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Canadian Geothermal Power Prospects

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ABSTRACT

Canada's known high-grade geothermal power resources are located in the western part of the Country, namely, in the Province of British Columbia and Yukon Territory. Medium-grade geothermal power resources are found in all regions of the Country and can be developed at a higher cost (compared to high-grade). This paper reports the status of active e geothermal power prospects in the Country. In British Columbia, new drilling and well testing at the South Meager Creek prospects have confirmed presence of at least 100 MW of geothermal power capacity. In the Pebble Creek (also known as North Meager), modeling of old slim hole data verified presence of at least 200 MWe. Deep rotary drilling in this prospect is planned to start in the fall of 2009. Geochemistry and recent geophysical survey at the Canoe hot springs (a geothermal prospect in the Rockies) show a substantial geothermal power potential. Slim hole drilling in this prospect is planned to start in the spring of 2010. Recent studies in Yukon, North West Territories and the Peace Region of British Columbia have found interesting geothermal anomalies which are likely to lead to future geothermal power projects in these Regions.

1. INTRODUCTION

West coast of Canada is part of the circum-pacific ring of fire. A dozen of young volcanic edifices and more than one hundred hot springs in British Columbia and Yukon provide surface evidence for substantial high-grade geothermal power resources. The total geothermal power potential associated with these resources is estimated at 3000 to5000 MWe (Ghomshei et al. 2005; Jessop, 1998, Souther, 1980). About half of this potential is located in remote areas and national parks where absence of power lines and power market or presence of regulatory constraints could make large-scale geothermal power development impractical. This paper gives an update of the active Canadian geothermal power exploration projects, which are all situated in British Columbia. Potential prospects in Yukon and North West Territories (NWT) are also briefly discussed, considering the rising demand for clean and affordable power in Canadian's Northern communities.

British Columbia is the only Province in Canada with regulations specific to geothermal power exploration and production. In other provinces and territories geothermal power resources fall under broader regulations (e.g. minerals, oil and gas, and groundwater).

In British Columbia, geothermal permits are granted by the Provincial Government through public tenders. Permits are valid for a maximum of 8 years. After confirming the resource, a permit can be converted to a long-term lease for power generation. Presently, there is only one geothermal lease in the Province, which is in the South Meager Creek area (Ghomshei, et al, 2004, 2005). There are also four geothermal permits, three of them in the North Meager Creek (known as Pebble Creek) (Nevin, 1992), and one permit in the Rockies (Ghomsnei and Kimball, 2009) (Fig. 1). This paper updates the information about these prospects. It also discusses about other geothermal areas under study, which are likely to be considered for detailed exploration and possible development in foreseeable future.

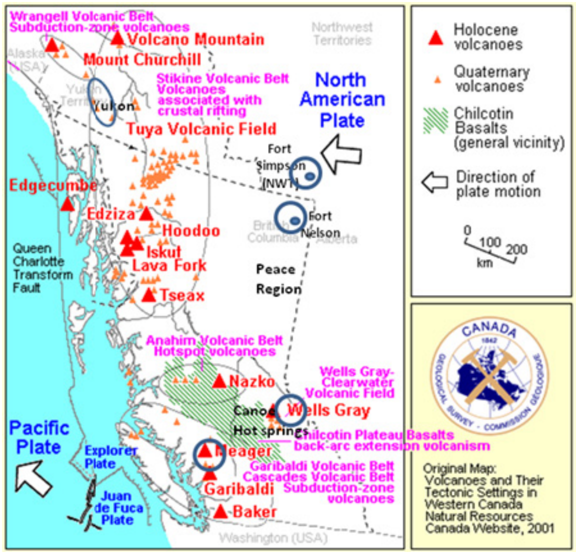

Fig. 1: Volcanological map of western Canada (after Natural Resources Canada, 2001), showing the location of geothermal Projects and study areas.

