THE ASSESSMENT OF LOW TEMPERATURE RESERVOIRS IN BRITISH COLUMBIA

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ABSTRACT

In south central British Columbia the earth's crust was heated 50 Ma BP by an extensive thermal event. Measurements throughout the area show that the terrestrial heat flow is greater than 70 mW/m^2. In this region the greatest potential for high crustal temperatures exists in deep sedimentary basins, and in crustal rocks having a high heat generation. An example of each is presented.

The volcanics forming the White Lake Basin were extruded between 48 and 53 Ma BP. The volcanoclastic sediments form an insulating blanket with an average thermal conductivity of between 1.67 and 1-85 W/K m. Geothermal gradients of up to 70 mK/m have been measured, and porosities vary up to a maximum of 10%. The energy available from hot water at a calculated temperature of 80°C from the thin Springbrook formation at the bottom of the basin is 10^3 MW years, assuming a temperature drop of 30°C. The total energy which could be mined from the formation is twenty-five times larger.

The Coryell syenites have a large amount of natural radioactivity, the average heat production being 5 $\mu W/m^3$. The geothermal gradients in two boreholes drilled within them are both 55 mK/m. It was anticipated that this might be a hot dry rock resource, but both holes produce water from fracture zones.

INTRODUCTION

Along the western margin of North America over the last 100 Ma offshore tectonic plates have moved northward with respect to the North American plate, alternating between convergence and north-westerly strike-slip faulting. This has allowed the assembly of exotic strips of crust through large northward movements. In the early Tertiary (Riddihough, 1982) convergence of the plates near Vancouver Island occurred at a rate of 100 mm/yr. During the Cretaceous and early Tertiary volcanics erupted in the Intermontane belt and eastern flank of the Coast Mountains, at the same time as the Coast Crystalline Complex was uplifted (Souther, 1977). The largest volume of volcanics forming the Thompson Plateau erupted between 48 and 53 Ma BP (Church, personal communication) and the related plutonic rocks, the Coryell Syenites (Little, 1957;1960) are now exposed mainly to the east (fig. 1).

Since the Early Tertiary convergence has again occurred, producing the northwesterly trending Pemberton Volcanic Belt (8-18 Ma) and later the Quaternary Garibaldi Volcanic Belt (Souther, 1980; Lewis and Souther, 1978). At Meager Mountain within the Garibaldi Volcanic Belt the most recent eruption was 2200 yr BP and temperatures in excess of 250°C have been encountered this year in a borehole (R. Openshaw, personal communication). Such areas of recent volcanism, hold great promise for high enthalpy geothermal energy.

What other areas have geothermal potential? In south central British Columbia where the crust was extensively heated 50 Ma BP when a large volume of magma was produced, the crust is still cooling, and has some remnant heat. This produces a terrestrial heat flow of about 70-80 mW/m^2 (Jessop and Judge, 1971; Lewis and Werner, 1982; and unpublished data) in the normal crust, as expected for a 50-Ma old crust.

We have investigated two geological situations which produce elevated temperatures compared to the normal 50 Ma old crust. From such structures hot water might be economically produced for space heating. First there are deep Tertiary basins in this region whose sediments act as insulating blankets producing higher temperatures at depth.

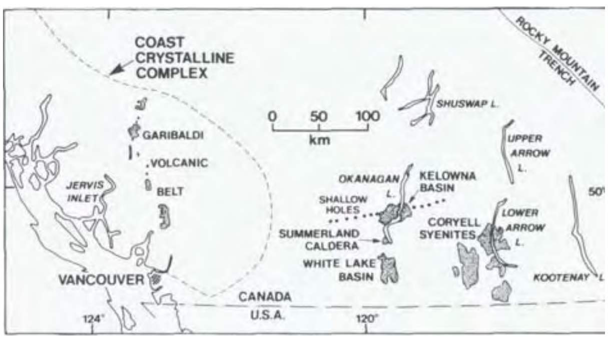

Fig. 1 Locations of the White Lake Basin and the Coryell Syenites.

