

# Tracking Radon Gas Above Deeply Buried Uranium Ore

**Mary Devine**

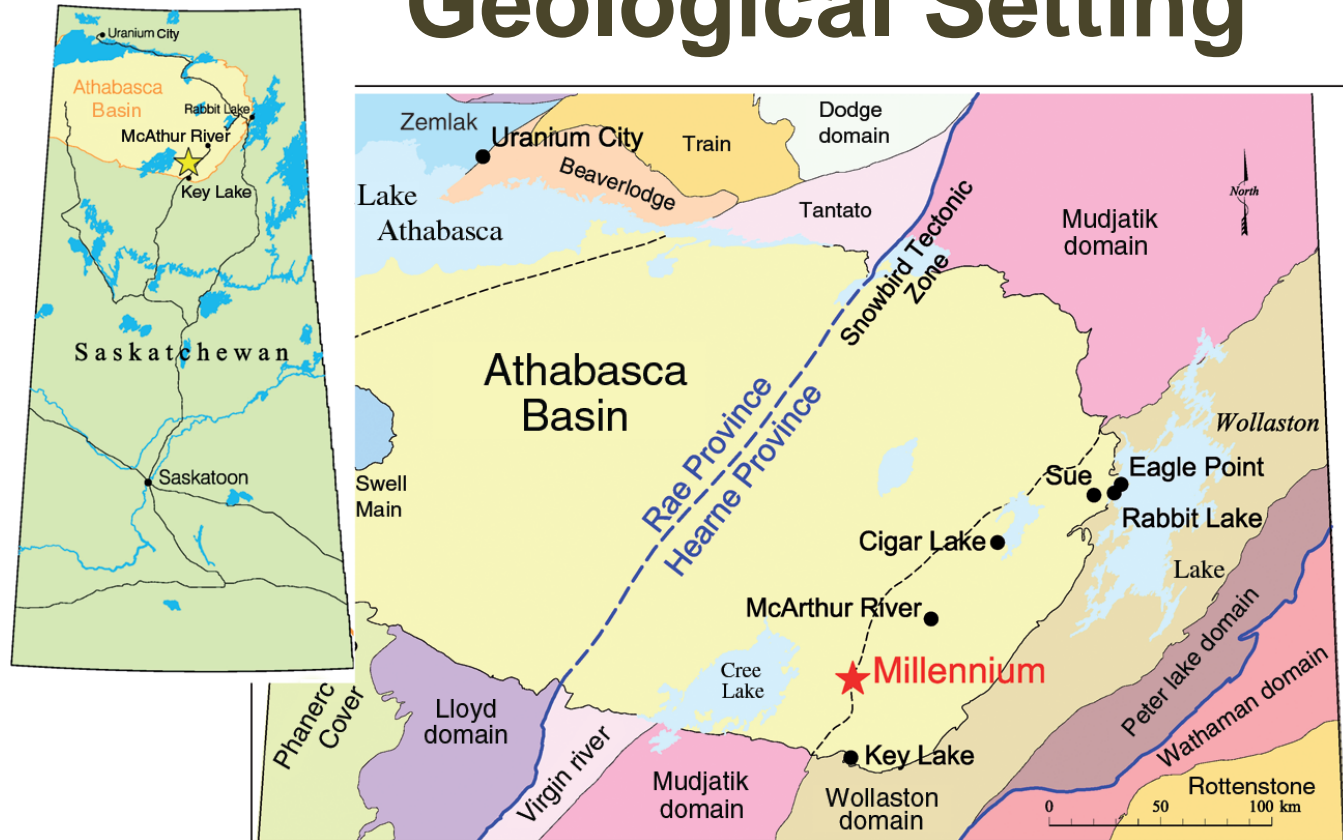
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Millennium Deposit – Athabasca Basin, Saskatchewan

GACMAC 2014 , University of New Brunswick



# Geological Setting



Juhojuntti et al., 2012

- Many U deposits in the Athabasca basin occur at great depth which poses a challenge in exploration.

# Objectives

**This study examines the behavior of radon (Rn) dissolved in groundwater at Cameco's Millennium deposit.**

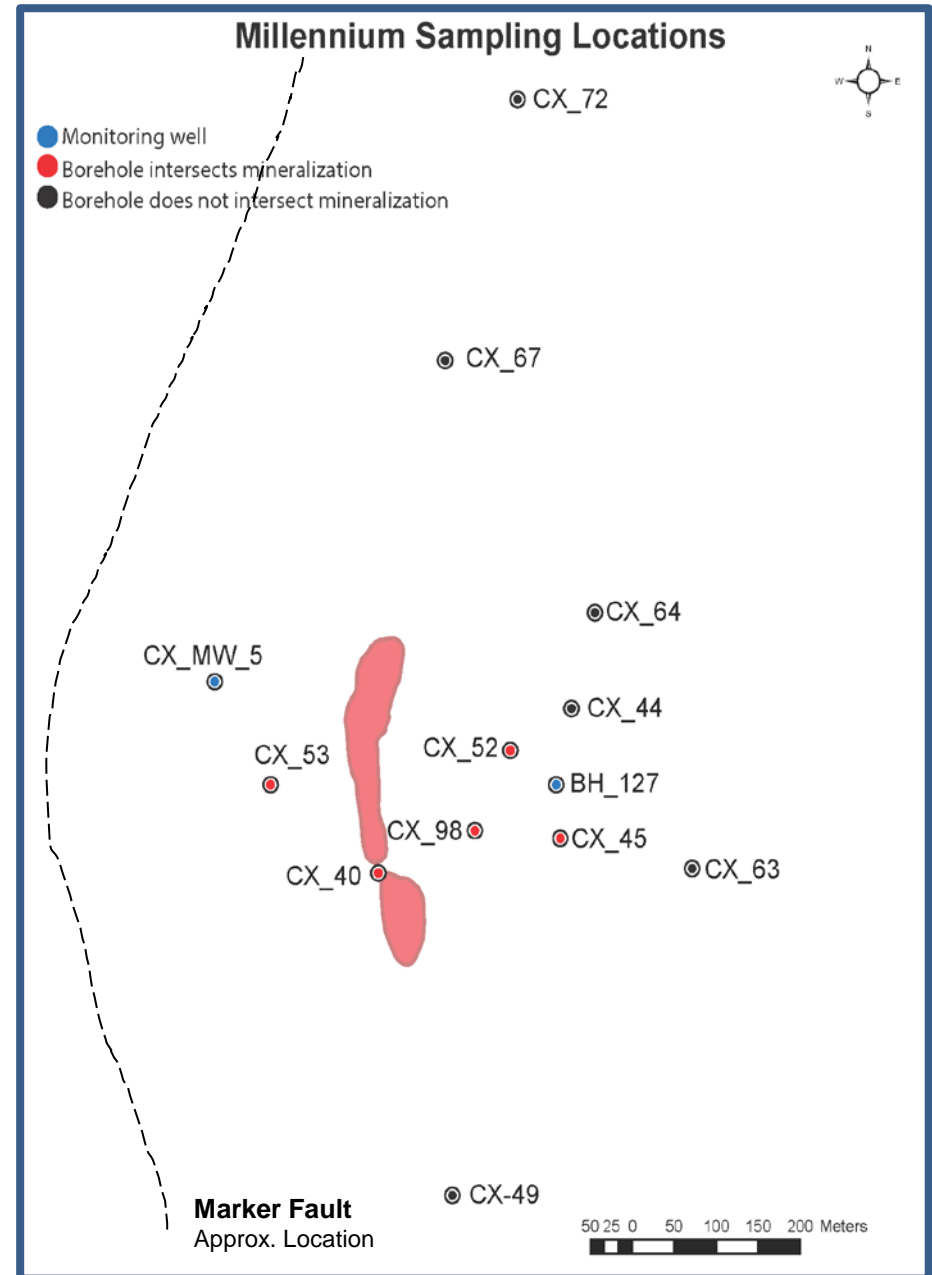
- Find effective sampling and analyzing techniques.
- Determine if Rn concentrations are anomalous.
- Determine how/if physical and chemical parameters of groundwater correlate with Rn activity.
- Identify the source of anomalous Rn.

