

# Surficial Geochemistry associated with the deeply buried Millennium and Phoenix Uranium Deposits, Athabasca Basin, Northern Saskatchewan

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## Introduction

The Millennium and Phoenix deposits are located in the southeastern corner of the Athabasca Basin, Northern Saskatchewan. Both unconformity-related deposits produced geochemical anomalies that were detected in soils and ground water during surveying in 2011 and 2012 (Power et al., 2013). This 2013 study aimed to: i) evaluate the reproducibility of geochemical anomalies, ii) increase the sample population and iii) determine which surface media (soil or gas) produces the most robust signatures.

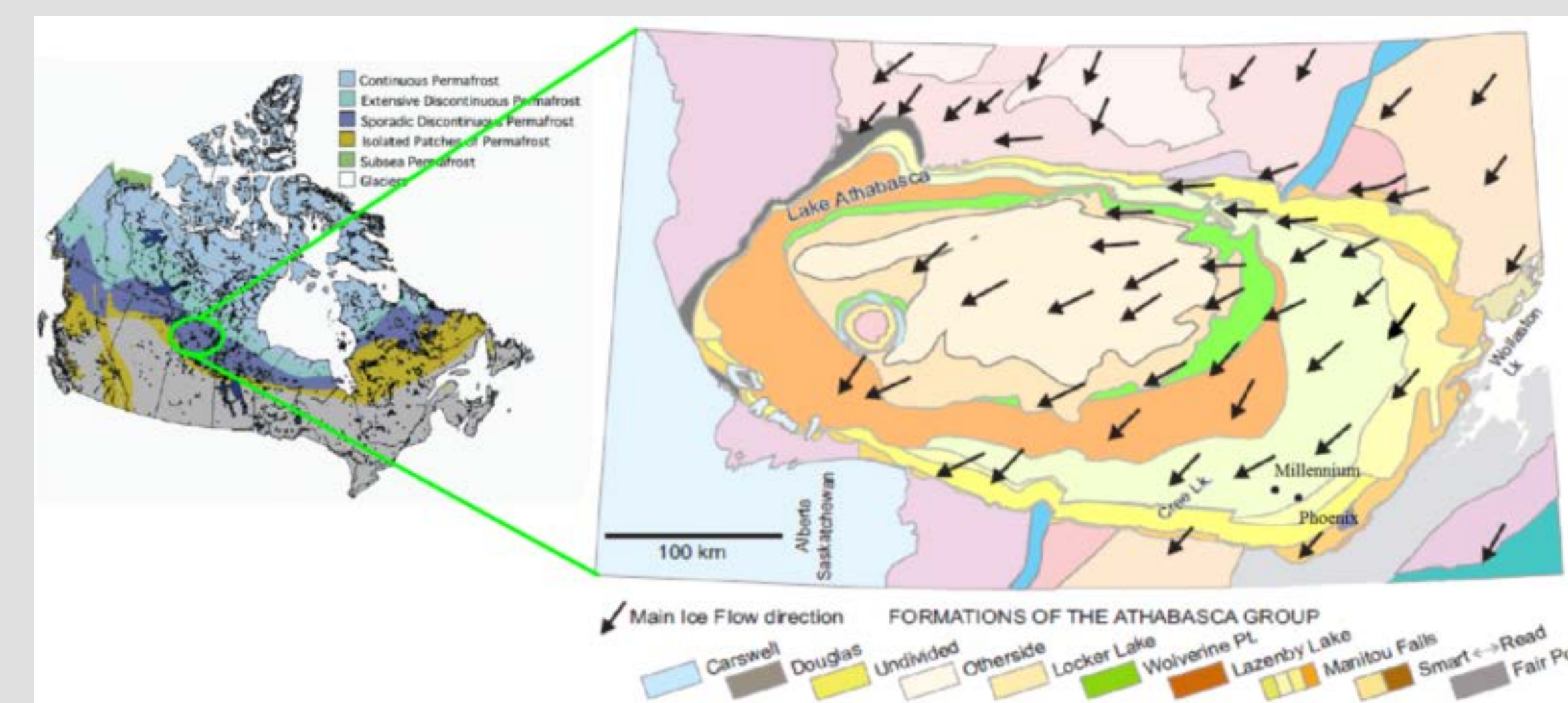


Fig. 1: Permafrost map of Canada shows that the Athabasca Basin is within the region of sporadic discontinuous permafrost (dark blue colored region; Burgess et al., 1999). Inset shows regional ice flow directions of the last glaciation (Campbell, 2007, and geology from Jefferson et al., 2007).

