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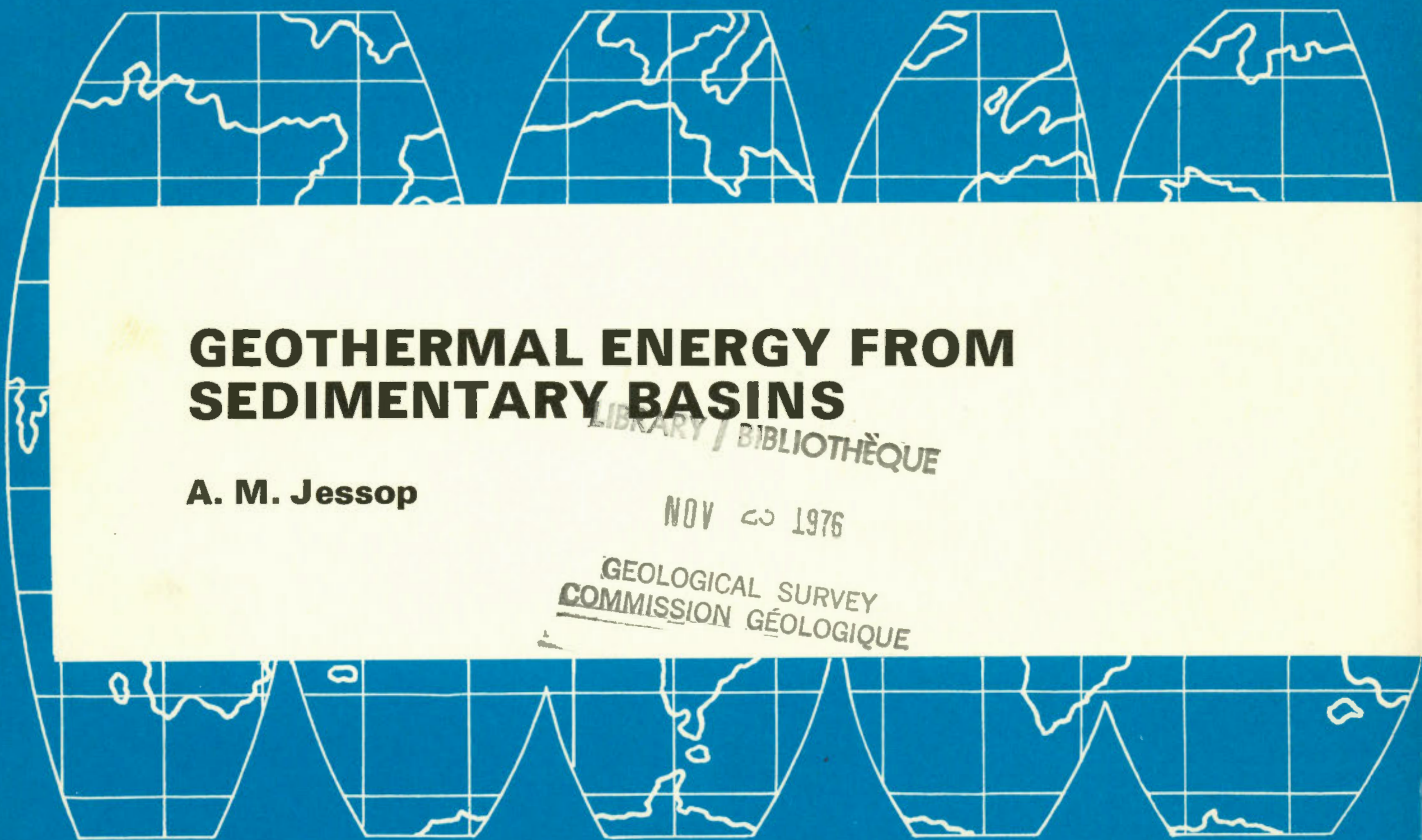

GEOTHERMAL ENERGY FROM SEDIMENTARY BASINS

A. M. Jessop

Geothermal Series Number 8
Ottawa, Canada 1976

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FOREWORD

Hot water from porous rocks of the Paris Basin is being used as a source of energy for heating apartment buildings. Canadian sedimentary basins are deeper and more extensive than those in France, and it is appropriate to enquire whether similar hot water is available to heat Canadian homes. This report describes the work done in Canada and compares it with the more advanced French accomplishments. There are many similarities in the data available to the two countries, and geological conditions in Canada appear to be at least as promissing as those in France. The population density in France is very much greater than in Canada, but the Canadian climate is the more severe. Economic factors in Canada have not yet been analyzed.

