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Assessment of Enhanced Geothermal Systems potential in Québec, Canada

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Introduction

Previous study of geothermal potential across Canada has focused mainly on the Canadian Sedimentary Basin (Western Canada), Cordillera (British Columbia) and mines of Nova Scotia (Eastern Canada). Because the potential of Québec territory has not been assessed, this study intends to fill in this gap. New detailed maps of heat flow density and deep temperature have been constructed. This is a first step in determination of geothermal resource base in Québec's conduction dominated systems. Areas with thick sedimentary rock wedge which exist in southern Québec will potentially provide temperatures higher than 120°C, the minimum requirement for the success of future Engineered Geothermal Systems.

Correction of temperature-depth data

Hydro-Québec's temperature-depth database based on MRNFQ (Ministère des resources naturelles et de la faune du Québec) and Basin data files includes uncorrected temperatures generally measured by the industry at the bottom of deep petroleum and gas prospection wells in Québec. Statistically derived corrections of the BHT data have been used (Figure 1). It can be seen that the correction increases temperature above 1km depth and decreases for shallower than 1km. Also, the geothermal gradient based on the Harrison correction is higher than for the uncorrected data (24.1°C/km vs. 16.2°C/km). After application of the Harrison correction, the SMU temperature correction has been applied (Blackwell and Richards, 2004b). This correction changes individual values, but the average geothermal gradient does not change much, being 23-24^{o}C/km.

Heat flux density

Hydro-Québec database includes 979 locations with bottom hole temperature data from drill holes into the sedimentary wedge. Additional precision measured heat flux density data from the Heat Flow Map of North-America (Blackwell and Richards, 2004) and IHFC (International Heat Flow Commission) have been used to produce new maps of heat flux density patterns for the Québec's

territory. By using typical rock thermal conductivity values for sedimentary and crystalline rocks, heat flux density values have been employed for farther calculations of temperatures at depths of 2km, 4km, 6km, 8km and 10km.

