SYNOPSIS

The Utility of Surface Geochemistry – THE MODEL

Athabasca Basin, Saskatchewan

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By

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INTRODUCTION

The Athabasca Basin is an ancient (Paleoproterozoic) sandstone basin located in northern Saskatchewan, Canada. The Athabasca Group sandstone and the underlying crystalline basement rocks host high-grade uranium deposits, either at the sandstone-basement unconformity (sandstone-hosted mineralization) or within the underlying structurally disrupted crystalline basement lithologies (basement-hosted mineralization). These unconformity-related uranium deposits account for about 20 percent of the world’s primary uranium production. The ore grades are high, typically grading 2% to 20% U₃O₈.

To find the next generation of high-grade sandstone-hosted unconformity-related deposits in the Athabasca Basin, innovative remote-sensing exploration techniques are required to identify uranium mineralization in deeper less explored terrain.

EXPLORATION CYCLES

Uranium exploration in the Athabasca Basin has gone through two major cycles (Figure 1). The first cycle (1960–1980) was prospector driven, in areas near the basin margin, at depths from 0 – 300 m. This exploration cycle was with people on the ground; conducting mapping, surface boulder prospecting, and shallow-imaging geophysical surveys. This resulted in the initial discoveries at Key Lake, Rabbit Lake and Eagle Point. The second exploration cycle (1980s to present) has been geophysics driven, heavily skewed toward surveys such as high-resolution electromagnetic imaging, gravity and magnetic surveys, looking for conductive targets at depths up to 500 m. This has resulted in the major discoveries of Cigar Lake and McArthur River and other deposits currently being developed such as Millennium, Phoenix and Centennial. The historical motivation for focusing exploration on drill targets generated by geophysical surveys is that all the known uranium deposits in the Athabasca Basin occur proximal to structurally controlled graphite-related basement-hosted electromagnetic (EM) conductors.

Figure 1: Athabasca Basin Exploration Cycles (after Harris et. al 2009)
Figure 2 further emphasizes the historical exploration focus on the margins of the Basin, drilling shallow targets (depths from 0 to 500 m) leaving the vast central portion of the Basin under-explored.

The problem with relying solely on geophysics to vector drilling is that at depths >500 m, the effectiveness to resolve meaningful drill targets is greatly diminished. More notably, there is an abundance of favorable-looking basement-hosted geophysical targets that transect the Basin but do not host uranium deposits, resulting in prospecting with the drill and targeting mostly ‘blind’ conductors.

Although all of the exploration tools discussed above should continue to be used, the obvious limitation to their effectiveness is depth. Hence, the beginning of the innovation-driven exploration cycle with the use of Uravan’s innovative surface geochemical techniques as a means to differentiate the potentially mineralized geophysical targets from the many barren ones. With this idea, Uravan’s technical group in collaboration with Dr. Kurt Kyser and his research team at the Queen’s Facility for Isotope Research (QFIR) at Queen’s University, Ontario, Canada, and Dr. Colin Dunn, an independent specialist in biogeochemistry, began to develop, using applied research, surface geochemical techniques that could potentially map the migration of elements from a deposit at depth (geosphere) to the surface environment (biosphere).
WHY SURFACE GEOCHEMISTRY? – THE MODEL

The MODEL for using surface geochemistry infers that:

1. During the geological and structural history of basin development and post deposition, there has been reactivation of basement structures and coincident hydrothermal activity. Basin fluid flow and mixing with hydrothermal fluids resulted in the formation of unconformity-related uranium deposits.

2. Microbial activity occurs within the redox environment of uranium deposits. This promotes the vertical migration of elements, some with unique isotopic compositions, and gaseous compounds from the uranium mineralization up through the overlying fractured and permeable sandstone to the surface environment for the signatures to be incorporated into soils and trees.

3. Figures 3 and 4 Illustrate the combination of these processes that gives rise to a preserved surface signature, or geochemical “foot-print”, of the underlying deposit that results from secondary migration of components from the ore deposit at depth.