AVANT-PROPOS

On utilise de l'eau chaude en provenance de roches poreuses du bassin parisien pour chauffer les maisons de rapport. Les bassins sédimentaires canadiens sont plus profonds et plus étendus que ceux de France, et il est tout naturel qu'on se demande si l'eau chaude en provenance de sources similaires au Canada ne pourrait pas être utilisée pour chauffer les maisons. Ce rapport décrit le travail accompli au Canada et le compare aux résultats plus marqués obtenus en France. Les données à la disposition des deux pays comportent plusieurs traits communs, et le régime géologique au Canada, semble être, au moins, aussi prometteur qu'en France. La densité de la population est beaucoup plus élevée en France qu'au Canada, mais le climat canadien est beaucoup plus sévère. Le facteur économique au Canada n'a pas encore été soumis à l'analyse.

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A. M. Jessop

INTRODUCTION

Hot water from sedimentary rocks of the Paris Basin is now being used to heat large apartment buildings. The water being used is recovered at a temperature of only about 60°C (140°F), but it provides heating more economically than conventional energy sources. Since there are large areas of Canada underlain by deep sedimentary rocks, and since these sedimentary formations have been extensively explored for oil and gas, it is appropriate to enquire whether useful hot water is available to heat Canadian homes.

Geothermal energy is often thought of as being the result of volcanic action, and as being necessarily confined to areas of young tectonism and volcanism. These areas are confined to the relatively narrow tracts of land that are associated with the edges of moving plates in modern theories of earth structure. The spectacular and well-known occurrences of geothermal energy are found in the volcanic zones, but there is heat that may be used for space heating wherever sedimentary sequences reach a depth of at least 1500 m (5000 ft.) and coincide with geothermal gradients that are at least equal to the world average of about 25 mK/m (14°F/kft.). The useful energy is held in the form of hot water that fills the porous rocks in the lower parts of the basins.

The most significant example of current usage is in the suburbs of Paris, France. The particular significance of the Paris Basin is that there is nothing geologically unusual about it. The Basin is not large, and it does not have a high geothermal gradient. Water at about 60°C (140°F) is being taken from a reservoir at a depth of about 1500 m (5000 ft.) to supply apartments at Villeneuve-la-Garenne and at Creil. Full details of the reservoirs may be found in 'Potentiel Géothermique du Bassin Parisien' (Housse and Maget 1976), hereafter referred to as the *BRGM report*.

Earlier developments in other parts of the world are described in the proceedings of the first U.N. Symposium on the Development and Utilization of Geothermal Resources. Heat from the Hungarian Basin is being used for space heating in Szeged, where 1200 apartments were being supplied in 1970 (Boldizsar 1970). The Hungarian Basin is known to have a high geothermal gradient. Large resources of heat in the Gulf of Mexico Basin are described by Jones (1970). This basin contains large zones of geopressured formations, which have unusually high thermal gradients and water content. Makerenko et al (1970) claim that water in the temperature range 40°C - 100°C (104°F - 212°F) is to be found beneath 20% of the territory of the USSR. These resources are being exploited in many areas (Tikhonov and Dvorov, Makerenko et al, 1970), and probably include large volumes of water in sedimentary basins.

In Canada the first look at hot water in sedimentary basins as an energy source has been taken by the Geothermal Service by means of a contract to Sproule Associates Ltd. of Calgary. The investigators examined the existing information and produced a report that gave a summary of the possible water reservoirs in selected areas. This report will hereafter be referred to as the *Sproule report*.

EXPLOITATION IN FRANCE

After a feasibility experiment at Melun l'Almont in 1970, four geothermal projects have begun in France.

At Creil the completed development will contain 4000 apartments, 2000 of which were originally built with conventional heating facilities. About 75% of the energy requirements will be met, using water at about 60°C (140°F).

At Villeneuve-la-Garenne 1700 apartments have been converted to the use of geothermal heat.

At Mée-sur-Siene a major programme has been begun for the heating of 6000 apartments, 50,000 m^2 (540,000 $ft.^2$) of office space and community facilities.

At Mont-de-Marsan an entire community of both old and new buildings will be heated by geothermal water. This site is in the Aquitaine Basin of southwestern France and, because of the warm climate, 90% of the heating requirements will be provided by the hot water.

The Paris Basin is smaller than the western plains of Canada, being about 500 km (300 miles) across and having the deepest reservoirs at a depth of about 2800 m (9200 ft.), where temperatures as high as 110°C (230°F) are found. The main water-bearing reservoirs occur in the Purbeck limestone and the Lusitanian limestone of the upper Jurassic, the Dogger series of the middle Jurassic, the Lias series of the lower Jurassic, and Rhaetian sandstone, Keuper sandstone, Muschelkalk limestone and Bunter sandstone of the Triassic. Generally the basin rests on a basement of pre-Permian rocks and is bounded by massifs of Hercynian age, but some Devonian limestone is to be found in the north of France.

The basic information for the evaluation of the aquifer formations was provided by the records of oil exploration companies. Data from about one thousand wells were used in a computer-based study of the lithology and hydrogeology of the Basin. It was not practical to carry out a detailed study of all aquifers, and selection criteria were adopted based on temperatures greater than 50°C (112°F), adequate thickness and wide lateral continuity. The data assembled included the basic geological sections obtained during drilling and various geophysical measurements, including self potential, resistivity, gamma-ray, neutron and sonic logs. Some porosity and permeability data were obtained from tests on drill cores, and data from formation and production testing were also used. Complete analysis of aquifer potential was hampered by the fact that the original data collection was directed towards a different purpose.