# Sampling Area

## Millennium Deposit

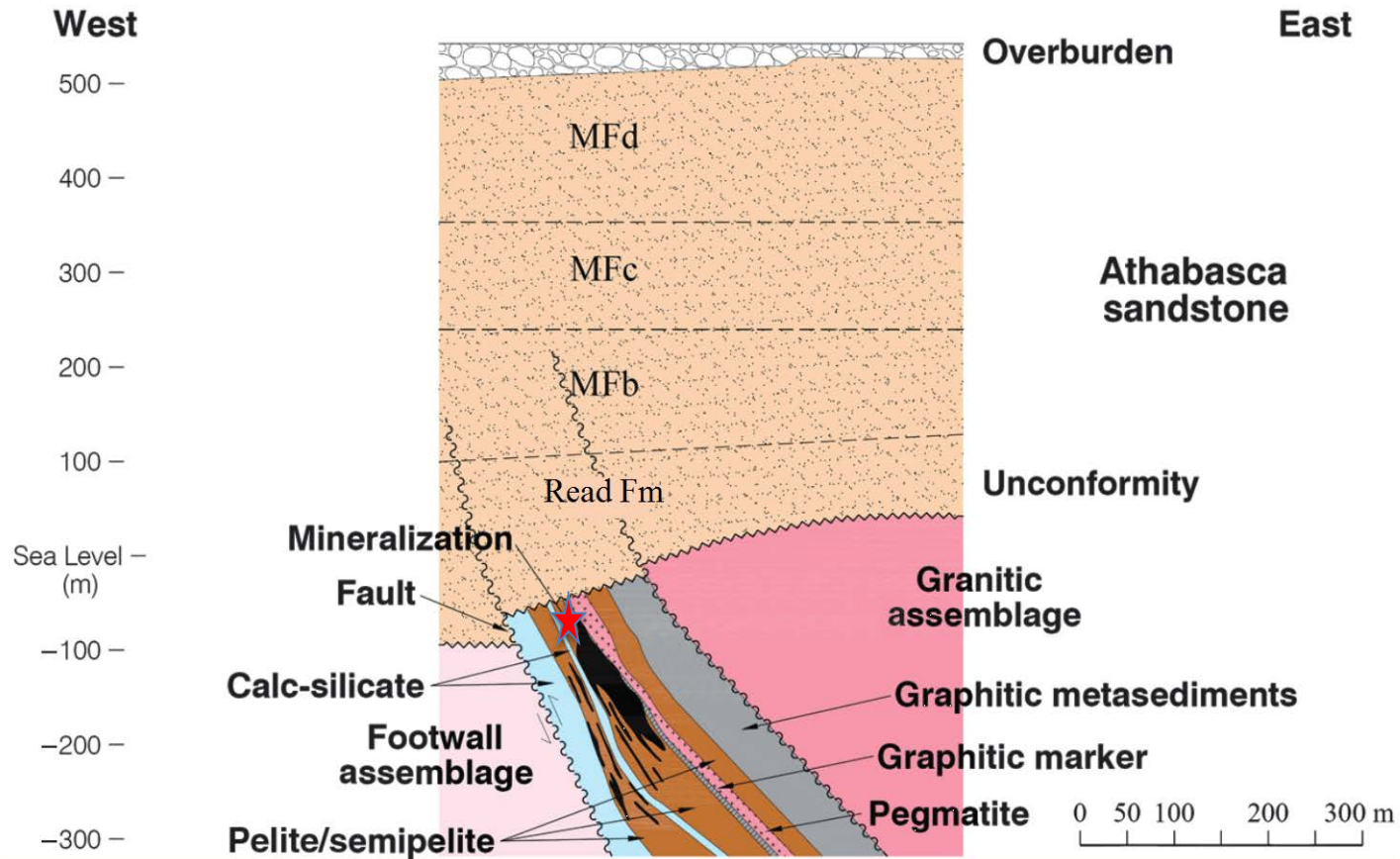
Sample locations were chosen based on proximity to the surficial expression of mineralization and accessibility.

Hole ID	Sampling Depth Below Surface (m)	Total Depth (m)
CX-MW-05	10	695
BH-127	9	n/a
CX-40	10, 20, 30, 40, 50	771.5
CX-45	13	776
CX-52	1, 10	767
CX-53	6	728
CX-98	6	705
CX-44	6	778
CX-49	5	706
CX-63	8	650
CX-64	5	863
CX-67	5	784.3
CX-72	5	727



