TERTIARY OUTLIER STUDIES: RECENT INVESTIGATIONS IN THE SUMMERLAND BASIN, SOUTH OKANAGAN AREA, B.C.


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INTRODUCTION

The Tertiary basins in the interior of British Columbia present opportunities for the development of geothermal resources but not without appropriate regard for environmental considerations such as the dispersion of heavy metals, the radioactivity of country rocks and the quality of groundwater.

The main object of this project was to test the geothermal potential of the Summerland basin with a view to locating a low-grade thermal source for space heating (mainly the local greenhouses). To this end the first phase of a drilling, Hole No. EPB/GSC 495, began in March 1990 at Summerland, sponsored by the South Okanagan – Similkameen Community Futures Group (based in Penticton), the Geological Survey of Canada and the British Columbia Ministry of Energy, Mines and Petroleum Resources.

The weakly lithified beds, characteristic of the Tertiary basins, are poor thermal conductors than commonly blanket older more conductive crystalline basement rocks. The natural dissipation of heat from the earth’s interior is impeded by this blanket, causing thermal accumulation. Combined with this, the inherent structural weakness of these young cover rocks facilitates faulting and fracturing allowing the entry of groundwater into the strata and the possible development of warm-water reservoirs at depth (N&n. Sadlier-Brown, Goodbrand Ltd., 1987).

The mixing of mineral-laden ground waters from deep sources with surface waters may present environmental concerns in ranching and urban areas. For example specific concerns were expressed by Bates et al. (1979, page 4):

“A problem exists at Eneas Creek west of Summerland, where uranium in creek water at the present time appears to be naturally in excess of the proposed public drinking water standard (20 ppb uranium)”.

Elevated uranium in surface water in the area, up to 2.5 ppm, was also noted by Church, 1980. The ultimate source of the uranium is believed to be groundwater from surrounding hills.

GEOLOGICAL SETTING

The Summerland basin is an Eocene volcanic caldera that was once part of a larger contiguous mass of volcanic and sedimentary rocks known as the “Penticton Tertiary outlier” (Church, 1982). The rocks in the Summerland basin consist of several major units of the Penticton Group such as the basal conglomerates (Kettle River Formation), massive volcanic beds (Marron Formation), feldspar porphyry trachyandesite lavas (Kitley Lake member), fine-grained trachytic lavas and ash flows (Nimpit Lake member), dome-forming dacitic lava and breccia (Marama Formation) and fluviatile and lacustrine sedimentary rocks (White Lake Formation). The total stratigraphic thickness of this assemblage is of excess of 1000 metres (Figures 2-1-1 and 2-1-2). A drill hole through to the keel of the basin in a central location would be expected to encounter most of the stratigraphic units.

Rifting and graben development caused by crustal extension along the Okanagan valley occurred about 50 million years ago (Church, 1973). At this time and subsequently, the rocks of the Summerland area were tilted and folded into an elliptical 5 by 10 kilometre synclinal trough, forming a natural catchment area for resupply of groundwater. Down dip on the beds the lateral movement of groundwater is impeded (and ponded?) along the Summerland fault at the southeast margin of the basin where down-faulted strata are juxtaposed against impervious massive granite.

Eneas Creek enters from the north, through the breached rim of the basin. It becomes intermittent and marshy toward the centre of the basin and eventually disappears into the glacial overburden. Elsewhere there are few streams; a number of ponds and marshes in closed depressions receive drainage directly from adjacent slopes.

At depth, groundwater is channelled along joints, bedding planes and faults, becoming trapped in permeable units such as conglomerate and sandstone beds and lenses of breccia in fault zones. In the elastic beds permeability is greatly reduced because of carbonate cement and abundant interstitial volcanic ash. Consequently much of the available groundwater is believed to be contained in the fractures. Slippage, as the result of folding, between the individual beds and along formation contacts, is believed to be the most promising mechanism for the formation of aquifers at depth.

DRILLING

The search for renewable energy sources began prior to the energy crisis of the mid-70s. To this end, Energy Mines and Resources Canada and the British Columbia Ministry of Energy, Mines and Petroleum Resources have supported a number of geothermal energy projects. The Geothermal Potential Map of British Columbia (Church et al., 1983)
Figure 2-1-1. Location of geothermal drill hole in the Summerland basin.
was preceded by more detailed investigations suggesting geothermal potential in the White Lake basin and other Tertiary outliers in south-central British Columbia (Church, 1973; Jessop and Judge, 1971).

The first borehole in the area was sponsored by the federal government as part of the Geothermal Energy Program (Lewis and Werner, 1987). This was a diamond-drill hole intended to test the geophysical and geological properties of granitic rocks just south of the Summerland basin. Later, a second hole, the "Mraz well," was drilled to a depth of 200 metres to test the bedded Tertiary rocks in the southern part of the basin.

Lewis (1984) confirmed a regional high heat-flow and suggested targets for further research. He concluded that a more quantitative evaluation of the geothermal reserve required additional test wells.