The available temperature data were used to produce a map of temperature gradient. It was found that the gradient varied with depth according to conductivity variations, and that anomalies due to poor data had to be neglected. The resulting map is shown in the BRGM report (P36). Observed gradients are in the range 33 to 40 mK/m (18 to 22°F/kft.), and are similar to gradients in the western Canadian plains.

Total dissolved solids are quoted as being up to 26,000 ppm in the Dogger series and up to 10,000 ppm in the Lusitanian formation. These figures are considerably lower than most figures in the Sproule report. The presence of hydrogen sulphide in the Dogger series was also noted.

A set of coloured diagrams, separate from the bound text, forms part of the BRGM report. These include cross-sections and maps showing extent, depth, thickness, temperature, hydrochemistry and transmissivity for each reservoir unit of the Lusitanian, Dogger, Lias and Trias. Synthesis maps of transmissivity and temperature are also included. Notes on the extent and properties of each reservoir are included in the text.

The BRGM report does not mention any data that were actively obtained for geothermal purposes. All the analyses are based on data resulting from oil and gas exploration. Such data are bound to exhibit some shortcomings when used for a purpose that was not originally intended, but the successful exploitation of the hot water has demonstrated that the data were adequate.

CANADIAN STUDIES

It seems probable that sufficient information concerning the sedimentary basins of western Canada already exists from which to develop plans for the exploitation of hot water. There are many thousands of wells, the data from which are stored in the files of exploration companies and provincial governments. Some observation wells, maintained for repeated testing, might also be used to obtain detailed formation temperatures, provided they are not in areas of gas or oil production.

The geothermal potential of a sedimentary unit depends on its temperature, porosity, permeability, thickness and lateral extent. Within sedimentary areas, and particularly around oil and gas fields and exploration targets, detailed information is maintained by the oil companies concerned and by Provincial agencies. In formations devoid of hydrocarbons knowledge is less complete. Studies of the composition, origin and movement of formation water have also been made in both Federal and Provincial Government establishments, e.g. van Everdingen (1968) and Hitchon and Friedman (1969). The useful working knowledge of the reservoir formations resides with the experienced geologists of the oil companies and consulting companies. It is difficult to extract the information that one requires from the mass of available records without the benefit of experience.

The measurement of temperature in drilled wells is usually less thorough than the measurement of other properties and conditions. Most temperature readings have been obtained by including a maximum-reading glass thermometer in the logging tool. Accounts of the development and difficulties of this method may be found in early reports of the British Association for the Advancement of Science (Everett, 1868), and the technique has long since been abandoned for accurate scientific measurement. For results to an accuracy of 1°C (2°F) maximum-reading thermometers are adequate provided care is taken in recording the results, but unfortunately the required care is not usually applied. The value of the data is further reduced by the fact that measurements are made at a time when the well is most disturbed by the process of drilling.

A convenient file of temperature data, known as the *Geothermal Survey of North America*, was available for use in the search. This data file was organized by the University of Oklahoma and was sponsored by the American Association of Petroleum Geologists. Temperature data were extracted from company and State records and were placed on a computer-based file. Canadian data were added to the file by a Canadian coordinator, beginning in 1971. Using this data base, temperature gradients have been calculated and contoured maps of gradient have been produced wherever data are sufficient. The gradient maps for western Canada show many small anomalies that depend on only one well, and these anomalies are probably spurious. The gradients also show a tendency to increase with decreasing thickness of sedimentary column. This also is probably spurious and is probably due, at least in part, to the practice of taking the mean annual air temperature to represent the surface of the ground, whereas the true mean ground temperature is higher than the mean annual air temperature by as much as 5°C. In shallow sedimentary sections the variation in average thermal conductivity may play some part in creating anomalies, but large lateral variations are not probable in thick sections except where thick shale sequences in young delta areas predominate. Lateral water movement within permeable formations could cause irregular gradients, but one is forced to the conclusion that many of the anomalies are the result of inadequacies of the temperature data, the neglect of the thermal conductivity and the unsatisfactory method of assessing surface temperature.

Anglin and Beck (1965) reached the same conclusions on the quality of the data in a study that was completed before the Geothermal Survey of North America was begun. Data from about 70 wells were accepted as reliable and lines of equal gradient and geotherms at sea-level were produced, as shown in Fig. 1. The area covered was southern Alberta, and the results showed temperature gradients increasing to the east and north, in the direction of decreasing thickness of sedimentary formations.

