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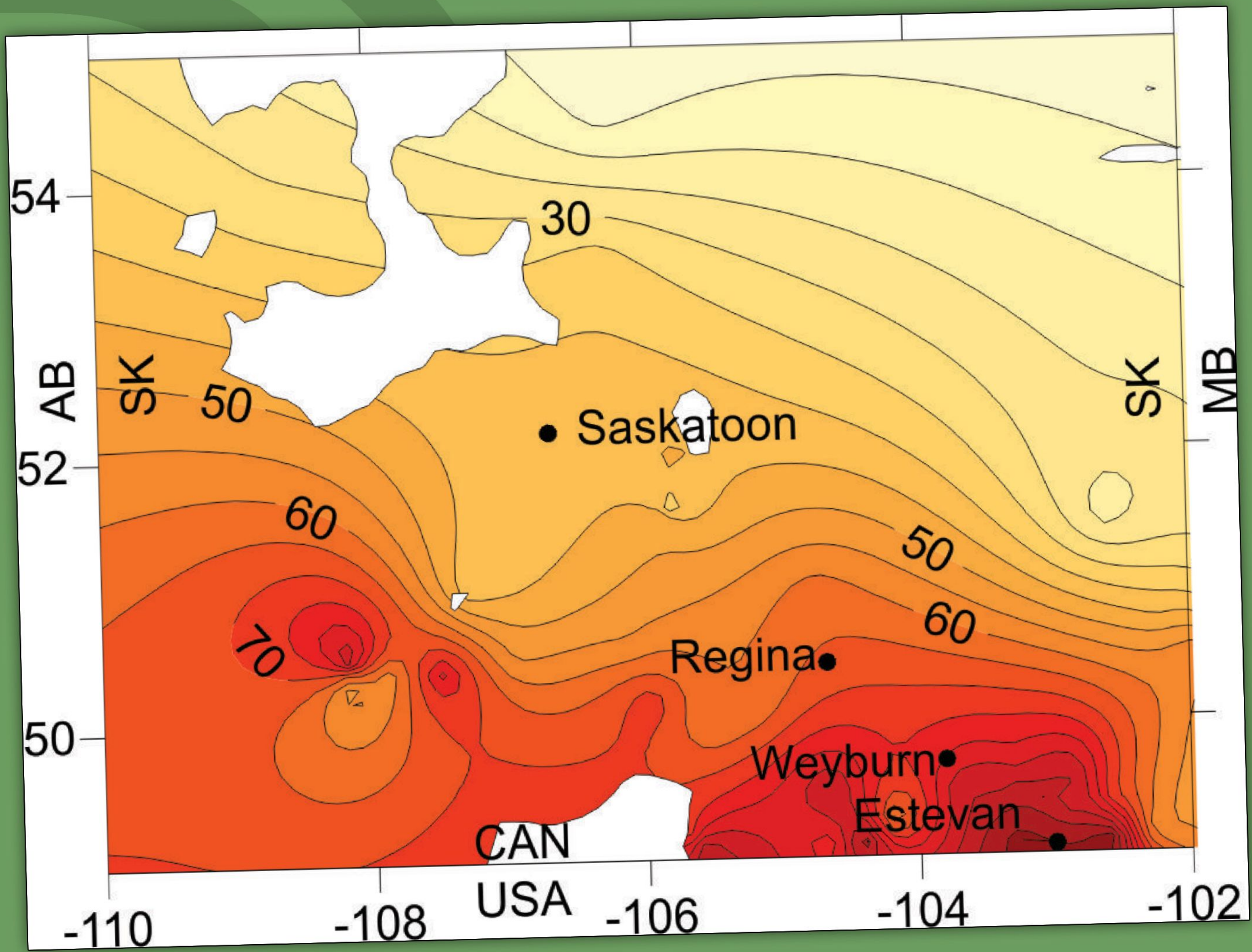
CanGRC Review

Issue 3 • Fall 2012



Map of uncorrected bottom hole temperatures in the Winnipeg and Deadwood formations in southern Saskatchewan (Ferguson, pg 5).

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Canadian Geothermal Research Council Mission Statement

Written by Ryan Libbey, Yuliana Proenza and Lena Patsa
CanGRC Co-Founders

Geothermal technologies are clean and reliable energy sources that take advantage of the thermal properties of the Earth's subsurface for direct use heating and cooling applications and electricity generation. Canada has already begun to utilize these technologies for heating and cooling purposes; however, it remains one of the only countries on the Pacific Rim to not produce electricity from geothermal resources. Studies released by the Geological Survey of Canada show these untapped subterranean resources to be vast, and new reservoir technologies may make geothermal electricity generation feasible nation-wide. Needless to say, geothermal research in Canada is a pertinent and stimulating field of study.

The Canadian Geothermal Research Council (CanGRC) is a voluntarily-run organization dedicated to serving Canada's geothermal research community. It does not exist as a government lobby group, nor is it intended to represent a unified voice of the research community. Rather, CanGRC exists to raise awareness about geothermal research in Canada, to showcase Canadian geothermal research and to elevate communication within the research community.

