INVESTIGATION OF GEOTHERMAL ENERGY AS A HEAT SOURCE FOR OILSANDS EXTRACTION IN NORTHERN ALBERTA

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INTRODUCTION

The oilsands of Northern Alberta represent some of the largest hydrocarbon deposits on Earth and their extraction presents a number of serious environmental problems. About 20% of the oilsands deposits are located within 75 m of the surface and can be accessed by surface mining. Large quantities of hot water are used to separate bitumen from sand, and this water is currently heated by burning large quantities of natural gas. The remaining 80% is too deep to mine but can be extracted using in-situ techniques such as Steam Assisted Gravity Drainage (SAGD). This also requires large quantities of steam to be generated by burning gas.

The large volumes of natural gas consumed by oilsands processing have significant environmental and economic costs.

ECONOMIC	Heating water for oilsands processing costs $720,000 per year per 1 C
ENVIRONMENTAL	Burning natural gas generates 50 million tons of CO_2 per year.

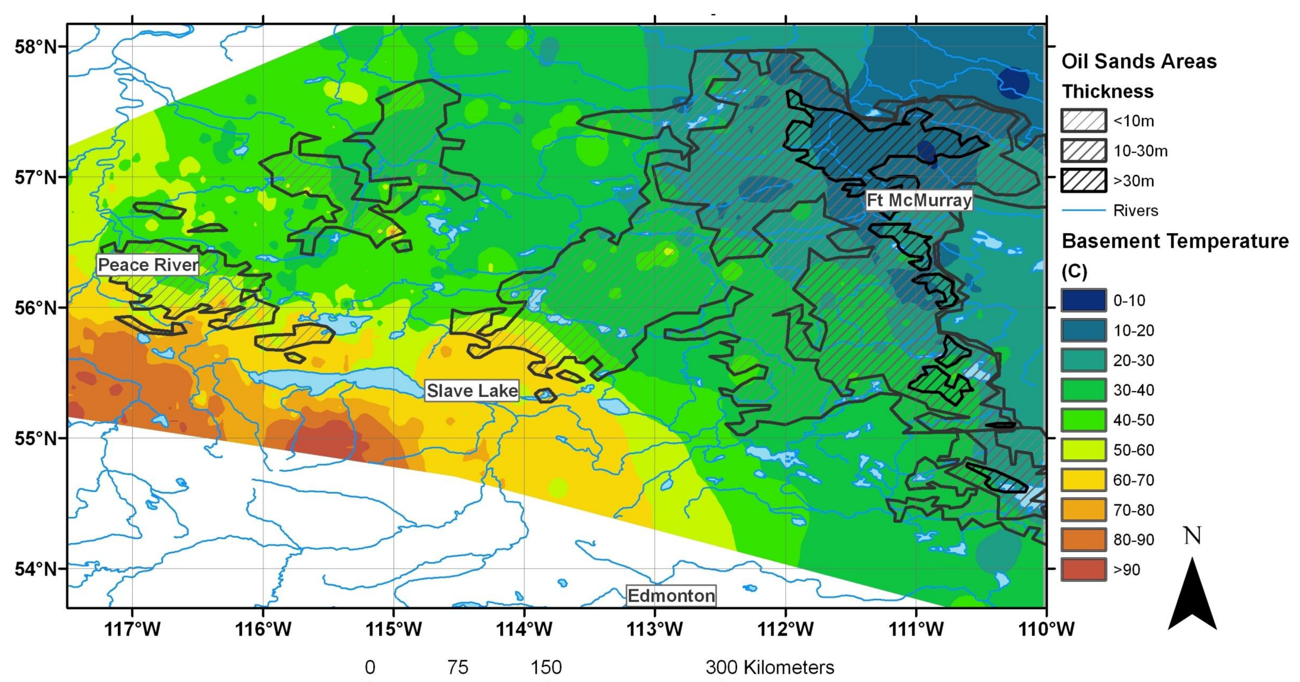
Geothermal energy could potentially supply the heat for both extraction and processing of oilsands. From 2004-2008 an industry consortium (GeoPos – Geopowering the Oilsands) investigated this question. This idea is being investigated as one of the research themes of the Helmholtz Alberta Initiative (HAI), which is an integrated program of research between Canadian and German scientists.