THE SPROULE REPORT

The work done by Sproule Associates Ltd. was intended as a first look at the possibilities of using hot water from sedimentary basins in Canada, and it was based entirely on existing data. The original intention was to choose several areas of anomalously high temperature gradient for detailed examination. It was found that the areas of apparent high gradient usually coincided with areas of shallow drilling and consequently they had low bottom-hole temperatures. As a result of

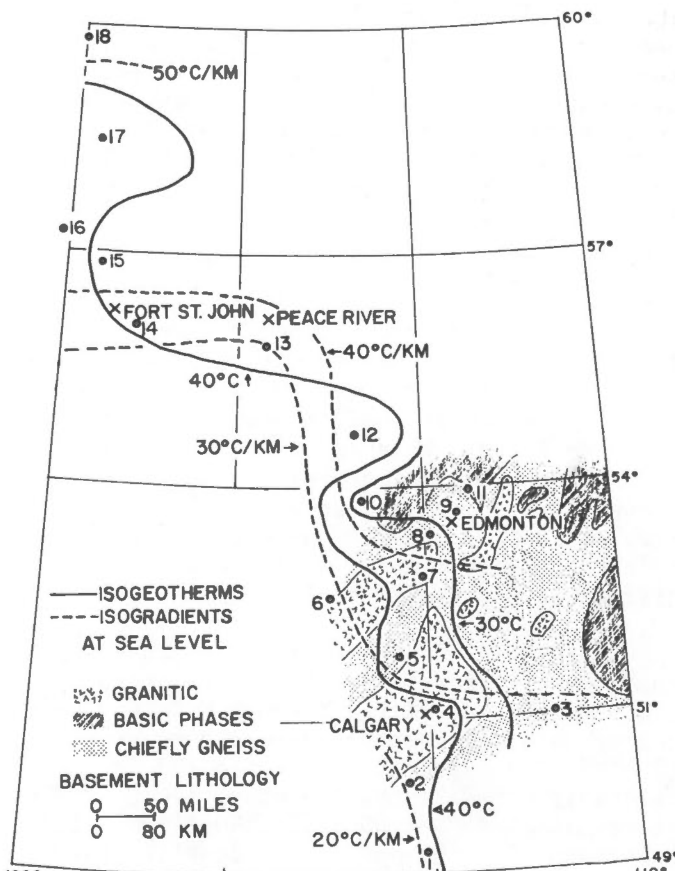

Fig. 1 Contours of isogeotherms and isogradients at sea level. Diagram by Anglin and Beck (1965).

this, the areas of detailed study were selected on the basis of high bottom-hole temperature rather than on the basis of high temperature gradient. The study consisted of the selection of a number of wells, usually five or six, from each area and a review of the data on porosity, salinity and temperature of the deep reservoir formations. Wells were chosen to produce profiles of 50 to 250 km (30 to 150 miles) in length, and information was displayed on large composite diagrams.

The areas studied are indicated in Fig. 2, with the maximum bottom-hole temperature indicated beside each profile. All temperatures quoted are based on the existing data and are subject to its general limitations, and they have been rounded downwards to the nearest 5°C (9°F). Since measured temperatures are usually below equilibrium rock temperatures because of cooling by circulation of drilling mud, these figures are probably minimum estimates of the temperature of the deepest reservoir formations. Other permeable formations are mentioned in the descriptions of the profiles, and temperature is roughly proportional to the depth. Fig. 2 also shows the boundaries of the region of sedimentary rocks, drawn to include the severely folded and faulted zone of the Rocky Mountains and Mackenzie Mountains. The sedimentary area is divided into areas where the majority of bottom-hole temperature readings are above 80°C (175°F) and below 80°C, regardless of depth. This dividing line runs through Alberta from north to south, the higher temperature being to the west of the line. There are insufficient data in the Northwest Territories to define the northward continuation. There is a further small area of southern Saskatchewan where temperatures over 80°C are found. This area is on the north flank of the Williston Basin, so that high temperature is related to great depth, but the area is in line with the high heat flow belt to the south associated with the Rio Grande Rift (e.g. Blackwell, 1971).

The highest temperatures recorded in the report are in the Pointed Mountain area, at the southern end of the Yukon-N.W.T. boundary. Bottom-hole temperatures are as high as 179°C (354°F) at a depth of 4419 m (14,498 ft.) and reservoir temperatures are about 170°C (338°F) at depths of 3400-4300 m (11,000-14,000 ft.). Unfortunately, the population density of the area is very low, the nearest settlement being Fort Liard. High temperatures are found in a continuous belt to the east of the Rocky Mountains, as far south as 50°N. There is a tendency towards lower temperature with lower latitude, but even in the Calgary area at about 51°N the temperatures are still about 120°C (248°F) at a depth of 3975 m (13040 ft.).

The Sproule report includes comments on the salinity of reservoir waters. In many of the areas covered by the profiles the total content of dissolved solids is high, and salinities in excess of 200,000 ppm are common. This may be compared with 35,000 ppm for average sea-water.