The second type of structure occurs where the younger intrusives have a very high radioactive heat production, causing an even higher terrestrial heat flow. This initial look is based on the available geological and geophysical data for an example of each of these situations.

THE WHITE LAKE BASIN

The White Lake Basin or Penticton Tertiary Outlier (Church, 1973) is one of several Tertiary Basins (Church, 1982), which are erosional remnants of what was once probably a continuous belt of mainly volcanic rocks in Central Washington and Central B.C. The eruption of the rocks was closely associated with block faulting, and many deposits are preserved in grabens, half grabens and cauldron-subsidence complexes. Close relationships between acid eruptive rocks and large epizonal plutons suggest that they were comagmatic. Vertical movement on graben faults is commonly hundreds of meters for these basins. Folds and fractures are elements of a north-south directed stress thought to be responsible for the overall basin and range style of this region.

Figure 2 is a stratigraphic cross-section of the Penticton Tertiary Outlier. The thickest volcanics (up to 1000 m), middle and lower members of the White Lake Formation, are feldspar porphyry lavas, lahars and pyroclastic rocks. There are two intermediate to basic sequences, both members of the Marron Formation: the pyroxene-rich vesicular basaltic andesite lava and breccia of the Kearns Creek member, and the generally massive, non-vesicular andesite lava of the Park Rill member. Between many of the flows of the Marron Formation there are thin interbeds of conglomerate, sandstones and soil. The Springbrook Formation of undivided boulder conglomerate and valley talus, is most likely to be pervious. Lying on top of the pre-Tertiary basement rocks, the Springbrook follows paleovalleys, ranging from unsorted breccia, deposits to clean conglomerate where it is thick-

Temperatures have been logged in 5 boreholes within the basin. These holes are projected onto the stratigraphic cross-section shown in figure 2. These data indicate that water is flowing in parts of each of these holes. The measured geothermal gradients, omitting the obviously disturbed temperatures, vary between 38 and 70 mK/m from hole to hole. The measured average thermal conductivity for each hole varies from 1.67 to 1.95 W/m K and the measured vertical heat flux densities range from 73 to 116 mW/m^2. In the absence of convection, the temperature at the bottom of the central basin would be higher than 100°C.

The presence of water flowing up most of the boreholes is evidence of Artesian pressures at these locations. Thin interbeds of pervious materials, flow tops of the basic lavas and the Springbrook Formation, as well as the near vertical faults, all provide paths for water flow. The variation in the measured heat flow density is probably caused by such convection. If the total water flow is not so large that it cools off the basin, then the basin contains much geothermal energy which can be removed in the form of hot water for space heating. The average porosities from two boreholes are 4.9% (Nimpit Lake Member: tan trachyte and trachyandesite lava and minor breccia) and 7.2% (Yellow Lake Member: pyroxene-rich mafic phonolite lava with local well developed phenocrysts of rhomb-anorthoclase and some primary analcite, abundant zeolite fillings in cracks and amygdales).

If the Springbrook Formation is taken as the best reservoir, an estimate of the largest possible volume of water to be stored is 0.3 km^3, assuming