CanGRC is an initiative by 3 graduate students from across the country - Ryan Libbey (McGill University), Yuliana Proenza (University of British Columbia) and Lena Patsa (University of British Columbia). CanGRC operations are guided by an esteemed Board of Directors, which includes geothermal scientists from academic, government and industry positions. Currently serving on this Board is Dr. Grant Ferguson (University of Saskatchewan), Dr. Catherine Hickson (Alterra Power Corp.), Mr. Craig Dunn (Borealis Geopower) and Dr. Steve Grasby (Geological Survey of Canada / Natural Resources Canada / University of Calgary). Dr. Jasmin Raymond (L'École de Technologie Supérieure/HydroGeoPro) has been recently recruited to the CanGRC team as our GeoExchange Representative.

Membership to CanGRC is completely free and includes a subscription to this semi-annual newsletter. We encourage everyone interested in geothermal research to join. If you haven't already done so, simply head to our website at www.cangrc.ca/members.html and fill out the form.

We greatly appreciate your interest and feedback, and hope that you enjoy this issue of the *CanGRC Review*.

Best wishes,
The CanGRC Team

Chief Editor. Ryan Libbey
Content Managers. Yuliana Proenza, Lena Patsa and Ryan Libbey
Graphic Design. Ryan Libbey

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To contribute an article to the CanGRC Review, please email your submission to info@cangrc.ca. Submissions should be in .doc format. Please send all related images as separate high-quality attachments.

All are welcome and encouraged to submit. It is the intention of this publication to showcase members from a range of sectors and disciplines. Student submissions are welcome.

CanGRC Review

Is it feasible to use Engineered Geothermal Systems to produce Electrical Energy in the Alberta basin?

Written by Dr. Jacek Majorowicz[1]
Simon Weides[2]

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Geothermal energy has the potential to reduce both the production costs and greenhouse gas emissions associated with oil sands production in Alberta. The idea of using geothermal heat for oilsands processing was previously described in previous edition of the CanGRC Review by Unsworth et al. (2012). The idea of using geothermal in offsetting CO_2 emissions produced by industry and especially by oilsands processing and production is being investigated as one of the research themes of the Helmholtz-Alberta Initiative (HAI), (Theme4), which is a research collaboration between the Helmholtz Association of German Research Centers and the University of Alberta.

The primary area of interest is the Alberta basin, the central part of the Western Canadian Sedimentary Basin (WCSB) where the Phanerozoic sedimentary succession is thickening from meters near the outcrops at contact with the Canadian Shield (Precambrian) towards the south-east near the Rocky Mountain Foothills in Alberta with thickness near 6 km (Figure 1).

We have just constructed new map that displays the drilling depth necessary to reach to the temperature of 100°C (Figure 1). This temperature of 100°C is, according to Baujard et al. (2008), an acceptable minimum requirement for >8% efficient ORC and/or Kalina thermal to electrical energy conversion cycles (Marcuccilli and Zouaghi, 2007). The Access Energy system of the University of North Dakota produces electricity from water with a temperature of 100°C for with an efficiency of 14 % (Will Gosnold, UND, communiqué, 2012).

Analysis of this map (Figure 1) confirms that temperatures greater than100°Ccould be found within the sedimentary strata in the far western part of the Alberta basin with locus around the area around Hinton and Edson near the Jasper National Park.

Original temperature gradients and effective thermal conductivity of sediments were applied to estimate heat flow as well as realistic Phanerozoic formations basement characteristics through the Alberta basin based on available well control. Heat flow has been corrected for the paleoclimatic effect of post-glacial warming (Majorowicz et al.,2012). Temperature at the Precambrian basement, granitic crustal thermal conduction and its heat generation allowed us to calculate temperature in the eastern part of the basin in numerous places where 100°C is in Precambrian rocks below the Phanerozoic base. Blanketing effect of the layered sedimentary strata, which have a lower conductivity than the granitic basement, results in higher thermal gradient in sediments. This means that we require lesser drilling depth to reach 100°C in the deeper basin. In the deepest western part of the basin temperatures >100°C are found in the sedimentary succession. In the eastern and north eastern part temperatures >100°C can be only reached in the granitic basement. This includes also all of the oil sands areas for which Precambrian basement is at depths 0.5-2 km mainly.

We can now assess the ability of the sedimentary system to be a source of heat and electrical energy production at basic well-accepted parameters.

Let us consider case scenario for which we can have 100°C produced fluids with a re injection temperature dropped to 50°C. The Access Energy system of the University of North Dakota produces electricity from water with a temperature of 100°C with an efficiency of 14 % which we assume here for further calculation. In our case scenario we produce 10 kg of fluid per second. With a specific heat of the geothermal fluid of 4230 J/kg, the case scenario site would have a thermal power of 2.12 MW_{th}. Using a cycle with an efficiency of 14%, our site would produce 0.3 MW electrical power. This would be economical if the water would flow out of the well without pumping needed (artesian flow). However, it would turn to be uneconomical if electrical pumps be needed to keep production and reinjection of fluids. We need to consider that we require at least one injection pump of 0.2-0.4 MW_{el} and one production pump at 0.2-0.7 MW_{el}. It would be uneconomical even at low numbers for the electrical pumps at 0.2 + 0.2MW_{el}. We would need flow rates as high as 50 kg/s to make 1.5MW_{el} and produce net 0.5- 1.1 MW_{el} at 0.4 – 1.0MW_{el} drawn by pumps needed to circulate fluids. For a comparison fluids circulation rates at the EGS system in

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Soultz-sous-Forets (Alsace France), run closer to 30 kg/s (Gerard et al., 2006).

