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Differentiating gravity responses of glacial sediment cover and mineralization in the Athabasca Basin using constrained and joint inversion

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Introduction

The Athabasca Basin in northern Saskatchewan, Canada, currently supplies over twenty percent of the world's uranium. The first mine was discovered in the Rabbit Lake area in 1968 and the world's largest high-grade uranium mine is currently located in the McArthur River area. In this area, beneath the Quaternary glacial sediments, the Proterozoic sandstones are separated by unconformity from the underlying strata of the Archaean metamorphic basement. Uranium deposits are mostly formed at the base of the sandstones and the top of the basement where the unconformity meets basement graphitic faults. Since the depth of the Proterozoic sediments in the eastern part of the Athabasca Basin is less than in the western part, the eastern part has seen most of the historic uranium exploration work, with geophysics playing a significant role. In these areas, alteration zones typically undergo a change of density, thereby also suggesting investigation by gravity surveys. The idea of this research is to use electromagnetic (EM) data to assess the depth of glacial sediments, which have a relatively high electrical conductivity compared to the rocks immediately beneath, thus allowing the contribution of the glacial sediments to gravity measurements to be accounted for. The residual gravity data can then be used to look for the mineralization zones in the sedimentary and basement rocks.

Geological setting

Uranium occurs in significant quantities in the mineral Pitchblende and currently about 70% of the world's uranium is provided from sedimentary basins while more than one third of uranium resources are found in Paleo- and Meso-proterozoic unconformity deposits. Typically, the ground structure from top to bottom in the eastern Athabasca Basin is as follows: glacial sediment cover with a variable thickness of 25 to 120 metres, sandstone to a depth of approximately 550 metres, then unconformity and metamorphic basement (Fig. 1). The faults and fracture zones in the area permit significant fluid flow across the unconformity. The uranium deposits, alteration (silicification) zones and graphitic faults are formed by the mineralization of these flows in the vicinity of the unconformity. Particular types of alteration zones are the linear zones of anomalous illite, chlorite and dravite in the area. These anomalies cover some important uranium deposits in the south-eastern part of the Athabasca Basin (Jefferson et al., 2007).

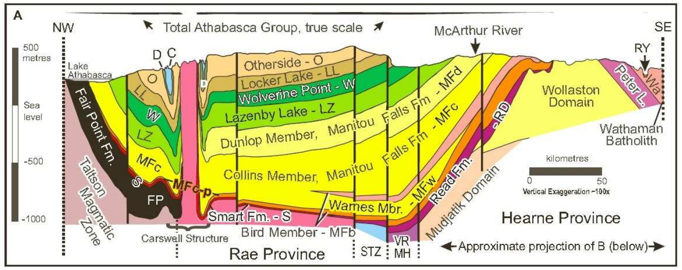

Fig. 1. Lithostatigraphic cross section of the Athabasca basin sediments (Jefferson et al., 2007). Sediments are mostly formed of sandstone and conglomerate. Metamorphic basement underlies the sediments.

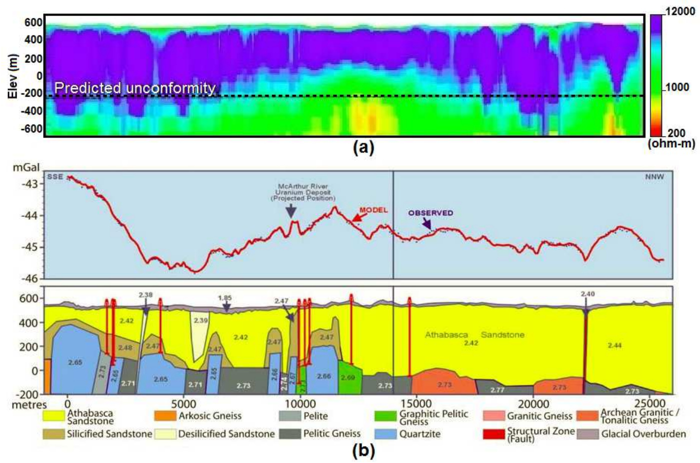

Fig. 2. a) Example conductivity-depth section of an EM profile in the Athabasca Basin (Irvine and Witherly, 2006). b) Gravity modelling for McArthur River profile (Wood and Thomas, 2002).

Constrained and joint inversion

The Canadian Shield is covered by variable glacial deposits which generally have distinct densities from other sediments. Such density can mimic or mask the gravity associated with the hydrothermal alteration that is an intrinsic component of the footprint of Uranium deposits in the Athabasca Basin. Geophysical methods can in principle locate graphitic faults and alternation zones that are often spatially associated with unconformity uranium deposits. The very low resistivity of graphite and high resistivity of silicified zones allow them to be located with EM methods. Also, the gravity method can potentially delineate the zones of silicification. However changes due to the variable depth of the contact between glacial cover and sandstone can mask the signal due to the silicification. To solve this problem, we shall use constrained and joint inversion of both EM and gravity data to recover a 3D model with sediment cover and mineralization. The thickness of the cover will be determined by 1D inversion of the EM data and the gravity response of the cover stripped from the gravity response. Also the thickness of the cover will be used as a constraint in 3D gravity inversion. Finally, a joint inversion of the EM and gravity data will be attempted. Figure 2 shows two previous samples of independent EM and gravity models for the Athabasca Basin.

Acknowledgements

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