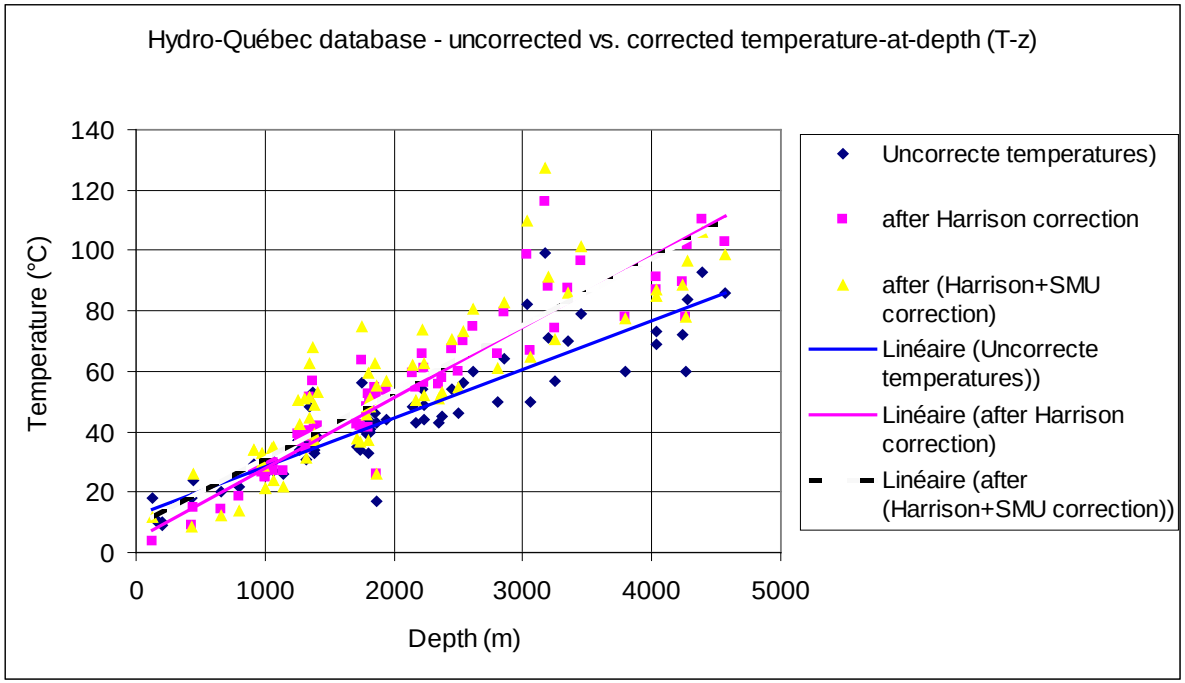


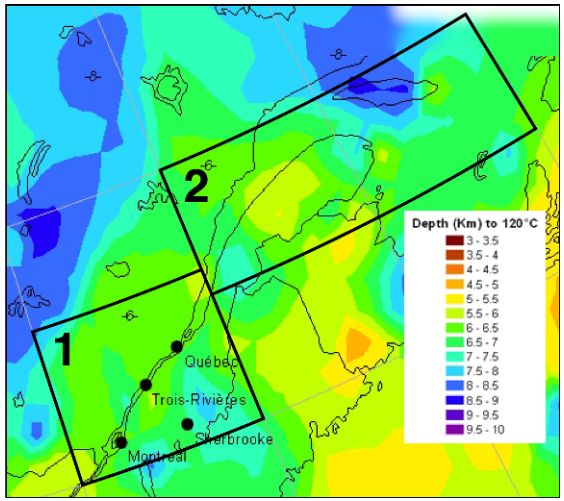
Figure 1. Comparison of temperature data from the Hydro-Québec (MRNFQ and Basin files) data base after application of both SMU and Harrison corrections.

The mean heat density value is $56.9*10^{-3}W/m^2$, with standard temperature deviation $SD=17.4*10^{-3}W/m^2$. This value is slightly lower than the average heat flux density of Canada ($64*10^{-3}W/m^2$ with $SD=16*10^{-3}W/m^2$). In Southern Québec, the geothermal heat flux density is in many places at $60-75*10^{-3}W/m^2$ and it can be considered as elevated in comparison with the rest of the province. It is fortunate that the highest heat flux density area coincides to a large extent with highest population areas.

Temperature-at-depth profiles

Figure 2a shows examples of temperature versus depth predictions based on possible high ($76*10^{-3}W/m^2$) and low ($39*10^{-3}W/m^2$) geothermal heat flux densities in Eastern Canada which covers wide range of temperature from very low (usual for the shied area) to

high (limited areas of high heat flow in the St.-Lawrence rift zone). The constructed depth-temperature maps and geotherms down to 10km depth reveal that temperature suitable for EGS systems (>120^{o}C) can be reached over large areas of Québec at reasonable drilling depths of less than 7km. It is especially possible in the southern part of Québec which has elevated geothermal heat flux densities and temperature conditions at these depths. Two large areas (#1 and #2) including the most populated cities (Montréal, Trois-Rivières, Québec City, Rimouski and Sherbrooke) were found to be most interesting for potential geothermal energy use in the St. Lawrence region and have been targeted in this study (Figure 2b). These areas include thick sedimentary rock wedge and potentially could provide temperatures higher than 120°C within sediments with initial high permeability. In case of prospect area #1 (within 45-48^{o}N 70-75^{o}W) and #2 (47.5-50^{o}N 60-70^{o}W) it can be seen that such temperatures can be reach at average depths of 6-7.5km (with SD = 35-44^{o}C) and 6.5-8km (with SD = 38 - 47^{o}C). However, 120^{o}C and 150^{o}C temperatures are frequent at much lesser depths, especially in areas with wells having higher temperature – depth than the average values + 1SD. There are twelve such wells in area #1 and eight wells in area #2. The depth to temperatures 150^{o}C can be reached in these two areas at depths less than 5 km and less than 6km, respectively.



(a) (b)

Figure 2. (a) Examples of modeled range of temperature-at-depth (low and high geotherms) for the area #1 of southern Quebéc vs. corrected available temperature records; (b) Map of areas #1 and #2 depicted as feasible prospects for the use of geothermal energy in Québec.

In few cases, there are lesser depths than 4.5km and 4km, respectively. There are four wells with depths to temperature of 150^{o}C at depths as low as 4km. These are single anomalous locations which need further detailed study. Because the maps of temperature – depth patterns tend to average and smooth out single anomalies, they can be real and related to deep structural tectonics faults and upward heat influx. Such locations would be most interesting for deep geothermal energy use.