The situation would be much better in limited areas of the Alberta basin where we can reach 150°C like Hinton-Edson (see Majorowicz and Moore 2008).

In the area around the towns of Hinton and Edson it is possible to reach 150°C because of the basin depth and the good thermal blanketing conditions. With these conditions we would reach twice the production considered in previous case scenario (100°C source) and 0.6 MW_{el} at 10kg/s and 3 MW_{el} at 50 kg/s. When we assume minimal power requirements for the pumps this site would produce 0.2 MW_{el} net at 10kgs/s and just over 2 MW_{el} at 50 kg/s with larger electrical pumps (total MW_{el}).

In conclusion there is a net energy loss if one needs to pump the low temperature fluid. In the areas with temperature at source larger than 100°C and within sediments we can potentially get net energy gain if flow rates are at high rate >30 kg/s and moderate power required for efficient injection and production pumps. This is possible to achieve in the deepest western part of the Alberta basin.

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J.Majorowicz&M.Moore (2008),Enhanced Geothermal Systems (EGS) Potential in the Alberta Basin. ISEEE Research Paper, University of Calgary, http://www.ualberta.ca/~unsworth/geothermal/Majorowicz_Moore_ISEEE_EGS_2008.pdf

J.Majorowicz, M.J.Unsworth, T.Chacko, A.Gray, L.Heaman, D.K.Potter, D.R.Schmitt&T.Babadagli, (2012), Geothermal energy as a source of heat for oilsands processing in northern Alberta, Canada, in: Heavy Oil/Oil Sands Petroleum Systems in Alberta & Beyond, edited by F. J. Hein, D. Leckie, S. Larter and J. Suter, American Association of Petroleum Geologists, Memoir, Chapter 28, (39 p., 18 Figs, 2 Tables)American Association of Petroleum Geologists, Tulsa, OK, USA.

F.Marcuccilli, S.Zouaghi, (2007), Radial inflow turbines for Kalina and Organic Rankinecycles. In: Proceedings of European Geothermal Congress, May 30th–June1st, Germany.

M.J.Unsworth, J.Majorowicz and G.Nieuwenhuis, (2012), Is it Feasible to use Engineering Geothermal Systems to Produce Heat for Oil Sands Processing in Northern Alberta? CanGRC Review, Issue2, p.2-6, Winter 2012

More information:
Helmholtz Alberta Initiative : http://www.helmholtzalberta.ca/
Video about this project : http://www.youtube.com/watch?v=T0WRNJX7r5w

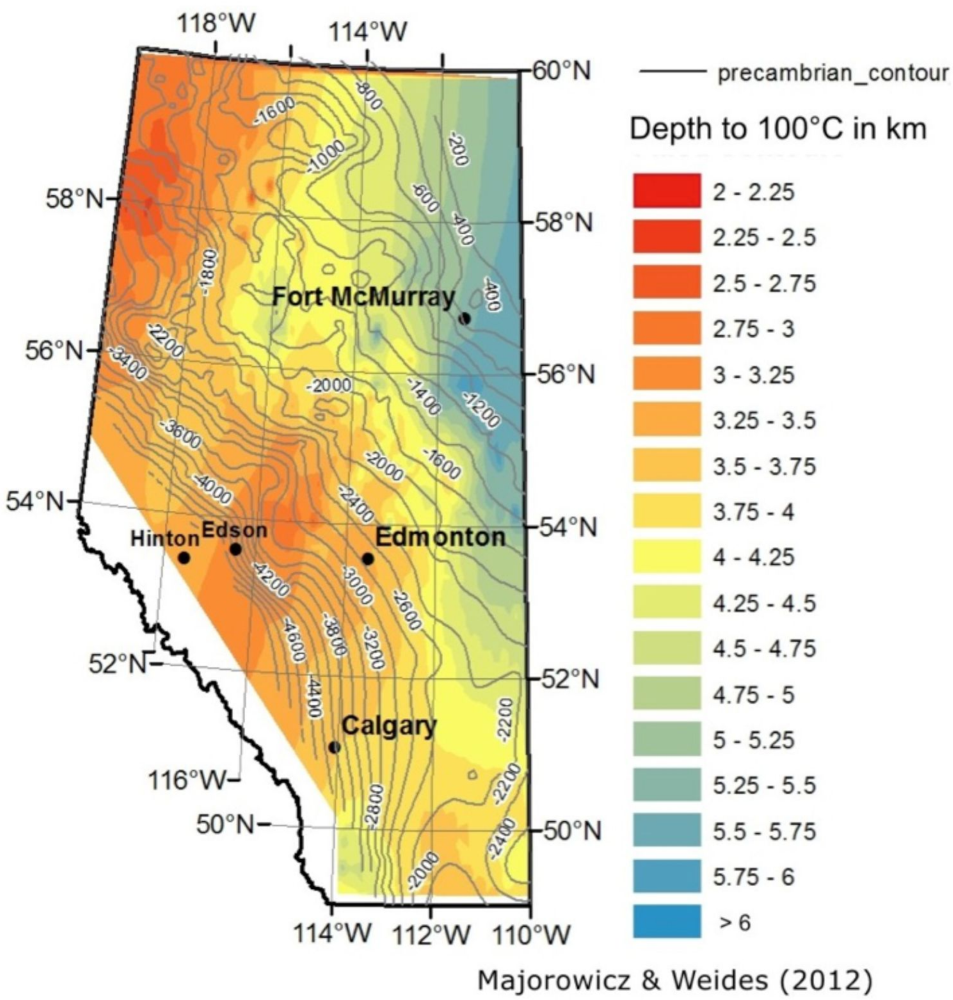


Figure 1. Calculated depth to reach 100°C in the Alberta basin vs. depth to base of Phanerozoic sedimentary fill.