The geology of Northern Alberta is characterized by 500-2000 m of sedimentary rocks overlying Precambrian age crystalline basement rocks of the Canadian Shield. Thermal gradients are relatively low in Northern Alberta and the estimated depth to 150 C is in the 4-9km depth range (Majorowicz and Moore, 2008). Where the sedimentary cover is thin (e.g. the Athabasca oil sands at Fort McMurray), geothermal energy production would involve heat extraction from the crystalline basement rocks. This would require Engineered Geothermal System (EGS) technology where the low permeability of a rock is artificially enhanced. In regions where the sedimentary successions are thicker (Peace River area in northwestern Alberta) saline aquifer systems could be utilized for EGS.

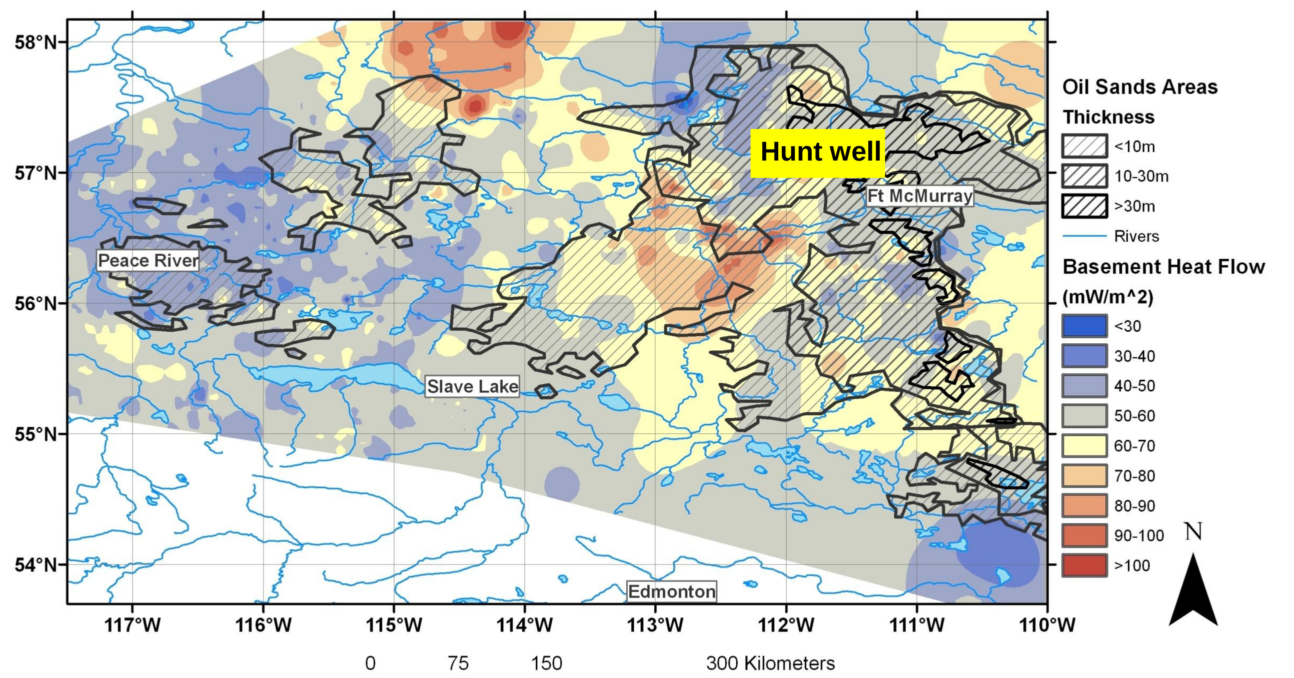
This poster summarizes an integrated research program that is being used to evaluate the feasibility of developing geothermal energy production in Northern Alberta.

