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Geothermal technology and exploration of geothermal resources in Northern and Central Alberta

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Introduction

For most parts of the Central and Northern Alberta Basin the geothermal gradient ranges between 20 - 30°C/km (Majorowicz and Moore, 2008). From a technological perspective it is possible to utilize even low enthalpy systems if they are engineered to enhance productivity and thermal extraction. The feasibility of developing geothermal energy production is currently being evaluated through the Helmholtz Alberta Initiative (HAI), which is a research collaboration between the Helmholtz Association of German Research Centres and the University of Alberta.

A comprehensive geological - geophysical characterization is the first step towards the sustainable development of a geothermal system. The geothermal assessment of the Alberta Basin shall delineate different geological-structural environments for potential geothermal use and involves exploration geology, geomechanics, thermal modeling, magnetotelluric surveys and re-evaluation of existing data from hydrocarbon exploration.

Geothermal technology

Integration of engineering and geosciences is paramount in the development of geothermal technology for the successful utilization of geothermal aquifer systems. With this concept an optimal reconciliation of surface technology with subsurface geological conditions can be achieved. A profound geological understanding plays a major role in the sustainable development of geothermal technology, especially in low enthalpy systems as we find in Alberta.

A key element in exploration geology for the development of Enhanced Geothermal Systems is quantitative geology: it enables an interdisciplinary transfer of geological knowledge. Our approach in exploration geology is cross-scaling and multidisciplinary. Subsurface conditions are studied from regional and local scale to micro scale. The characterization of geothermal conditions and determination of the stress field is a major activity in our present research. This approach facilitates the definition of site specific exploration strategies and the delineation of favorable drill sites.

Possibilities of geothermal energy development in Alberta

The utilization of deep geothermal energy holds the potential to conserve conventional energy resources and decrease the emission of carbon dioxide. One potential application for geothermal energy production in Alberta is the provision of warm water for the oil sands industry.

The extraction of the Northern Alberta oil sands requires a significant amount of thermal energy which is currently supplied through the burning of natural gas. Today oil sands production already accounts for a significant part of Alberta´s natural gas consumption, and the amount used is anticipated to increase within the next decade. Geothermal energy could replace some of the demand.

Besides providing industry with warm water there are further application possibilities. Geothermal energy from deep aquifers could be used to supply office buildings and private houses with heat. In remote areas geothermal production of heat and/or electricity could reduce the dependency on expensive diesel supply or even replace diesel generators.

Alberta Basin

The geology of Alberta is characterized by the northeastward tapering sedimentary wedge of the Alberta Basin that overlies the Precambrian crystalline basement. The sedimentary succession reaches a thickness of over 5 km close to the Rocky Mountains in the southwest and thins towards the northeast, where it is terminated by erosion or non–deposition.

Geothermal exploration study

Our study focuses on two regions: the area around Fort McMurray in the shallow northeastern part of the basin, and the region around Edmonton in the deeper central part of the basin (Figure 1).

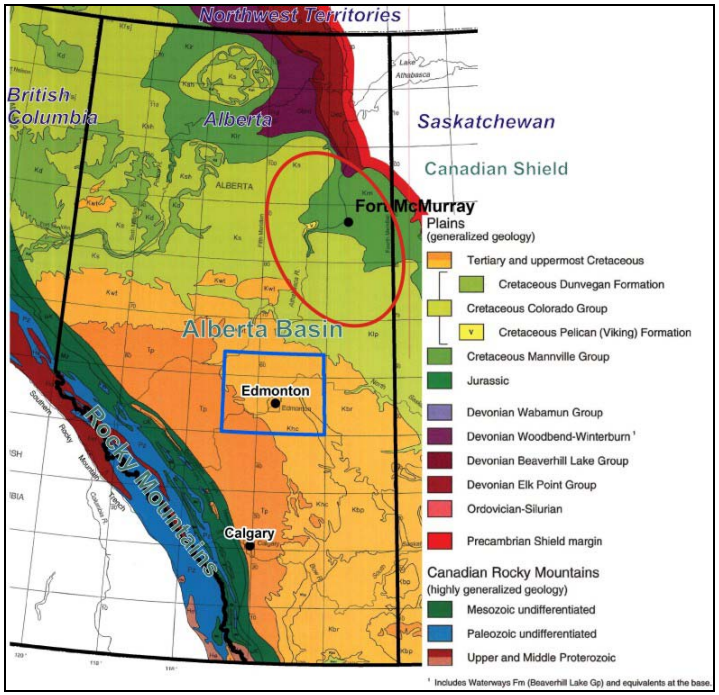

Figure 1: Geology of the Alberta Basin and study regions (blue = Saline Aquifer Mapping area in deeper basin; red= shallower basin area: geological map modified from from Mossop and Shetsen, 1994).