CanGRC Review

Borealis GeoPower Obtains First Ever Land Use Permit and Water License from the MVLWB in NT for Geothermal Power Project

Written by Craig Dunn (Chief Geologist, Borealis GeoPower Inc.)

The McKenzie Valley Land and Water Board (MVLWB) has granted Borealis GeoPower Inc. the first ever geothermal land use permit and water license in the Northwest Territories. The issued permits, currently in draft form, allow for the development and operation, in partner with the Acho Dene Koe First Nations, of what is likely to be the first operating geothermal power plant in Canada. The plant is to be located just outside the Hamlet of Fort Liard, NWT and has been designed to supply the remote northern community with 600kW of electricity, with the future option to utilize waste heat in direct use applications.

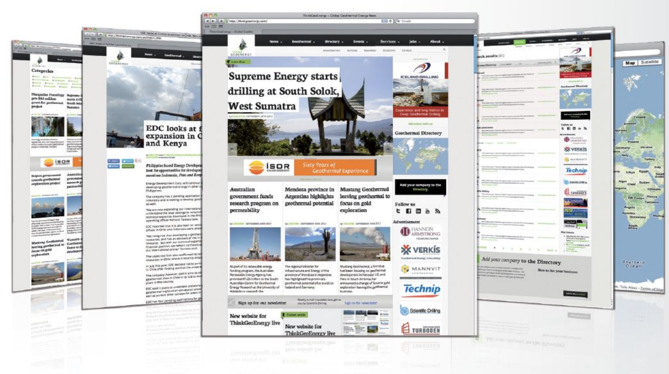
The permitting process was begun early January 2012 and recently culminated in the issuing of draft Land Use Permit MV2012X0001 and Type A Water License MV2012L4-0001. The Land Use Permit is valid for the period from June 7, 2012 – June 6, 2017 and covers the drilling of the production and injection wells as well as the development and operations of the geothermal power plant facilities. The Water License is valid from June 20, 2012 – June 19, 2022 and covers water use and the disposal of waste for the purpose of generating geothermal power. Drilling is expected to commence in the 2012/13 winter season, with power coming online by late 2013, or early 2014.

The following organizations were involved in providing input during the application process: Aboriginal Affairs and Northern Development Canada (AANDC), Environment Canada (EC), the National Energy Board (NEB) and the Government of the Northwest Territories, Environment and Natural Resources Division (GNWT-ENR).

We would also like to thank the Clean Energy Fund and the Government of the Northwest Territories – Environment and Natural Resources, for their support during the design, development, and permitting of the proposed geothermal plant.

Tim Thompson, Borealis's Chief Executive Officer, said, "This represents a watershed moment for our partners and ourselves and demonstrates that geothermal power generation is a real and viable option for the Northwest Territories."

To obtain more information, please contact:
Craig Dunn, P.Geol
Chief Geologist, Borealis GeoPower
(http://www.borealisgeopower.com)



Williston Basin Geothermal Potential

Written by Dr. Grant Ferguson (University of Saskatchewan)

University of Saskatchewan

The development of the Bakken Formation in southern Saskatchewan has created an oil boom in the province. Lurking 1000 m beneath this formation lies a resource that could answer energy needs long after Bakken oil is a but a memory. Saskatoon's DEEPCorp is currently looking to develop 5 MW of power from a sandstone reservoir at the base of the Williston Basin near Estevan, Saskatchewan. The long-term plan is to develop 100s of MW from this reservoir. The initial development is following the model used in other ongoing projects at Fort Liard, NWT and Swan Hills, AB, where data from extensive oil and gas exploration and production is used to analyze geothermal potential and reduce the risk encountered during development.

The Deadwood and the Winnipeg Formations are often collectively referred to as the basal clastics and form a reservoir at the bottom of the Williston Basin. The formations extend from Manitoba to as far away as Wyoming and have a combined thickness of up to 300 m in some areas. They have their greatest depth in southeastern Saskatchewan and adjacent areas of North Dakota, where they lie 3000 metres beneath the surface.

Bottom hole temperatures of over 100°C have been found in exploration wells in this region. These formations have high permeabilities and are a preferred target for brine disposal wells at potash operations. Some of these wells dispose of a few m3/min without any noticeable effect on neighbouring wells. Geothermal development of this reservoir is unlikely require extensive stimulation, which may help avoid some of the recent controversy around hydrofracking.

In addition to the usual obstacles that geothermal energy development encounters, development here faces competition from another proposed solution to greenhouse gas emissions. The Aquistore project, managed by Petroleum Technology and Research Council (PTRC), seeks to store carbon dioxide captured from SaskPower's Boundary Dam Power Station in the Deadwood Formation only a few kilometres from DEEPCorp's proposed project. How these projects might impact each other is unclear at this point, nor is it clear which project would benefit society the most in the short or long-term.

