Geochemical anomalies in surface media and uppermost sandstones overlying the concealed Phoenix uranium deposit, Athabasca Basin, SK.

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Introduction

The Wheeler River Property, host of Denison Mines Corporation's Phoenix uranium deposit, is situated near the southeastern rim of the Athabasca Basin in Northern Saskatchewan (Figure 1). The mineral resources drilled to date are inferred to contain 39.5 million pounds U_3O_8, within 4 distinct ore bodies that remain open along strike (Arseneau and Revering, 2010). This deposit was originally thought to have no surficial expression, and occurs near the unconformity between the early Paleoproterozoic crystalline basement rocks and the overlying Athabasca Group sandstones approximately 400 metres below the surface.

In September 2011, we initiated a study to evaluate i) whether geochemical anomalies related to such a deeply-seated deposit exist in surface media (soil, gas, water, till) and the uppermost sandstones over the deposit, ii) which type of surface media display anomalies, and iii) what is the most efficient analytical method to detect these anomalies.

Fig. 1: Location of Denison Mines Corporation Wheeler River property, hosting the Phoenix Deposit, in the Athabasca Basin.

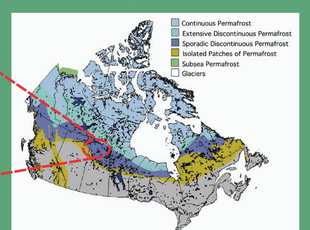

Fig. 2: Distribution of permafrost area. The Athabasca Basin is within the region of mainly sporadic discontinuous permafrost (Burgess et al., 1999).

Study Area

The Athabasca Basin experiences a sub-arctic climate (Figure 2) with long, dry, cold winters and warm, wet summers. The surface topography on the Wheeler River Property consists mainly of gently rolling hills of glacial moraines and till (Figure 3), and has experienced several ice flow episodes (*cf.* Campbell, 2007). The area is covered with ~3 m tall young black spruce trees, caribou moss and minor shrubbery (Figure 4). The overburden is typically 25 to 100 m thick and overlies sandstones of the Manitou Falls Formation. The study area receives approximately 475 mm of annual precipitation.

Fig. 3: Lease road at the Wheeler River Property. The small hills in the background indicate gentle topographical relief.

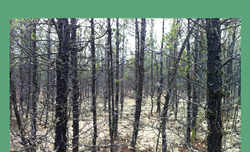

Fig. 4: View through the forest, with abundant young black spruce and extensive mossy undergrowth.

Sampling & Analysis

In September 2011, a total of 226 soil samples (humus, B-, E-, and C-horizons) from 59 sites along 3 transects over the "A" and "B" ore zones were collected approximately 10 metres apart in undisturbed forest (Figures 5 and 6). Humus and C-horizon samples were subjected to *aqua regia* digestion, whereas B-horizon soil samples underwent both *ammonium acetate* and *hydroxylamine* leaches, with all elements measured by ICP-MS. Soils were dried at 60°C to minimize loss of volatile elements, and screened at 180 m (-80 mesh ASTM).

pH and conductivity were measured for soil-water *in-situ* shortly after sampling. The 74 sandstone core samples used in this study were subjected to near total digestion and subsequent analysis with ICP-MS and also ICP-OES.

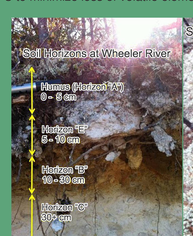

Fig. 5: Soil horizon profile at Wheeler River, with a marker in the upper left for scale. It is characterized by a thin humus layer with substantial E- and B-horizons at most sites.

Fig. 6: Soil profile at the site PHX 041, with the humus, E- and top of B- horizons clearly visible.