2. SOUTH MEAGER GREEK

Since the late 1970s, the geothermal resource potential of the South Meager area has been investigated using various exploration techniques including geology, geochemistry, geophysics, and the drilling of numerous temperature gradient wells (slim-diameter wells used to measure subsurface temperature), deep slim wells and several full-diameter wells (Ghomshei et al., 1986; Ghomshei and Stauder, 1989). During one flow test, one of the full-diameter wells - drilled by B.C. Hydro - was used to supply a 40 kW pilot geothermal power facility.

During 2001 and 2002, a magneto-telluric ("MT") geophysical survey was followed by three slim holes. The results provided strong evidence for the presence of a large, high temperature geothermal reservoir at relatively shallow depth.

In 2004/2005, Western GeoPower drilled three deep (M6, M7 and M8) production-size wells to confirm the resource which was identified earlier by MT and slim hole drilling (Ghomshei et al., 2004, 2005).

Well MC-6 was drilled in a northeasterly direction to a depth of 2,662 meters and following initial air lifting, the well flowed unassisted for more than seven hours. Temperature survey results obtained demonstrated a maximum down-hole temperature of 260°C at a depth of 2,632 meters. Based on a preliminary injectivity test conducted at the time of completion, GeothermEx estimated the power capacity of MC-6 could be 4.8 MW.

Well MC-7 was drilled in a northwesterly direction to a depth of 3,291 meters. Temperature and pressure surveys of well MC-7 carried out in 2006 measured a maximum down-hole temperature of 260°C. As the permeability of MC-7 was found to be lower than the permeability in wells MC-6 and MC-8, well MC-7 was used as an injector well for flow testing well MC-8.

Well MC-8 was drilled in an easterly direction to a depth of 2,380 meters and completed in summer of 2005. At 2,345 meters, the first major fracture was encountered and circulation of the drilling fluid was lost completely, following which drilling proceeded without any fluid returns to surface ('blind' drilling), to 2,347 meters. The well was then drilled with aerated water to 2,380 meters, with additional fractures intersected at 2,353 to 2,369 meters.

Wellbore simulation carried out by GeothermEx on data provided by an injectivity test of well MC-8, indicated the well would be commercial. An airlift-assisted flow test of MC-8 in September 2008 demonstrated potentially commercial permeability in the reservoir, but MC-8 itself did not sustain self-flow. However, wellbore simulation indicated that a well targeting the same permeable zone from a lower elevation could flow at the equivalent of more than 6 megawatts of electrical output.

The results of the exploration work completed to date strongly indicate the presence of a geothermal reservoir with an area extent of 4.5 to 7.5 km² and an average temperature of 220 to 240°C with a maximum measured temperature of 275°C. These attributes identify the South Meager field as a "high temperature" field (defined as one with 200°C or higher temperature) and a major geothermal site (defined as a site with 100 MW or more of potential development capacity).

3. PEBBLE CREEK (NORTH MEAGER)

Pebble Creek geothermal prospects consist of tree geothermal permits in the north of the Meager Creek volcanic complex (location of the youngest volcanic events in the area). Early exploration activities in these prospects were carried out about three decades ago by BC hydro and consisted of resistivity survey, drilling 9 slim holes to a depth of 1100 m, geochemistry and geology (Nevin, 1992).

Old temperature and lithological data from slim holes were recently integrated in a GIS database (consisting of most recent geological, geochemical and topographic data). Temperature models were created to delineate the geothermal up-flow zone and to assess the extent of the high-enthalpy reservoir, accessible from the permit areas.