The most recent hole (EPB/GSC 405) is located on the Boreboom farm (Mountain View Farms), just south of Encus Creek, approximately 1 kilometre northwest from the centre of Summerland (Plate 2-1-1): (latitude 49°36’30”, longitude 119°41’18”; elevation 505 metres). The location of this hole was chosen based on geology and proximity to a potential customer. The Boreboom farm proved to be well positioned on the west limb of the basin where a drill hole of reasonable depth could penetrate to the base of the Tertiary pile. This optimized the blanket effect and increased the possibility of intercepting a warm-water aquifer at the contact of the Tertiary beds with the underlying granite. The farm is a large user of natural gas for heating greenhouses and the owner was clearly interested in a cheaper source of energy.
The new well began as a 6-inch (15.2 cm) diameter rotary hole. It was drilled (March 10 to May 15th) to a depth of 544 metres, penetrating 56 metres of gravel and glacial till before entering bedrock. The hole was completed by BQ diamond drilling (July 2nd to July 31st) to a depth of 712 metres.

The geological profile of the bed-rock in this hole shows mostly alternating ash flows and lava flows typical of the Nimpit member of the Marron Formation, that is tan to dark grey trachyte/trachyandesite with small phenocrysts of diopside pyroxene and microlites of plagioclase and alkali feldspar in a fine-grained matrix. Quartz is rarely seen. Some admixture of shale and coal with the volcanic fragments recovered from the rotary drilling suggests penetration of part of the White Lake Formation or intercalation of similar sedimentary rocks in the volcanic pile.

The petrography of the lower, cored section of the drill hole is consistent with the chip samples obtained above. Most of this section appears to be Nimpit tuff-brecia with a few interlayered lava flows and crosscutting dikes. Flattening and welding of pumice fragments is seen at several levels. The angle between bedding and core axis averaged 45°.

A temporary water-flow of about 100 litres per minute was reported at approximately 150 metres depth; a geophysical log of the hole indicated possible water movement at 523 metres and other disturbances at 50 and 350 metres. Water movement is also believed to have been responsible for hematization in shear zones such as between 569 and 573 metres and by the local abundance of calcite and laumontite-filled fractures between 554 and 557 metres.

Preliminary results (Jessop, unpublished) gives a bottom hole temperature of slightly more than 33°C (at 706 metres) and a uniform thermal gradient close to 34 microkelvins per metre in the lower part of the hole.

ENVIRONMENTAL CONSIDERATIONS

The first caution regarding the environmental hazard of uranium in the Summerland area was from Bates et al. (1979, page 4): "A recent intensification of exploration and drilling in this area might have the effect of further increasing the uranium content in this (Eneas Creek) and other creeks".

In this regard it is noteworthy that testing rock samples and water from hole EPB/GSC 495 has shown no anomalous uranium concentrations nor high radioactive levels (Learning, personal communication, 1990). However, accumulation of young uranium in the peat of nearby Prairie Flats was noted by Culbert (1980) and Culbert and Leighton (1988).

The Prairie Flats area is marshland on the edge of Summerland (Figures 2-1-1 and 3). According to Culbert et al. (1984) concentration of uranium in peat samples from Prairie Flats locally exceeds 1000 ppm in the surface layer; a maximum of value of 62.3 ppm uranium was obtained by the writer from a suite of 28 samples collected from the same general area (Table 2-1-1). The total accumulation of UO₂, to a depth of 1 to 3 metres, is estimated to be 230 tonnes (Culbert et al., 1984). It is believed that this uranium was deposited since the last ice age and mostly within the last 2000 years (Levinson et al., 1984).

Young uranium with few gamma-active daughter products occurs in semi-arid regions of the southern interior of British Columbia and northeastern Washington State. The uranium was leached from felsic igneous rocks and fixed in organic-rich sediments. In the Fodelle Creek area of Washington uranium has been recovered from organic-rich sediments in a series of old beaver ponds — the source is a nearby uranium-rich granodiorite (Johnson et al., 1987). Similarly, in the Eneas Creek area near Summerland the source of uranium appears to be groundwater feeding from fractured granitic rocks underlying the upper course of the stream.

The semi-arid climate of the Okanagan region has facilitated transport of uranium in streams. Evaporation has resulted in an increase in the alkalinity and bicarbonate content of these waters, both of which are important local factors for the solution of uranium at surface (Culbert and Leighton, 1978; Church and Johnson, 1978). Uranium was concentrated initially by evaporation and held by adsorption and ion exchange such as occurred in the Fodelle Creek deposit (Johnson et al., 1987). Zielenki and Meier (1988) indicate that uranium at Fodelle Creek may be held loosely on organic matter as uranyl carbonate and phosphate complexes, then fixed, together with other metals, by the reducing action of bacteria. However, no specific uranium-bearing minerals have been identified and the exact mechanism of metal fixation on organic matter is not completely understood.

These young deposits are not readily detectable by conventional scintillometer surveys because of the lack of significant radioactive daughter products. They are of environ-
mental concern because they contain significant concentrations of poorly fixed uranium and some other elements such as molybdenum, and inadvertent cultural disruption may generate transient, perhaps harmful, levels of dissolved uranium in local ground and surface waters (Zeilinski et al., 1987).

