Uranium Exploration in the Athabasca Basin using Low-Noise Airborne Gravity Gradient Data

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SUMMARY

The Athabasca Basin, northern Saskatchewan, Canada, is renowned for the largest, high-grade uranium deposits in the world. Historically, most of the deposits have been discovered within the Basin with as much as 700 metres of overlying sandstone cover. A new generation of shallow, basement-hosted deposits are currently being explored for near the margins and outside of the Basin. We will show examples of low-noise airborne gravity gradient data, and how it is sensitive to zones of hydrothermal alteration which could be indicative of uranium fertile fluid systems. The gravity gradient data was combined with structural interpretations of airborne magnetic and EM data to highlight prospective drill targets.

Key words: Airborne Geophysics, Gravity, Magnetic, Uranium

INTRODUCTION

The Athabasca Basin comprises a 1500 m thick, red bed succession of four quartzose fluvial sequences, known as the Athabasca Group, and occupies an area of some 100,000 km2. This is underlain by older metamorphosed crystalline basement rocks belonging to two major subdivisions of the Saskatchewan Shield; the eastern Hearne Craton and the western Rae Craton. A number of factors control uranium mineralization in the Basin, which include: the Athabasca Group-basement unconformity; faulting to provide fluid conduits; the proximity of graphite in the basement rocks (not in every case), and the necessity for uranium-enriched oxidized fluids. The last control mentioned speaks to the importance of redox relationships from oxidized fluids percolating down through the Basin and ultimately mixing with hydrothermally-altered and reduced basement rocks, creating an eletcro-chemical trap, known as redox, that precipitates uranium.

The hydrothermal fluids result in extensive argillic alteration halos that commonly form around uranium deposits. The alteration halos are the main target for the airborne gravity surveys. However, gravity methods will only be effective at mapping potential alteration zones in areas where the Basin is shallow, or where the Athabasca Group has been eroded and basement rocks are exposed. A new generation of shallow, basement-hosted deposits are currently being explored for near the margins and outside of the Basin. These shallower uranium deposits have the potential to be significantly less expensive to mine than the traditional deposits that form at the unconformity under hundreds of meters of Athabasca Group cover.

EXPLORATION METHODOLOGY

Four major controls on uranium mineralization were introduced above, but as we move to the margins of the Basin to explore for basement-hosted deposits, we are no longer concerned with the measurable effects of the Athabasca Group-basement unconformity. However, much of the 1.7 Ga Athabasca Group has been eroded and we can assume that the Basin was much larger than its current size, therefore we can infer that uranium-enriched oxidized fluids from the Basin were still important in these areas when the main uranium mineralization events occurred, circa 1.5 Ga. For basement-hosted deposits beyond the current Basin margins, we are left with two controls that we will explore further:

- Faults and fluid conduits
- The presence of graphite in the basement rocks

Identification of large-scale faulting is relatively easily achieved in the basement rocks underlying the Athabasca Basin interpreting magnetic data. For shallower deposits the increased amplitude and resolution of the magnetic response from faulting makes interpretation of these features less ambiguous. Similarly, the likelihood of the presence of graphite can be ascertained by mapping the conductivity of the subsurface using some form of electrical method – time domain electromagnetic (TDEM) or magneto telluric (MT) surveys are common.

