Integration geoConvention 2013 | geoscience engineering partnership

Regional Geophysical Study for Geothermal Exploration in NE Alberta

Elahe P. Ardakani*, Department of Physics, University of Alberta
pouresla@uakberta.ca
and Douglas R. Schmitt, Department of Physics, University of Alberta

Summary

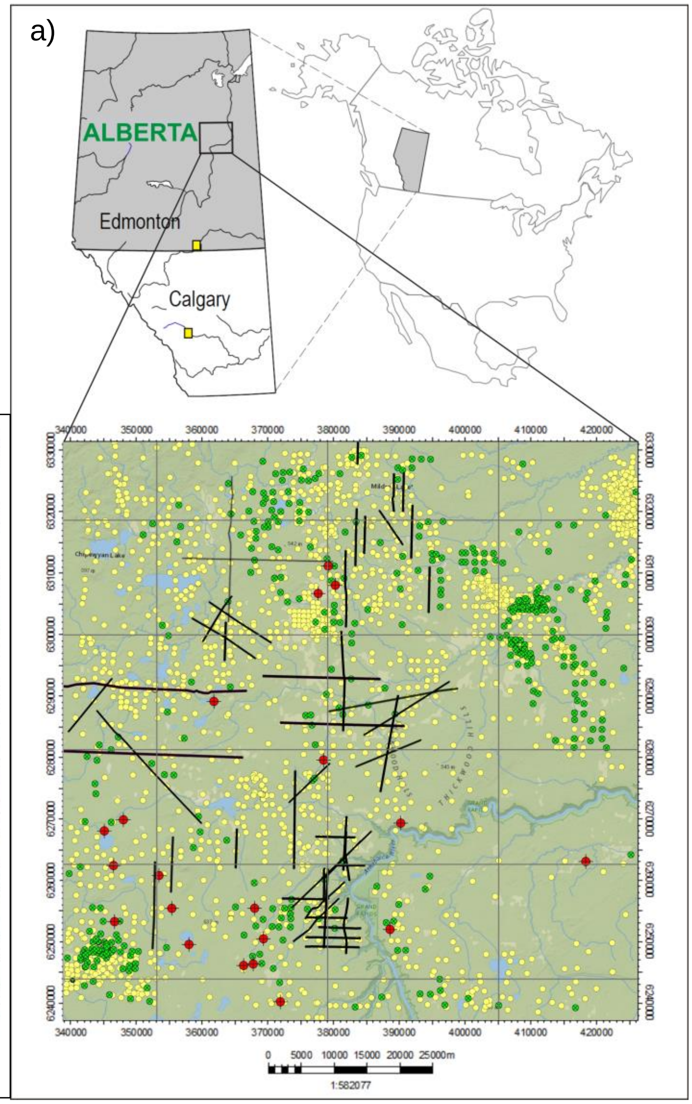
NE Alberta hosts many producing oil sand projects. These projects require large amounts of thermal energy to produce most of which is currently provided by burning natural gas; and this increases the greenhouse gas footprint to producing such hydrocarbons. One possible solution is to instead use geothermal heat directly with hot fluids produced using Engineered Geothermal Systems. Geothermal exploration always starts with broad geological structure reconnaissance of the area. Unfortunately, the larger geological context particularly beneath those relatively shallow depths (typically less than 400 m) of interest to hydrocarbon exploration is still poorly understood. As such, we have selected a rectangular area of 22,000 km^2 extending across 56.25˚ to 57.12˚N and 111.92˚ to 113.52˚W that we refer to as the Athabasca region. The main two categories of data which are in used consist of over 600 km seismic reflection profiles and 22,000 km^2 High Resolution Aeromagnetic data. Also there is a large amount of available well-logs from 1,000 boreholes in this area that have a key role in interpretation of seismic profiles. These integrated data sets are used for outlining sedimentary basin, mapping geological formation tops, locating fault zones and other structural lineaments, finding true depth of metamorphic basement, and finally building a detailed geological model of the region. To date all the seismic profiles are interpreted and HRAM data is successfully corrected and gridded through the area. The 3D geological model is constructed using these available data that reveals some detail about the gross structure of the region. This model shows that the Precambrian basement reflector is a smoothly undulating surface that could be consistent with minor faulting. The topography of this surface affects the structure of overlying sedimentary formations.