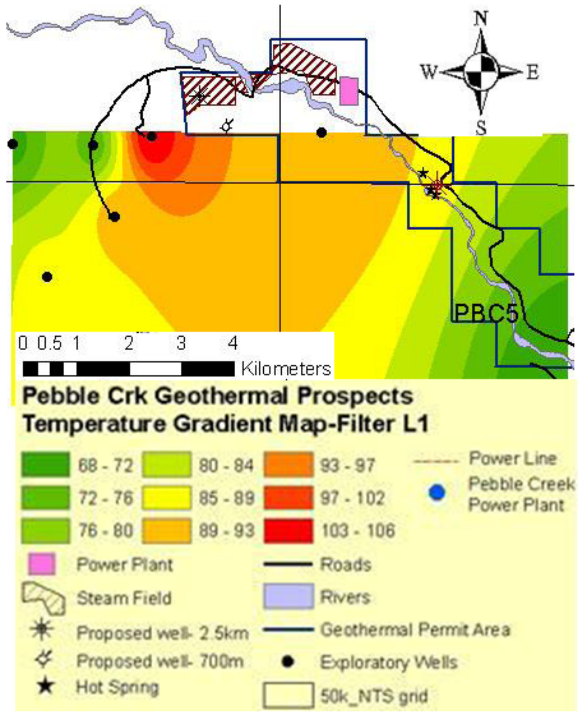

Fig. 2: Temperature gradient model in the Pebble Creek geothermal prospects. An anomalously high temperature gradient (above 100°C/km) from one of the wells (L1) is likely a convective gradient. The gradient in other wells is conductive. A temperature gradient of 85 to 95°C/km is a reliable estimate for most of the prospect area.

Temperature gradient models (Fig. 2) were extrapolated to a depth of 3000m. The temperature model at 2500 m was considered for calculating the extent of the high-enthalpy geothermal power reserve. The minimum high enthalpy reserve was estimated based on the extent of the high-enthalpy zones (above 230°C) accessible at an average depth of 2500 m. The extent of the high enthalpy zones is estimated to be at least 10 square kilometres.

The total high-grade heat energy convertible to power is conservatively estimated above 55 million Megawatt hours of electricity, which can support a 230 MWe generating capacity for 30 years.

Temperature data obtained from old slim holes conform with recent geothermometric data obtained from analysis of Pebble Creek hot springs. Presence of permeability is evidenced by observed primary and fracture permeability in slim holes (Nevin, 1992).

Deep confirmatory drilling is scheduled to commence in the fall of 2009. The project is expected to bring its first 100 MWe on line by 2012.

A 230 kV line is needed to tie the Meager Creek South and North (Pebble Creek) geothermal fields in to the B.C. Transmission Corp. system. Preliminary studies have identified two potential routes utilizing existing transportation corridors - the Pemberton Valley to tie-in at Pemberton, and the Birkenhead Valley to tie-in at Poole Creek. The Pemberton Valley line which is the most likely corridor is about 60 km (connecting the Meager fields to a BCTC junction in the City of Pemberton).

4. CANOE HOT SPRINGS

Canoe hot springs (or Canoe Reach) geothermal permit area includes a series of surface thermal manifestations spread over 1.5 kilometers along the Kinbasket Lake in the west of the Canadian Rockies (Fig.1). The temperature of the hot spring fluids (as they appear at the surface) reaches 70°C to 80°C. These thermal springs are among the highest-temperature hot springs discovered in British Columbia. The Canoe Hot Springs exceed in both flow and temperature other hot springs in the Rockies, such as Radium and Fairmont. Geochemical geothermometers of Canoe hot springs indicate that the deep undiluted geothermal waters under the property may have temperatures above 200°C (Ghomshei and Kimball, 2009, Lund, 2003).

One possible source for the heat can be the old basement gneiss (rich in natural radioactive elements) which may be considered as a plausible candidate for radiogenic heat source in the area. A more plausible heat source may be related to the rising mantle in the Southern Rocky Mountain Trench (SRMT). Whatever the source, data on Canoe hot springs indicate presence of large temperature geothermal fluids at depth which can be used for power generation.

The Canoe geothermal permit is accessible via the local forestry service road, a journey of approximately 2 km from Valemount, and can also be accessed via Kinbasket Lake.