In the shallow basin around Fort McMurray, where most of today's oil sands development takes place, geothermal energy production would require the development of geothermal systems within the crystalline basement rocks.

Research in this area focuses on:

- Re-evaluation of the existing thermal data from boreholes;
- Computing of revised thermal gradient maps, including extrapolation to depths required for economically significant temperatures;
- Geophysical characterization of the basement rocks with combined aeromagnetic, seismic and magnetotelluric data.

Our study in central Alberta focuses on the development of geothermal systems by extracting heat from deep aquifers. Results of this study could also contribute to the utilization of geothermal heat for the extraction of oil sands in the Peace River Arch in northwestern Alberta.

The first stage of research in this deeper part of the basin was to evaluate existing geothermal data and to determine promising lithological formations for geothermal exploration.

The second stage of research in the deeper basin involves the development of a 3D structural model study of the Saline Aquifer Mapping (SAM) project area of the Alberta Geological Survey (AGS). In this area, which is located around Edmonton and is approx. 150 km *190 km in size, the depth of the basin ranges between 1800 m and 3500 m (Figure 1).

Based on publicly available well data, a 3D horizon model will be developed with special focus on deep saline aquifers. The next step will involve a structural analysis of formation tops and the identification of fault zones (Figure 2). Validation of interpreted fault directions and characterization of faults will be carried out by analyzing the orientation of natural fractures in drill cores from deep saline aquifers. Further research in the HAI geothermal study involves reprocessing of the 2D seismic “Lithoprobe” – profiles to basin depth level and the development of a large scale 3D geomechanical numerical model of the whole Alberta Basin that provides the absolute stress states, i.e. magntiudes and orientation of the three principal stresses for any site within the model (Heidbach et al., 2010). Drilling induced fractures, caliper logs and FMI data logs will be analyzed for stress field determination and calibration of the geomechanical numerical model.

On a local scale, this will enable an assessment of stress states and reactivation potential of fractures in deep aquifers by applying the slip tendency technique on the 3D structural geological model (Moeck et al., 2009; Morris et al., 1996). The knowledge of the reactivation potential of faults is a critical issue in the development of EGS reservoirs where hydraulic stimulation treatments are applied to enhance permeability, thereby increasing productivity.

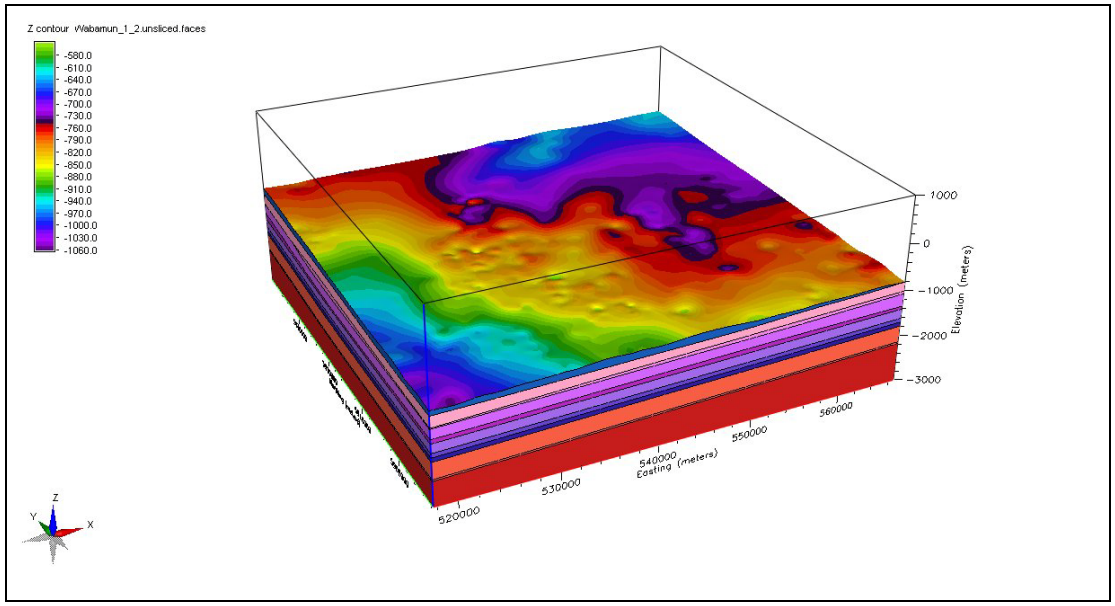

Figure 2: preliminary 3D geological model of the SE part of the research area; z – contours of Banff – Fm. (Wabamun Lake Area; data provided by ERCB/AGS)

Together these integrated research themes will evaluate the potential for geothermal heat production in the shallow and deep part of the Alberta Basin and delineate strategies for the development of geothermal resources in Alberta.

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