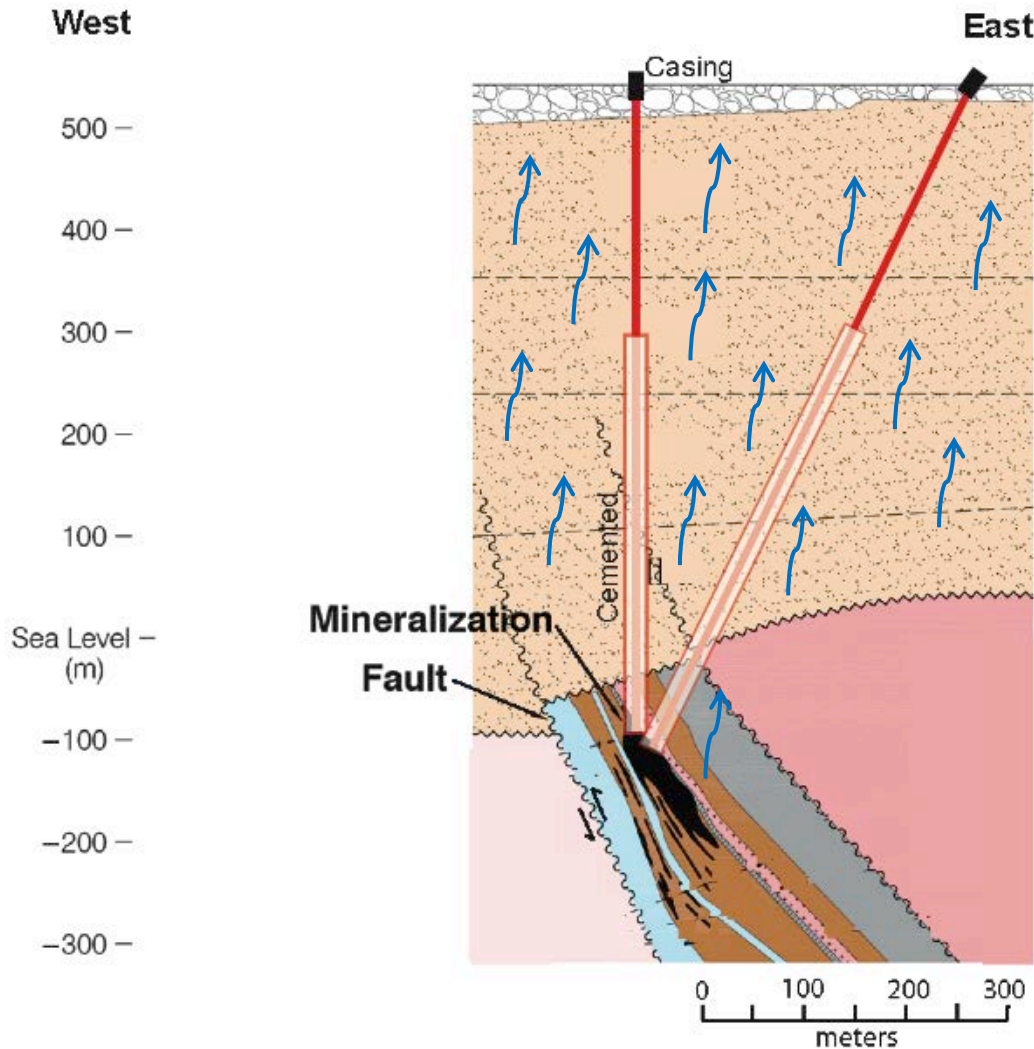
# Millennium Deposit

68.2 M lbs (indicated resource) and 22.3 M lbs (inferred resource)  $\text{U}_3\text{O}_8$



Juhojuntti et al., 2012

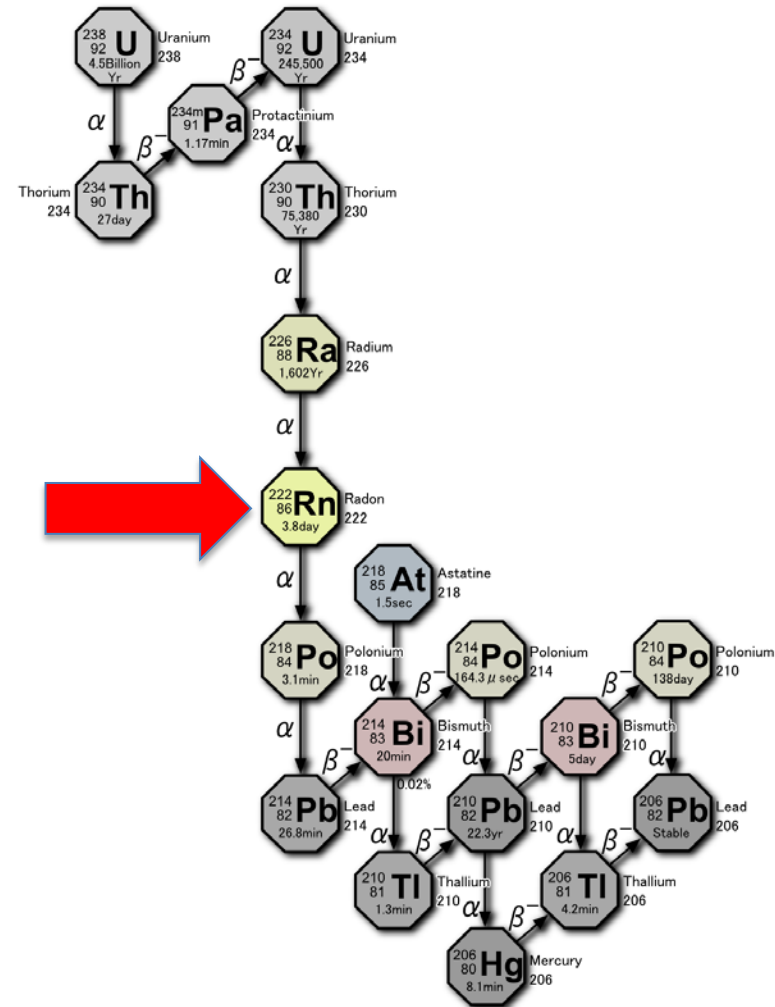
# Groundwater Sampling Locations



- He and Rn within groundwater envelope the boreholes up to the surface.
- The transport mechanism responsible for anomalous Rn and He 700 m above mineralization is not yet identified.

# Measuring Rn:

- Radon has three natural radioactive isotopes  $^{219}\text{Rn}$ ,  $^{220}\text{Rn}$  and  $^{222}\text{Rn}$ .
- $^{222}\text{Rn}$  is a gaseous decay product of  $^{226}\text{Ra}$ .
- $^{222}\text{Rn}$  has the longest half life = 3.82 days
- $^{222}\text{Rn}$  emits  $\alpha$  particles as it decays to  $^{218}\text{Po}$  and  $^{214}\text{Po}$  – this is what we measure using liquid scintillation spectrometry.



# Field Methods

## 1. Lab-Extraction Method

Lefebvre et al., 2013



- Water is poured from bailer into a glass bottle.
- Analyzed within one week of sampling to reduce error associated with decay correction.

## 2. Field-Extraction Method:



# Field Methods

## 3. Diffusion Sampler Method

- A permeable silicon tube attached to Cu tubes is filled with mineral oil and submerged in water.
- The Rn in water diffuses into mineral oil.
- Mineral oil is collected and analyzed.