## Field Area

The area has a sub-arctic climate with cold, dry winters and warm, wet summers. Undisturbed boreal forest and unconsolidated glacial sediments characterize the property. Glacial sediments are 20–25 m thick above the Phoenix and Millennium sites. The dominant land forms are lakes, eskers and drumlins oriented to the southwest.

## Techniques

Soil horizon thickness varies depending on topographic relief and vegetation. Samples were collected approximately 20 m apart in undisturbed forest (Fig. 2).

Samples were analyzed with ICP-MS after aqua regia digestion (humus) or ammonia acetate leaches (B-horizon) at Acme Labs in Vancouver.

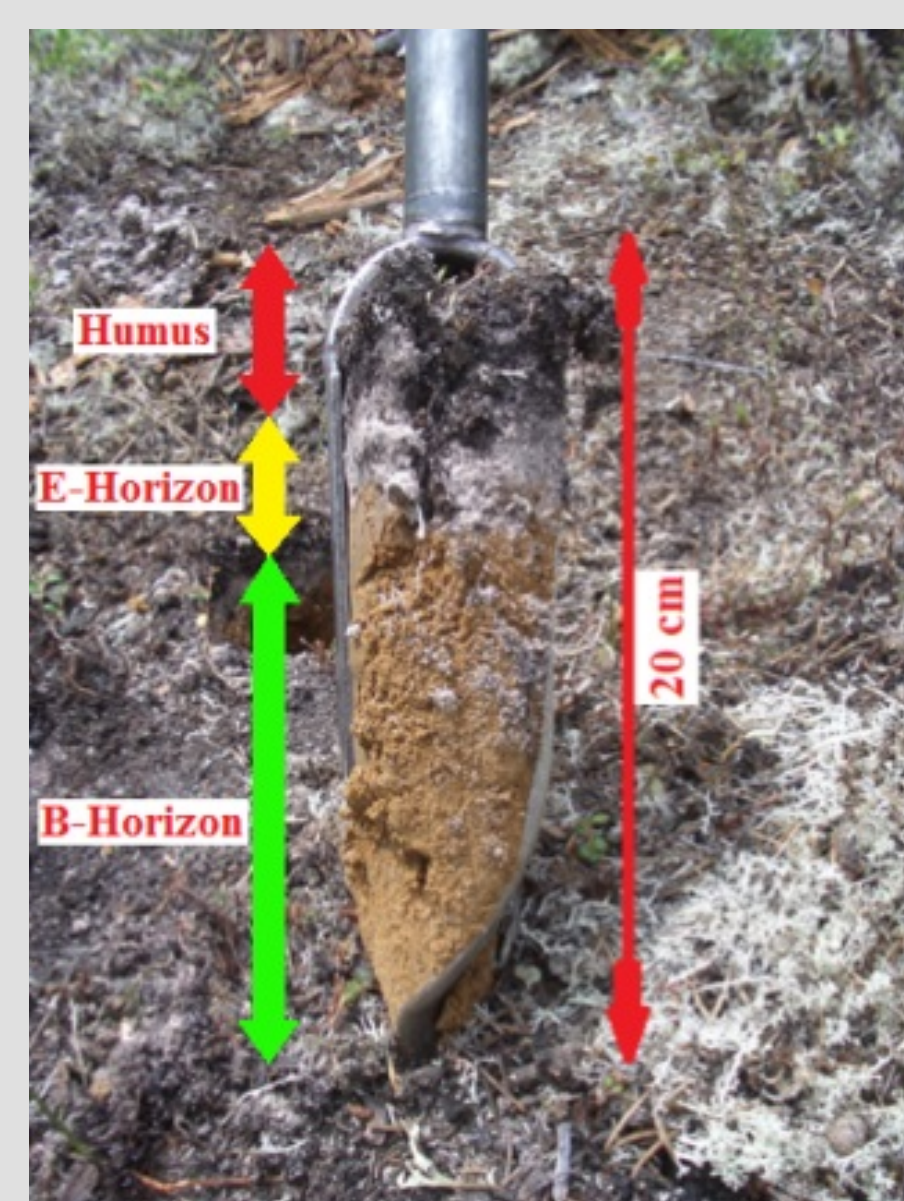
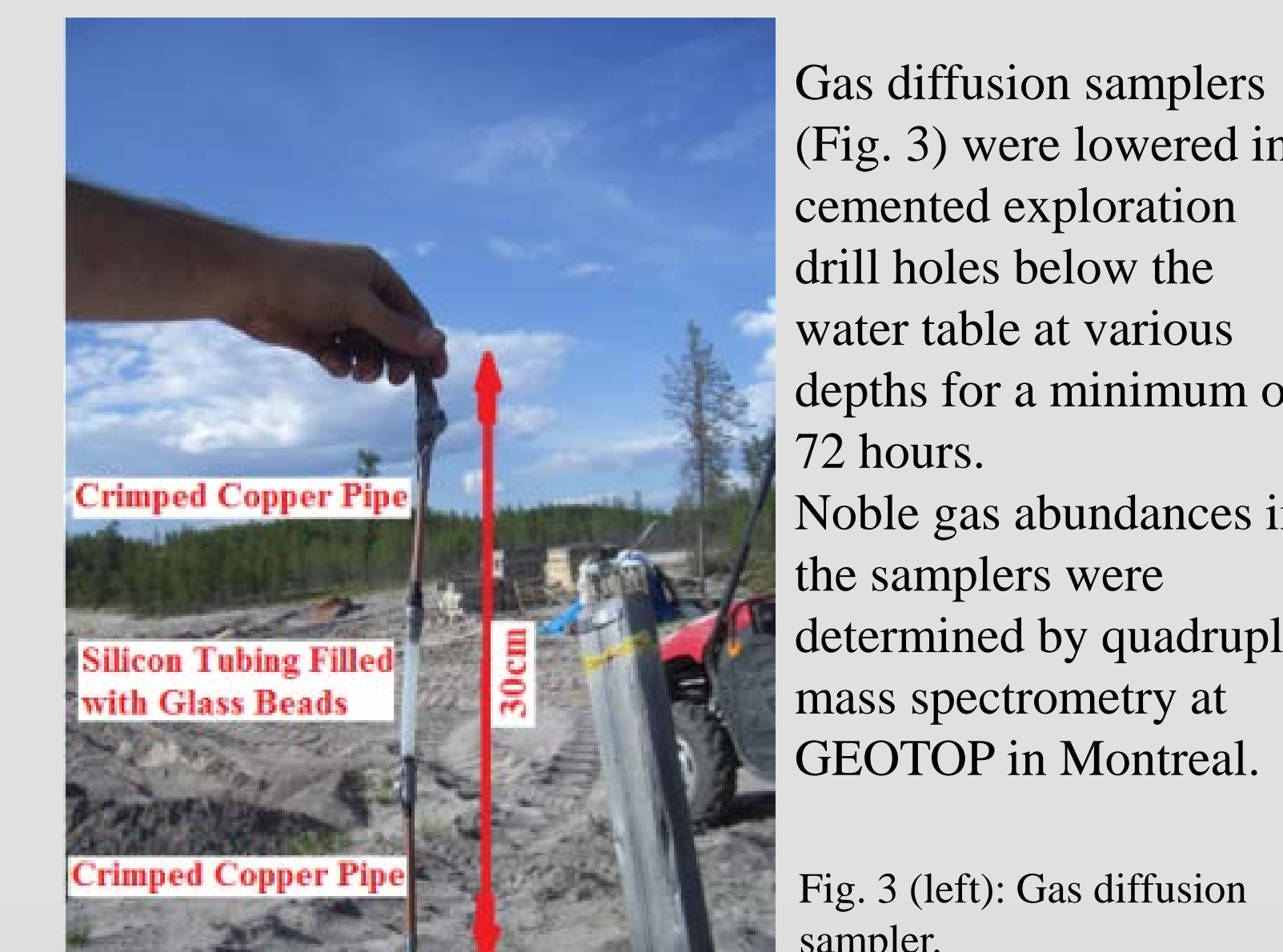


Fig. 2: Dutch auger with representative soil profile.