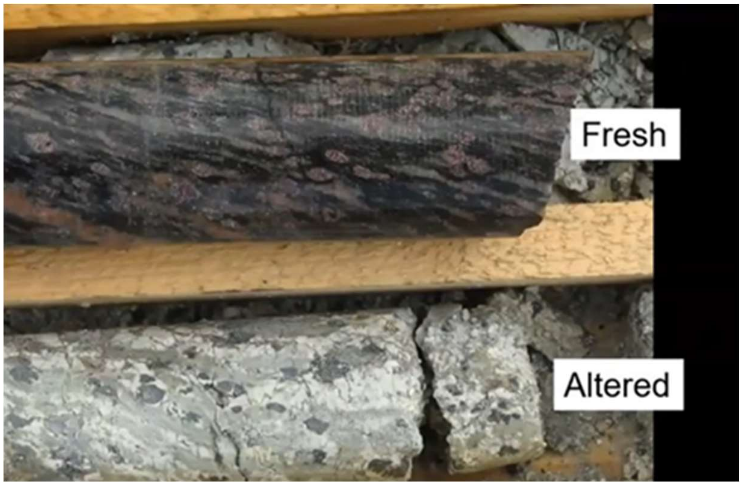

Figure 1: Drill core from basement rocks beneath the Athabasca Group showing samples without hydrothermal alteration (Fresh), and where significant hydrothermal alteration is present (Altered). McCready, 2008

However, identifying large fault zones that exhibit elevated conductivity due to the presence of graphite does not indicate whether hydrothermal fluids flowed in that location. Ground gravity surveys have been used in the Basin to determine if alteration zones are also present in these locations with coincident magnetic low/conductive high corridors. Argillic alteration lowers the density of the rocks and this creates an apparent anomalous gravity low.

FALCON PLUS AIRBORNE GRAVITY GRADIENT SYSTEM

The Falcon Plus system is a low-noise variant of the Lockheed Martin produced Falcon Airborne Gravity Gradient (AGG) system operated by Xcalibur Multiphysics (Dransfield et al, 2004). The Falcon Plus system has a reduced response when exposed to aircraft motion (turbulence), which is the major source of noise in airborne gravity gradient surveys (Figure 2).

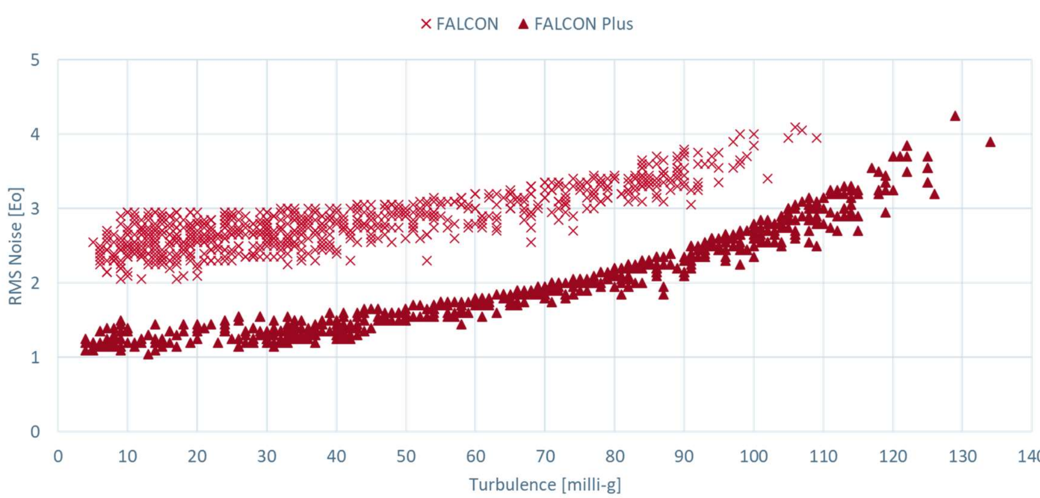

Figure 2: Root Mean Square (RMS) noise vs. Turbulence plot for a historical selection of Falcon (crosses) and Falcon Plus (triangles) survey lines.

The hardware improvements have been complemented by improvements in data processing. The improved method exploits the different spatial frequencies of system noise and geologic signal. After converting the data into the 2D spatial domain, a custom spatial filter is applied that removes the system noise, while retaining the remaining geologic signal. The process limits the data resolution to the survey line spacing (Christensen et al, 2014)

HOOK AIRBORNE SURVEY AND ACKIO URANIUM DISCOVERY

In May 2021, coincident AGG and airborne magnetic data was collected over Baselode Energy's Hook project in the basement domain to the east of the Athabasca Basin margin. The AGG data was combined with structural interpretations of airborne magnetic and separately collected EM data to highlight prospective drill targets.