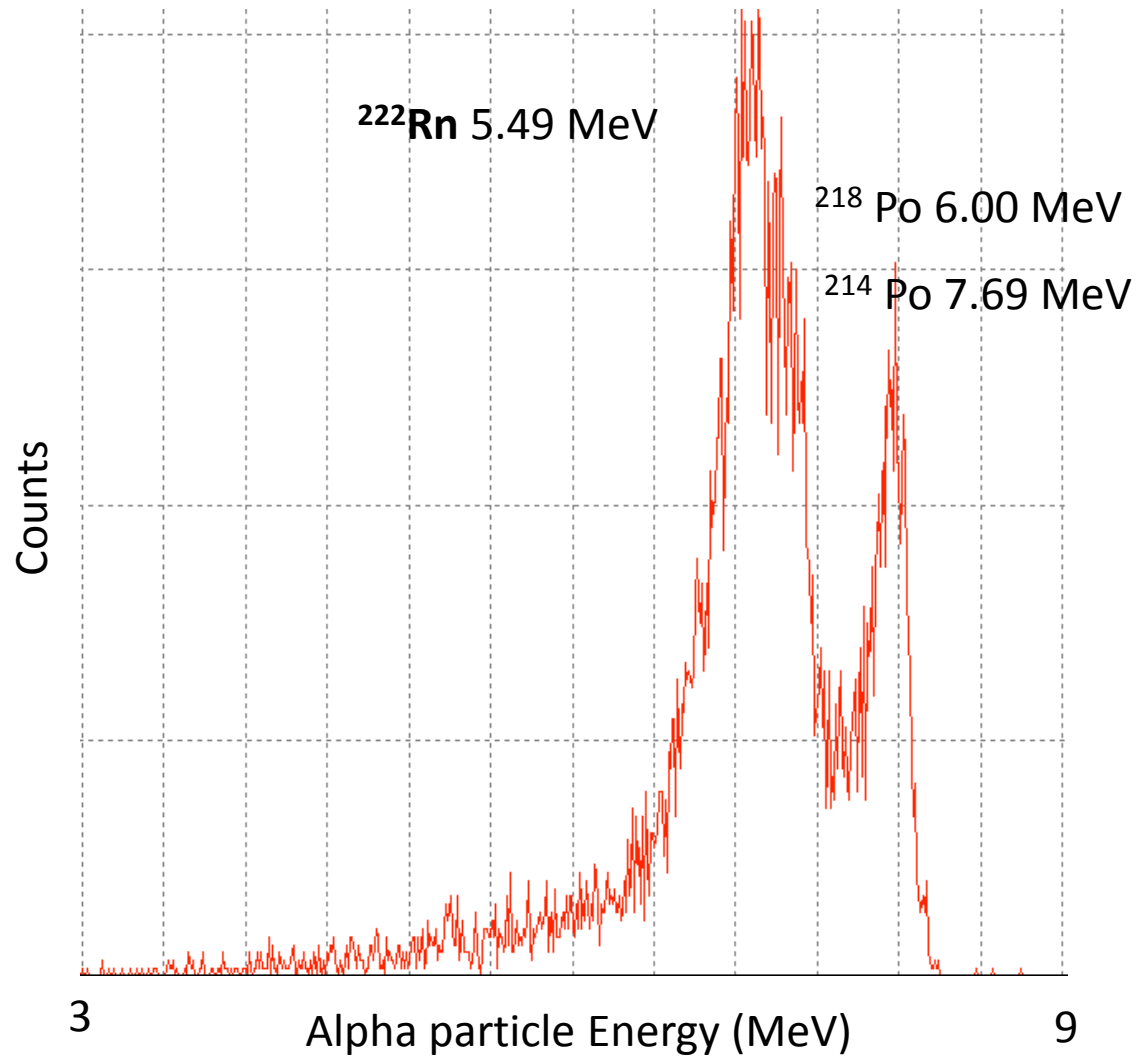
Diffusion Sampler

Mineral Oil



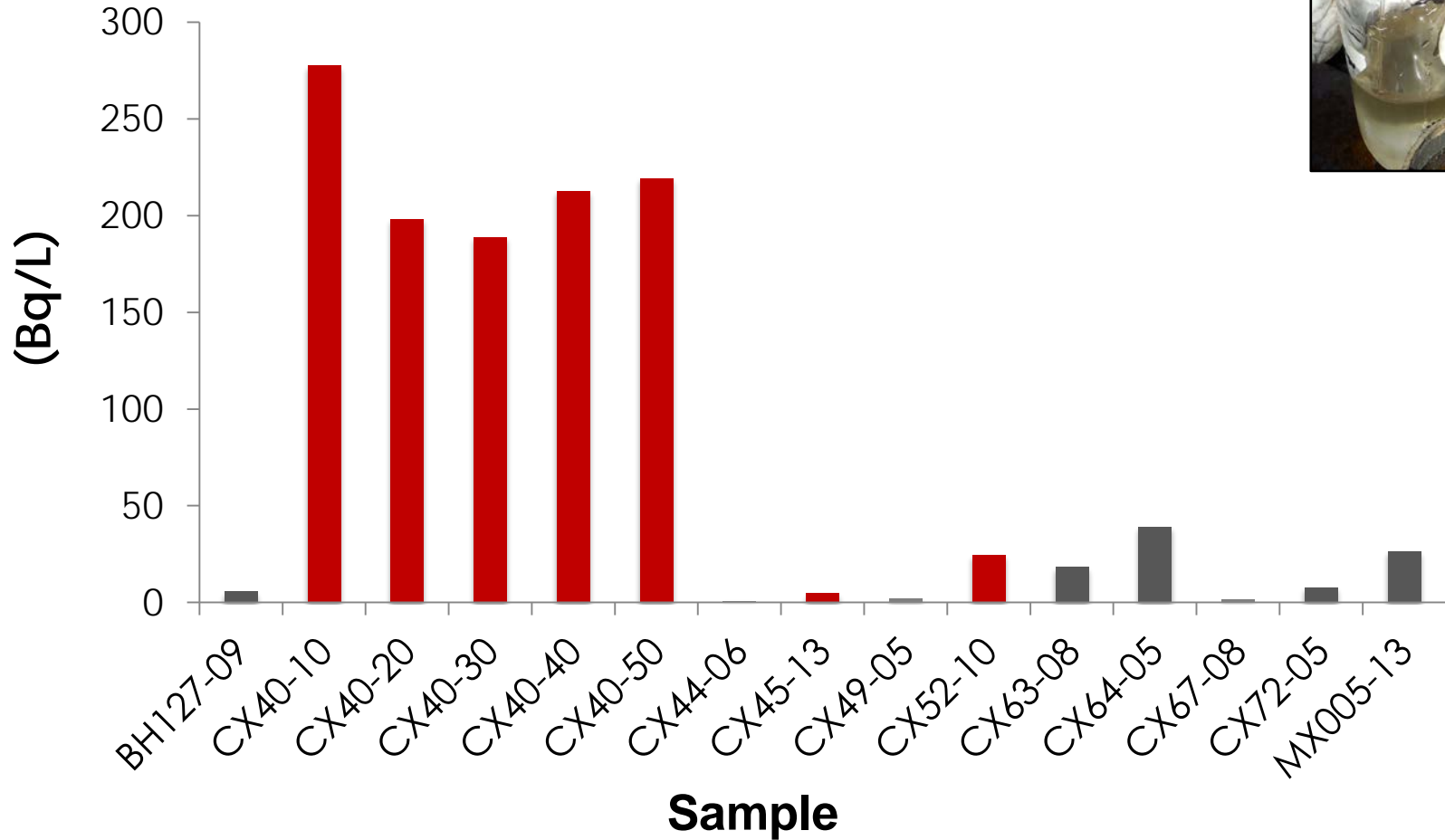
# Liquid Scintillation Spectrometry

- Samples are counted in the range of 3-9 MeV.
- $^{218}\text{Po}$  half life  
= 3.01 min
- $^{214}\text{Po}$  half life  
= 164  $\mu\text{s}$