The project is approximately 7 km away from a substation on the BC Hydro Power grid. The resource is therefore commercially viable for power generation, using medium-scale binary generation or large-scale flash steam technology (should an extensive high-grade resource be confirmed). Shallow temperature gradient and deep core-hole drilling in the Permit area is scheduled to start in the spring of 2010.

5. PEACE REGION

Peace Region is in the north east of British Columbia (east of Rocky Mountains) (Fig. 1). Temperature data from oil and gas wells in Milo and Clarke Lake areas (near Fort Nelson) indicate the presence of a significant geothermal anomaly. The average measured temperature gradient for the Clarke Lake gas field is 54ºC/km (Fig. 3). These data suggest that the area has a significant potential for commercial geothermal power generation. Furthermore the proximity of the area to power lines (and Alberta power market) enhances the economics of a geothermal power project in the region.

The deep geothermal power potential of this prospect is comparable to that of Soultz-Sous-Forets in Alsace, France (Cuenot, et al., 2008). Shallow geothermal resources (1,500 to 2,500 m) in these areas can be accessed for power generation using ORC technology. For flash steam technology, deeper geothermal drilling (3,500 to 4,500 m) will be needed. Geothermal power generation facility in this area can supply usable heat for near-by communities. A market for both geothermal heat and electricity exists in Fort Nelson (Fig. 1) with a population of about 4,664 and 1,705 dwellings.

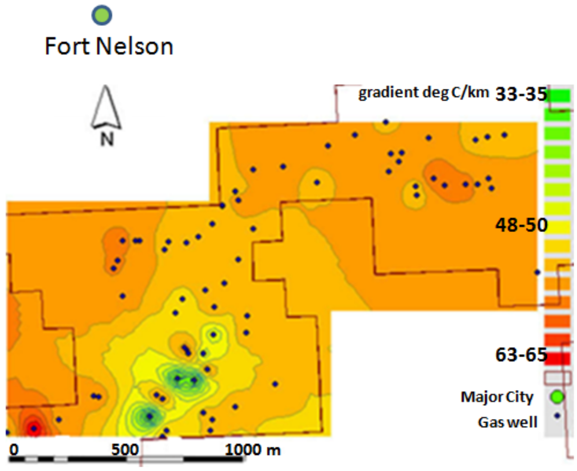

Fig. 3:Temperature gradient map of the Clarke Lake gas field (near Fort Nelson). Gradients are in °C/km, After Arianpoo et al., 2009.

6.0 NORTHERN TERRITORIES

In Yukon and North West Territories, increased mining activity has lead to rising power demand. Presently a major component of the power generating capacity in these northern territories is diesel fuel, which is supplied at high economical and environmental costs.

6.1 Yukon Studies

Yukon is a rapidly developing northern territory of Canada, where economic growth is highly dependent on local power resources. With limited availability of hydropower capacity, the Territory is looking for other base-load power resources to meet its increasing demand (especially in the Mining Sector).

Location of the Yukon on the Circum-Pacific volcanic belt (also known as Ring of Fire), makes the Territory a great candidate for development of geothermal power.

Geothermal potential in the Yukon Region is linked to marginal volcanism. The Wrangell volcanic belt (Souther 1980, Ghomsei, 2008) stretches across South-western Yukon from British Columbia to central Alaska. The young volcanic rocks of this belt are predominantly andesitic, which are considered as a favorable source for large geothermal systems. There are also several young basaltic events which can be considered as potential geothermal heat source.

The youngest volcanic rocks in Yukon are associated with the White River ash which is only 1200 to1500 years old and stretches eastward from White River (in Alaska, near the Yukon border). Most of the quaternary volcanic vents are located in Alaska. There are also, a few important quaternary volcanic vents in Yukon. The Wrangell lavas West of Kluane Lake consists of 1.5 km wide flows which indicate the possibility of a significant geothermal potential.

Presence of young volcanic vents and hot springs are surface indications of high-temperature geothermal resources at depth. Based on the limited available volcanological data, it is estimated that a total of 500 to 1500 MW geothermal power capacity may be present in the Yukon Territory.

