Surface Media Expressions of buried uranium: the Phoenix & Millennium deposits, Athabasca Basin, Saskatchewan, Canada

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Abstract. To detect buried uranium deposits using surficial geochemistry, we selected two known deposits: Phoenix and Millennium. The Phoenix has indicated resources of 52.3 million lbs U_3O_8 at ~400 m depth, whereas Millennium has indicated resources of 46.8 million lbs U_3O_8, at ~750 m depth. Both are located in the southeastern Athabasca Basin, Saskatchewan, Canada. Sampling in 2011 above Phoenix yielded anomalous U, Pb, Ni, Cu, Mo, As and W in humus, B-horizon soil, till and uppermost sandstones above the deposit and WS Shear zone. 2012 sampling reproduced anomalies in soil (2-17 ppm U, 10-27 ppm Cu, 4-7 ppm Ni, 1-1.5 ppm As) in total and partial leaches. Leaching of humus in various acid solutions shows that metals are tightly held in organics. Soil sampling over Millennium in 2012 yielded broad anomalies in U (0.4-0.6 ppm), Pb (15-35 ppm) and Cu (5-15 ppm) in partial leaches of humus and B-horizon soil above the deposit & B1 and Marker faults. Results suggest upward migration of mobile metal ions from these deposits to surface.

Keywords. surficial geochemistry, uranium exploration, glaciated terrain, Athabasca Basin.

1 Introduction

In order to evaluate surficial geochemical anomalies over deeply buried uranium deposits, we selected two deposits with no apparent surface expression of mineralization: the Phoenix and Millennium deposits (Fig. 1). The Phoenix deposit, owned by Denison Mines Corporation, occurs along the unconformity between the dominantly siliciclastic Athabasca Group sandstones and the crystalline basement rocks. It has currently defined indicated resources of 52.3 million lbs U_3O_8 situated ~400 m below the surface (Roscoe, 2012), whereas Cameco Corporation's basement-hosted Millennium deposit has indicated resources of 68.2 million lbs U_3O_8 at a depth of ~750 m (Cameco internal report).

Both deposits are located in the southeastern margin of the Athabasca Basin in northern Saskatchewan, a region of sporadic discontinuous permafrost (Burgess et al., 1999). 25-30 m thick glacial tills comprised of moraine plains, streamlined moraines and subordinate eskers cover the area (Schreiner 1984; Campbell 2007). Whole rock compositions of till samples from both properties suggest that the glacial sediments were sourced from a mixture of granitic basement rocks and Athabasca Group sandstones.

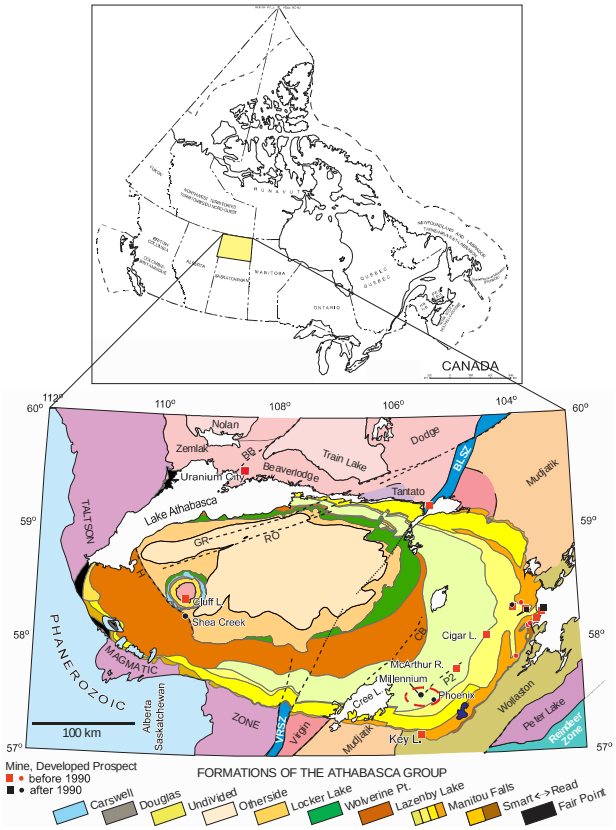

Figure 1. Location map of the Athabasca Basin, Saskatchewan, Canada, and the study area (dashed red oval) hosting the Phoenix & Millennium deposits in the southeastern Athabasca Basin. Geology from Jefferson et al. (2007).