# Radon in Groundwater

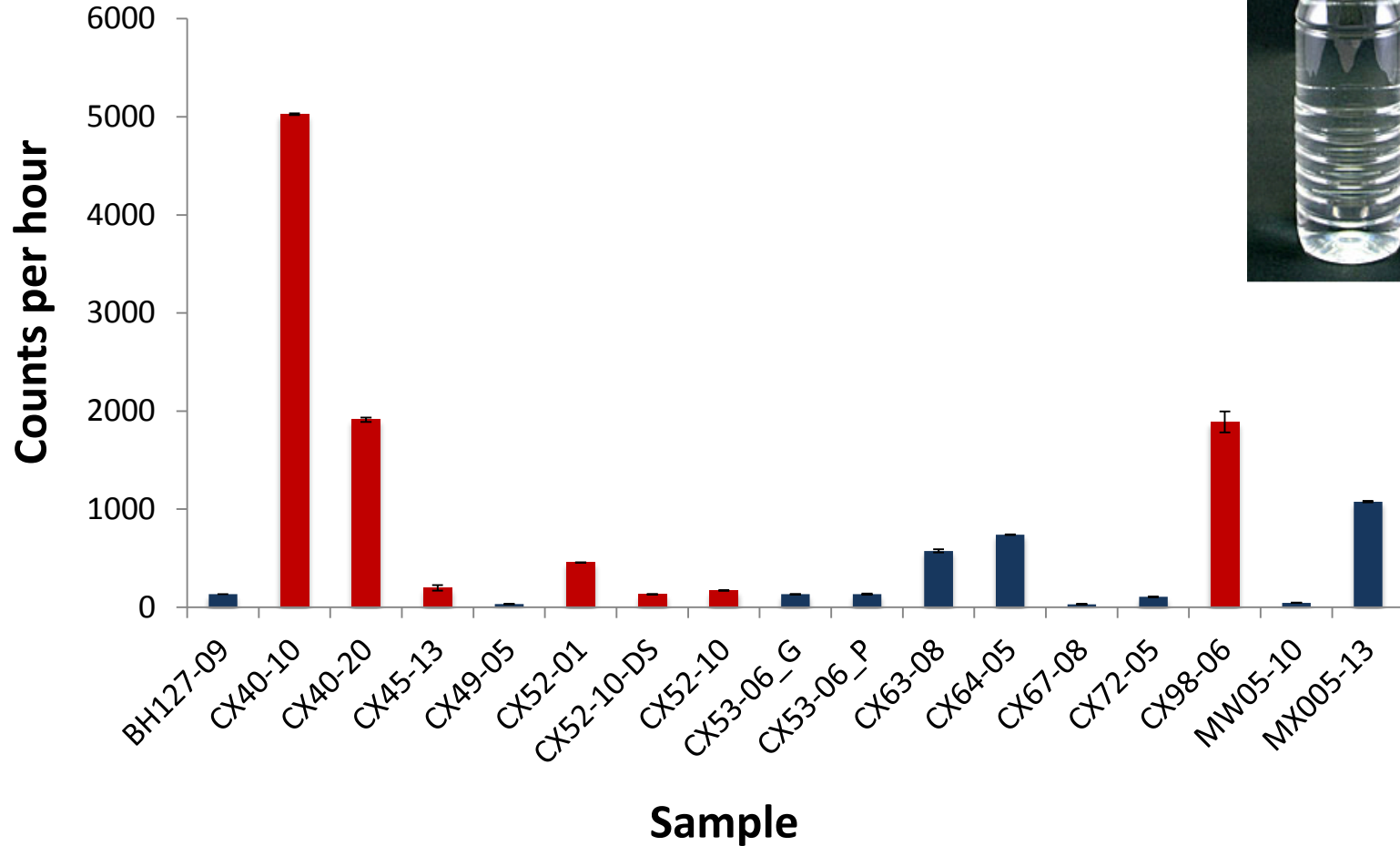
Lab Extraction Method - Water



★ Borehole intersects mineralization at depth

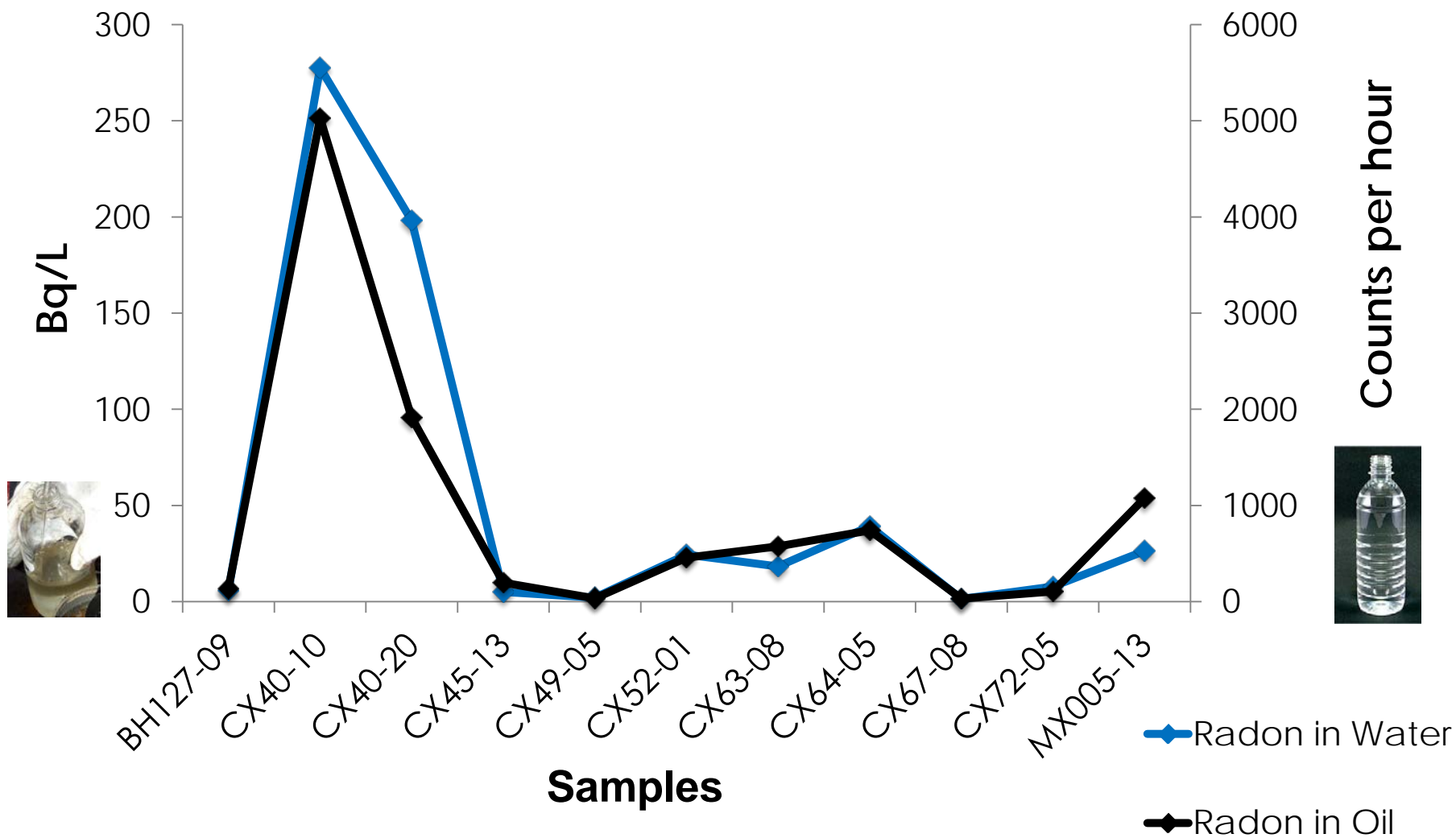
# Radon in Groundwater

Field Extraction Method - Oil

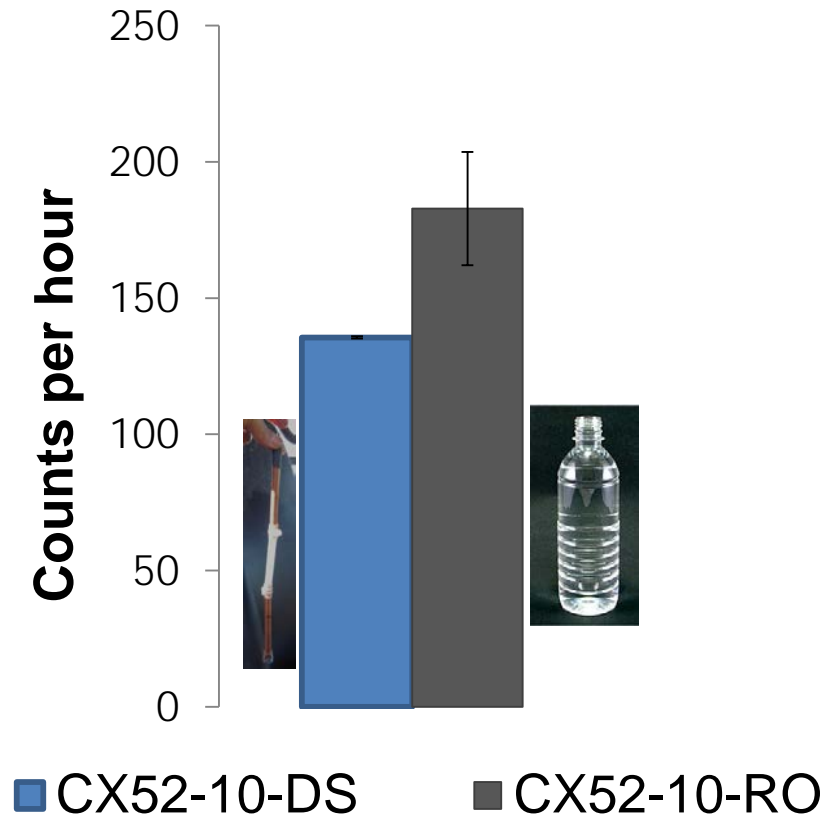


★ Borehole intersects mineralization at depth

# Rn Analysis Comparison

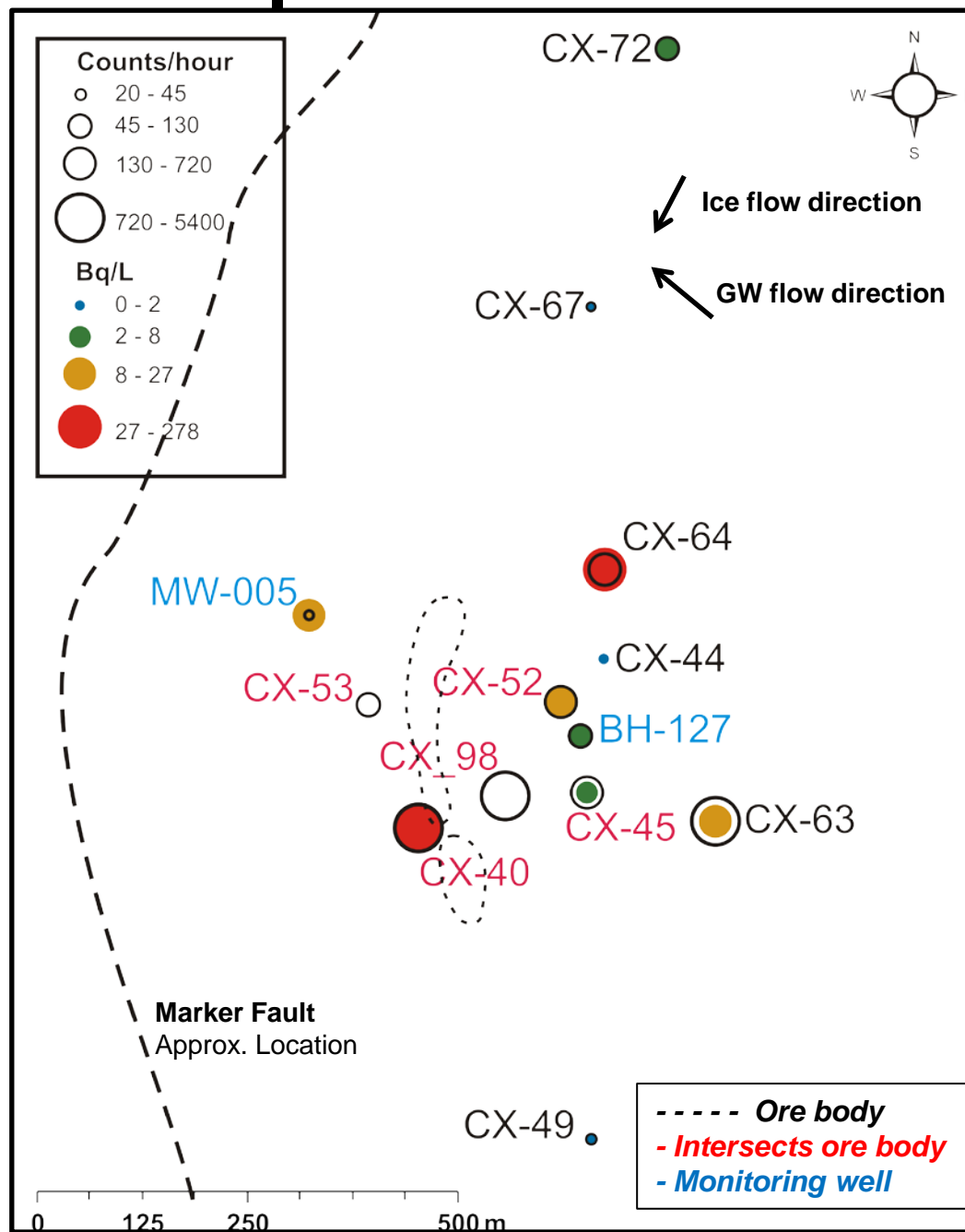