Recent geochemical studies on hot springs and hot well waters in McArthur Hot Springs, the Haines Junction-Jarvis River areas in south west of the Territory, show moderately high geothermometric temperatures (65.5°C to 163.7°C) (Ghomshei, 2008, EBA, 2009). The upper range of these calculated temperatures indicates presence of high to medium-grade geothermal power resources, which may be exploited using conventional or binary geothermal power generating technology.

6.2 Fort Simpson Project (North West Territories)

A recent study was conducted on the temperature gradient data from South Eastern part of North West Territories. Moderately high temperature gradients (between 40 to 70°C/km) are present in extensive areas north of Mackenzie river (near Great Stave Lake). A prefeasibility study (Ghomshei, 2008) showed that the resource can be viable for several mega watts of power generation to provide affordable electricity to the City of Fort Simpson, where presently price of electricity is above 40 cents per kWh.

Besides MT and seismic indications of presence of deep-seated heat in the Fort Simpson area, real field data on heat flow are available through temperature gradient and heat flow measurements in exploratory boreholes in the region (Fig. 4).

The field data, combined with regional geophysical information, provide strong indications that the Fort Simpson area is located on a positive geothermal anomaly with temperature gradients above 50°C/km (which is twice the average continental gradient of 25°C/km) (Fig. 4). This means that the likelihood of intercepting a geothermal resource for direct use applications at a depth of 1 km is very high. Higher temperatures for cogeneration of power and heat can be found at deeper levels (more than 2 km). Existing temperature gradient data from Fort Simpson area imply that rock temperature is likely to be above 90°C at a depth of 2 km. Such a resource can be used for power generation, using off-the-shelf "binary" technology (as developed and marketed by ORMAT). Note that the lowest temperature used for power generation is 74°C (in Chena, Alaska).

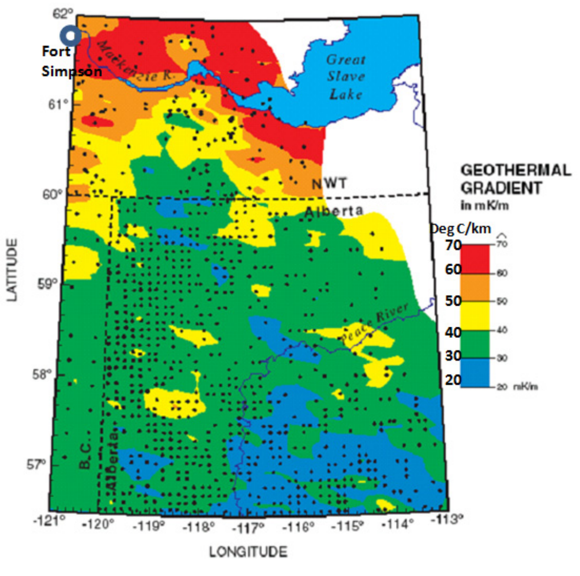

Fig. 4: Temperature gradient map for North West Territories after Majorowicz and Hannigan (2007). Fort Simpson is located in the high gradient zone (above 50°C/km).

7. CONCLUSION

High enthalpy geothermal resources of Canada are located in the Province of British Columbia and the Yukon Territory. Active geothermal power exploration projects in Canada are in the Meager Creek (South Western BC) and Canoe Reach (in the Rockies).

In the South Meager Creek, recent drilling and testing of three deep production-size holes have lead to confirmation of 100MW power generating capacity.

In the North Meager Creek (also known as Pebble Creek), slim hole data indicate a resource potential exceeding 200MWe. Deep confirmatory drilling and reservoir testing is scheduled to be completed by early 2010.

Recent MT Surveys at Canoe hot springs indicate a significant medium to high-grade geothermal potential in the Canadian Rockies.

Other areas under study for geothermal power generation include western Yukon, Fort Simpson area (in NWT) and Fort Nelson (Clarke Lake) area in the Peace Region (BC).

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