THE MODEL

Figure 3: Uravan-QFIR surface geochemical model as it relates to unconformity U deposits. Distinctive pathfinder elements, gaseous compounds and elements with isotopic signatures are present within the redox environment of the deposit. These unique components are then dispersed all the way to the surface media through structural reactivation, followed by post-sandstone fracturing. A unique geochemical signature forms as an alteration halo within the sandstone column and becomes incorporated into the surface environment where it can be defined using Uravan-QFIR techniques.
WHY WE USE LEAD ISOTOPES IN URANIUM EXPLORATION

Figure 4 Description of U-Pb isotope system and its use in exploration for U deposits.

HISTORICAL STUDIES AND SURVEYS

The development of Uravan’s geochemical sampling and analytical protocols was initiated in 2009 with an orientation survey over the western portion of the Cigar Lake uranium deposit (the ‘Cigar West Study’; Drever et al., 2009; Kyser et al., 2015) (report web link), and then further refined and developed in 2013 with a second orientation survey over the Centennial uranium deposit (the ‘Centennial Deposit Surface Geochemical Study’; Griffiths et al., 2013) (report web link). Both studies were in collaboration with Cameco Corporation (Cameco), Areva Resources Canada (Areva) and QFIR.

Following the Cigar West and Centennial deposit studies, Uravan, in collaboration with QFIR and NSERC (Natural Sciences and Engineering Research Council of Canada), conducted six exploratory surface geochemical surveys over active exploration projects in the Athabasca Basin. These applied research surveys advanced and refined the sampling protocols and analytical methods and improved the overall understanding of our surface geochemical techniques.

More recently, a study was initiated under the auspices of the Canadian Mining Innovation Council (CMIC) (http://cmic-footprints.ca/program-summary/basinal-u-subproject) to integrate legacy data with new data from the vicinity of the Millenium-McArthur River corridor to define the “footprint” of the deposits. The consortium of companies involved includes Cameco, Areva, Denison and PNC, in collaboration with QFIR and NSERC. It is one of several studies under the CMIC “Footprints Project”. Dr. Kurt Kyser and his research team at QFIR are involved in examining fractures in drill core, and investigating surface soil and tree-core
geochemistry (using protocols developed by Uravan and QFIR) to determine mechanisms and pathways to help explain how the geochemical signals get to the surface.

**THESE STUDIES AND SURVEYS WERE DESIGNED TO DETERMINE**

1. If unique geochemical, microbial and isotopic signatures could be identified in surface media overlying known high-grade, unconformity-related uranium deposits at depths >500 m;

2. If pathfinder elements, gaseous compounds, microbial and isotopic signatures can be characterized as distinct, deposit-sourced expressions versus natural geochemical variations related to surficial geology or environmental effects, and;

3. If unique surface geochemical signals can be correlated with other remote sensing deposit indicators and physical rock characteristics (such as electromagnetic (EM) conductors, magnetic-low, resistivity-low and gravity-low geophysical responses, and structural and lineament trends) to more precisely vector drilling toward a deposit at depth.

The combined anomalous surface geochemical signals obtained from the various surface media analyzed (tree-cores, clay-sized fractions of soils, and MET (Microbial Exploration Technology)) over these known high-grade uranium deposits (Cigar West and Centennial) clearly defined the projection to the surface of these deposits and their associated structures. The spatial relationship and surface distribution of certain pathfinder elements, radiogenic lead (Pb) isotopic ratios ($^{207}$Pb/$^{206}$Pb), and microbial by-products in the media analyzed, have provided a compelling, coincident surface anomaly that, when displayed with other known geophysical data and interpreted structural patterns, would clearly direct drilling to a deposit in a ‘green-fields’ exploration setting.

