well in each township. The information was plotted within the township

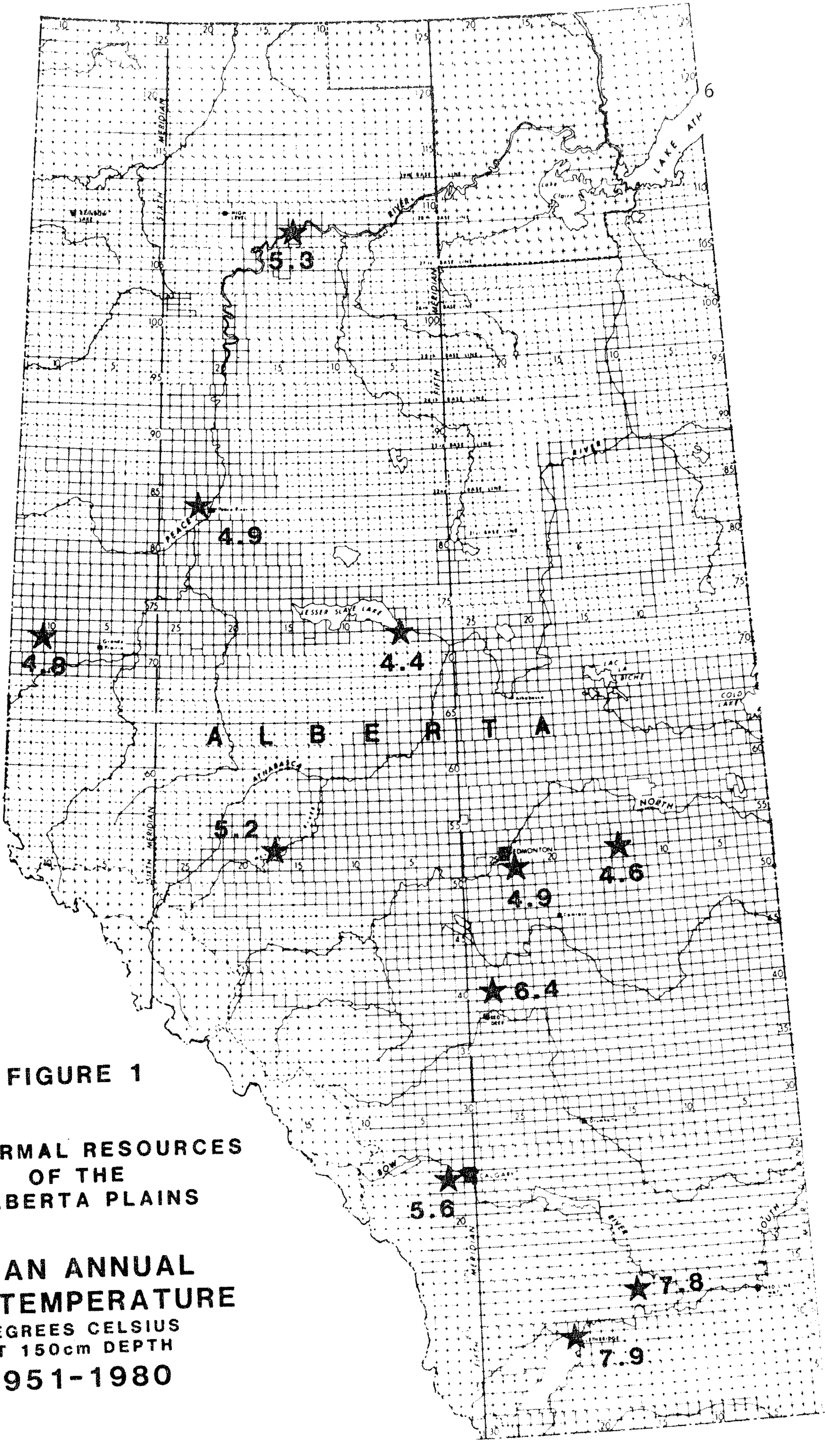

FIGURE 1

GEOTHERMAL RESOURCES OF THE ALBERTA PLAINS

MEAN ANNUAL SOIL TEMPERATURE

DEGREES CELSIUS AT 150cm DEPTH

1951-1980

and contoured on 100 metre or 500 metre intervals as deemed appropriate.

Water Salinity

The salinity of the formation waters was determined from the catalogue of Formation Water Resistivities of Canada produced by the Canadian Well Logging Society. This publication presents maps with individual formation water resistivities, adjusted for temperature, plotted on every significant aquifer in the sedimentary column for western Canada. The data is designed to be used in analysis of well logs to determine the presence of hydrocarbons, and therefore is a measure of total dissolved solids. The appropriate maps relating to this project rock strata units were contoured to reflect the total dissolved solids expressed as salt solutions (PPM of NaCl). The data shows only modest variability in a given area and the interpretation are considered reliable and accurate.