Introduction

Currently, the GFZ-Potsdam and the University of Alberta in Edmonton are carrying out exploratory research for the potential development of low-enthalpy geothermal energy. This work is motivated by the need to find sustainable and lower greenhouse gas emission solutions for production of bitumen from Alberta's oil sands. The generally low heat fluxes observed in Alberta, however, make exploration and development of such resources challenging. However, the ability to heat water to even modest temperatures could supplement the current thermal energy requirements that are satisfied primarily from the burning of natural gas. The focus of this study is on the regional scale characterization of an area in NE Alberta extending across 56.25˚ to 57.12˚N and 111.92˚ to 113.52˚W from which new in situ projects for extraction of bitumen from sands and carbonates are now just beginning. In order to evaluate the potential for developing geothermal systems in this area, the main object is having an insight to the regional geothermic and structural geology. According to the available industrial thermal data, depths in excess of 4 km may have to be attained in order to reach 100˚C in NE Alberta. The average gradient in this part of Alberta is 22 mK/m however this value is questionable since the temperature data points are limited and not spread over evenly [Grey et al., 2012]. This heat would be enough for water pre-heating to get used for in situ oilsand production through the Engineered Geothermal System (EGS). Our study is focused on reconnaissance of the regional structural geology.

Regional geophysical datasets available

In the way of achieving the goal of construction of a regional geological/geophysical model for the area referred as the Athabasca region we employ three complementary classes of data: seismic reflection, geophysical well-logs, and high resolution aeromagnetic (HRAM). Nearly 600 line km of legacy 2D seismic data obtained through purchases and donations from a number of petroleum exploration companies (Fig.1a). An industry data base to which we have access shows that 2,917 boreholes exist in the study area. Only 1066 boreholes have digital or raster logs and among these wells just 255 of them possess Digital Sonic (DT) and Density (RHOB) logs. Among these 255 boreholes only 21 of them are deeper than 500 meters. The HRAM data covers the whole study area of 22,508 km^2 (Fig.1b).



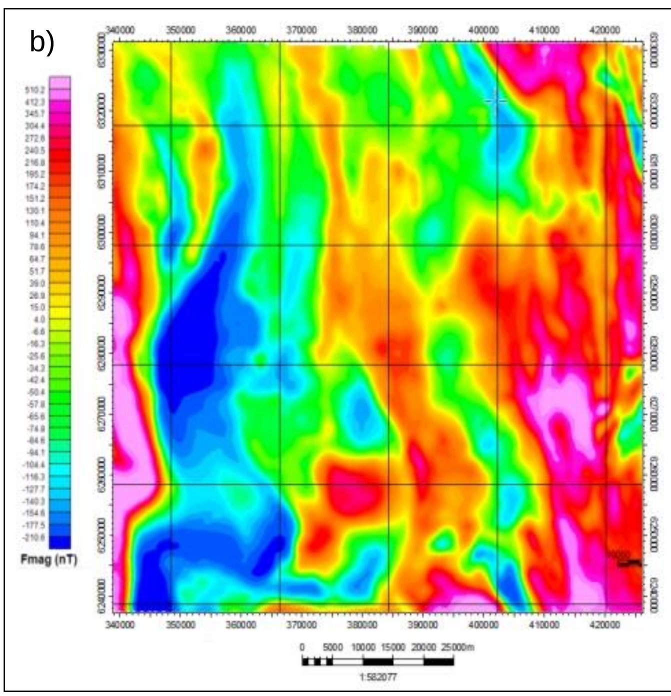


Fig.1. a) The 2D profiles (solid lines) and borehole (circles) locations in the study region. Darker colored circles are the boreholes drilled deeper than 500m and contain DT and RHOB in their log datasets. b) Map of final total magnetic field after applying diurnal, leveling and cultural corrections.