Temperature maps

Lambert conformal equidistant projection has been used to produce temperature contour maps in the St-Lawrence River area for depths as low as 3 km and as high as 9km. The main EGS prospects are with shallower depths and depths within sedimentary cover especially. Figure 3 shows the temperature pattern at 7km depth. It ca be seen that the best prospects for high temperatures are in the populated areas of St-Lawrence River in Montréal-Trois-Rivières axis (western part), as well in South-West of Rimousky (eastern part).

Conclusions

Based on Hydro-Québec's deep temperature database, this paper shows some hints of higher geothermal potential in the St.-Lawrence valley. High temperatures at depth or relatively low depth (3-5km) to >120^{o}C are mainly in the area of Québec's sedimentary rocks. However, the measurements in the St.-Lawrence valley in the sediments might be biased by shallow and deeper water circulation systems, and not be representative of deeper temperatures. This suggests that the background deep crustal heat flux density is even higher than that suggested by well drilling temperature measurements. The existence of faulting and significant rock weakness in the study zone can be positive towards enhancing fracturing in geologically already naturally fractured zones. In such sedimentary rocks, it is easier to drill deep through and easier to fracture than through crystalline rocks.

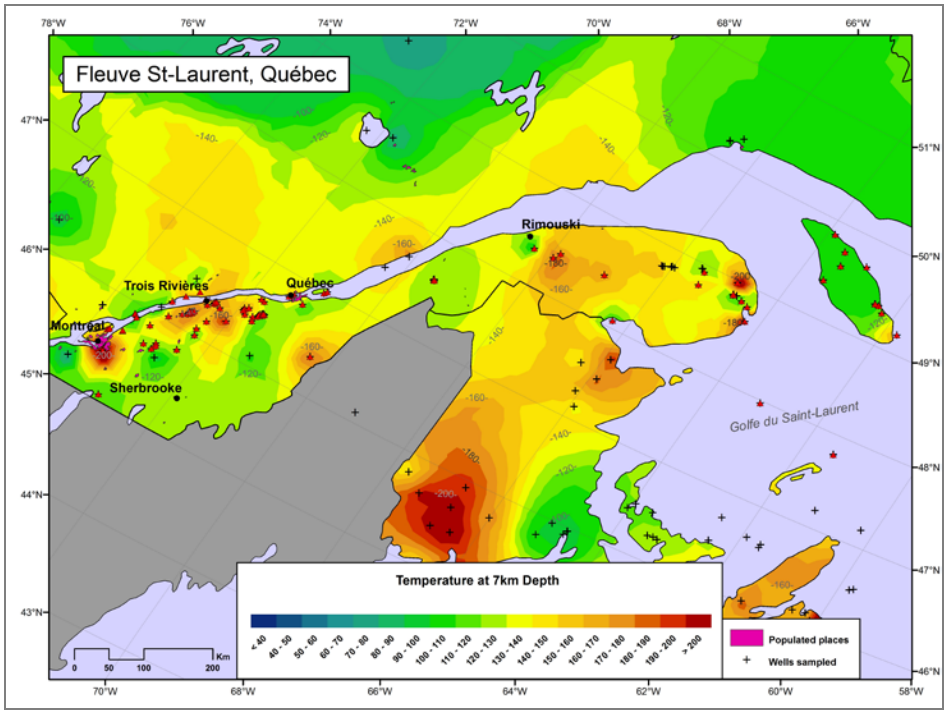


Figure 3. Temperature pattern at 7 km depth

Acknowledgements

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References

Blackwell, D.D., Richards, M., 2004. Geothermal map of North America: Explanation of resources and applications, Geothermal Resources Council Trans., vol. 28, pp. 317–320.

Jessop, A.M., Ghomeshei, M.M., Drury, M., 1991. Geothermal Energy in Canada. Geothermics, 20, pp.369-385.

Majorowicz, J.A, Grasby, S., 2010. Heat flow, depth–temperature variations and stored thermal energy for enhanced geothermal systems in Canada, J. Geophys. Eng. 7 (2010) 1–10