Gas diffusion samplers (Fig. 3) were lowered in cased exploration drill holes below the water table at various depths for a minimum of 72 hours. Noble gas abundances in the samplers were determined by quadrupole mass spectrometry at GEOTOP in Montreal.

Fig. 3 (left): Gas diffusion sampler.

## Reproducibility of soil geochemical anomalies at the Phoenix Deposit

Dense sampling at one site along the Transect C confirmed a three year reproducibility of anomalies from 2011 through 2013 (Fig. 4a). Elevated uranium contents are found in humus overlying deposit B and are located on the surface projection of the WS Hanging Wall shear zone (Fig. 4).

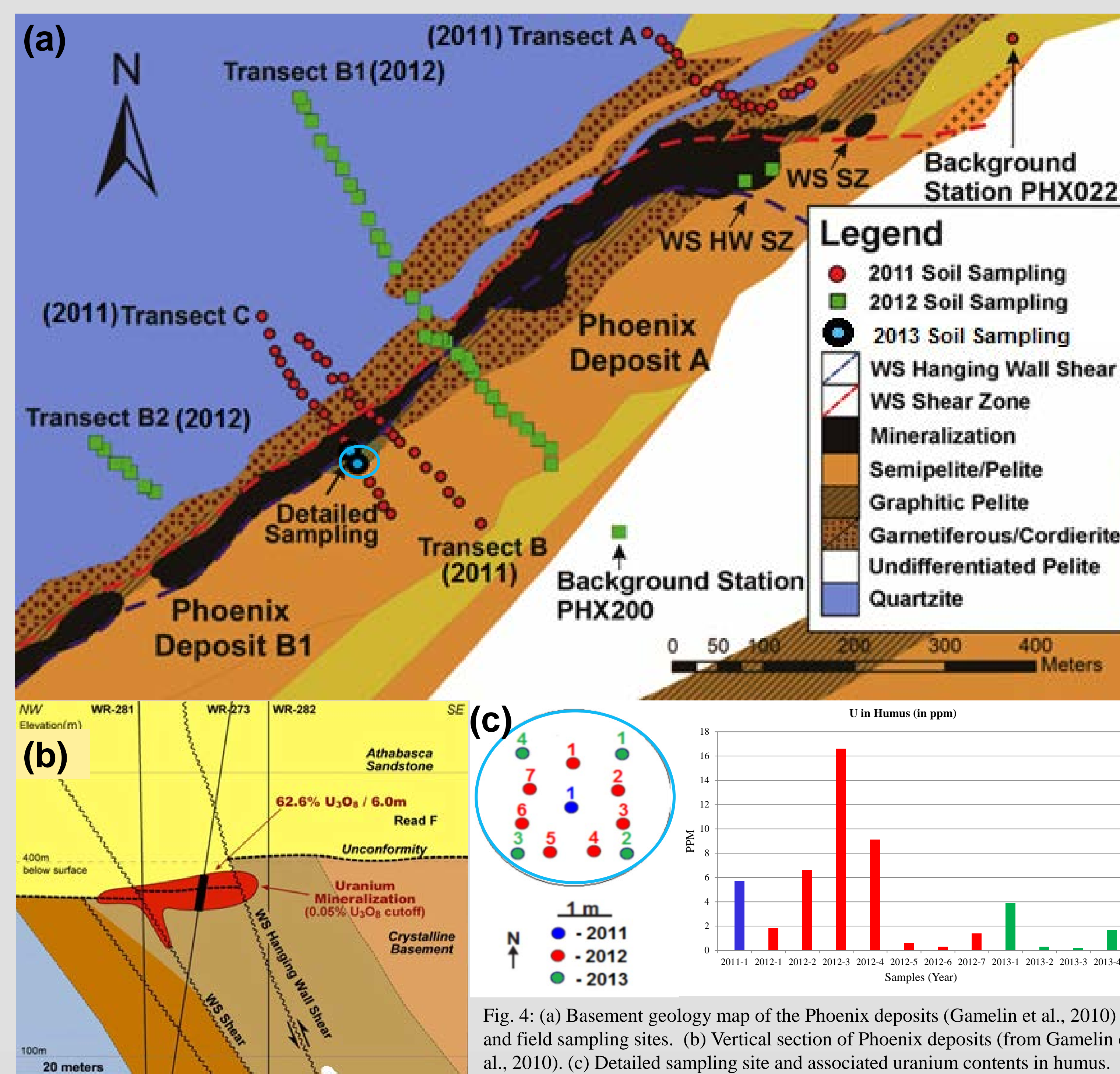


Fig. 4: (a) Basemetal geology map of the Phoenix deposits (Gamelin et al., 2010) and field sampling sites. (b) Vertical section of Phoenix deposits (from Gamelin et al., 2010). (c) Detailed sampling site and associated uranium contents in humus.

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## Millennium-Transect 3 soil analysis

Anomalous concentrations of Cu, U and Pb occur in humus and B-horizon samples from Millennium. The anomalies are located on the surface projections of the Mother, Marker and B1 faults and the area over the mineralized zones (Figs. 5 & 6). Surface traces of the faults illustrated on the map are based on reflection seismic data provided by Cameco Exploration.

The Q-Q plots represent all samples taken from Millennium during the 2012 and 2013 field seasons (total of 99 samples).