# Diffusion Sampler Method vs Field Extraction Method



# Millennium Sample Locations

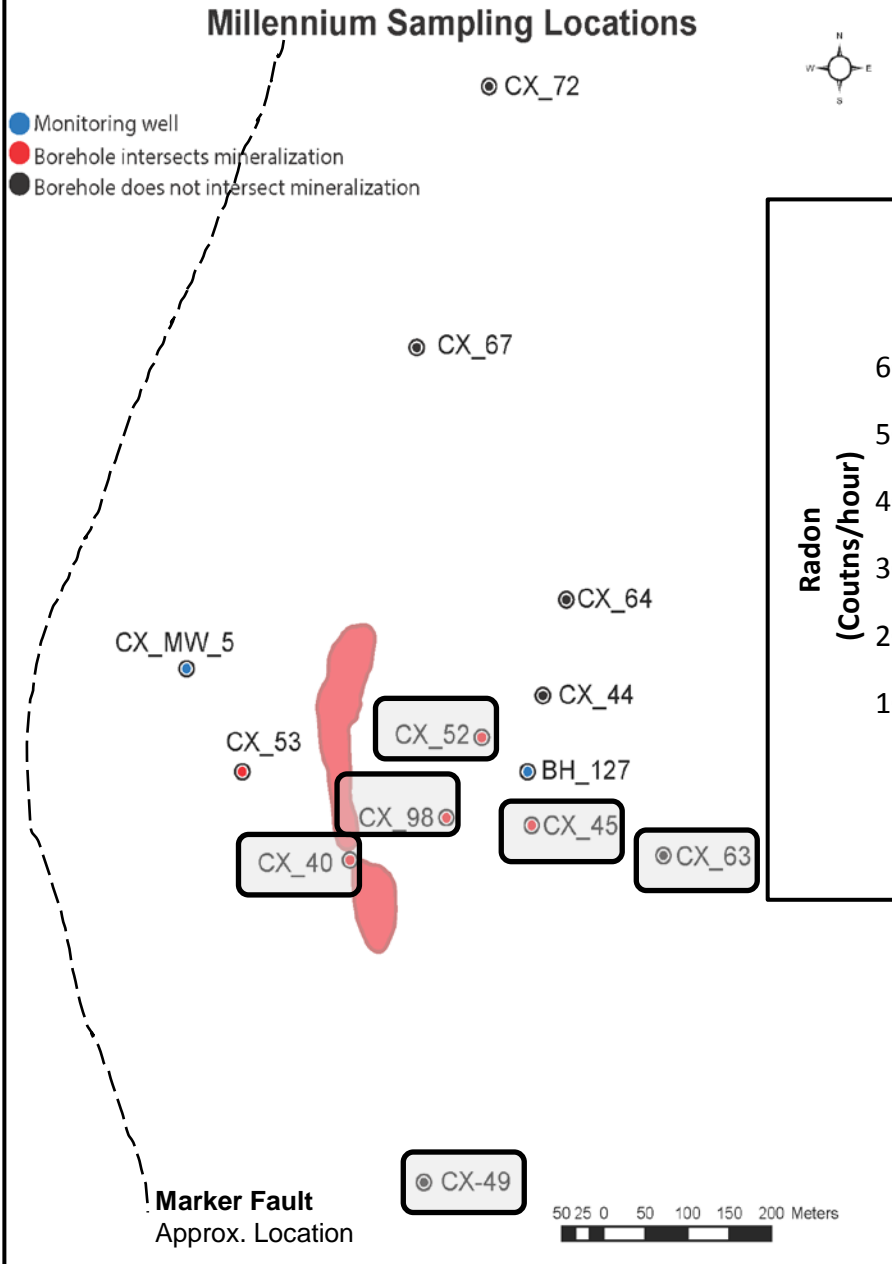
- All samples in this 1.5 km by 1 km area show Rn activities from 0.8 - 278 Bq/L.
- Highest Rn activity at **CX - 40**.
- Lowest at CX - 44 ~300 m from the surface projection of the deposit and upslope of groundwater flow.