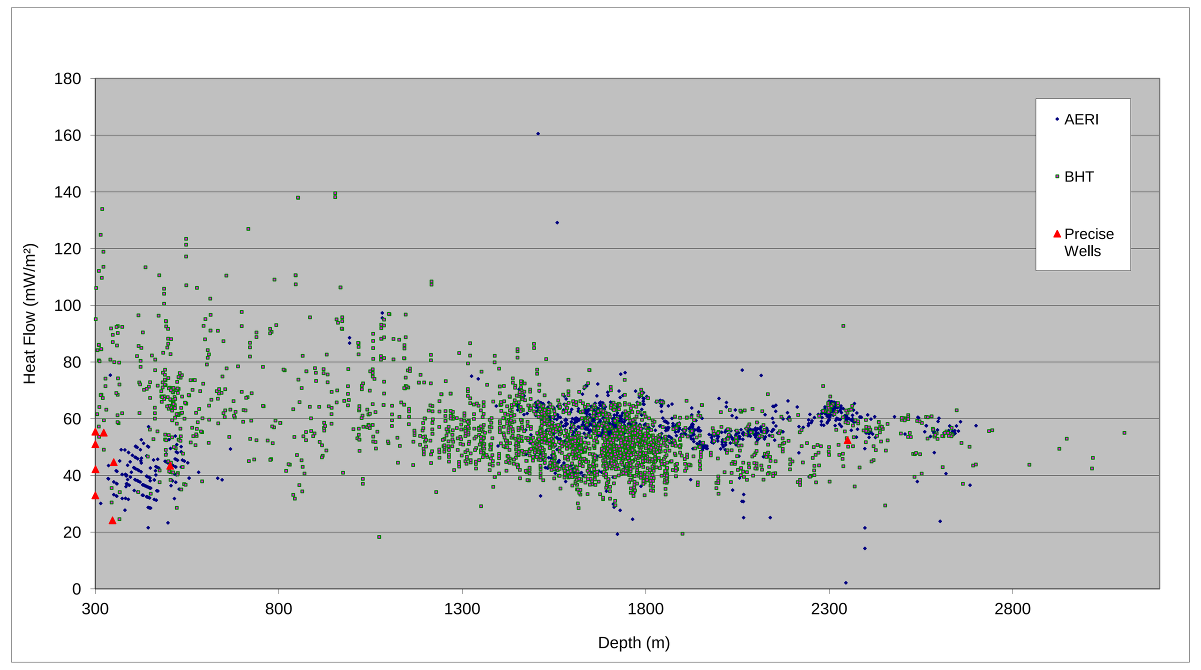
The first stage of this research has involved a re-evaluation of the existing thermal data from boreholes. The second stage of the research will involve detailed geophysical characterization of the sedimentary and basement rocks with combined aeromagnetic, seismic and magnetotelluric data. Revised geological maps and sections are being constructed from surface exposures, well log data and available basement core samples. Geological and hydrogeological characterization of carbonate saline aquifer systems will delineate regions of high and low permeability in the Alberta Basin.

THERMAL GRADIENT AND HEAT-FLOW MAPS



Map of temperature at the top of the Precambrian basement after removal of noisy data. Oilsands areas shown with stippled regions. This shows that temperatures > 60 C may be found in the sedimentary strata beneath the Peace River oil sands. Beneath the Athabasca oil sands, these temperatures will only be found in Precambrian basement (granite). Thermal gradient is 31 15 C/km.