Subsequent to the Uravan surface geochemical surveys, four reconnaissance drill programs were conducted between 2011 and 2015 on a number of Uravan’s active projects. These drill programs tested anomalous surface geochemical clusters and trends that were coincident with magnetic and EM geophysical features. The evaluation of the data collected clearly supports the concept that unique combinations of elements, gaseous compounds and isotopic signatures migrate from mineralization at depth through faulted and fractured sandstone to the surface environment where they can be geochemically measured by analyzing soils and trees. Many of these drill holes are viewed as near misses by Uravan’s technical group (i.e. Halliday Lake, 2012, Stewardson Lake Area A, 2014 and Stewardson Area B, 2015) ([web link](#)). Drilling at Stewardson Area B in 2015, targeting surface geochemistry and coincident airborne ZTEM geophysical conductors, was successful in identifying a significant sandstone-hosted U-enriched hydrothermal system as part of a first pass drill program in an area where the depth to the unconformity is greater than 1100 m ([press release link](#)). A follow up drill program in this area will be conducted in the near future.

**SURFACE MEDIA AND ANALYSIS**

Uravan’s surface geochemical studies and property surveys involve the systematic sampling of soils and tree cores over a predefined grid (200 m to 500 m spacing). Media include:

1. B- and C-horizon soils for the separation of the clay-size fraction (<2 μm) followed by analysis for 53 elements plus all rare earth elements (REEs) and lead (Pb) isotopes by ICP-MS and ICP-ES;
2. Tree cores (from black spruce and jack pine) for the analysis of 50 elements and lead (Pb) isotopes by High-Resolution ICP-SFMS and;

3. A2-horizon soil for analysis of present-day surface microbial activity.

In addition to the various surface media sampled, certain meta-data are collected, such as in-hole radiometric measurements, soil Ph., soil moisture, sandstone boulders for clay mineral identification using short-wavelength infrared (SWIR) spectroscopy and surface lithologic pebble counts. This information is vital for the evaluation of analytical results obtained from the surface media, and critical for the integration with geophysical data.

**EXAMPLE - SURFACE GEOCHEMICAL SAMPLING PROGRAM**

The following is a cost estimate of a hypothetical surface geochemical sampling program based on certain survey parameters as described below:

<table>
<thead>
<tr>
<th>Program Details</th>
<th>Program Size (Ha)</th>
<th>Grid Size (m)</th>
<th>Sample Sites</th>
<th>Media Collected (per site)</th>
<th>Total Samples</th>
<th>Sample Sites/day</th>
<th>Program Days</th>
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<tr>
<td></td>
<td>15,000</td>
<td>500</td>
<td>600</td>
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<th>Personnel Details</th>
<th>Crew Size</th>
<th>Crews/Survey</th>
<th>Supervision</th>
<th>Total Personnel</th>
<th>Personnel Cost/Man-day</th>
<th>Supervision Cost/Man-day</th>
<th>Collection Cost/days</th>
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<th>Sample Prep &amp; Analysis Details</th>
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<th>Clay Fraction Prep (Per sample)</th>
<th>Clay Analysis (per sample)</th>
<th>Tree Core Prep (Per sample)</th>
<th>Tree Core Analysis (Per sample)</th>
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<th>Planning/Logistics</th>
<th>Mob/Demob</th>
<th>Camp-Op/Day</th>
<th>Helicopter Support (Per day)</th>
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Based on the surface program parameters defined above, a 15,000-hectare property can be evaluated by collecting three media at 600 sample sites (500 m grid spacing) totaling about $448 per sample site (Table 1). To streamline this survey, thereby collecting and analyzing only clay-size fraction (<2 μm) from the B- or C-horizon soils the per sample site costs drops to $218.
**CONCLUSIONS**

Uravan’s surface geochemical techniques are not seen as a stand-alone exploration tool. However, by leveraging these novel techniques with other remote-sensing technologies, such as geophysical data, radiometric and radon data, they will promote:

1. The rapid evaluation of under-explored deeper terrain in sandstone basin environments,

2. More cost-effective exploration, by identifying geochemically fertile geophysical trends rather than blind drilling, and;

3. Vectoring drilling to specific, more prospective targets, along the trends of geophysical anomalies thereby reducing the number of drill holes to discovery.

**REFERENCES:**