Transects for Sampling

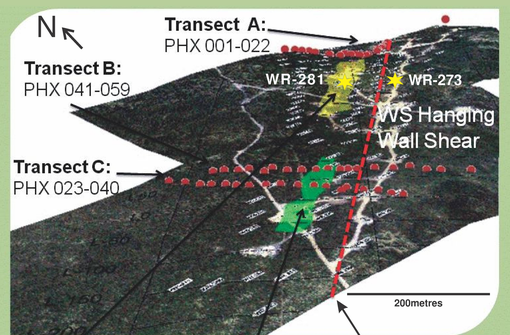

Fig. 8: Sampling was conducted along three transects A, B, and C (red dots) that include the areas directly above the ore zones and northeast-trending WS Hanging Wall Shear Zone. The basement projection of two ore zones (yellow and green areas) and the WS Hanging Wall Shear Zone (red dashed line) are shown on the map.

Cross Section

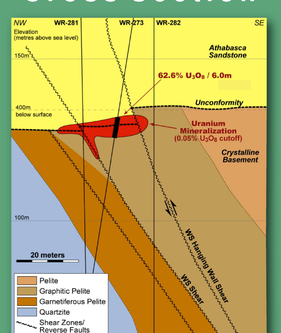

Fig. 7: Schematic cross section of the Phoenix deposit by Gamelin et al. (2010). The deposit straddles the unconformity between the crystalline basement and the Athabasca Manitou Falls sandstone units. Note the presence of the WS Hanging Wall shear zone, which extends to the surface and may have acted as a conduit for fluid movement.

Results

Results show strong anomalies of Co, Ni, U, Mo, Ag, W in humus, lesser anomalies of U, Pb, Ni and W in B-horizon soil and Mo, Cu and Ni in C-horizon till not only overlying the A and B zones, but also immediately southeast of the deposit where a northeast-trending WS Hanging Wall Shear Zone is located. Anomalies are also present in the uppermost sandstone map, based on drill hole data (locations shown with small blue dots). The traverse sampling method provided the location of anomalies and background values in these given environments.

Humus & Sandstone

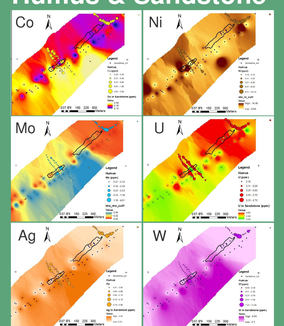

Fig. 9: Element transect maps overlain on concentration of the same elements in the uppermost sandstones. Anomalies in surface media are up to 20 times background values for Ni, Cu, and U, more than 50 times for Mo, ~ 250 times for Ag and ~ 70 times for W. Sandstone values are comparable to the humus values. Interpolation by Inverse Distance Weighting (IDW)

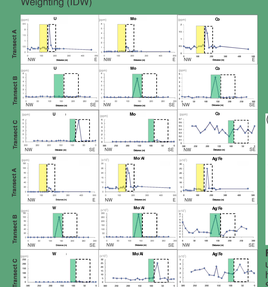

Fig. 11: Aqua regia digestion of humus along the 3 transects. Highlighted are the surface projections of ore zones (coloured) and the WS Hanging Wall Shear Zone (dashed line).

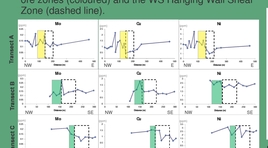

Fig. 15: Aqua regia digestion results of till C-horizon. The anomalies above the basement expression of the shear zone suggest upward movement of elements from the ore bodies.

B-horizon & Sandstone

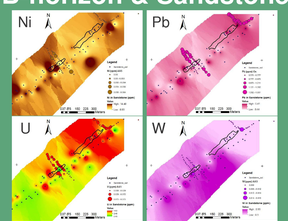

Fig. 10. Element transect maps of Ni, Pb, U and W for B-horizon samples treated with ammonium acetate (AA5) leach (Ni, U, W) and hydroxylamine (Ox) leach (Pb), underlain by concentrations of the same elements in the uppermost sandstones. Anomalies were more pronounced with respect to the background in weak leach such as AA5.

