

Modelling the 3D Architecture of Rocks and Structures of the Athabasca Basin: How Saskatchewan is Tackling the Challenge from Down Under

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SUMMARY

The Athabasca Basin of Saskatchewan hosts the highest grade uranium deposits in the world and is one of the world's most prolific uranium producing districts. The deposits are focussed near the unconformity between the flat-lying Athabasca Group and highly deformed and metamorphosed basement rocks. South Australia is also one of the world's largest uranium producers, largely due to production from the giant Olympic Dam deposit. In addition, the basement rocks beneath the Pandurra Formation make it prospective for unconformity-related deposits. Three dimensional structural analysis and GIS modelling techniques are providing a framework to compare the Athabasca Group and Pandurra Formation, and their basement rocks. This work is being undertaken under the auspices of a Memorandum of Understanding (MOU) between the Saskatchewan and South Australia geological surveys. A key goal of the MOU is to provide enhanced insight into the uranium mineral systems of both jurisdictions.

INTRODUCTION

The Athabasca Basin of Saskatchewan not only hosts the highest grade uranium deposits in the world but is also one of earth's most prolific uranium producing districts. The basin, elliptical in plan view, extends for 405 km on its east-trending long axis and is up to 215 km wide. The deepest drill hole, collared near the middle of the basin, intersected 1.5 km of predominantly fluvial sandstones of the Mesoproterozoic Athabasca Group. Unconformity-related uranium deposits are found either at or near the unconformity between highly strained, high-grade Archean and Paleoproterozoic metasedimentary basement units and the flat-lying, unmetamorphosed, weakly deformed Athabasca Group (e.g. Jefferson et al., 2007). The uranium is thought to have been delivered via oxidised basinal fluids that interacted with reduced fluids derived from the basement; pre-existing and commonly graphitic basement shear zones provided conduits. The most common source of uranium was likely relatively late-phase anatectic granitoid rocks generated during the waning stages of the Paleoproterozoic Taltson and Trans-Hudson orogenies. Most of the known deposits are in the eastern part of the Athabasca Basin, e.g. McArthur River; however, new discoveries in the under-explored, western part of the basin, e.g. Centennial and Shea Creek, demonstrate the potential of the area.

In addition to Kazakhstan and Saskatchewan, South Australia is one of the world's major uranium producers. The vast majority of uranium production comes from the giant Olympic Dam iron oxide-copper-gold-uranium (IOCGU) breccia deposit, the largest uranium deposit in the world. There are numerous other IOCGU deposits and prospects within the Proterozoic Gawler and Curnamona Provinces in South Australia, however, which provide a rich source for uranium production in these and other younger sedimentary hosted deposits. The dominant uranium-rich lithology in the crystalline basement of both provinces is the late-Mesoproterozoic Hiltaba Suite

granites and equivalents, broadly synchronous with the formation of Olympic Dam. Oxidised fluids draining off this highly uraniferous basement have accumulated uranium in a number of different environments, in particular throughout Tertiary sandstones that host numerous sandstone uranium deposits, e.g. Beverly. Moreover, it is highly likely that redbeds of the Mesoproterozoic Pandurra Formation (Cowley, 1991), overlying Hiltaba Suite granites, which have intruded sheared iron and graphite-rich sediments of the eastern Gawler Craton, are suitable hosts for unconformity-related mineralisation in the Cariewerloo Basin. Historic company exploration results have indicated some uranium anomalies but exploration for “Athabasca-style” uranium deposits is a recent strategy.

In March, 2009, with the objective of advancing and promoting best practices in geoscience activities, and to maximise the development of their respective mineral sectors, the province of Saskatchewan and the state of South Australia signed a Memorandum of Understanding (MOU). One of the primary focusses of the cooperative geoscience being undertaken under the auspices of the MOU is modeling the 3D architecture of the Athabasca Basin and its Archean and Paleoproterozoic basement rocks. In recent years, geologists of the South Australian Geological Survey have recognised that this type of collaborative modelling, resulting in generation of new data and enhanced exploration concepts, might bring about the addition of unconformity-related uranium mineralisation to the suite of known uranium enrichment present in South Australia.