Capacity

The net porous rock in each rock strata unit was obtained from the International Petrodata Limited file and plotted on the basis of one well per township. The data shows considerable variability. Using the porosity data and the writers long experience working with these rocks, a series of maps illustrating the qualitative capacity of the rocks were prepared. The maps show four grades of capacity.

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

(4) No aquifer is to be expected.

GEOLOGY

General

The purpose of this discussion is to give a general overview of the rocks for those persons not familiar with the strata sequence in Alberta. The main rock types and their distribution are described and the principal aquifers identified (Table 1). Those persons interested in a specific site should seek professional advice about the information available from wells drilled nearby. Over 100,000 wells have been drilled in the province and stratigraphic information from them is available from the Alberta Energy Resources Conservation Board.

The sedimentary rocks of the province form a westward and southward thickening wedge extending from a zero edge in the extreme northeast corner of the province to attain a thickness of about 2200 metres in the southeast corner of the province and approaches 5,000 metres in thickness along the Disturbed Belt in the southwest corner of the province. In broad terms the sedimentary envelope can be subdivided into three groups of rocks. Uppermost are the shales and sands of the Mesozoic age that represent about 50% of the total rock volume. The middle slice consists predominantly of carbonates of the Upper Paleozoic age and represents about 35% of the rocks. The basal Lower Paleozoic rocks, representing 15% of the rock volume, are predominantly shales and sands along with considerable evaporites.

The geometry of the sedimentary envelope of Alberta dictates that the western portion of the province has the best potential for geothermal energy because the rocks are deeper and hotter. The accompanying suite of maps bears clear witness to this simple fact.

<u>Lower Cretaceous Rocks</u>

The Lower Cretaceous consists of a sand - shale sequence of unconformable strata that overlies progressively older rocks to the eastward. These rocks average about 200 metres thick but thicken dramatically to westward along the Disturbed Belt and in the Grande Prairie area where they may be over 1000 metres thick. Lower Cretaceous strats constitute the shallowest high capacity aquifer in the stratigraphic column, and have the greatest density of well control. Therefore, they offer the most likely potential for low-grade geothermal energy in Alberta. Capacity is excellent in the west-central area of the province, but becomes less reliable to the southward and along the margin of the Disturbed Belt. However, local aquifers abound and site specific studies are required to properly evaluate these rocks. The most likely aquifers include the Viking formation, located near the top of these strata, and the basal sands lying on the unconformity which masquerade under a variety of local formation names.

Jurassic Rocks

The Jurassic consists of a wedge of mainly clastic rocks, shales with minor sands, that thins eastward to an erosional edge in west-central Alberta, from up to 2000 metres in thickness along the edge of the Disturbed Belt. These rocks have no aquifers worthy of note, so they were not mapped in this study.

Triassic Rocks

The Triassic consists of a wedge of clastic and minor carbonate rocks that occurs in west-central Alberta. Up to 600 metres of strata are present along the Disturbed Belt which thin to an erosional edge to the west of Lesser Slave Lake. The Halfway and Montney formations, in the area west of Lesser Slave Lake constitute good potential aquifers in these rocks. Other areas have no worthwhile geothermal potential.

Permo - Pennsylvanian Rocks

These mainly clastic rocks are limited to the Grande Prairie area in west-central Alberta where they attain a thickness of up to 100 metres. They are of geothermal interest chiefly because of a sand with excellent aquifer potential, namely the Belloy formation, is contained within them. The Belloy has excellent porosity and permeability and deserves serious consideration as a geothermal source rock within the limited area that it occurs.

Turner Valley - Debolt Rocks

This suite of limestone and dolomite rocks extends westward from an erosional edge to attain a thickness of up to 300 metres in southern Alberta and up to 600 metres in central Alberta. The Elkton and Turner Valley formations constitute excellent aquifers in the southwestern portion of the province and the Debolt and Elkton are prominent aquifers in the west central area.

Shunda - Pekisko - Banff Rocks

This is a sequence of limestone and shales up to 300 metres thick, thinning to an erosional edge to eastward. Aquifer quality is generally poor with the following exceptions. The Pekisko formation to the southwest of Lesser Slave Lake is generally porous. Further, the Shunda and Pekisko formations along their erosional edges may have local areas of good capacity development where the rock has been dolomitized.

Wabamun - Winterburn Rocks

These rocks are predominantly carbonates up to 250 metres thick that may have good geothermal potential where dolomitized. The Nisku formation, which occurs at the base of the unit, in particular has local reef development with excellent capacity potential. Examination of local stratigraphic data is essential to assessing the potential of the Nisku.

Woodbend Rocks

The Woodbend consists of dolomites and limestones of ancient Leduc reef build-ups up to 300 metres thick and infilled with shale in the off-reef areas. The reefs offer excellent capacity potential while the off-reef areas offer none. These rocks are highly developed for hydrocarbon production so are of great interest as geothermal energy producers as an adjunct to oil production activity. One problem with the Leduc reefs is that the large quantities of hydrocarbons that have been produced has lowered the aquifer pressure of the remaining water. Thus less reservoir energy is available for water production than would be expected.