Table 1 summarizes the data from the fourteen sections and three single wells included in the report. The ranges of total depths and bottom-hole temperatures given apply only to the wells used in the survey. In most areas there are many more wells that are not included in the profile, and any formations mentioned usually extend for large distances (hundreds of kilometers) around the selected profiles. Although the profiles were selected on the basis of high bottom-hole temperature, the choice was still somewhat arbitrary and regional representation was intended. The particular profiles selected should not be taken as an indication of unfavourable interposed areas.

COMPARISONS

The Sproule report has already started along the path followed by French workers. The readily available temperature data have been examined, and the general areas most promising from the point of view of temperature have been indicated. Problems with the quality of the data have been commented on by both French and Canadian users. Brief comments on depth, thickness and permeability of the reservoirs and chemical composition of the water have been included, but no detailed account of these factors has been prepared.

French workers have made a detailed study of the whole central part of the Paris Basin, neglecting only the areas where sedimentary rocks are too thin to accommodate high temperatures. This amounts to an area roughly 300 km across in all direction. This distance is two to three times greater than the length of the profiles in the Sproule report.

From the point of view of markets, the Paris Basin is a thickly populated area, containing one of the world's major cities and many other cities and towns. In contrast, the Canadian plains are thinly populated, containing Edmonton (442,000), Calgary (433,000) and Regina (147,000) within the areas of reasonable probability of geothermal development. Other major municipalities are listed in Table 2. At Villeneuve-la-Garenne a complex of 4000 apartments is to be served by the

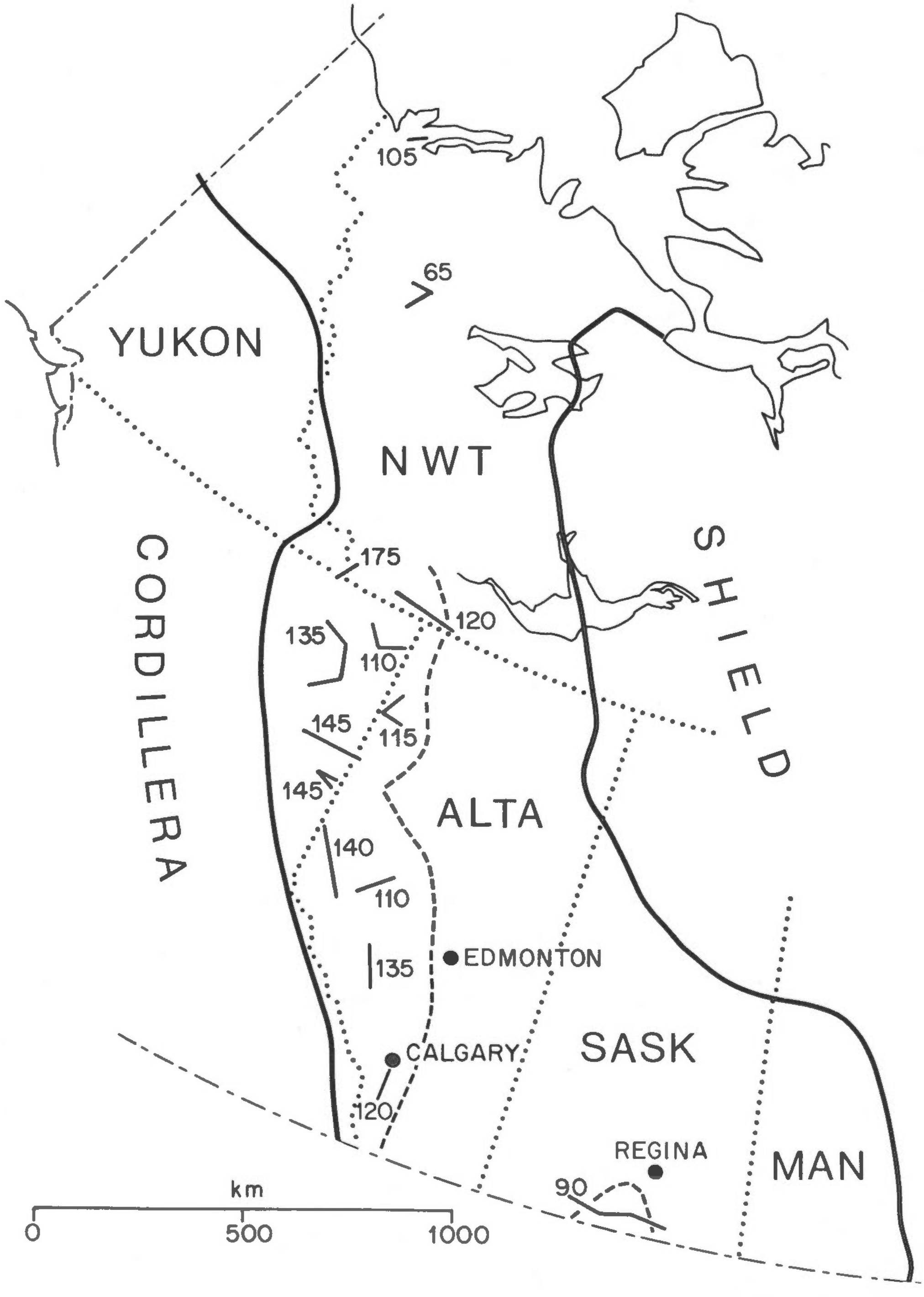

Fig. 2 Temperature in the lowest sedimentary formations based on data condensed from the Sproule report. The dashed line divides areas having bottom-hole temperatures above and below 80°C (176°F).