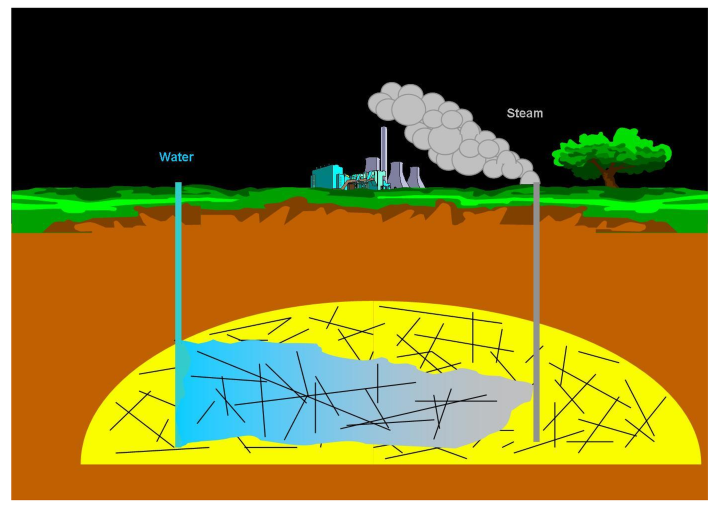




BHT = bottom hole temperature. AERI = Alberta Energy Research Institute

Estimated heat flow is in the 40-80 mW/m² range. It is calculated from corrected geothermal gradient and estimates of the effective thermal conductivity from net rock analysis and mean rock and water thermal conductivity values.

GEOTHERMAL RESERVOIR SIMULATION



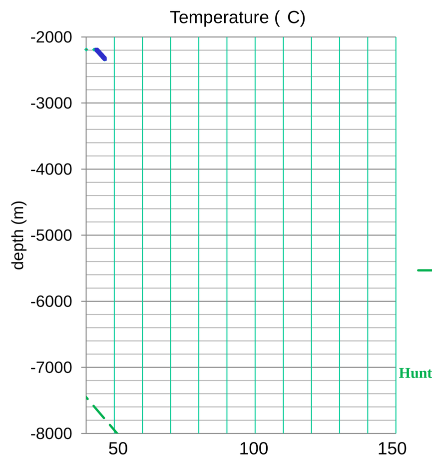
Analytical, numerical and stochastic approaches will be used to simulate heat flow and fluid flow in a fractured media.

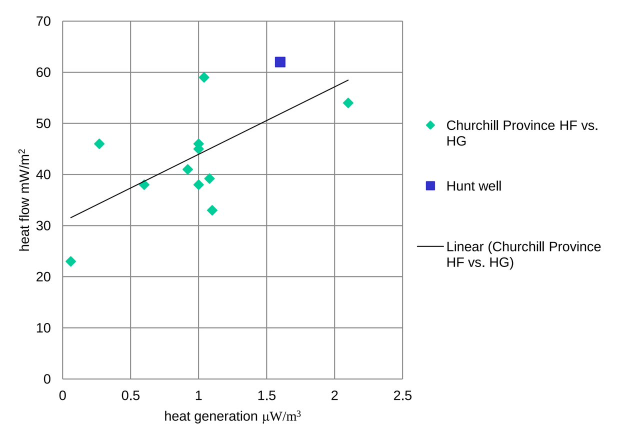
Parameters affecting the rate of heat extraction from a fractured rock reservoir include fracture geometry, flow rate, etc.

Reservoir modeling will be constrained by geological and geophysical data from Fort McMurray and Peace River.

Goal will be to understand which hydraulic fracturing options will yield the highest rates of heat recovery. Economic analysis through numerical modeling.

HUNT WELL AT FORT McMURRAY (2400 m deep)