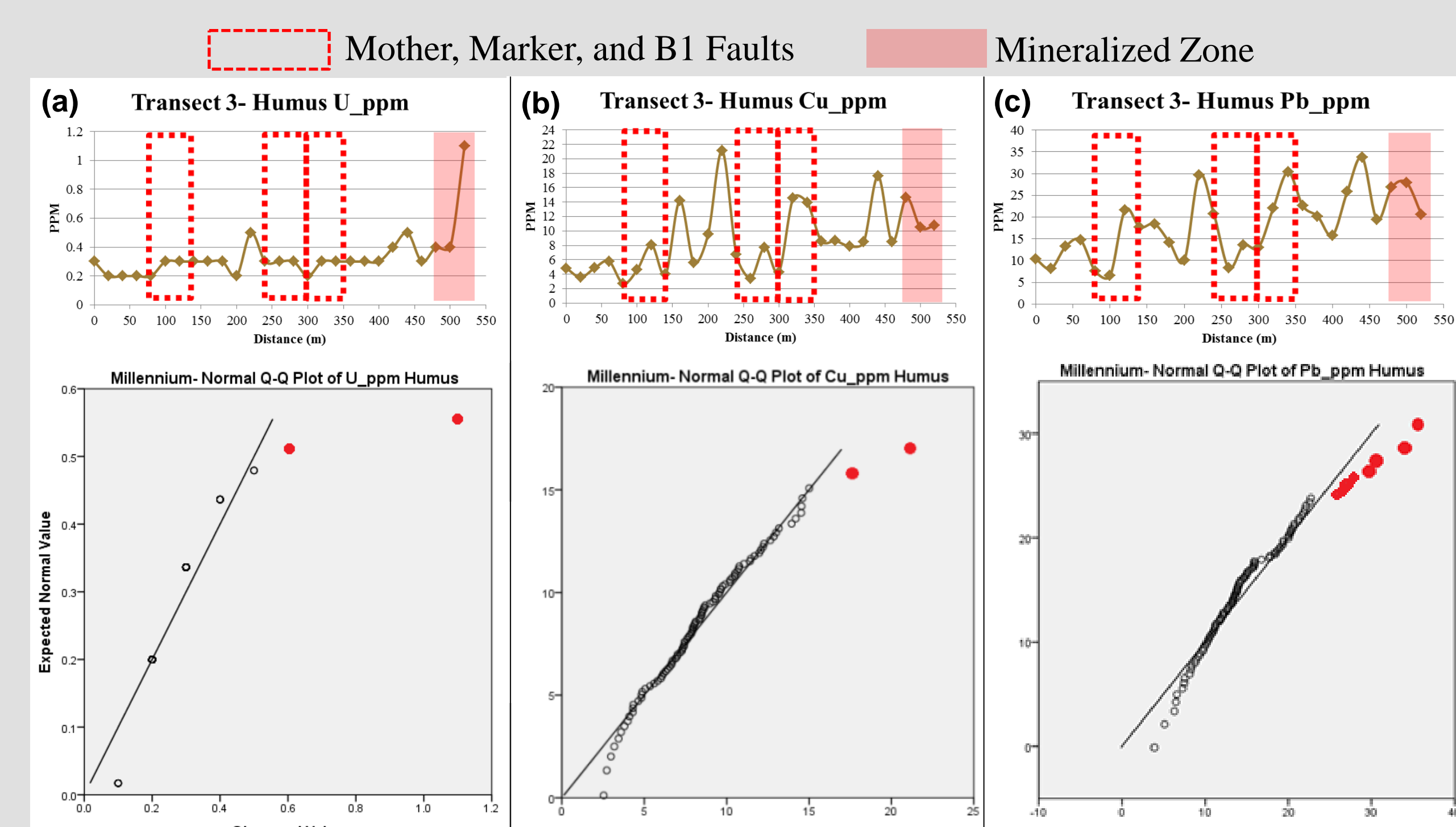


Fig. 5: (a) Uranium, (b) Cu and (c) Pb concentrations and associated Q-Q plots of humus along Transect 3.