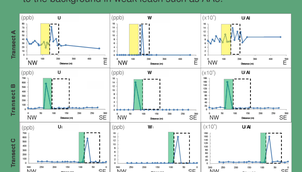

Fig. 12: Ammonium acetate leach results of B-horizon soil. The anomalies above the shear zone suggest upward movement of elements from the ore bodies.

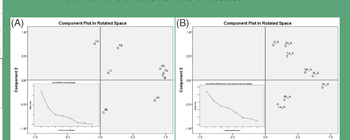

Fig. 13: Principal component analysis (with associated screeplots) of uranium and associated pathfinder elements in humus (A) and B-horizon (B, hydroxylamine leach method) exhibiting distinct groupings of elements. IBM SPSS Statistics version 20.0 was used to generate the plots.

C-horizon & Sandstone

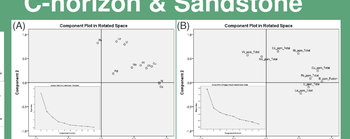

Fig. 14: Principal component analysis and associated screeplots of uranium and associated pathfinder elements in till C-horizon (A) and the uppermost sandstone units of the drill cores (B). U, La and Pb group together in both media whereas the pathfinder elements exhibit different elemental associations.

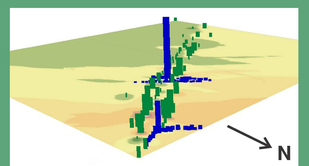

Fig. 16: 3-D peak to background view of humus aqua regia leach results (blue bars) and uppermost sandstone data for U (green bars) looking from NE to SW as well as the sandstone raster in 2D for reference

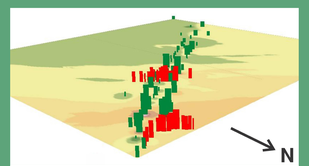

Fig. 17: 3-D peak to background view of soil results for aqua regia leach of C-horizon till (red bars) and uppermost sandstone data for U (green bars) looking from NE to SW, as well as the sandstone raster in 2D for reference

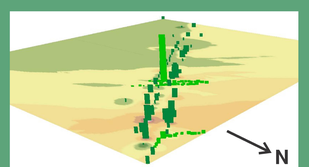

Fig. 18: 3-D peak to background view of acetate leach data of B-horizon soil (lime green bars) and uppermost sandstone data for U (green bars) looking from NE to SW as well as the sandstone raster in 2D for reference.

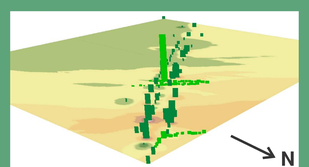

Fig. 19: 3-D peak to background view of the data after hydroxylamine leach of B-horizon soil (lime green bars) and uppermost sandstone data for U (green bars) looking from NE to SW as well as the sandstone raster in 2D for reference.

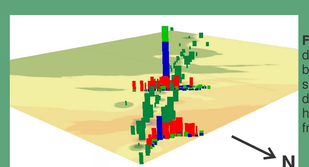

Fig. 20: 3-D peak to background view of all soil data and uppermost sandstone data for U (green bars) looking from NE to SW as well as the sandstone raster in 2D for reference. Aqua regia digestion of humus (blue), acetate leach of B-horizon soil (lime green), aqua regia digestion of silt fraction of C-horizon (red).

Summary

- Low background values suggest that there is no effect from potential sources of contamination, such as dust particles from the nearby Key Lake uranium milling facility.
- Geochemical anomalies exist in surface media, although the distribution is narrow, restricted to within 10 metres of either the surface projection of the deposits or above the WS Hanging Wall shear zone.
- Broad anomalies in the uppermost sandstones near shear zones suggest upward movement of metals from the ore bodies through sandstone.

Ongoing Work

- Geochemical analysis of water samples from drill holes
- Noble gas abundance analysis of gas samples collected from selected drill holes
- Lead isotope compositions will be determined with a TIMS
- Evaluate the migration mechanisms of elements from a deposit at 400 m below the surface & integration into exploration geochemical models

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