Beaverhill Lake - Slave Point Rocks

This rock sequence is very similar to the overlying Woodbend and contains Swan Hills reefs that build up to 150 metres in thickness. It also is a prolific producer of hydrocarbons and the comments made about Woodbend rocks apply here as well.

Elk Point Rocks

The Elk Point rocks of geothermal interest occur in the northwest portion of the province. Two distinct areas occur that are separated by a prominent ridge of Precambrian granitic rocks called the Peace River Arch. North of the arch is an area of predominantly carbonate rocks along with evaporites and includes the prolific oil-producing Keg River reefs that are about 250 metres thick. The remarks made about Woodbend rocks also apply here. South of the Peace River Arch the Elk Point consists mainly of evaporates with a veneer of sands at the top that may attain 60 metres in thickness, called the Gilwood formation, that has excellent potential for geothermal potential in local areas. The Gilwood is also a prolific oil producer so offers potential for geothermal development as a related activity.

Cambrian - Granite Wash Rocks

This suite of rocks, which may attain a thickness of 1000 metres along the Disturbed Belt, lies directly on the Precambrian granites at the base of the sedimentary envelope. Thus these rocks are the hottest rocks available for geothermal considerations. Broad areas of the Precambrian are overlain by a basal sand that may be up to 100 metres thick and is identified as the Basal Cambrian Sand south of township 70 or Granite Wash sand to the north. This excellent aquifer is present everywhere over the southern half of the province and locally present in many areas north and east of Lesser Slave Lake where it is associated with considerable oil production. The considerable depth of the Basal Cambrian Sand across the southern part of the province, coupled with the fact that it does not attract much oil-exploration related activity, means that this otherwise promising geothermal resource will be difficult to access in the near term.

Precambrian Surface

The Precambrian Surface represents the base of the sedimentary envelope of rocks, therefore, is the lower limit of potential reservoir capacity and associated geothermal potential from formation waters. This surface was mapped to provide the user with a map that indicates the temperature and depth limit of geothermal potential on the Alberta plains.

EXPLORATION TECHNIQUES

Even upon cursory consideration it is apparent that the capital cost of installing a purpose-built geothermal energy recovery operation would be prohibitively high on the Alberta plains. The depth of the resource (approximately 1.5 kilometre) means that an expensive hole must be drilled. Therefore any possible economic geothermal recovery operation must focus on reducing the cost of accessing the resource. The obvious possibility of achieving this is through a joint venture with the petroleum industry. Several options seem possible:

(i) Oil production often involves the production of large volumes of hot formation water along with the oil. This water must be disposed underground by the producer. After separating the oil from the water, it would be relatively inexpensive to install a heat exchanger in the water disposal loop and draw energy out for other purposes.

(ii) Exploratory wells may be cased and tested and then found to be incapable of producing oil or gas. The industry practice is to then abandon the hole after recovering whatever amount of casing is possible. Abandonment involves some costs and the operator of the well bore would likely be willing to give the cased hole to a party interested in exploiting the geothermal possibilities.

(iii) Many exploratory wells are unsuccessful and are abandoned after logging and testing. The operator of such a well would likely be willing to assign the interest in the hole to a geothermal operator who would then case the hole at his cost. Thus the capital cost of drilling the hole (approximately $120,000 per kilometre) would be saved. The cost of casing a wellbore is approximately $60,000 per kilometre.

(iv) Oil and gas wells have a finite life and when they are no longer capable of producing hydrocarbons at economic rates they may still be capable of producing hot water for geothermal purposes. The water may come from the hydrocarbon zone or another behind the casing. A purchase of the wellbore is possible.

(v) In the course of producing oil, often substantial quantities of water are injected into the oil pool. Often this water is produced from an aquifer in a nearby well. Perhaps arrangements could be made whereby this water could be run through a heat exchanger prior to injection.

A geothermal operator who wishes to pursue one of these options or a variation of them is advised to establish contact with the oil operator as soon as possible to ensure that a cost effective plan may be instituted prior to starting of critical field operations. All drilling activity is announced by the Alberta Energy Resources Conservation Board who publish a list of wells licensed on a daily basis. The matter of obtaining geothermal rights would also be addressed through the Conservation Board if

Crown lands were involved.

The matter of establishing a procedure for accomplishing all of this is not possible to describe on a hypothetical basis. The only way to establish the viability of a potential geothermal project is to deal with an actual situation. Anyone who is interested in attempting one of the many possible variations to the above suggestions should obtain the services of a competent consultant conversant with oil industry production operations to assist in establishing a tachnically feasible plan and negotiating a mutually acceptable deal with the oil operator.

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