Geothermal energy faces a steep climb to prove itself in this environment mainly due to financial obstacles. While geothermal energy companies have struggled to raise capital for pilot projects in Canada, $22 million have been raised to support the Aquistore project. Investment in areas of opportunity for geothermal energy development such as southeastern Saskatchewan would do wonders for the industry in Canada.

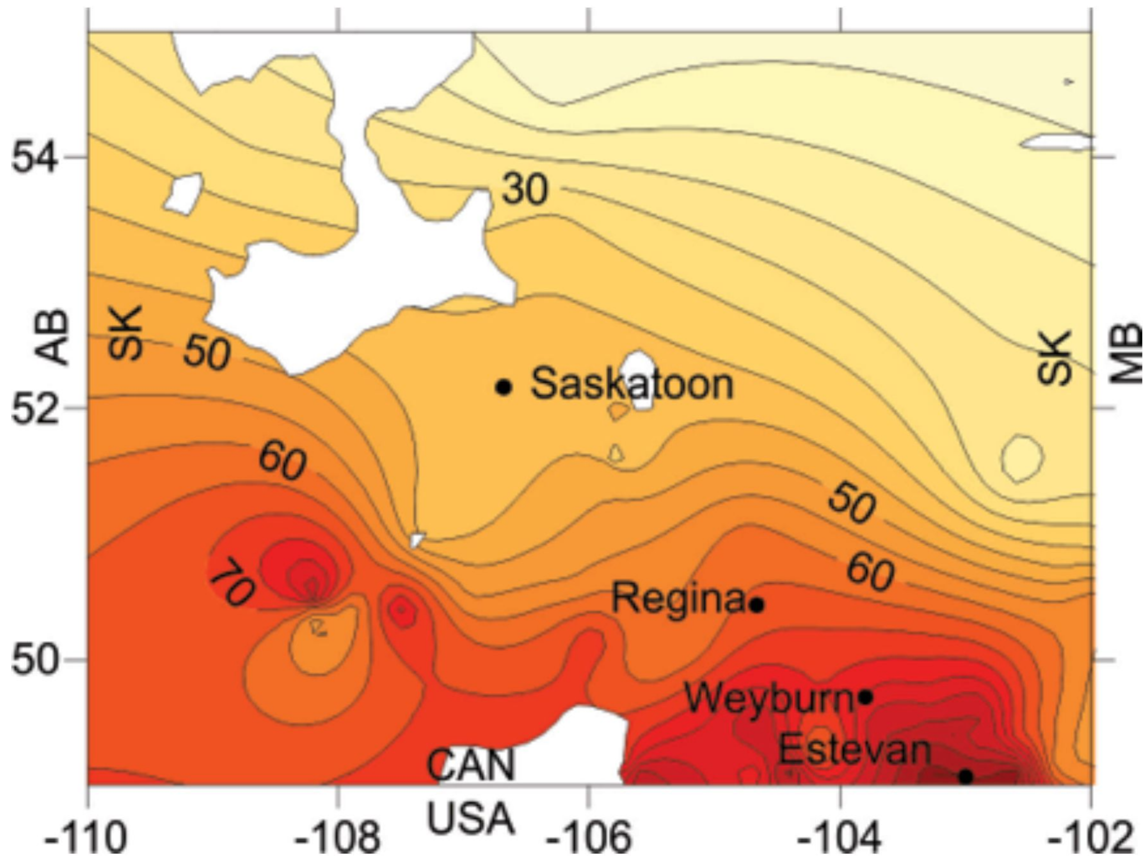


Figure 1: Map of uncorrected bottom hole temperatures in the Winnipeg and Deadwood formations in southern Saskatchewan.

CanGRCReview

Assessing the Compatibility of Aboriginal Values and Geothermal Resource Development

Written by Titilope Kunkel, PhD(C) NRES
University of Northern British Columbia
Supervisors: Drs Ellen Petticrew, Robert Ellis

Geothermal resource is at an infancy stage of its development in Canada. The resource was identified as having the potential to meet the future energy demands of the country and to provide sustainable economic development for communities. The communities in the Cariboo Chilcotin region are seeking ways to build, diversify, and to sustain their economies. The limited understanding of Aboriginal values has contributed to resource development conflicts in the region. The objectives of my research are to build First Nations capacity in geothermal resources, to assess the compatibility of Aboriginal values and geothermal resource development within the Cariboo Chilcotin region, to contribute to alternative energy development knowledge within the region, and to develop research capacities within these communities. The research questions are:

1) what are Aboriginal values around resource development, and
2) are these values compatible with geothermal resource development?

The first research question has been answered through projects as summarized below. The initial assessment shows that Aboriginal values can be compatible with geothermal resource development.

The study area, Cariboo Chilcotin region of Northern British Columbia (BC), is the homeland of 15 different First Nation communities. These communities represent three distinct language groups, the Shuswap, Southern Carrier, and Tsilhqot'in, from two language families, the Dene and Shuswap (Furniss 1995). These communities have different cultures and world views, and continue to use their traditional territories in different ways (ibid). The Cariboo Chilcotin region also has an abundance of identified geothermal resources (Fairbank and Faulkner 1992, Fairbanks Engineering 1991). Experts believe that this resource is available across the country and can potentially meet Canada's future energy demand (Grasby et al. 2011, Lebel 2009). It is also believed that this resource can be one hundred percent sustainable if it is extracted at a rate equal to or below the local geothermal heat recharge of the reservoir (Burgess 1989, Grasby et al. 2011, Lebel 2009, MIT 2006, and NEAMIC 2004).