TABLE 1. Summary of Data in Sproule Report

Section	Wells	Total depth m & (ft)	B.H. Temp. °C & (°F)	Porosity	Dissolved Solids ppm	Towns or Cities
A	5	2644 - 3178 (8675 - 10426)	59 - 89 (139 - 198)	Several Fmtns.	15,000	Weyburn
B	6	2670 - 3975 (8760 - 13040)	79 - 122 (175 - 251)	Turner V	60,000	Calgary High River
C	7	4263 - 4843 (13986 - 15890)	113 - 138 (235 - 280)	Nisku Leduc	200,000	Harlech
D	6	4289 - 5480 (14070 - 17980)	121 - 142 (250 - 288)	Leduc Beaverhill	150,000	Grande Prairie
E	6	3108 - 4115 (10200 - 13500)	79 - 112 (174 - 234)	Cathedral Gilwood Stephen	200,000	
F	6	3545 - 4022 (11630 - 13196)	107 - 148 (224 - 299)			Fort St. John Dawson Creek
G	5	3184 - 3876 (10447 - 12715)	106 - 148 (222 - 298)			Fort St. John
H	9	2083 - 2932 (6835 - 9619)	92 - 116 (198 - 240)	Chinchaga Keg River Muskeg	18,000	
I	6	2450 - 3463 (8039 - 11361)	104 - 138 (220 - 280)	Cambrian Slave Point Elk Point		Fort Nelson
J	7	2035 - 2661 (6675 - 8730)	103 - 113 (218 - 235)	Keg River Slave Point Elk Point		
K	4	4369 - 4528 (14335 - 14856)	168 - 179 (335 - 354)	Nahanni	200,000	
L	7	1900 - 2484 (6234 - 8150)	69 - 122 (156 - 252)	Slave Point Keg River	150,000	
M	3	1724 - 1951 (5606 - 6400)	33 - 69 (92 - 156)	Ronning		Fort Good Hope
N	3	3205 - 3734 (10515 - 12250)	78 - 109 (172 - 228)	Devonian		
Tununuk	K-10	3757 (12326)	102 (215)			
Mayogiak	J-17	3681 (12077)	102 (216)			
Ellice	0-14	2898 (9507)	69 (157)			

TABLE 2. Municipalities in excess of 10,000 inhabitants within area of probable geothermal potential

Alberta	
Edmonton	442
Calgary	433
Lethbridge	44
Red Deer	28
Medicine Hat	27
St. Albert	18
Grande Prairie	15
British Columbia	
Dawson Creek	12
Saskatchewan	
Regina	147
Moose Jaw	32
Swift Current	16

Figures are in units of 1000 persons and are taken from the 1971 Census.

geothermal development. An average occupancy of only two persons gives a total population of 8000, which is greater than most communities on the Canadian plains. On the other hand, because of the difference in climate, the energy that serves 4000 apartments in France will supply fewer units in Alberta, perhaps only 1000 or 1500. This situation will be helped by the fact that the temperature of the water is higher in Canada than in France, although this is counteracted to some extent by greater depth of the reservoirs.

ESTIMATES OF ENERGY

In order to obtain an estimate of the total energy contained in the formation waters of the western sedimentary basin it is necessary to make some simple assumptions. Hitchon and Friedman (1969) estimate the total pore volume as 63,600 cubic miles ($265 \times 10^{12} m^3$). Assuming a density of 1.0 Mg/m^3, this means that the rocks contain 265×10^{15} kg of water. Figure 3 shows the depths and temperature from Table 1, plotted to show geothermal gradient. Two linear geothermal gradients are drawn so that 50% of the points lie between them and 25% lie on each side. The gradients of these lines are 39.6 mK/m (21.7^{o}F/kft) and 27.6 mK/m (15.1^{o}F/kft). For ease of computation an average gradient of 33.3 mK/m (18.3^{o}F/kft) is assumed. Water at less than 50^{o}C (122^{o}F) is of little value and is neglected. Using the assumed average geothermal gradient, 50^{o}C corresponds to a depth of 1500 m (4920 ft). Only one point in Figure 3 is at a depth greater than 5000 m (16400 ft), and depths below this level are neglected. The temperature at 5000 m is 165^{o}C (329^{o}F), and two points exceed this limit. By adopting maxima of 5000 m and 165^{o}C errors are introduced, but they are small and tend to produce an underestimate of the total energy. The upper and lower limits are shown in Fig. 3, and between these limits the points appear to be evenly distributed. Since these points represent the bottoms of wells, many of which are terminated near the base of the sedimentary sequence, it is assumed that they represent the true base of the sediments, and it is further assumed that this depth is uniformly distributed between outcrop at the surface and maximum depth at 5000 m. It is also assumed that pore volume is uniformly distributed. Since the uppermost 51% of the sediments are at a temperature of less than 50^{o}C, only 49% of the volume is considered. The specific heat of the water is assumed to be 4.19×10^{3} J/kg K.