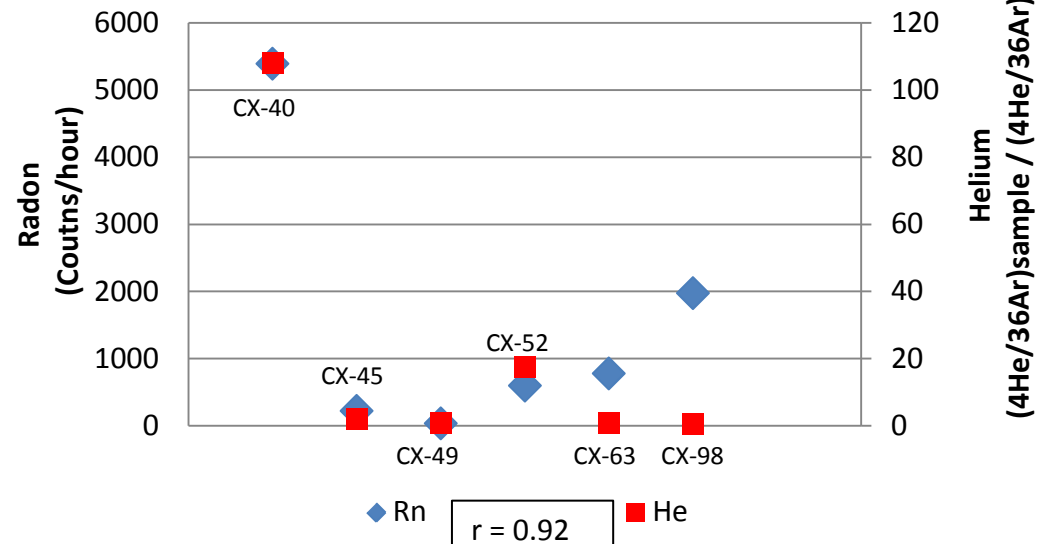
# Rn and He

## Millennium Sampling Locations

- Monitoring well
- Borehole intersects mineralization
- Borehole does not intersect mineralization



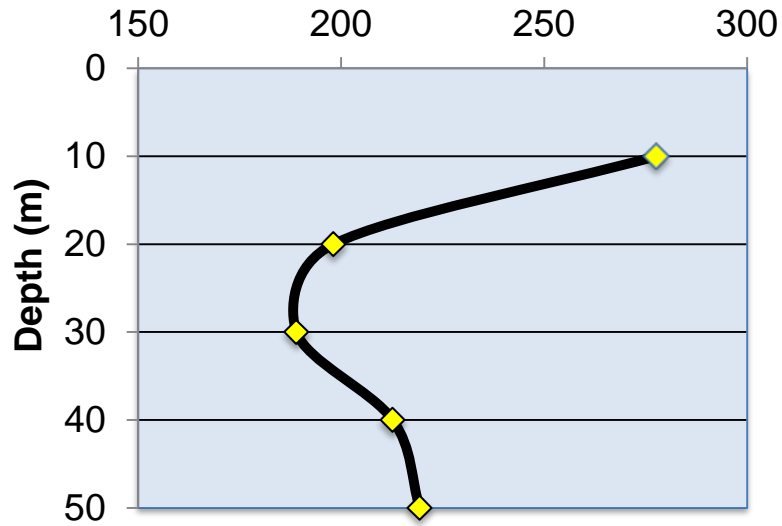
## Radon & Helium Correlation



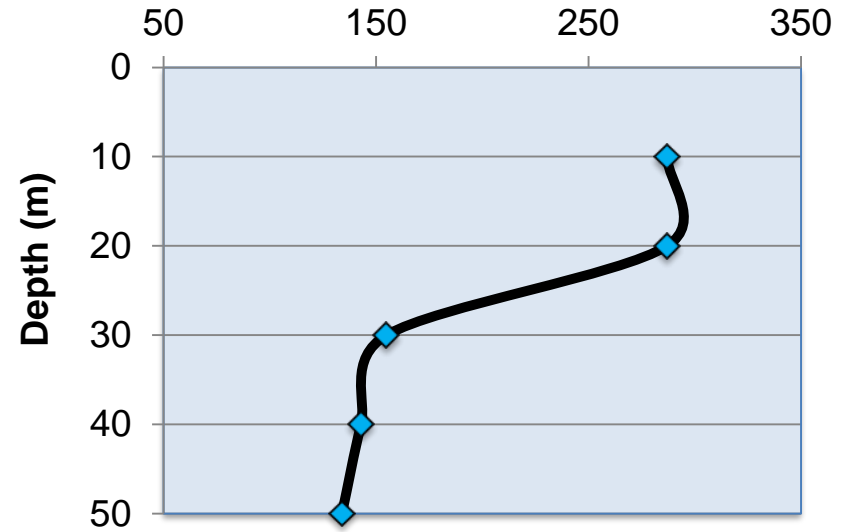
Helium data courtesy of Austin Krahenbil - BSc. Thesis Project

