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CMIC-NSERC Exploration Footprints Research Network

The Dispersion of Radon Above Deeply Buried Uranium Ore: Millennium Deposit, Athabasca Basin, SK

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Introduction

The Athabasca Basin, Saskatchewan, hosts world-class high-grade uranium deposits and many occur along the unconformity between the crystalline basement and proterozoic Athabasca sandstones. The unconformity is at shallow depths in the eastern part of the Athabasca Basin (500 m), but it is at deeper levels (<1.5 km) towards the centre of the basin. Many of these U deposits occur below thick sandstones and overburden up to 900 m deep which poses a challenge during exploration. This study examines the behavior of radon (Rn) dissolved in groundwater at Cameco's Millennium deposit: a high-grade (~4-5 % U_3O_8), basement-hosted uranium deposit, which has 68.2 M lbs (indicated resource) and 22.3 M lbs (inferred resource) U_3O_8 at a depth of approximately 750 m.

Research Objectives

- Are Rn concentrations above the Millennium deposit high enough to be detected?
- How widespread are the anomalous values?
- What are the most effective sampling and analyzing techniques?
- Do other groundwater parameters (pH, conductivity and halogen content) correlate with Rn activity with depth?
- Do the physical properties of sample waters affect the analysis?

Field Methods

Sample locations were chosen based on varying proximity to the surface projection of the buried high-grade uranium. At each drill hole, water was collected close to the water level using copper bailers.

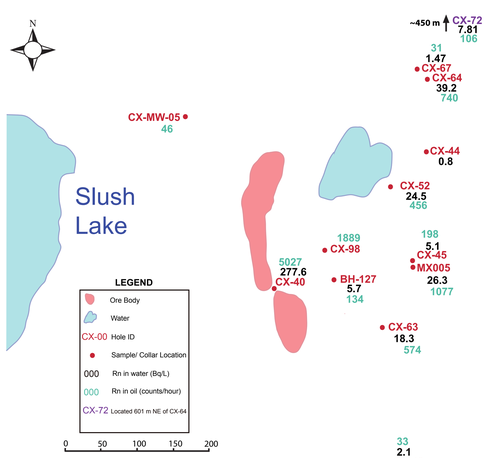

Fig. 1. Modified from *Location Map, Cameco Exploration, 2012.*
Plan view map showing sampling locations and surface projection of ore body. Black values indicate radon concentrations in Bq/L and green values indicate raw counts/hour of alpha spectrometry. Note that the high concentrations occur close to the ore body at CX-40 and CX-98.

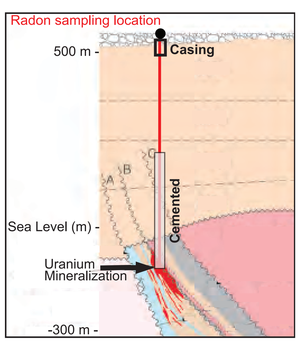

Fig. 2. Geological cross section of the Millennium deposit showing sample location relative to ore mineralization. Modified from Wood et al. (2012).

Analytical Methods & Results

Samples (n = 32) of gas dissolved in groundwater were collected from cased and cemented drill holes (n = 11) and shallow monitoring wells (n = 2). For this reason, it is considered that radon is dispersing from the uranium ore to shallow depths via groundwater and fractures within the basement and sandstones.

Three different sampling methods were used and compared:

1. Water Extraction Method

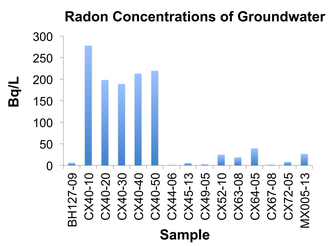

Fig. 3. Concentration of Rn in groundwater (Bq/L) of 10 drill holes and 1 monitoring well at the Millennium site.

2. Mineral Oil Extraction Method

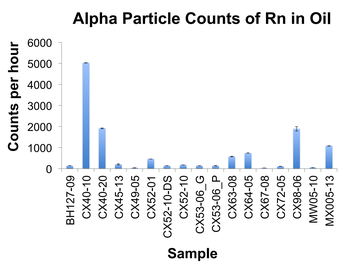

Fig. 4. Concentration of Rn in groundwater (counts/hour) of 11 drill holes and 2 monitoring wells at the Millennium site.

3. Diffusion Sampler Method

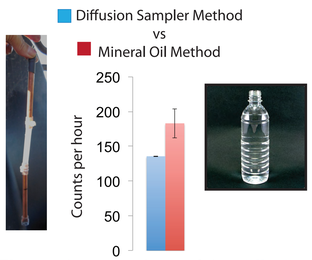

Fig. 5. A comparison of the diffusion sampler method and the mineral oil method for samples at CX-52.