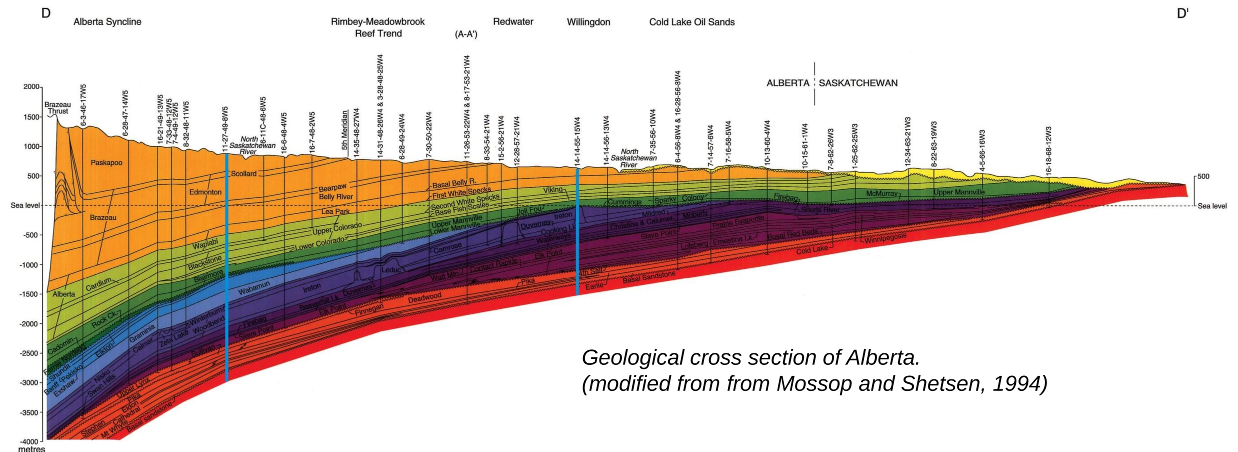




In 2003, Warren Hunt drilled a 2400 m deep well at Fort McMurray, which intersected ~500 m of Phanerozoic-age sedimentary rocks and ~1900 m of Precambrian-age granitoid rocks. Granitoid drill core samples recovered from near the base of the well comprise about 45-65% feldspar, 25-45% quartz and 5-8% orthopyroxene. This mineralogical composition (and U, Th, K concentrations) predict a thermal conductivity (TC) of 3 W/m*K. The actual value was measured using Popov's laser scan TC method, and indicate a wider range of 1.9-3.8 W/m*K. A thermal gradient of 21.7 mK/m and a heat generation of 1.6 μW/m³ are also predicted by the data. This fits the general trend of an increasing heat flow with increasing rock heat generation for the Churchill province (Canadian shield). Potential EGS sites will require regions with high radiogenic heat production (e.g. minerals with U, K and Th).

GEOLOGICAL STUDIES

A related research theme is investigating if geothermal energy could be extracted from deep saline aquifers in the Western Canada Sedimentary Basin. The Saline Aquifer Mapping (SAM) project of the Alberta Geological Survey (AGS) is a regional scale test study taking place in the Edmonton area. A second study will take place in the Peace River oilsands area.



Geological cross section of Alberta.
(modified from from Mossop and Shetsen, 1994)

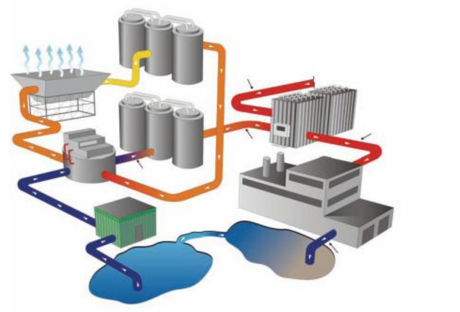
In both study areas, fault zones will be identified and interpreted by structural analysis of horizon contours of the 3D model. Validation of interpreted fault orientations will be carried out by measurements of fracture orientation in drill cores from deep aquifers. In combination with the results of the geomechanical modeling study of the Alberta Basin it will be possible to map the stress states and reactivation potential of fractures in deep aquifers by applying the slip tendency technique (Moeck et al., 2009; Morris et al., 1996). Knowledge of the reactivation potential of faults is a critical issue in the development of EGS reservoirs where hydraulic stimulation is needed to enhance reservoir permeability and productivity.