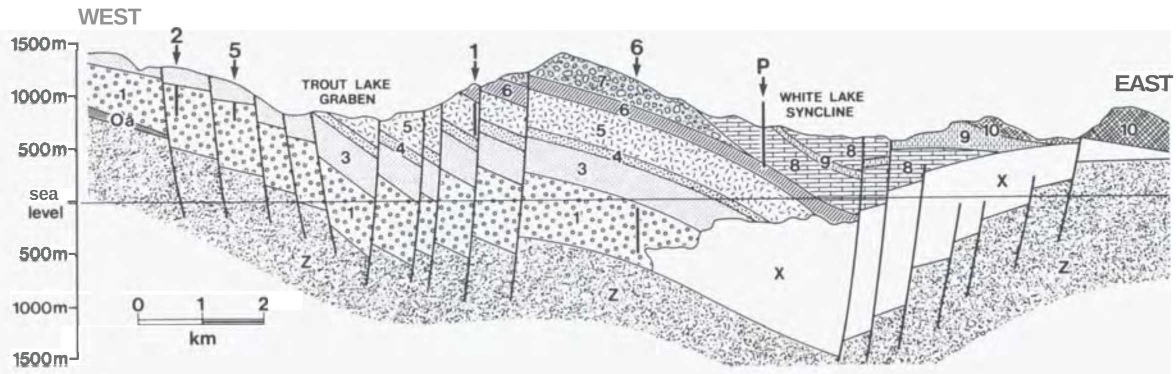

Fig. 2 A stratigraphic cross-section across the Penticton Tertiary Outlier, after Church (1979). The formations are: z Pre-Tertiary basement rocks, o Springbrook Formation, x Undivided Marron Formation, 1 Yellow Lake Member, Marron, 3 Kitley Lake Member, Marron, 5 Nimpit Lake Member, Marron, 6 Park Rill Member, Marron, 7 Marama Formation, 8 Volcanic conglomerate, sandstones and shales, White Lake Formation, 9 Mostly volcanic breccias, White Lake Formation, 10 Skaha Formation. The heavy, vertical lines indicate the positions of boreholes projected onto this section. The hole designated P was described by Jessop and Judge (1971).

a porosity of 5% and an average thickness of 60 m (30% of its maximum thickness) over an area of 100 km^2. The heat contained in such a volume at 80°C (compared to 500) is 4 x 10^{16} J or 10^3 MW years.

The amount of heat stored in the volume of rock of a 200 m thick Springbrook Formation under the same area, 100 km^2, is 95 x 10^{16} J or 30 x 10^3 MW years, assuming a heat capacity of $2x10^6 J/m^3K$ and a temperature of 80° C. In other words mining the heat from this volume would produce 25 times as much heat as contained in the water of the reservoir.

CORYELL SYENITES

The Coryell Intrusives (Little, 1957; 1960) are a group of Eocene batholiths, stocks and plugs in southeastern British Columbia. Small stocks, plugs and dykes occur up to 80 km to the east of the main body. The Coryell rocks are a typical alkaline suite - mainly syenite, with some granite, shonkonite, and related monzonite. Accessories are apatite, magnetite, titanite and zircon. The large amount of background radiation observed by exploration geologists indicates a high heat generation. The older Nelson batholith, which is intruded by the Coryell rocks, has an averge heat production of 2.1 $\mu W/m^3$ (Lewis, 1976).

Two 400 m holes were drilled 10 km apart in the Coryell syenites (Lewis et al., 1979). The heat generation of 20 surface samples and borehole cores at one site was high, averaging 4.9 $\mu W/m^3$. The second hole is located in a roof pendant of the older Nelson batholith. At this site the average heat production of 16 of 20 samples was 1.4 $\mu W/m^3$ but the averge of the remaining 4 was 5.6 $\mu W/m^3$. The average heat generation of the Coryell rocks at these locations is taken to be 5.0 $\mu W/m^3$.

Since both drill sites were in valleys, it was anticipated that water driven by hydrostatic pressure might flow into the bores. Consequently bottom hole temperatures were measured just before the start of each day's drilling. This data as well as a final log of a hole are shown in figure 3. The data show that water is entering the hole at a minimum of 5 different depths, and that the bottom hole temperatures indicate a very linear equilibrium geothermal gradient. These gradients for the two holes were 54 and 55 mk/m.