The study is a collaborative research with Aboriginal communities in the region. The participating communities have different goals. While some communities are looking at ways of creating sustainable economies, others are seeking to develop community infrastructures. The study started over three years ago with support from communities and funding from different organizations including UNBC, Geoscience BC, and Westcana Electric Inc. Data gathering include two teleconference calls, three information sharing events, two regional focus group forums, a field trip to visit two resource development sites, participation in community activities and events, chats and discussions with participants, and review of community documents. In May 2010, a delegation from some First Nations communities travelled to Reno Nevada to visit two geothermal power plants. Following on from the field trip, the delegates were interested in comparison information on the different types of renewable energy. The Community Information Sharing Event, which formed part of this research, was organized as an Energy Forum. Practitioners and agency representatives were invited to share information about alternative energy projects and available development resources as requested by the research participants.

The Community Information Sharing Event took place at Williams Lake on October 25, 2010. The event was organized and co-hosted by the Fraser Basin Council and myself. There were 43 participants at the event. First Nations Council members, local community members, economic development practitioners and Chiefs representing 13 Cariboo-Chilcotin First Nation bands, two tribal councils in the Quesnel and Williams Lake areas participated in the presentations and discussions of approaches to alternate energies. There were also industry and agency representatives from local non Aboriginal organizations at the event. The Energy Forum ended with a regional discussion between all the communities represented. During this discussion, further questions and information needs of the communities around renewable energy development were solicited. This formed part of the data gathering activities.

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Following on from the Energy Forum, I visited some communities in the region to triangulate, interpret, and validate data. The collected data provided useful information on background, support, and context for this research. Analysis of data so far shows that Aboriginal values matter in the context of resource development. However, the communities do not have these values written down in ways that can be used by resource developers. A follow on project, as part of this research, is to work with communities to create an information booklet which would clearly articulate Aboriginal values around resource development. This booklet would also serve as a guide for further discussions on the compatibility of Aboriginal values and geothermal resource development. The communities can also choose to use the information booklet as a guide when having discussions with resource developers. I am still working with some of the communities to fully understand if Aboriginal values are compatible with geothermal resource development.

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Upcoming Launch of CanGRC's Canadian Geothermal Reference Library

Written by Yuliana Proenza (CanGRC Co-Founder)

The Canadian Geothermal Research Council (CanGRC) and the Pacific Centre for Geothermal Education & Research (PCGER) are pleased to announce the development of a Canadian Geothermal Reference Library. One of the mandates at CanGRC is to promote and raise awareness about geothermal research in Canada and we anticipate this tool to be a valuable source of information.

The Geothermal Reference Library will be open to the public, making it easier for students, researchers and anyone interested in geothermal research in Canada to gain access. Resources will include journal articles, books, and government publications specific to research within Canada and/or by Canadian researchers. As a starting point, the database is populated with reference material from two major sources with extensive bibliographies on Canadian research: the Geological Survey of Canada Open Files 4887 and 6914 (Jessop et al., 2005; Grasby et al., 2012). Features of the Library will include basic and advanced searches, and providing a direct link to a .pdf if applicable.

Other organizations have implemented similar databases or publication lists, such as the US Geothermal Resources Council, (www.geothermal-library.org) and Germany's Geothermal Information System (www.geotis.de).

Stay tuned for the upcoming official launch of the Canadian Geothermal Reference Library. Do not hesitate to contact us at info@cangrc.ca with ideas, comments or feedback.

Grasby, S.E., Allen, D.M., Bell, S., Chen, Z., Ferguson, G., Jessop, A., Kelman, M., Ko, M., Majorowicz, J., Moore, M., Raymond, J., and Therrien, R., 2012. Geothermal Energy Resource Potential of Canada, Geological Survey of Canada, Open File 6914 (revised), 322 p.

Jessop, A.M., Allen, V.S., Bentkowski, W., Burgess, M., Drury, M., Judge A.S., Lewis, T., Majorowicz, J., Mareschal, J.C., and Taylor, A.E. 2005: The Canadian Geothermal Data Compilation. Geological Survey of Canada, Open File 4887

CanGRC Suggested Reading

Compiled by Ryan Libbey (CanGRC Co-Founder)

This section provides a list of articles related to the subject material in this issue of the CanGRC Review, as well as other recent Canadian geothermal publications.

Majorowicz, J. and Minea, V (2012) Geothermal energy potential in the St-Lawrence River area, Québec. Geothermics, 43, 25-36.

Previous estimates of geothermal energy potential in Canada give an indication of available heat to be 'farmed' at depth with focus on Western Canadian Cordillera and Western Canadian Sedimentary basin as prime targets. This paper examines in more detail temperature–depth realtionships near large population centres in Québec, in order to provide a first order assesment of enhanced geothermal systems (EGS) potential for electrical and heat generation. Results show areas with significant EGS potential in the StLawrence River valley related to high heat flow density and thermal blanketing of thick sedimentary cover. At >120°C found to be a prospect for several areas in Québec (drilled to depths of over 4.5 km in Trois-Rivières area, near 4.5 km in the Eastern St-Lawrence River (Rimouski, Gaspé and Golf, including Anticosti Island) and just 4 km in Quebec area) the potentially available geothermal power from EGS hydrothermal systems in deep sediments can be of significance.