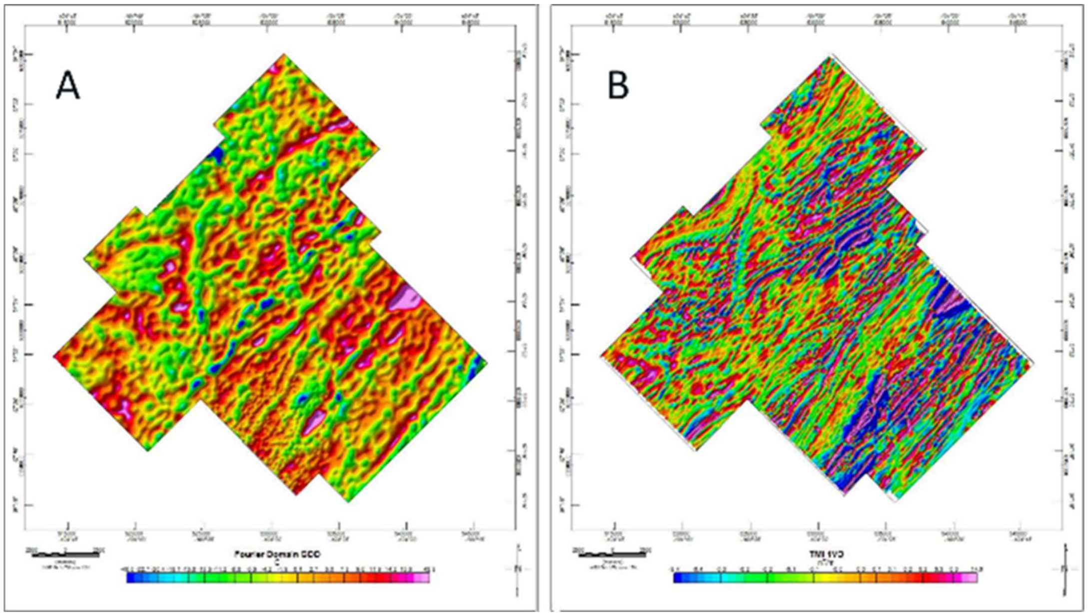

Figure 3: Survey data from the Hook survey block showing the vertical component of the airborne gravity gradient data (A) and the first vertical derivative of the simultaneously collected magnetic data. Both images use a histogram equalized colour stretch.

The AGG data of the Hook survey area (Figure 3), highlighted two areas of relative gravity lows thought to be related to hydrothermal alteration, and consequently uranium mineralization (Figure 4).

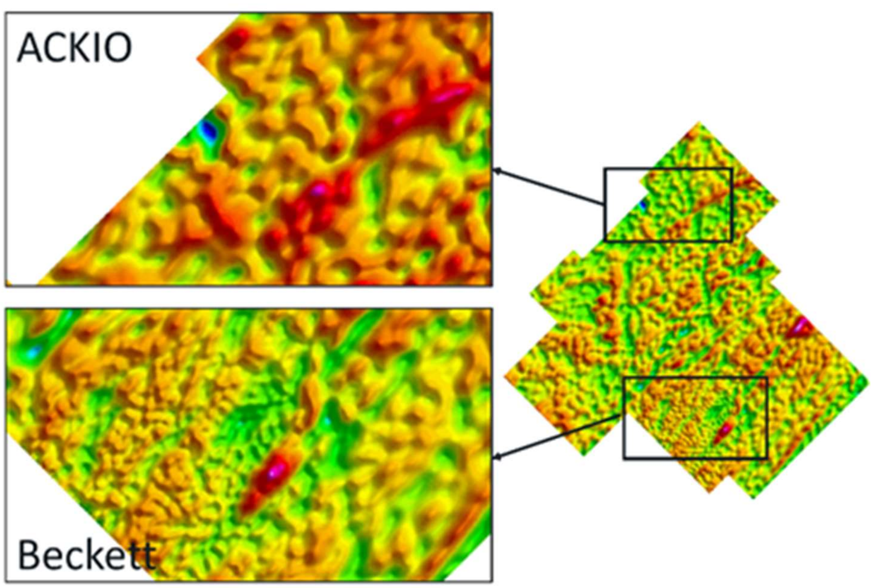

Figure 4: Linear color stretch images of the vertical component of the airborne gravity gradient (AGG) data highlighting the ACKIO and Beckett drill target areas.