At Phoenix, the mineralization is mostly pitchblende, with anomalous amounts of Cu (up to 3,100 ppm Cu) and Pb (up to 9.83 wt % Pb), and minor Ni (up to 461 ppm Ni), Co (up to 119 ppm Co), As (up to 170 ppm As), Zn (up to 1,070 ppm Zn) and Ag (up to 0.1 ppm Ag) (Kerr, 2011; this study).

For both systems, alteration mineralogy in the overlying Athabasca Group is typical of Athabasca unconformity-related uranium systems with varying silicification and de-silification, tourmaline, chlorite, illite, kaolinite, hematite and drusy quartz. Of note, both properties also occur within the northeast-trending, regional illite and chlorite trend defined by Earle and Sopuck (1989).

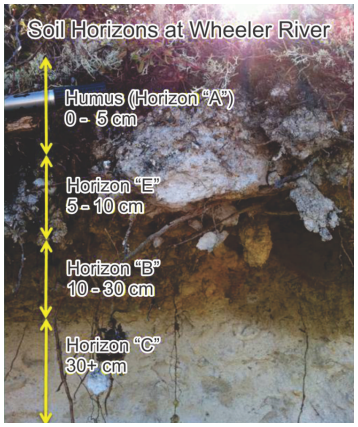

Figure 2. Typical soil horizon profile at Phoenix. The humus layer includes charcoal from a previous forest fire event. The photo was taken at 57° 30' 32.285" N, 105° 23' 10.768" W

2 Results from the Phoenix Study

2011 field sampling (sampling method, Fig. 2) above the Phoenix deposit yielded anomalous concentrations of U, Pb, Ni, Cu, Mo, As and W in humus, B-horizon soil and C-horizon glacial till in the areas directly above the A and B ore zones and the WS Shear zone (humus, Figs. 3 & 4). 2012 sampling reproduced similar geochemical anomalies in soil samples (2-17 ppm U, 10-27 ppm Cu, 4-7 ppm Ni, 1000-1500 ppb As; Figs. 4 & 5). Furthermore, leaching of humus samples in H_2O, HBr, HNO_3 and HF-HBr solutions showed that these metals are not simply adsorbed on the surface; instead, they are tightly held in organics (Fig. 6). Finally, analyses of the uppermost Manitou Falls Dunlop Formation sandstones by partial HF-HNO_3-HCl digestion above the ore zones contain anomalous U (up to 2 ppm, Fig. 4).

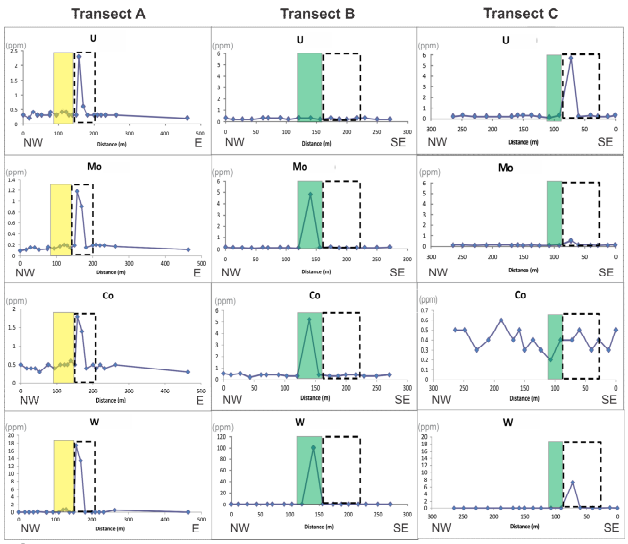

Figure 3. Metal abundances along the 2011 transects at Phoenix: U, Mo, Co, W in humus from the 2011 sampling programme after aqua regia digestion. The boxes indicate the areas directly above ore Zones A & B1, and the dotted rectangle encompasses the expression of the WS Hanging Wall shear at the unconformity.