Kunkel, T., Ghomshei, M. and Ellis R. (2012) Geothermal energy as an indigenous alternative energy source in British Columbia. Journal of Ecosystems & Management, 13(2), 1-16.

British Columbia is anticipating a shortfall in electricity supply because of an expected increase in demand for energy by about 45% within the next 20 years, as well as the phasing out of old utilities. The reliance on fossil fuel and the ongoing discourse on climate changes have resulted in a shift towards carbon-neutral energy alternatives. The province's current energy policy goals include achieving electricity self-sufficiency by 2016 through clean or renewable sources. British Columbia has an abundance of geothermal resources with wide ranging temperatures available for both power development and direct use. Smaller ecological footprints and lower environmental impacts make the geothermal resource a choice for sustainable energy development as part of a diversified energy portfolio. This article reviews the benefits and impacts of geothermal resource development as a complementary indigenous, alternative energy source for the province and as a potential resource to create sustainable economic development within rural and remote communities.

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Majorowicz, J., Gosnold, W., Gray, A., Safanda, J., Klenner, R. and Unsworth, M. (2012) Implications of post-glacial warming for northern Alberta heat flow—correcting for the underestimate of the geothermal potential. GRC Transactions, 36, 693-698.

The research into a geothermal energy option for Northern Alberta basin is currently underway. Correct estimates of heat flow and geothermal gradient for the sedimentary strata (direct heat energy option) and deeper crystalline basement are needed. A series of detailed geophysical logs and boreholes studies have recently been collected in the Hunt well AOC GRANITE 7-32-89-10. The well was drilled 2.36 km into basement granitic rocks just west of Fort McMurray. A temperature log acquired as part of the University of Alberta Helmholtz-Alberta Initiative (HAI) geothermal energy project in 2010-2011shows that there is a significant increase in thermal gradient in the granites. Inversion of the measured T-z profile between 550 m – 2320 m indicates a temperature increase of 9.6+/- 0.3 °C, at 13.0 +/- 0.6 ka and that the glacial base surface temperature was - 4.4+/- 0.3 °C. This inversion computation accounted for granite heat production of 3 W/m^3. We find from the Hunt well study that heat flow in the basin has been underestimated for wells shallower than 2 km due to the paleoclimatic effect. A significant increase in surface temperatures since the end of the last ice age in northern North America causes a perturbation of shallow <2 km heat flows. For this reason, estimates of gradient based on single or numerous data from different depths are not necessarily characteristic of the whole sedimentary column and can lead to spurious predictions of temperature at depth needed for geothermal energy or hydrocarbon models.

Majorowicz, J. and Grasby, S.E. (2010) High potential regions for enhanced geothermal systems in Canada. Natural Resources Research, 19(3), 177-188.

Previous estimates of geothermal energy potential in Canada give an indication of available heat to be 'farmed' at depth. This article examines in more detail depth–temperature relationships near large population centers in western Canada, as well as remote communities in northern Canada, in order to provide a first order assessment of Enhanced Geothermal Systems (EGS) potential for electrical generation. Quantities of EGS thermal power output and electrical generation are dependent on output temperature and flow rate. We relate these potential power rates as a whole to drilling and installation cost for the doublet systems and triplet system. Results show areas with significant EGS potential in northern Alberta, northeastern British Columbia, and southern Northwest Territories related to high heat flow and thermal blanketing of thick sedimentary cover. Estimated installation costs in 2008 dollars are under 2 mln\$/MW$_e$. We also estimate significant reductions in CO2 emissions by conversion to geothermal electric production.

Grasby, S.E., Allen, D.M., Bell, S., Chen, Z., Ferguson, G., Jessop, A., Kelman, M Majorowicz, J., Moore, M., Raymond, J., Therrien, R. (2011) Geothermal Energy Resource Potential of Canada. Geological Survey of Canada, Open File 6914, 322 .

Canada has enormous geothermal energy resources that could supply a renewable and clean source of power. There are many constraints, however, in utilizing this energy resource, including geological, technical, and regulatory issues. The intent of this report is to examine the geothermal potential in Canada, and the geological controls on the distribution of high grade resources as well as controls on the economic development and production of geothermal energy. This assessment is based on a new compilation and digitization of data produced through over 48 years of geothermal research in Canada. Recommendations on current and future research needs to reduce barriers to resource production are made at the end of the report. Currently Canada has no geothermal electrical production; however, direct use and heat exchange systems are used widely. Several projects are currently being examined by industry and government to develop electrical potential in Canada. A key economic constraint for these projects is the high risk of exploration due to costs of deep drilling. The cost of delivered geothermal power is projected to decline and be competitive with coal fired production within the next 15 years, given current levels of technology. Canada's in-place geothermal power exceeds one million times Canada's current electrical consumption (Fig. 1). However, only a fraction of this total potential could be developed. Much of the resource lies beyond current drilling technology, outside of areas served by high-capacity transmission lines, and at some distance from load centres. Nonetheless, the available high grade geothermal resource is considerable. High temperature hydrothermal systems can be brought on line with proven technology. Many of the tools required to bring geothermal energy to full realization, however, are not commercially proven to date and require further research and technology development. We can expect a strong learning curve and price response as geothermal energy is developed while other energy sources such as coal and nuclear will begin to see fleet and capacity retirements.

