Preliminary 3D Geophysical Modeling of the Aberdeen Sub-Basin, Thelon Province, Nunavut

Victoria L. Tschirhart*
McMaster University, Hamilton, Ontario
tschirv@mcmaster.ca

William A. Morris
McMaster University, Hamilton, Ontario, Canada

Hernan A. Ugalde
McMaster University, Hamilton, Ontario, Canada

and

Charles W. Jefferson
Natural Resources Canada, Ottawa, Ontario, Canada

Summary

The Paleoproterozoic Thelon Basin, transecting the border of Northwest Territories and Nunavut, is both tectonically and stratigraphically similar to the Athabasca Basin, known world-wide for its unconformity-associated uranium deposits. This poster reports a compilation and interpretation of the existing geophysical and geological data for the Aberdeen Sub-Basin located in the northeastern part of the Thelon Basin. Limited seismic profiling along with sparse borehole data permits only broad scale regional models of the sub-basin. An improved version of the unconformity surface between the Thelon Formation and underlying basement is derived by integrating 2D forward modeling of the regional scale gravity and aeromagnetic data. Limited geological constraints on the forward models are provided by borehole logs, seismic shot points and physical property attributes from the Kiggavik deposit and Athabasca Basin. The resulting depth to basement model invokes a more magnetic and dense basement which is unconformably overlain by non-magnetic and less dense siliciclastic strata of the Thelon Formation. Integration of the results of the model cross-sections in 3D suggests that the Aberdeen Sub-Basin is deeper than previously thought. Aeromagnetic data demonstrate high potential for lithological interpretations. The gravity and aeromagnetic models set the stage for acquiring new basic petrophysical and borehole constraints to map basement rock units and structure beneath the Thelon Basin.

Introduction

The Paleoproterozoic Thelon Basin, transecting the border of Northwest Territories and Nunavut, is both tectonically and stratigraphically similar to the Athabasca Basin, known world-wide for its unconformity-associated uranium deposits. Preliminary exploration and research in the 1970's and 1980's located uranium prospects in the Thelon similar to those in the Athabasca, but magnitudes and spatial extents of these resources were incompletely documented (Fuchs, 1989; Gandhi, 1989).

The 1.85-1.70 Ga Dubawnt Supergroup strata unconformably overlie the ~2.2-1.9 Ga Amer Group and 2.7–2.6 Ga Archean supracrustal rocks, anorthosite-gabbro, granitic and older Archean gneiss. The Dubawnt Supergroup comprises three unconformity bound dominantly terrestrial successions: Baker Lake, Wharton and Barrensland groups. The latter comprises the siliciclastic Thelon Formation, the Kuungmi Formation ultrapotassic mafic lavas and the Lookout Point Formation carbonate strata. This study focuses on the Aberdeen Sub-Basin that preserves only the Thelon Formation as three low-density, non-magnetic, upward-fining sequences of conglomerate, sandstone and mudstone. These unconformably overlap the Wharton, Amer and Woodburn Groups – the Baker Lake Group is not known here. The basal unconformity surface of the Thelon Formation is marked by the continent-scale Matonnabee paleoweathering surface (Gall and Donaldson, 2006). MacKenzie diabase dykes cut the Thelon Basin at 1.27 Ga.

High-resolution geophysical data for the Thelon Basin region are being compiled under an agreement with eight exploration companies, however, their data are confidential and a framework is required to organize the new material. This poster shows models that can be derived from public-domain low-resolution data, such as the first-ever 3D model of the unconformity surface between basement and the overlying Thelon Formation, a vital framework for evaluating uranium potential and planning exploration for buried deposits.

Theory and/or Method

The gravity and aeromagnetic data contributing to this poster were downloaded from the Geological Survey of Canada (GSC) Geoscience Data Repository. The gravity database was corrected for elevation, terrain and Bouguer effects. The residual Bouguer gravity was reduced with a slab density of 2.4 g/cm^3 to correct for the low density Thelon Formation and overburden. Diurnal and tie-line corrections on the aeromagnetic data minimized the effect of diurnal drift and noise. Residual between-line corrugations were diminished by microlevelling. The final datasets were gridded to 200m and 12km for aeromagnetic and gravity data, respectively.

Overton’s 1979 seismic depth estimates were digitized and imported into Oasis Montaj. Of the 35 seismic shot points recording depth to basement across the Thelon Basin, only six are located within the Aberdeen Sub-Basin because his sites were constrained to large frozen lakes which are sparse in its interior. Exploration boreholes were georeferenced and plotted alongside the seismic depths; ten pierced the unconformity and eleven provided minima. The 27 depth estimates were combined into a single data set and gridded to 20km. The unconformity surface modelled in this way was too low in resolution to define sharp discontinuities that might be associated with fault displacements; however explicit fault offsets documented by stratigraphic offsets in drill core (e.g. Davis et al., accepted) and mapped offsets of the basin margin will be incorporated into future models.