3 Results from the Millennium Study

Soil sampling was carried out along transects over the Millennium deposit in the summer of 2012. These samples yielded anomalies in U (0.4-0.6 ppm), Pb (15-35 ppm) and Cu (5-15 ppm) from aqua regia digestions of humus as well as anomalies in ammonium acetate leaches of B horizon soils above the ore zones and surface traces of B1 and Marker faults (Fig. 7). Broad surficial geochemical anomalies in the property likely reflect abundant faults and fault-bound mineralization.

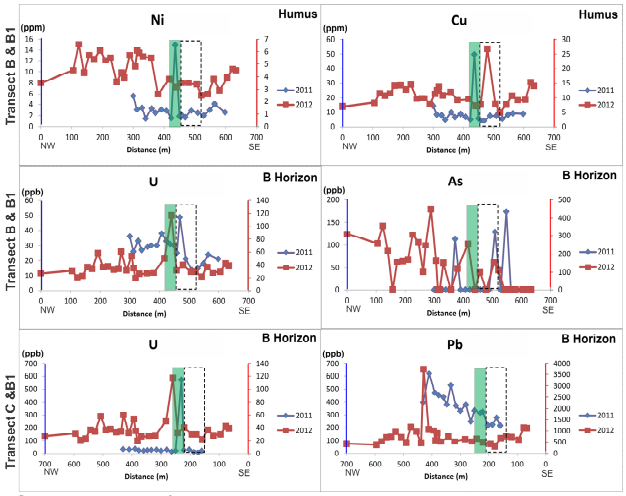

Figure 4. Metal abundances along the 2011 B and C transects & 2012 B1 transect at Phoenix: Ni, Cu, U, As and Pb after aqua regia digestion. The box indicates the area directly above Zone B1, and the dotted rectangle encompasses the expression of the WS Hanging Wall shear at the unconformity.

4 Conclusions

The combined results suggest upward migration of mobile metal ions from the ore zones to the surface. As such, geochemical analysis of surface media is potentially an efficient and inexpensive exploration tool for detecting deeply-buried uranium deposits.

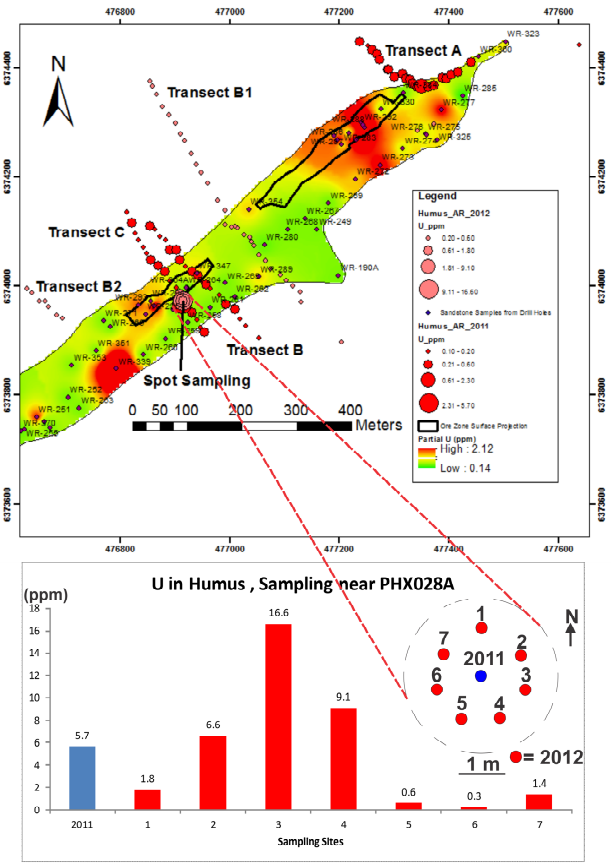

Figure 5. Graded geochemical results for U in humus soil samples from Transects A to C (2011), Transects B1-B2 & spot sampling (2012) and uppermost Dunlop Member sandstone (underlying raster). Inset is of dense 2012 humus soil sampling within 1 m from the 2011 site (PHX028) that showed the highest U value. The value on the left is the highest in the 2011 survey, and data in columns 1-7 are from 2012 spot sampling. The results confirm the reproducibility of the anomalous mobile metals trace elements observed in 2011.