It may now be calculated that the average temperature of the formation water below 1500 m is 89^{o}C (192^{o}F) and that the total heat content is 4.8×10^{22} J (4.6×10^{19} BTU) or 1.5×10^{15} Watt-years. This estimate is the total heat above 0^{o}C in the formation water that is above 50^{o}C. No account is taken of the heat in the solid rock.

The area of sedimentary outcrop is about 2×10^{6} km^2 (7.7×10^{5} square miles), but only 70% of the area contains sediments exceeding 1500m in depth. The stored energy per unit area is about 3.5×10^{16} J/km^2 or about 1000 MW years/km^2 (8×10^{13} BTU/square mile) for the western Canadian sedimentary basin.

The French literature (DGRST, 1976) describes a system having a rate of flow of 100 m^3/hour of hot water at temperature of 50^{o}C. It is assumed that the water returned to the formation is at 10^{o}C after passing through the heat pumps. This provides a heat extraction rate of 4.7 MW. Peak flow rates are somewhat higher, and supplementary conventional energy is used at times of peak load, so this figure can be taken as an average. The spacing between the producing and the return well is about 1 km, which means that the area being drawn upon is about 3 km^2 in extent. The expected lifetime of the wells is 30 years. The expectation of energy supply is thus about 47 MW years/km^2 in the areas that are now being exploited.