For this first geophysical model of the unconformity surface, simplified homogeneous densities were assigned to broad sandstone and basement units to quantify their relative contributions to the observed regional Bouguer gravity signal. Hasegawa et al. (1990) assigned an average density of 2.7g/cm3 to the Woodburn Group around the Kiggavik Main Zone on the eastern edge of the basin, here extrapolated as uniform “basement” unconformably underlying the Thelon Formation throughout the entire sub-basin. As no density measurements have been published for the Thelon Formation, it was assigned the bulk typical density of the Athabasca Group sandstone from Wood & Thomas (2002): 2.43g/cm3.

Six east-west and two north-south profiles were extracted from the regional GSC gravity grids, cross-cutting the Aberdeen Sub-Basin (Figure 1).

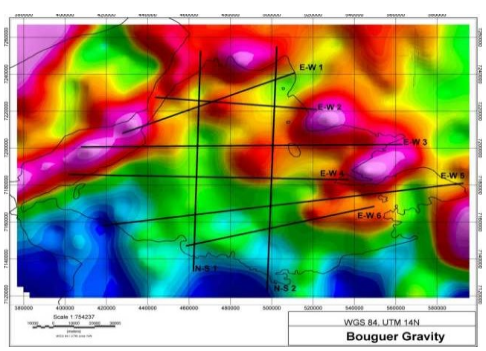

Figure 1: Locations of model profiles (thick black lines) overlain on Bouguer gravity map. The thin black line is the mapped boundary of the Aberdeen Sub-Basin, located approximately 100km west of Baker Lake, Nunavut.

To refine the subsurface geology of the basement along the transects, coincident profiles were extracted from the microlevelled aeromagnetic data. The final forward model computed for each profile is based on both the aeromagnetic and gravity data. The basement units were assigned susceptibilities ranging from 0.001 to 0.008 SI and the non-magnetic basin fill a uniform 0.0 SI.

Examples

Figure 2 illustrates one of the generated east-west profiles. The depth estimate profiles were created by closely matching the computed Bouguer signal with the observed Bouguer signal above the cross-sections. The 3D model for the sub-basin (Figure 3) incorporates all of the computed profiles.

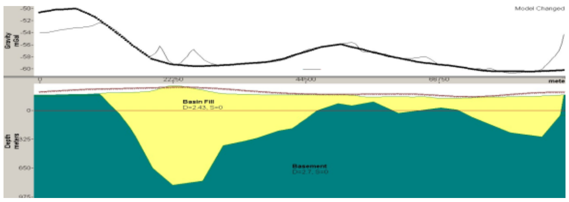

Figure 2: GM-SYS Bouguer gravity profile for the EW-1 transect. Top: Observed (heavy dotted line) and computed (thin black line). Bottom: Computed model; basement rocks shown in teal; Thelon Formation (basin fill) shown in pale yellow.

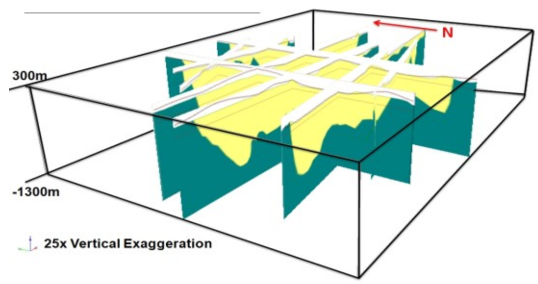

Figure 3: Pseudo-3D Model constructed from all 2D Bouguer profiles located in Figure 1, mapping the depth to the unconformity at the base of the Thelon Formation.

Depths estimated by the gravity models reach 1000 m in the interior of the Aberdeen Sub-Basin. Until now, the greatest depth estimate was 856m below sea level (Overton, 1979).

Aeromagnetic profiles were incorporated into the gravity models to test differentiation of basement units along the unconformity by estimating magnetic susceptibility for generalized units (Figure 4).