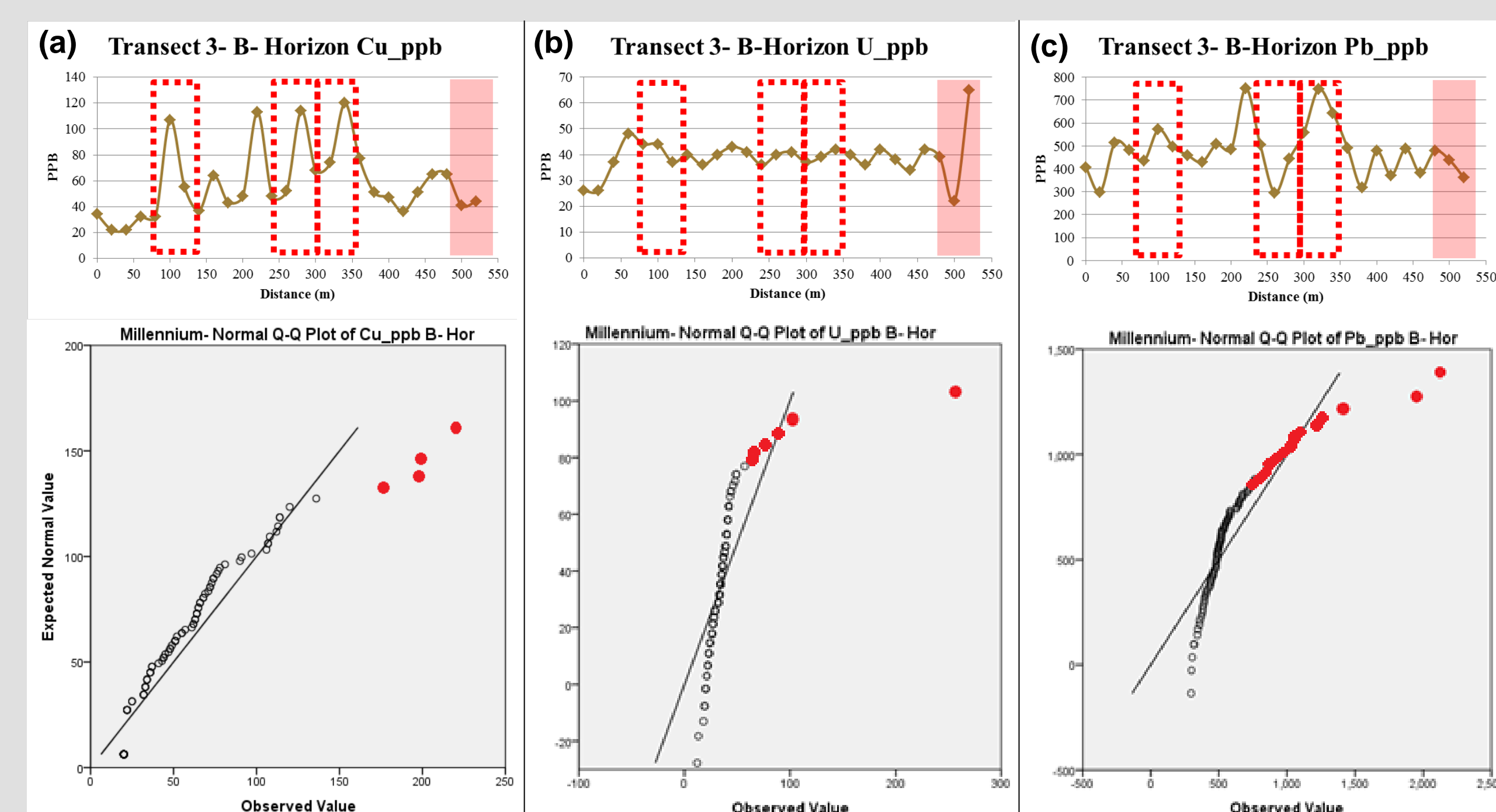


Fig. 6: (a) Copper, (b) U and (c) Pb concentrations and associated Q-Q plots for in ammonia acetate leach data of B-horizon soil along Transect 3 at Millennium.

## Millennium-helium gas data

Since <sup>4</sup>He is produced by the decay of uranium, elevated <sup>4</sup>He/<sup>36</sup>Ar values relative to that in equilibrium with the atmosphere indicate release of <sup>4</sup>He from the deposit into the groundwater. In 2012 and 2013 anomalous <sup>4</sup>He/<sup>36</sup>Ar ratios were recorded in drill holes near the deposit. All drill holes have steel casing through the glacial overburden (ca. 20 m) and are cemented at depth to prevent groundwater discharge. The ground water levels were approximately 10 m below the surface. The depth in the table is meters from the groundwater levels.

DDH	Year	Depth (m)	<sup>4</sup> He/ <sup>36</sup> Ar (sample)	<sup>4</sup> He/ <sup>36</sup> Ar (air)
CX-40	2012	10	108	
CX-40	2013	21	77	
CX-43	2013	16	45	
CX-52	2012	50	715	
CX-52	2013	10	18	
CX-52	2013	30	259	
CX-52	2013	47	120	
CX-58	2013	10	1.2	
CX-63	2013	20	0.8	
CX-86	2012	11	240	
CX-86	2013	30	216	
CX-98	2013	23	0.6	

## Reproducibility of soil geochemical anomalies at Millennium

Repeat sampling around the site that yielded high U in 2011 (Power et al., 2013) yielded anomalous concentrations of uranium in B-horizons soils.