Discussion and preliminary interpretation

Seismic images have the potential to detect geological features that could influence the regional structure such as major faulting, collapses, channels and reefs. Magnetic data is used for mapping structure lineaments as a reference for seismic interpretation [Peirce, 2010]. Borehole data usually is used for seismic interpretation. Here, the 3D geological model seeds are large amount of geological tops determined by well-logs and seismic horizons. Seismic horizons are used to make up for the lack of information between boreholes. Figure 2a shows the constructed geological model for the study area. Broadly, this model displays the gross structure of the region with the gentle dips to the west of the structure from the Precambrian unconformity up through the Paleozoic sediments. The geological groups that are modeled from top to base are Colorado, Mannville, Woodbend, Beaver Hill, Upper and Lower Elk Point and Precambrian basement. The Precambrian basement reflector may suggest a smoothly undulating surface that could be consistent with minor faulting below seismic resolution limits. Figure 2b illustrates the seismic-corrected Precambrian unconformity surface extracted from the model. This surface displays surface topography in elevation depth domain.

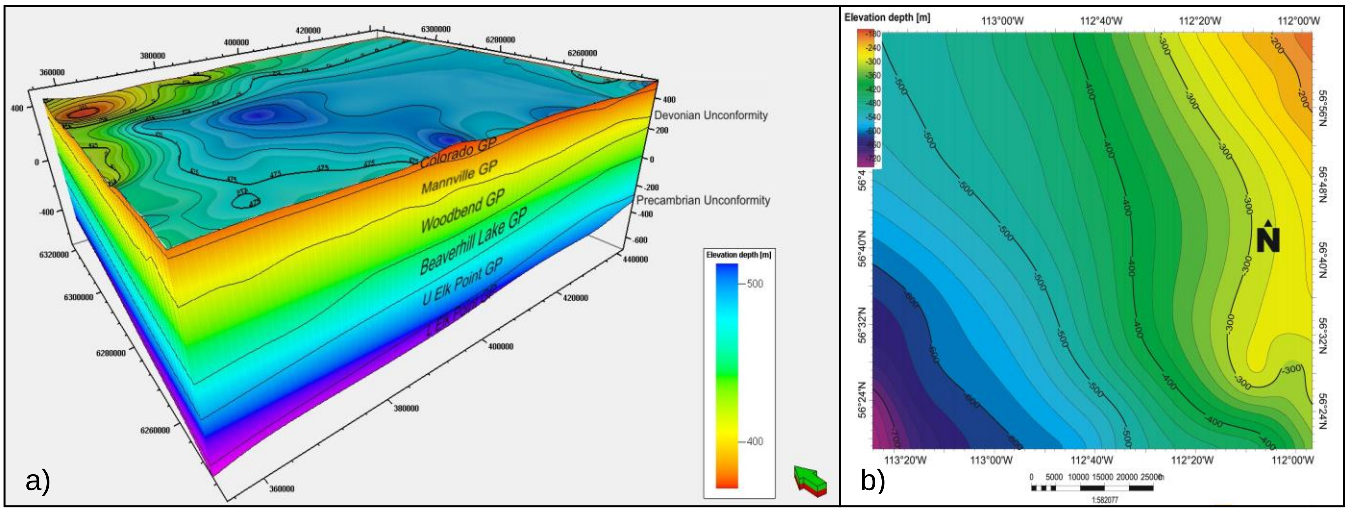


Fig.2. a) 3D geological model in the study region in elevation depth domain. The axes units are in UTM-NAD83-Zone12 projection system. b) The seismic-corrected Precambrian unconformity surface in the study area in elevation depth domain.

Conclusions

The presented paper is an update on progress of an integrated research to evaluate the regional geology of the Athabasca area. Although this main motivation for this work has a geothermal theme, it is also attempting to address some of the longstanding questions that, for example, may related tectonics to the existence of the Grosmont platform and the bounding reef trends. This work is innovative since we developed the first geological model of the area that integrates seismic and HRAM data, all data prior to this has been developed on the basis of well logs.

Acknowledgements

Special thanks to Jacek Majorowicz for providing thermal gradient data. This work would not be possible without the assistance from the petroleum and mining industries for help with acquiring seismic and HRAM data and IHS for providing us access to the well-log data. Funding for this work comes from the Helmholtz-Alberta Initiative.

References

Grey, A., Majorowicz, J., Unsworth, M., 2012, Oil industry thermal data in exploring of geothermal state of the basin– biases and corrections - northern Alberta case study: Geophysics and Engineering, **9,** 534–548.

Peirce, J.W., 2010, constraining seismic interpretation with aeromagnetic data: Search and Discovery Article #40606, 4.