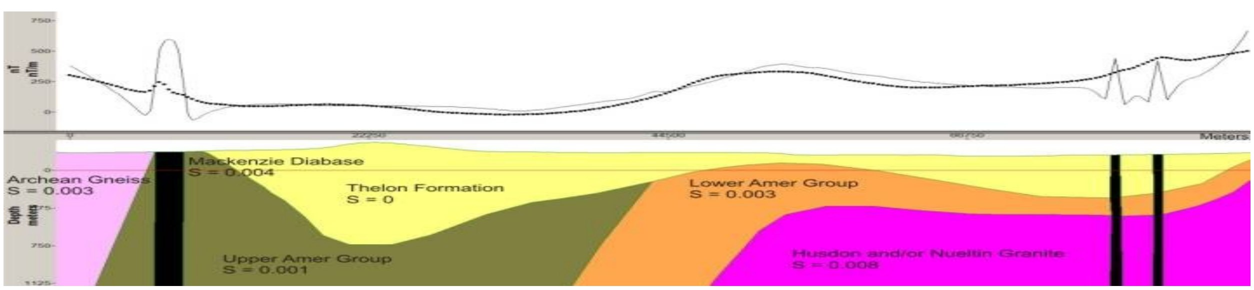

Figure 4: Extracted total magnetic intensity profile for EW-1. Top panel: Observed (heavy black dots) and computed (thin black line) magnetic anomaly. Bottom panel: computer generated geological model based on magnetic data. Different colours represent different susceptibility models for simplified major rock units as labelled here.

The Hudson and Martell plutons or sills are commonly associated with large magnetic highs, whereas Nueltin granite tends to be non-magnetic (Scott et al., 2010). These suites are exposed along the Amer mylonite zone just northeast of the EW-1 label in Figure 1, and are here projected beneath the Thelon Basin in Figure 4, mantled by varying thicknesses of Amer Group units.

Conclusions

Integrating Overton's seismic with regional magnetic and borehole data was the basis for modeling the subsurface geological framework of the Aberdeen Sub-Basin, giving new structural insights. It is deeper than had previously thought with the sandstone-basement unconformity surface located as much as 1000m below sea level. Initial analysis of the aeromagnetic data demonstrated the feasibility of mapping and depth modeling basement lithological units. Dyke swarms and iron formations can already be identified due to their high magnetic contrasts. The detailed morphology of the Thelon Basin was in part controlled by faults which were active both during and after sedimentation; however such faults were not incorporated into this basin floor grid model because of the regional scale resolution of the gravity and magnetic data. Higher resolution data would support a basal surface model that incorporates fault discontinuities.

Acknowledgements

This poster was derived from a Bachelor of Science thesis by the first author at McMaster University. This project is supported by the Northern Uranium for Canada Project under the Geomapping for Energy and Minerals (GEM) Program at the Geological Survey of Canada, a student NSERC grant to the first author and a Discovery NSERC grant to WAM at McMaster University. Guidance from Pierre Keating was much appreciated.

References

Davis, W.J., Gall, Q., Jefferson, C.W. and Rainbird, R.H., accepted, Diagenetic Fluorapatite in the Paleoproterozoic Thelon Basin: Structural-stratigraphic context, In situ Ion Microprobe U-Pb ages and fluid flow history: Bulletin of the Geological Society of America.

Fuchs, H.D. and Hilger, W., 1989, Kiggavik (lone gull): An unconformity related uranium deposit in the Thelon Basin, Northwest Territories, Canada. Uranium Resources and Geology of North America: International Atomic Energy Agency, Tech. Doc. 500, 429–454.

Gall, Q. and Donaldson, J.A., 2006, Diagenetic fluorapatite and aluminum phosphate-sulphate in the Paleoproterozoic Thelon Formation and Hornby Bay Group, northwestern Canadian Shield: Canadian Journal of Earth Sciences, 43, 617-629.

Gandhi, S.S., 1989, Geology and uranium potential of the Thelon Basin and adjacent basement in comparison with the Athabasca Basin region. Uranium Resources and Geology of North America: International Atomic Energy Agency, Tech. Doc. 500, 411-428.

Hasegawa, K., Davidson, G.I., Wollenberg, P. & Lida, Y., 1990, Geophysical exploration for unconformity-related uranium deposits in the northeastern part of the Thelon Basin. Northwest Territories, Canada: Mining Geology, 40, 83–95.

Overton, A., 1979, Seismic reconnaissance survey of the Dubawnt Group, districts of Keewatin and Mackenzie: Current Research, part B, Geological Survey of Canada, Paper 79-1B, 397-400.

Scott, J., Peterson, T.D., and Jefferson, C.W. 2010 (abstract), Proterozoic (1.85-1.7 Ga) Granitoid Rocks and Uranium in the Baker Lake – Thelon Basin region, Nunavut: this meeting.

Wood, G. & Thomas, M. D., 2002, Modelling of high resolution gravity data near McArthur River uranium deposit, Athabasca Basin, Saskatchewan; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Sask. Industry Resources, Misc. Rep. 2002-4-2, CD-ROM, Paper D-16.