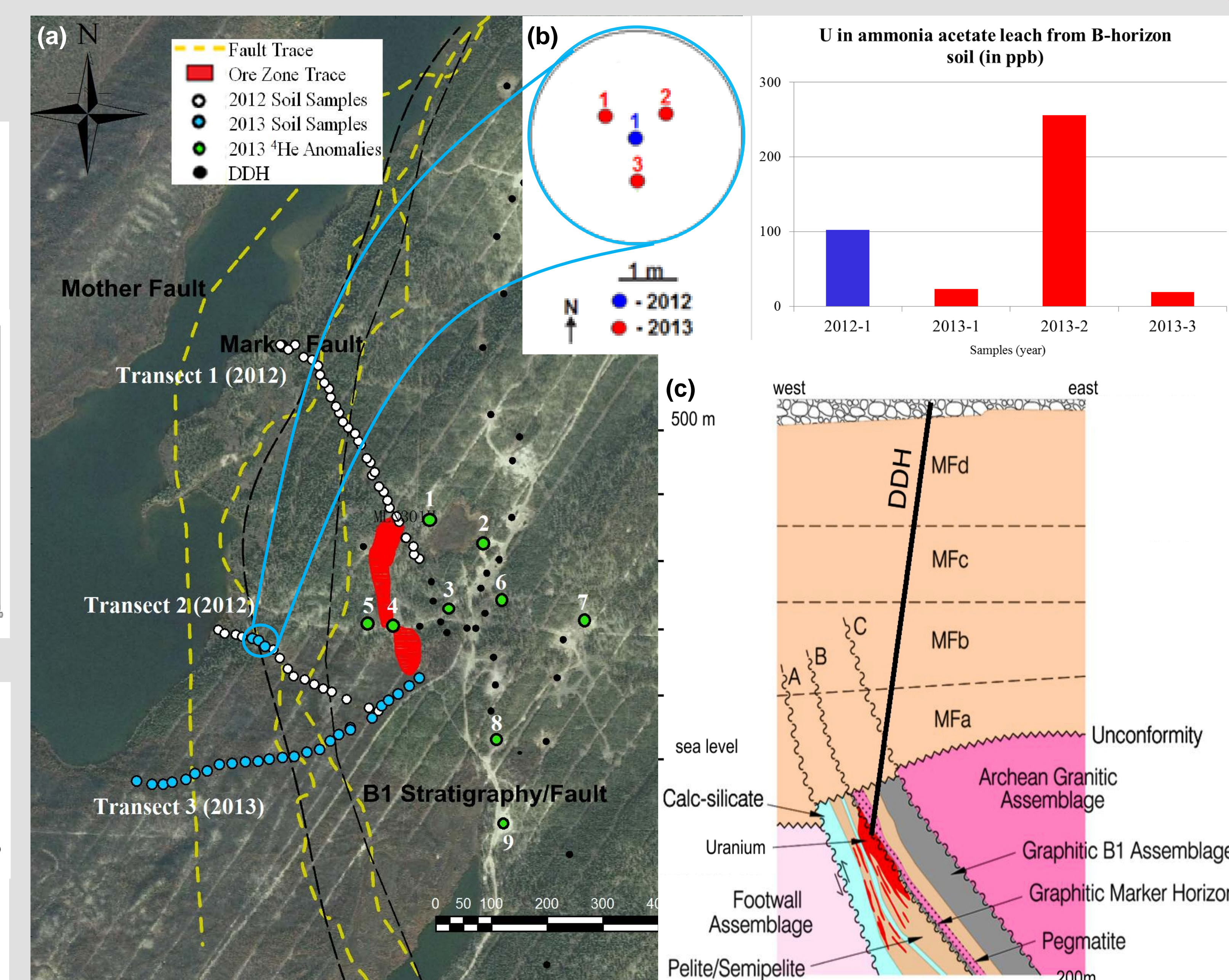


Fig. 7: (a) Aerial photo of the area, overlain with sampling sites and surface projections of the deposits and faults. (b) Uranium contents within the dense sampling area. (c) Vertical section of the Millennium deposit (modified after Wood et al., 2012)

## Summary

- At Millennium, 2013 results reproduced elevated Cu, U and Pb contents in both humus and B-horizon soil samples along the new transect.
- At Phoenix, elevated uranium contents were detected in humus samples for a third consecutive year.
- At both Millennium and Phoenix, surficial geochemical anomalies are spatially associated with faulting and shear zones, suggesting upwelling of metal-rich fluids along the faults.