The northern target area (ACKIO) exhibits a markedly lower gravity gradient response than any other area within the survey block. The southern target area (Beckett) is more complex, with two gravity gradient lows on either side of a central high.

Drilling in both areas has confirmed extensive hydrothermal alteration is present, as well as elevated radioactivity levels due to uranium mineralization (Figure 5). The depth of these zones is relatively shallow at 100m to 300m below surface.

Figure 5: Core sample from hole AK21-01 in the ACKIO area showing visible uranium at 139.1m depth. This piece of core was part of a 0.5 m interval that assayed 1.29 wt% U3O8.

The hydrothermal alteration halo intersected at the ACKIO discovery is widespread and continuous that has been drill defined for more than 200 m wide and 300 m deep. Much of the drill core has experienced argillic alteration. Mineralization at the ACKIO area is typical of Athabasca basement-hosted uranium deposits. The Baselode team is confident the AGG gravity low is a manifestation of the extensive hydrothermal alteration halo at ACKIO.

Hydrothermal alteration was also intersected in the Beckett area, however, it was patchy and discontinuous. Elevated levels of radioactivity and uranium mineralization were also intersected with diamond drill holes, however, they were all directly associated with quartzo-feldspathic pegmatites. The Beckett drilling encountered many thick sequences of these pegmatites within the centre of the AGG gravity low target. Diamond drilling on the edges of the gravity low anomaly yielded far less pegmatite concentrations and more background rocks with increased mafic minerals such as biotite and amphiboles. The Baselode team is confident the increased concentration of low density minerals (quartz and feldspar) with respect to the background rocks enriched with high density minerals (mafics) produced the apparent gravity low.

CONCLUSIONS

The application of low-noise AGG data to the benefit of detecting hydrothermal alteration as a proxy for uranium mineralization is a practical success. However, airborne gravity data should not be used on its own and should be cross-referenced with other geophysical methodologies, such as magnetics and electromagnetic or resistivity methodologies.

As the hydrothermal target zones are relatively small spatially and exhibit small differences in gravity signal amplitude to the surrounding geology, ground gravity has traditionally been used to solve this problem. However, with the introduction of low-noise, high-resolution AGG systems, the use of airborne systems is becoming more widespread in uranium exploration. Xcalibur's case example of Baselode's ACKIO discovery is a first confirmed proof of concept. Additionally, collecting geophysical data from the air is; i) quicker, ii) more cost-effective, and iii) overcomes many logistical challenges of ground data acquisition in remote environments such as Athabasca Basin area of northern Saskatchewan.

REFERENCES

Christensen, A.N., Van Galder, C. and Dransfield, M.H., 2014, Improved resolution of fixed wing airborne gravity gradiometer surveys. SEG Technical Program, Expanded Abstract, 1319-1323.

Dransfield, M.H. and Lee, J.B., 2004, The FALCON airborne gravity gradiometer survey systems. In: Lane, R. (Ed.) Airborne Gravity 2004 – Abstracts from the ASEG-PESA Airborne Gravity 2004 Workshop, Geoscience Australia, 15-19.

McCready, A.J., Elash, T.A., Robertshaw, P., Reilkoff, B., Hajnal, Z., and Dale Wallster, D., 2008, First Insights Into Hathor Exploration's Roughrider Zone Uranium Discovery: Breathing New Life Into A Mature Basin. Open House 2008, Abstract Volume, Saskatchewan Geological Survey