Weides, S., Moeck, I., Huenges, E. (2011) Exploration of geothermal resources in the central Alberta basin (Canada). GRC Transactions, 35, 1061-1063.

The utilization of deep geothermal energy holds the potential to conserve conventional energy resources and decrease the emission of carbon dioxide. The aim of this study is to explore geothermal resources of the central Alberta Basin and to evaluate the feasibility of developing geothermal heat production from deep hydrothermal systems in this region.The study focuses on an area in the central part of the Alberta Basin

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around the city of Edmonton. In this research area of approx. 150 km * 200 km size the basin is between 1.8 km and 3.5 km deep. Potential reservoir rocks for a geothermal development are found in the deep aquifers of the Basal Cambrian Sandstone and overlying Devonian carbonate layers. A 3D geological model of the research area was developed based on stratigraphic picks from more than 7000 wells that were drilled by the petroleum industry. Consistency of the stratigraphic framework was established through revision of the data by the Alberta Geological Survey (AGS). Through population of the model with poro / perm data from core analyses and well logs it will be possible to delineate areas in the deep aquifers that have a higher porosity and permeability and are favourable for a geothermal utilization.

Gosnold, W., Majorowicz, J., Klenner, R., Hauck, S. (2011) Implications of post-glacial warming for northern hemisphere heat flow. GRC Transactions, 35, 795-799.

Several observations lead us to suggest that the geothermal gradient in regions near the Pleistocene ice margin may contain a transient signal that causes significant underestimation of present day heat flow. Heat flow increases with depth in northern hemisphere periglacial regions in Eurasia and North America. Temperature gradients increase with depth in thick clastic rocks in the Williston Basin where compaction causes an increase in thermal conductivity. Thermally mature oil source rocks occur in the Williston Basin where subsidence history suggests that rocks should be immature unless paleo-heat flow was higher. Pollen analyses in upland lakes in southern Manitoba indicate that MJJA surface temperatures are 13 °C higher than they were 12,500 ka. Conductive heat flow models using the pollen temperature history as a forcing signal for surface temperature produce temperature vs. depth profiles with increasing gradients that are similar to profiles observed in the Williston Basin. The post-glacial warming signal appears to have been of the order of 10 to 15, thus northern hemisphere heat flow may have been underestimated by 30 to 60 percent depending on the depth of the original temperature gradient measurement. The implications for EGS in the northern hemisphere are that the resource may be at shallower depths than projected in recent studies.

Kimball, S. (2011) Resource, infrastructure, and market factors in a geothermal favourability map of British Columbia, Canada. GRC Transactions, 35, 1185-1194.

British Columbia's internal demand for power and opportunities for export are increasing the need for new power generation in the province. Moreover, the transition to a low carbon economy stipulates that power supply must be from renewable and low emission sources. Although British Columbia's supply is dominated by hydro-electricity, both large-scale and run-of-river, geothermal energy systems offer significant benefits for diversification as B.C. hosts Canada's best geothermal resources along the Coast Mountain Range.

This paper presents a series of maps that examine and compare the spatial distribution of B.C.'s geothermal resources, transmission infrastructure, and power markets. Using ArcGIS, these factors have been combined into a map identifying the most favourable regions for geothermal development in the province. Multi-criteria evaluation of 10 evidence layers was completed in a knowledge-driven model. Publicly available data for temperature gradient, heat flow, volcanic centres, geothermometry, hot springs, geology, faults, and earthquake indicators comprise a map that characterizes the Resource Factor. Evidence layers from a Market and Infrastructure Factor map include: distance to transmission, regional pricing, and population density. Evidence layers were assigned weights based on a judgment of their importance to geothermal favourability using the Analytical Hierarchy Process.

This new approach to creating a Favourability map builds on the 1992 Geothermal Resources Map of British Columbia by incorporating new data, and applying spatial buffers based on studies from producing geothermal fields from around the world. The research demonstrates the importance of integrating economic and infrastructure factors into the evaluation of a region's geothermal resources.

Gosnold, W., LeFever, R., Klenner, R., Mann, M., Salehfar, H. and Johnson, J. (2010) Geothermal power from coproduced fluids in the Williston Basin. GRC Transactions, 34, 557-560.

All sedimentary basins have potential for development of geothermal power due to the existence of deep aquifers having sufficient temperatures and high fluid production capacities. Advances in commercial development of organic Rankine cycle (ORC) and other heat-to-power conversion technologies make geothermal power generation economical with water temperatures as low as 90 ºC and flow rates of 30,000 bbls/day. The Williston Basin in particular possesses several advantageous characteristics for oil field geothermal power: 1) high geothermal gradients which lead to high temperatures at relatively shallow depths, 2) a large number of permeable formations that are producing oil and are capable of producing hot water, 3) a cool climate, which provides a large temperature drop for the ORC process, 4) a highly-developed petroleum industry infrastructure with a large demand for additional electrical power. This paper provides an overview of the potential to use coproduced fluids to generate electrical power.

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