- At Millennium, anomalous concentrations of <sup>4</sup>He are dissolved in groundwater overlying the Millennium deposit. <sup>4</sup>He anomalies are found in cemented drill holes that intersect and do not intersecting the deposit.
- The 2013 results confirm that strategic soil sampling is an efficient and inexpensive exploration technique to detect a deeply buried uranium deposits. Geochemical exploration is effective when combined with other exploration tools such as geophysical data.

## Acknowledgments

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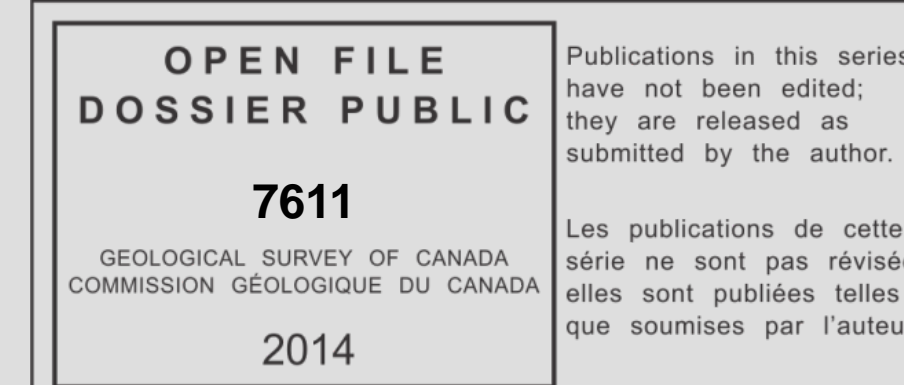
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