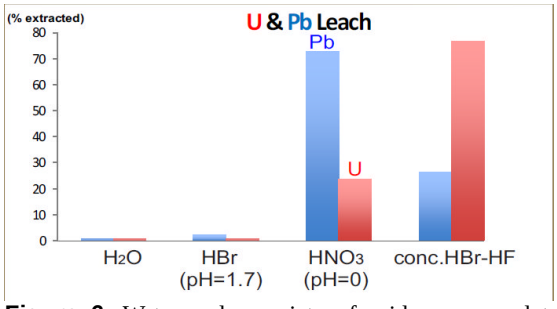

Figure 6. Water and a variety of acids were used to extract metals (Cu, Ni, Co, As, U, Pb) from a humus sample. Humus did not release significant amounts of metals in water and weak HBr (pH=1.7). The samples were dried at 60°C, and sieved to -80 mesh (0.177 mm). After adding Milli-Q water, we manually shook the samples several times and let them stand at room temperature for about an hour, after which they were again shaken manually. After removing the solids, then solution was then centrifuged, and analyzed via ICP-MS. Similar procedures were repeated with 0.02 M HBr, 1 N HNO_3 (25°C) and a hot (100°C) concentrated mixture of 3:2 HF-HBr.

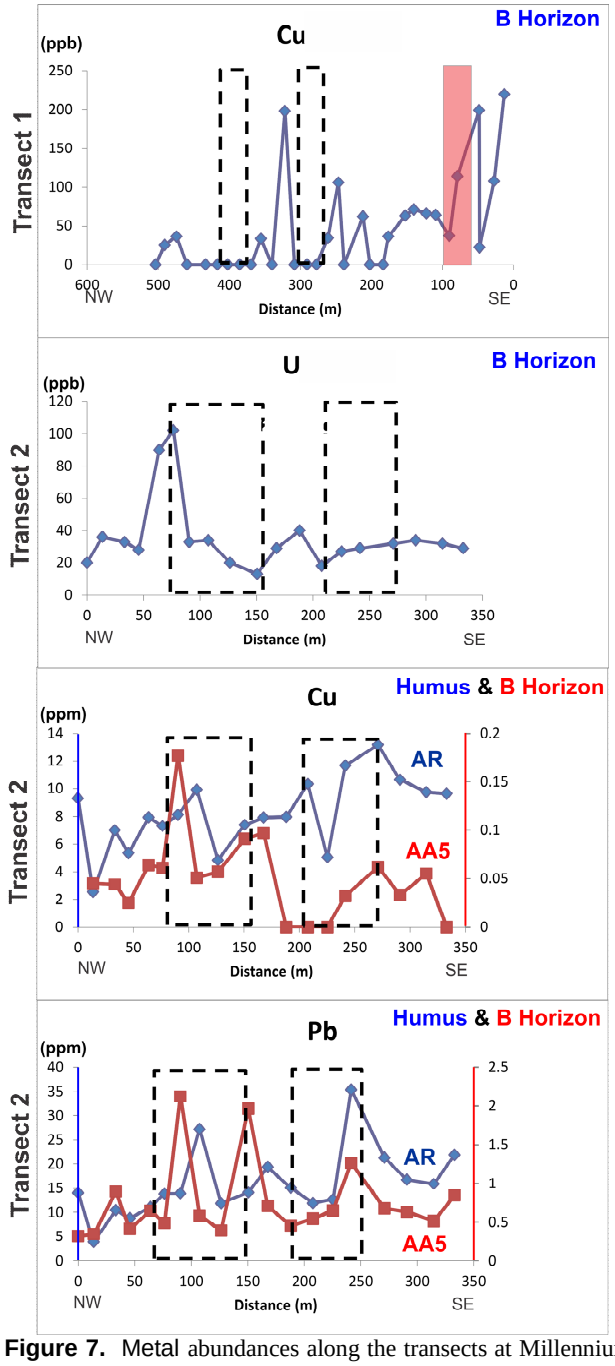

Figure 7. Metal abundances along the transects at Millennium: Cu, U and Pb after aqua regia digestion and ammonium acetate weak leach of humus and B horizon soils, respectively. The shaded area indicates the area directly above the ore zone, and dashed lines indicate the likely surface expression of the Marker and B1 faults.

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