Depth Profiles

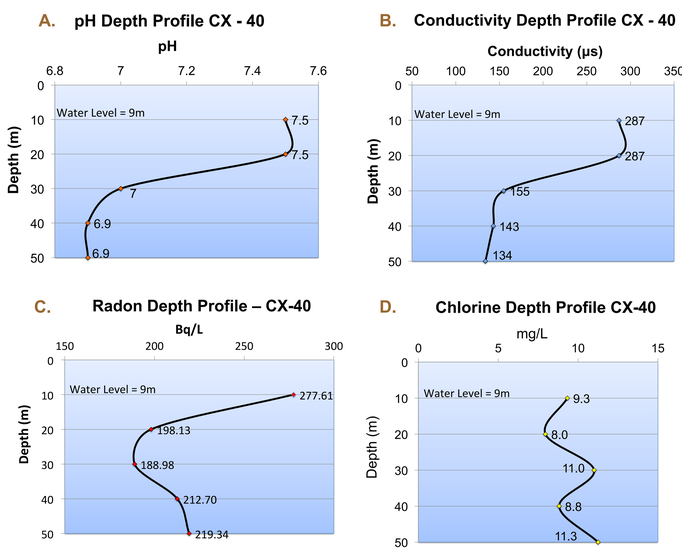

Fig. 6. Samples collected at 10 m depth intervals within DDH CX-40 show how pH (A), conductivity (B), ^{222}Rn (C) and Cl^- (D) vary with depth.

Comparable Results of Liquid Scintillation Counters

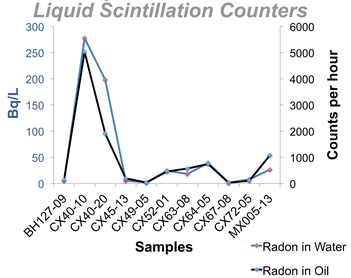

Fig. 7. Analytical results from the "**radon in water**" and "**radon in oil**" show a very similar trend. Radon concentrations in oil samples were not calibrated, so results are not quantitative, but show relative concentrations of samples.

Do the physical properties of samples affect counting efficiency?

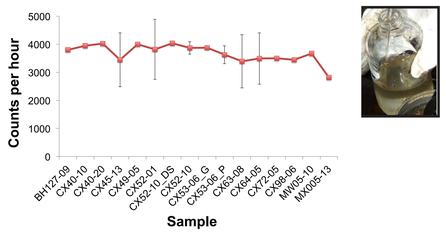

Fig. 8. Fully decayed and equally spiked samples yielded similar counts, suggesting that physical properties have little effect on scintillation quenching.

Summary

- All samples, including samples from DDH CX-72 (collected approximately 650 m from the surface projection of the deposit) show high activities of Rn.
- Rn activity was highest in DDH CX-40, directly above the deposit, and the lowest in DDH CX-44, approximately 300 m from the surface projection of the deposit and upslope of groundwater flow.
- A depth profile from 10 m - 50 m of DDH CX-40 shows Rn activity is highest at 10 m below surface (278 Bq/L), and lowest at 30 m (189 Bq/L).
- The variation in Rn activity does not correlate with other parameters of water such as pH, conductivity, and halogen contents.
- This study indicates that the measurement of Rn provides information useful in exploring for deeply buried uranium deposits.

Acknowledgements

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References

Jefferson, C.W., Thomas, D.J., Gandhi, S.S., Ramaekers, P., Delaney, G., Brisbin, D., Cutts, C., Quirt, D., Portella, P., Olson, R.A., 2007. Unconformity- associated uranium deposits of the Athabasca Basin, Saskatchewan and Alberta, Geol. Ass. Canada, Mineral Deposits Div. Sp. Publ. No. 5, p. 273-305.

Lefebvre, K., Barbecot, F., Ghaleb, B., Larocque, M., & Gagné, S. (2013). Full range determination of 222Rn at the watershed scale by liquid scintillation counting. Applied Radiation and Isotopes, 75(0), 71-76.

Leaney, F., & Herczeg, A. (2006). A rapid field extraction method for determination of radon-222 in natural waters by liquid scintillation counting. Limnology and Oceanography: Methods, 4, 254-257.

Wood, G., O'Dowd, C., Cosma, C., & Enescu, N. (2012). An interpretation of surface and borehole seismic surveys for mine planning at the Millennium uranium deposit, northern Saskatchewan, Canada. Geophysics, 77(5), WC203-WC212.

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