METHOD

By applying three dimensional structural analysis and GIS modelling techniques utilised elsewhere in South Australia, models are being constructed allowing a more robust comparison between the Athabasca Group and Pandurra Formation (and underlying basement) in GoCad , Geomodeller, Intrepid and ArcGIS software (e.g. Figure 1). Combining structural and geophysical interpretation of basement and basinal geology with stratigraphic and metallogenic expertise between collaborative groups has provided insight into the uranium mineral system of both areas and can be extended into other areas such as fluid-flow modelling and new geophysical surveys.

Much of the exploration drilling in the Athabasca Basin has focussed on the perimeter of the basin, which is shallower, and specifically the eastern part, where most of the mines are located, leaving wide data gaps in stratigraphic, depth to basement and subcrop rock type information. In addition, exploration is focussed on particular basement rock types, in this case pelitic metasedimentary rocks, and therefore there is little information in areas deemed to be not prospective by the exploration companies. As such, the Saskatchewan Geological Survey undertook subcrop mapping and high-resolution stratigraphy projects for the Athabasca Basin as part of the EXTECH IV project in hope of stimulating further exploration in the region. These projects are ongoing. An example of the products is a basement map for the western Athabasca Basin (Card, 2006). It was produced by integrating bedrock mapping near the basin perimeter, available drillholes, most of which are within 40 kilometres of the basin boundary, and using digitised analog aeromagnetic and gravity data. The result was a remote predictive map covering about 35 000 km² for which there were geological data control points for only about 11 000 km². The remaining areas were interpreted primarily from aeromagnetic images. The result is a product with high levels of uncertainty in over two thirds of the area investigated (Chung et al., 2007). To help to address this uncertainty the Saskatchewan Geological Survey, in partnership with the Geological Survey of Canada under their Geomapping for Energy and Minerals Program, has been undertaking new, high-resolution airborne magnetic/radiometric surveys over the Athabasca Basin and flanking areas (e.g. Buckle et al., 2009) with the hope of improving subcrop maps. Similar resolution problems are inherent in Athabasca Group modelling, as there are few available data points in the deepest parts of the basin. Assuming an

effectively layer cake stratigraphy, which detailed lithostratigraphy across the basin implies, a number of cross sections of the basin have been developed (e.g. Ramaekers et al., 2007). The challenge remains to extrapolate these sections into parts of the basin with a data void.