ANALYTICAL RESULTS

Table 2-1-1 gives the results of analyses of 28 samples of peat from Prairie Flats (Figure 2-1-3). Eleven chemical variables were chosen to characterize the deposit, the main variables being loss on ignition (LOI) representing organics (mostly carbon), silica (SiO₂) representing the elastic sedimentary fraction; and uranium (U) representing chemical precipitate. Other elements analysed are barium (Ba), cerium (Ce), lanthanum (La), molybdenum (Mo), scandium (Sc), thorium (Th) and vanadium (V).

Loss on ignition is the weight loss of the sample after heating to 550°C. This is an indication of its organic content.

Silica ranges from 22.3 to 63.5 per cent and is generally the most abundant component in the peat. It is concentrated in the silty layers as detrital quartz and in silicates such as feldspar, the clay minerals and mica.

Other major oxides and LOI constituents comprise much of the remainder. These include alumina (Al₂O₃), carbon (C), carbon dioxide (CO₂), water (H₂O), and probably minor amounts of lime (CaO), magnesia (MgO), potash (K₂O), soda (Na₂O) and phosphate (P₂O₅), although these variables have not been individually determined for this report. The LOI ranges from 6.8 to 61.0 per cent.

The minor element values are mostly elevated compared to other sediments. It is well known that peatbogs and marshlands can be sites for anomalous concentrations of metals, especially heavy metals (Zeilinski et al., 1987). This is especially true for uranium, molybdenum (Mo), and vanadium which are concentrated up to two or three magnitudes above the levels in source rocks. The exception is thorium which averages 5 ppm, a value lower than some of the source rocks in the region (Church and Johnson, 1978).
Table 2-1-2 presents the correlation matrix (r-coefficients) for the elements listed in Table 2-1-1 (log transformed). It can be seen that the abundances of uranium and molybdenum are positively correlated with LOI as is cesium (Cs), which is a heavy alkali metal absorbed in clays. Scandium adsors on clay explaining the positive correlation of this element with cesium — it may also substitute to some extent for ferrous iron, especially in micas. The association of clay and organic material in the peat deposit suggested by these data, is not surprising and the strong negative correlation of silica (representing elastic material) and LOI (that includes organics), r=-0.909, fits a
model indicating that some of the peat is relatively free of
clastic input, perhaps distal from the source area. The
alkaline-earth and lanthanide elements, barium, lanthanum
and cerium, are positively correlated with silica suggesting
transportation in clastic minerals, perhaps in alkali feldspar.
Lanthanum and cerium are also known to concentrate in
apatite which may survive transport as a clastic component,
together with quartz.

Figure 2-1-4 is a trend-surface map of uranium content
based on the random array of sampling stations in the
Prairie Flats area (Figure 2-1-3). The contours form an
asymmetric elliptical bull’s eye rising abruptly on the south-
east side of the deposit from 100 to more than 600 ppm over
a distance of 200 metres. This is a 6th order polynomial
surface (coefficient r=0.57); the procedure for preparation
of trend-surface maps is described in detail by Krumein,
1959. The general shape of the contours coincides with the
northeast elongation of the marshland, with the highest
concentration of uranium in the east-central part. Possible
erosion or leaching of the deposit along the southeast side
may account for the rapid change in uranium values here.
Alternatively, the uranium may already have migrated from
the centre of peat accumulation farther to the west.

Figure 2-1-5 is the result of trend-surface analysis of
normalized silica data for the Prairie Flats area. The silica is
normalized to a LOI-free basis to better reflect the distribu-
tion of the clastic sedimentary fraction in the area. This
assumes that the coarse clastic fraction is mainly quartz.
Normalized silica ranges from 51.49 to 70.37 per cent, with
the highest values peripheral to much of the marshland area.
The map contours have a parabolic outline with values
diminishing from the maximum of about 70 per cent on the
north and southeast margins of the Prairie Flats area to
about 50 per cent on the west. This is also a 6th order
polynomial surface (coefficient r=0.61). It appears that
these contours are roughly parallel to the original margin or
strand line of the peat basin which evidently had a
northeast-southwest elongation.

In conclusion, variations in the abundance of selected
elements show the influence of a combined clastic and
chemical depositional environment on the formation of the
Prairie Flats marshland — an environment where alkalinity
and oxidizing/reducing conditions were important.

The original geometry of the basin is suggested by the
shape of the trend-surface contours for normalized silica.
These contours are parabolic in outline and open to the west
possibly defining the strand line of the original marsh. This
suggests that the centre of the marshland may have been
farther west (prior to erosion) than the present Prairie Flats
location.

The highest concentration of uranium, over 600 ppm, is
in the east-central part of the Prairie Flats area. Steep ura-
nium contours on the southeast side suggest some chemical
remobilization of uranium in the marshland to the southeast.
This may have been caused by inadvertent cultural distur-
bance such as farming or urban activities at the outer Sum-
merland town limits. However, further studies in the area
are necessary to confirm these conclusions.

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