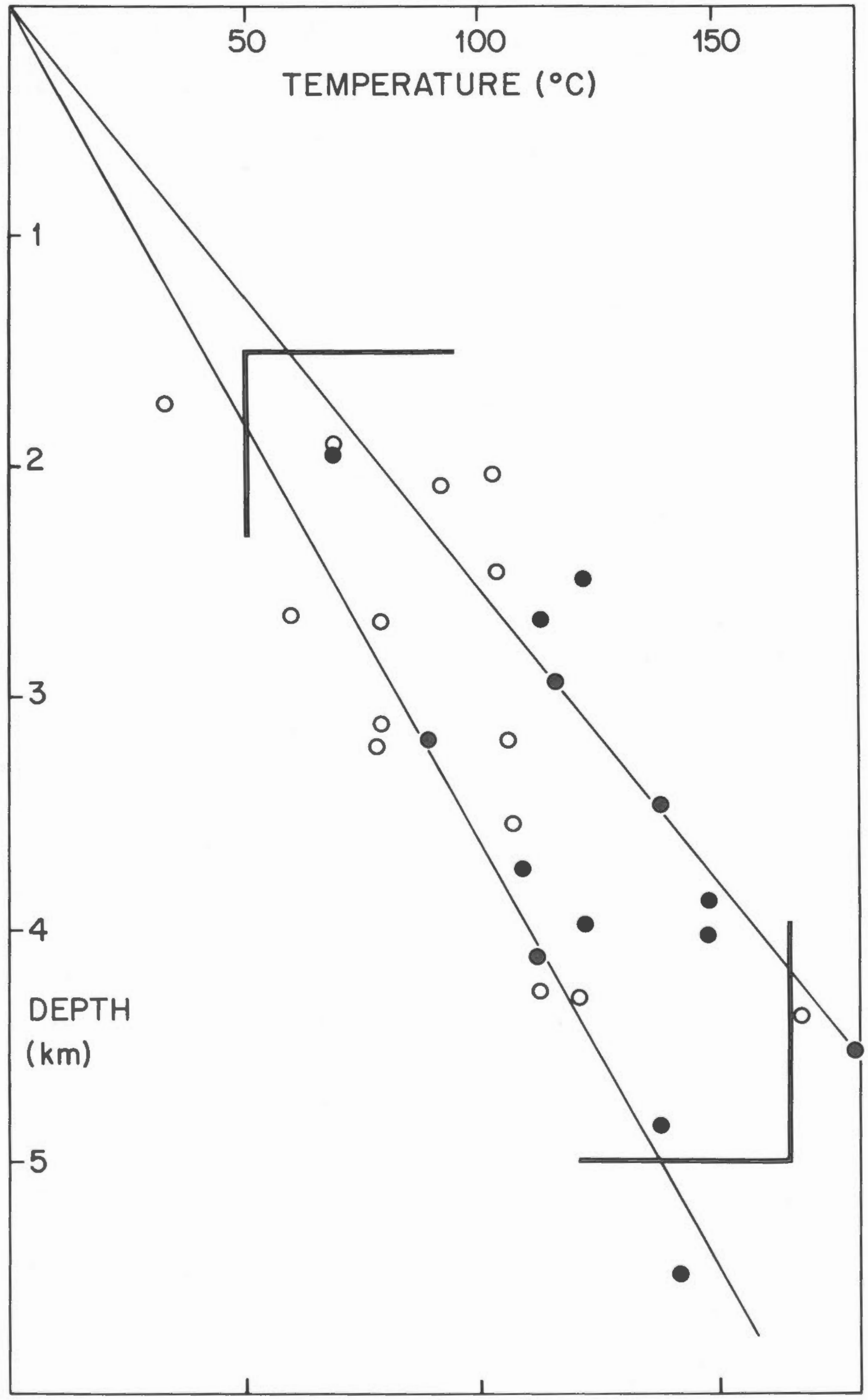

Fig. 3 Data from the Sproule report plotted as temperature against depth. Solid circles show the highest temperature in each section and open circles show the lowest. Bars show the assumed limits to useful water in the estimation of energy potential.

The difference between these two results is a result of the fact that the estimate of Canadian resources refers to total water-borne heat in all formations, whereas the estimate of French usage refers to the rate of production from one reservoir level only. If it is now assumed that one well can only draw on the water from 10% of the porosity in any one column the estimate of probable supply in Canada is 100 MW years/km^2, which is in good agreement with French experience. Because of the greater depth and temperature of aquifers in Canada, it is reasonable that the estimate of energy potential should be somewhat higher than that derived from French experience. In view of all the uncertainties in the assumptions related to Canadian conditions, 50 MW years/km^2 is a conservative figure for probable heat production, and favourable areas and deep reservoirs may yield considerably more.

No provision has been made for the energy required to produce the hot water. The static pressure in reservoirs is usually sufficient to support a water level that reaches a large fraction of the distance to the surface, and some formations produce artesian flow. However, some pumping is almost certainly required for water production. The potential energy required to lift the water is equivalent to 2.3 mK/m (1.3^{o}F/kft), which is about 7% of the average geothermal gradient. Disposal of water in a reinjection well may also require pumping, but the maximum pumping for production is paired with the minimum pumping for reinjection, and a figure of about 10% represents the probable maximum energy cost.

OTHER SEDIMENTARY BASINS

The sedimentary basin of the western plains is not the only part of Canada where temperature and thickness of sediments may be sufficient for the existence of useful hot water.

The Cumberland Basin contains Carboniferous sediments of thickness up to 9 km, and much of northern Nova Scotia and eastern Prince Edward Island is underlain by at least 5 km of sediments. Published data (Jessop and Judge, 1971) show that the area has a low heat flow in accordance with the great age of the basin. Temperature gradients probably do not significantly exceed 20 mK/m (11^{o}F/kft) and temperatures in excess of 100^{o}C (212^{o}F) at 5 km (16400 ft.) depth are probably not widespread. The Cumberland Basin thus offers prospects for geothermal heat considerably less attractive than those of the Paris Basin.

The Quebec Basin reaches depths of only about 2 km and heat flow is known to be low. Older folded sediments of the south shore of the St. Lawrence River between Quebec and Gaspé may be deeper, but unpublished data indicate temperature gradients of not more than 20 mK/m (11^{o}F/kft). Prospects must be regarded as poor.

The deeper parts of the Michigan Basin may contain useful hot water, but the Canadian part of the basin contains large thicknesses of rocks of high thermal conductivity. The heat flow is moderately low and the high conductivity ensures low temperature gradients of not more than 20 mK/m (11^{o}F/kft). Since the depth of sediments in Canada is not more than 3 km, prospects for hot water are poor.

In the Sverdrup Basin sediments extend to a depth of more than 6 km before metamorphosed sediments are reached. Unpublished data indicate high heat flow and temperature gradients that are generally greater than 30 mK/m (16^{o}F/kft). Prospects for hot water are good, but sufficient markets are not available.

In the Mackenzie Delta temperature gradients are about 30 mK/m (16^{o}F/kft), and high water pressures have been reported. Over-pressured formations would probably produce artesian hot water, but markets are again lacking.

CONCLUSIONS

From the general overview provided by the Sproule report, it appears that geological conditions for the production of hot water are at least as favourable in Canada as they are in France. Depending on the engineering requirements of producing water from deep aquifers, it may be possible to extract considerably more energy in Canada than is possible from an equivalent area in France. The low population density, the high requirement for space heating in the harsh Canadian winter, and the availability of other energy sources influence the economic situation, but this has not been thoroughly analyzed. Economic studies cannot be usefully pursued until more specific information is available concerning the possible rates of supply of energy and the lifetime of equipment and production.

The next step in Canada will be the detailed examination of the data of temperature, permeability and volumes of potential producing aquifers in selected areas of possible application. When the availability of supply is known with confidence the economic and engineering studies can begin.

Even if this source of energy does not turn out to be economically attractive now it is important to be aware of possible alternate sources of heat energy. Hot water from sedimentary basins may become a valuable means of maintaining the comfort of Canadians and of conserving supplies of high grade fossil fuels for those applications that need them.

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