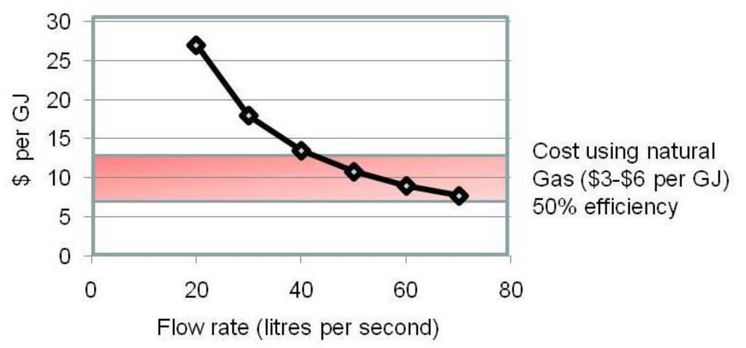
ECONOMICS OF GEOTHERMAL HEATING FOR OILSANDS

Would it be economic to heat water with Engineered Geothermal Systems?

Detailed computer modelling will be used in the HAI research to answer this question. Simple approaches can also be used to establish the viability. These calculations assume the following:

•Data from Fort McMurray predict temperatures of 100 C at 4.8km and 150 C at 7.2 km.
•Drilling a well doublet to 6 km would cost ~ $30 million.
•Water is circulated through a fractured granite reservoir and flow rate is sustained for 10 years.
•Water from the geothermal loop is used to heat water for oilsand processing and heats it by 60 C.





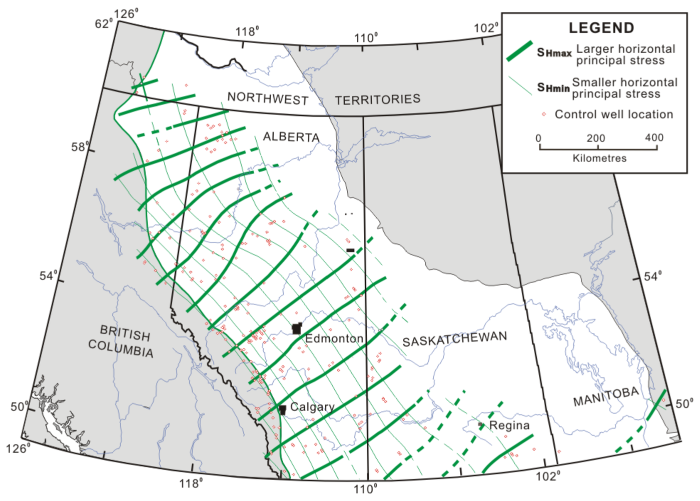
With these assumptions, the costs shown above can be calculated. A flow rate of 50 litres per second has been sustained at some geothermal projects. At this rate of flow, geothermal can be seen to be competitive with the cost of using natural gas (3-6 $/GJ at 50% boiler efficiency). The HAI geothermal project will investigate if this type of plant can actually be applied to oilsands extraction.

GEOPHYSICAL STUDIES

When rock is artificially fractured to create a geothermal reservoir, the new fractures are generally reactivated, pre-existing fractures. It is essential to know (a) the existing stress regime and (b) the distribution and geometry of existing fractures. These will be investigated by:

•Measurements at the Hunt Well to study the pattern of fracturing with logging, televiewer, and hydraulic studies.

•Regional stress regime from Gough and Bell (1982) is shown on right. This predicts that it will be easiest to generate hydraulic fractures in a NE-SW direction. This stress study will be updated through analysis of well data from across Alberta.



•Seismic reflection and magnetotellurics will be used to characterize basement structure, with an emphasis on locating zones of fracturing. Selected Lithoprobe seismic lines will be reprocessed.

•Analysis of aeromagnetic data will be used to determine if there are correlations between magnetic susceptibility and heat generation.

SUMMARY

- The Helmholtz Alberta Initiative geothermal project will provide a detailed assessment of the potential of geothermal resources for oilsands extraction and processing.
- Study will consider areas where oilsands are extracted by surface mining and in situ processes.
- Investigation will include areas where heat will be extracted from both crystalline basement rocks and sedimentary rocks of the Western Canada Sedimentary Basin.

ACKNOWLEDGEMENTS

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