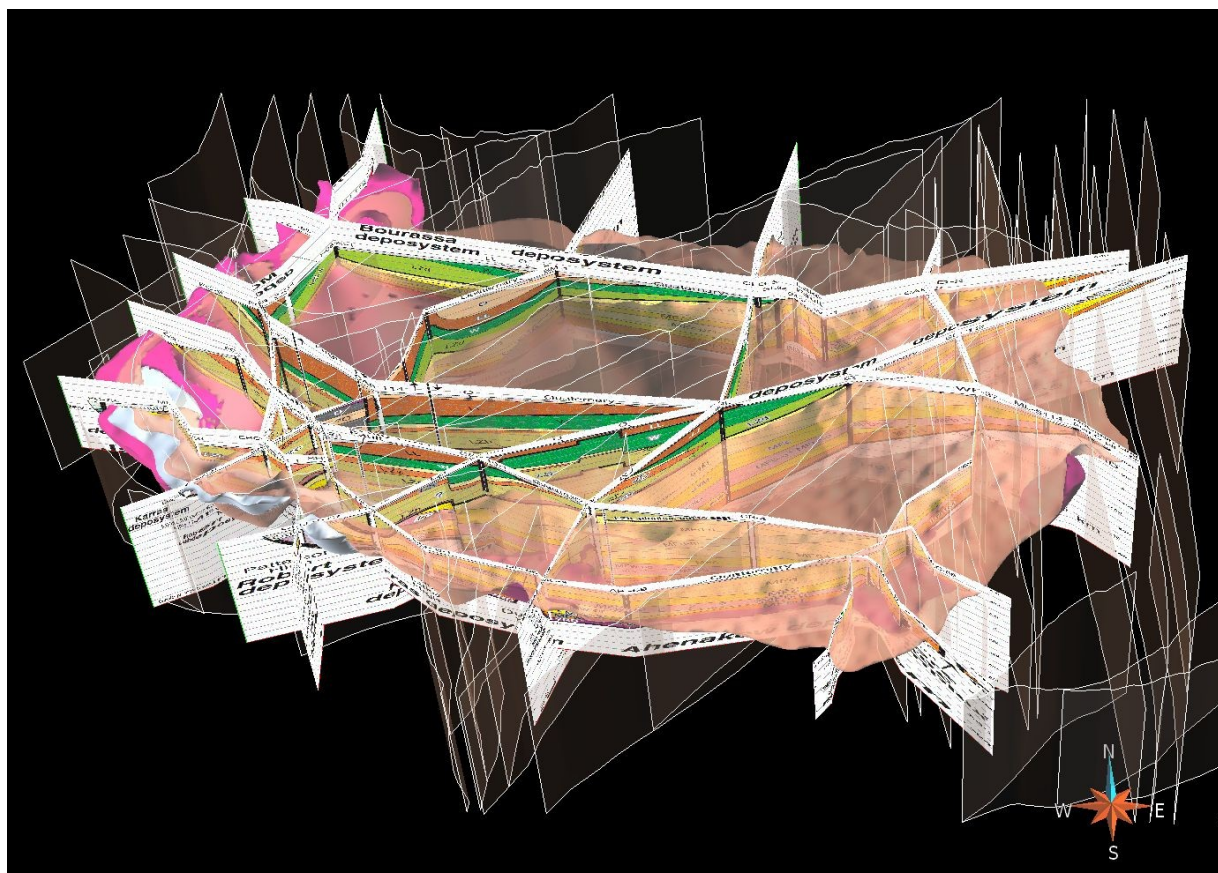


Figure 1: Preliminary model for the Athabasca Basin. EXTECH stratigraphic sections for the Athabasca Group have been georeferenced and imported into a 3D space. Volumes of the Fair Point (pink), Read (purple), Smart (white) and Manitou Falls units are visible, with the Manitou Falls (top volume) set to a transparency of 20%. Also included is the EXTECH fault dataset with transparency set to 80%.

Geoscientists from the South Australian Geological Survey have visited Saskatchewan to bring their expertise in modelling regions with limited bedrock exposure to the Athabasca Basin. Phase one of the project involves reprocessing of the available aeromagnetic and airborne gravity information. New grids of the available aeromagnetic and gravity data were created and a variety of enhancements were applied to those data (e.g. Milligan and Gunn, 1997). These include reduced to pole aeromagnetic images for total magnetic intensity from which a number of other images were derived, including first vertical derivative, automatic gain control, tilt, horizontal gradient and analytic signal. Similar products were generated for the gravity data. These products aid in interpreting the basement structure and lithostratigraphy by sharpening the geophysical signature at different levels, i.e. deep versus shallow structures. In addition, multi-scale edges (worms) were produced at a number of heights using upward continuation of the fields to aid in determining the dip direction of various features. Finally, the depths to major geophysical anomalies were calculated with the goal of creating a depth to source model that can be used as a foundation for depth to unconformity modelling.

Phase two will integrate the work done on the basement data sets and the overlying Athabasca Group. This includes modelling of the Athabasca Basin in 2.5 and 3 dimensions by using various data sets including geological, geochemical and geophysical (Figure 1). Using drill core data integrated with these data sets aids in developing more accurate interpretations of areas with poor drillhole control. The modelling provides a basin scale interpretation of the overburden and unconformity surfaces, lithostratigraphic framework, the location and projection of large-scale faults, and alteration patterns (e.g. Figure 1).

CONCLUSION

The goal of the project in the Athabasca Basin is to produce a 3D-GIS model that will be a starting point for new subcrop mapping and stratigraphic revisions. Initial results from the study, in the form of more appropriate geophysical grids and images and preliminary 2.5 and 3D models will be released in various formats and guises (such as pseudo sections on maps, 3D datasets, images and maps). Preliminary basement models exist for beneath the Pandurra Formation and are being generated for the Athabasca Basin, as are stratigraphic models for both. An example of a proposed output will be a joint map publication for the Athabasca Basin highlighting the new data and images. A better understanding of the controls on mineralisation in both basins, such as fluid-flow architecture, redox sites near or at the unconformity, fault-hosting reductants in the basement, and the distribution of alteration are important factors arising from the project.

Throughout the life of the project, improved understanding of the 3D configuration of the Athabasca Basin, along with improved understanding of the comparative stratigraphy of the Pandurra Formation, will ultimately lead to a better understanding of the mineral system of both areas. This, in turn, will lead to improved area selection for company exploration and enhanced chances of exploration success in both provinces. It is anticipated that the formal project knowledge transfer and outputs will be complete during 2010, but the knowledge links generated will continue to have an impact for many years to come.

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