The thermal conductivity of representative core disks were measured on a divided bar, and the average values are 1.84 $\pm$ .20 for the first hole and 1.86 $\pm$ .21 W/m K for the second hole (34 samples for each hole). Combining these values with the vertical geothermal gradients yields heat flows of 99 and 102 mW/m^2 before correction for

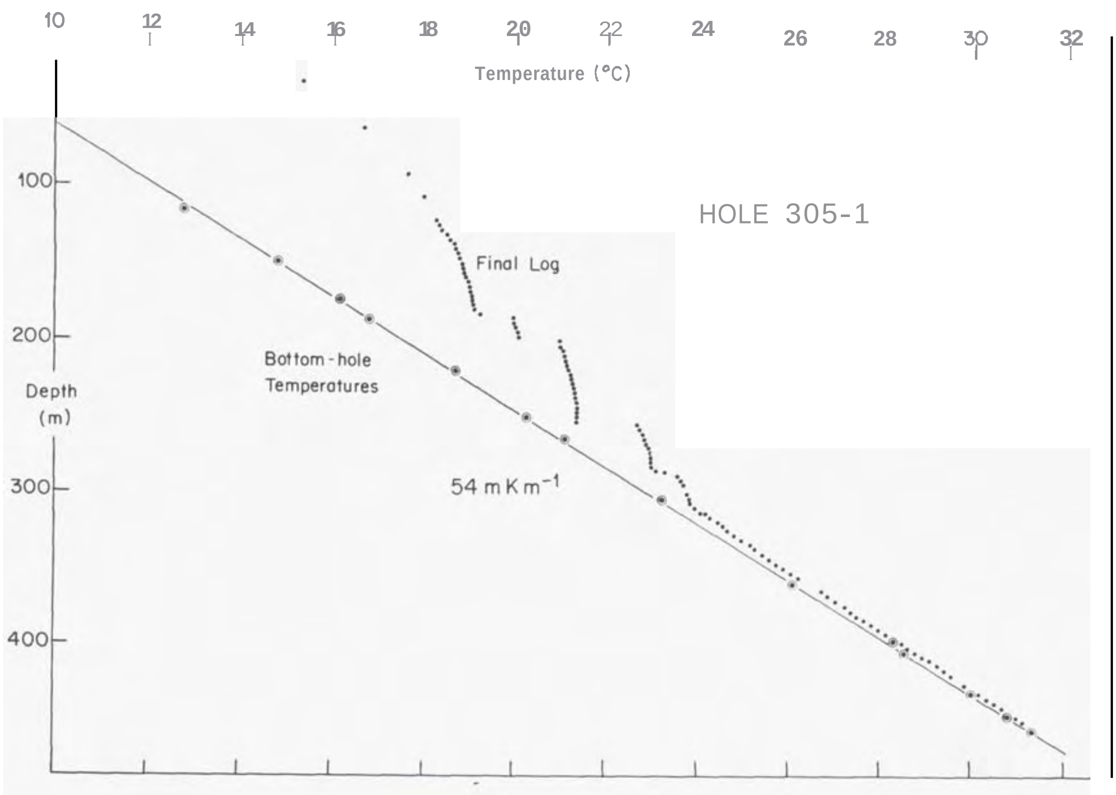

Fig. 3 Bottom hole temperatures and a final log of hole 305-1. The "steps" in the final temperature log indicate where water is flowing into the hole.

topography and glacial efforts. These values compare well with results from southern England (Whieldon et al., 1981) where the measured heat flow before corrections varies between 79 and 129 mW/m^2 for 30 "granite" holes (average 98 mW/m^2) and the average heat production is 4.2 $\mu W/m^3$ for 22 of these holes.

In assessing these sites in the Coryell rocks in terms of a hot dry rock type of geothermal resource, the temperatures at depth are calculated to be 106 K at 2 km depth and 156 K at 3 km depth. The permeability evident along fractures in the top 400 m may or may not be present at greater depths. These temperatures probably could produce hot water for space heating.

CONCLUSIONS

On the basis of geological and geophysical data, low temperature reservoirs exist in Tertiary sedimentary basins and in Eocene crustal rocks with high heat generation. Both of these resources could supply hot water for space heating. Whether or not such resources are economic should be based on a combined engineering and financial study. However on the basis of similar resources elsewhere it is anticipated that the hot dry rock resource could not be economically exploited at the present costs of alternative sources of energy. If the deeper rock is permeable, then it might be economical to produce hot water, and this would be similar to the situation in the Tertiary basins.

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