# Depth profiles of DDH CX- 40

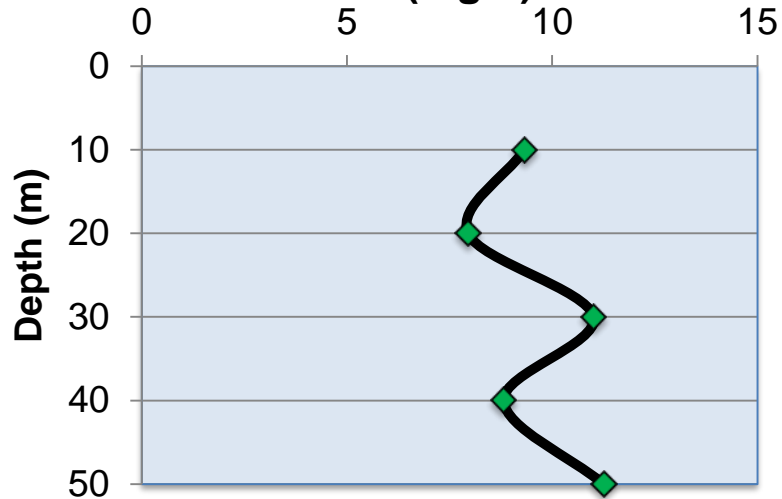
Radon (Bq/L)



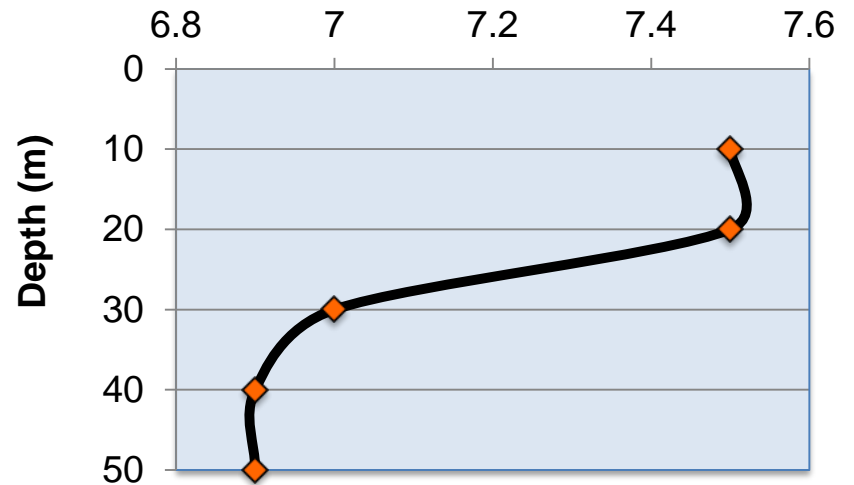
Conductivity ( $\mu\text{S}/\text{cm}$ )



Cl (mg/L)



pH



# Possible Radon Sources

## 1. Uranium Ore:

- Diffusion from the deposit at ~700 m depth requires diffusion coefficient  **$D = 2.12 \times 10^{-4} \text{ cm}^2/\text{s}$**
- Average diffusion coefficient of radon in water:  
 **$D = 10^{-5} \text{ cm}^2/\text{s}$**
- Therefore, diffusion alone cannot explain anomalies.
  - Advection through faults?
  - Groundwater flow?

# Possible Radon Sources

## 1. Uranium Ore

## 2. Glacial till and soil

- Till and soil derived from transported sediments and bedrock may contain uranium and/or radium which will decay to radon.
- May explain anomalies further from mineralization.
- This does not explain why highest Rn anomaly is closest to mineralization.
- Can determine if the Rn detected in groundwater is sourced from soil/till by measuring:
  - Radon activity in pore water of soil and till.
  - Concentration of uranium and intermediate daughters in till/soil.

# Possible Radon Sources

## 1. Uranium Ore

## 2. Glacial till and soil

## 3. Dissolved radionuclides

- Uranium and radium are soluble in water at certain chemical conditions.
- Groundwater moves upwards through fractures and faults.
- U and Ra precipitate and decay to Rn.
- Is this the source of Rn in groundwater?
- ✓ Chemical analysis of fractures may answer this question.

# Possible Radon Sources

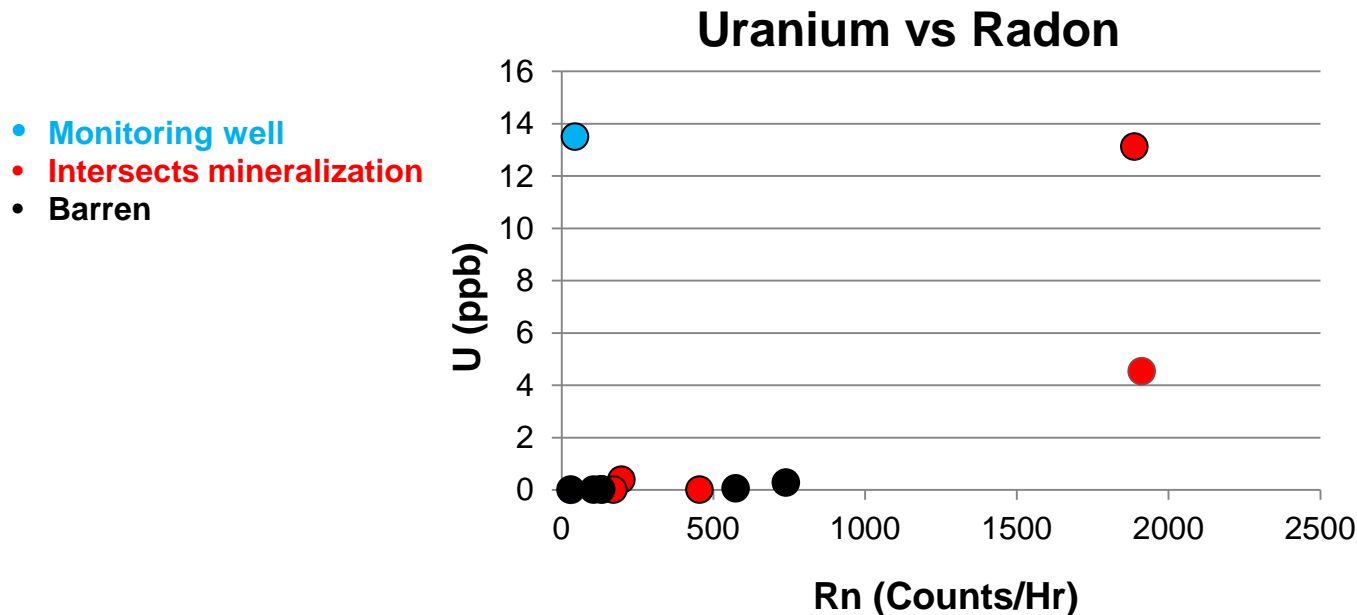
## 1. Uranium Ore

## 2. Glacial till and soil

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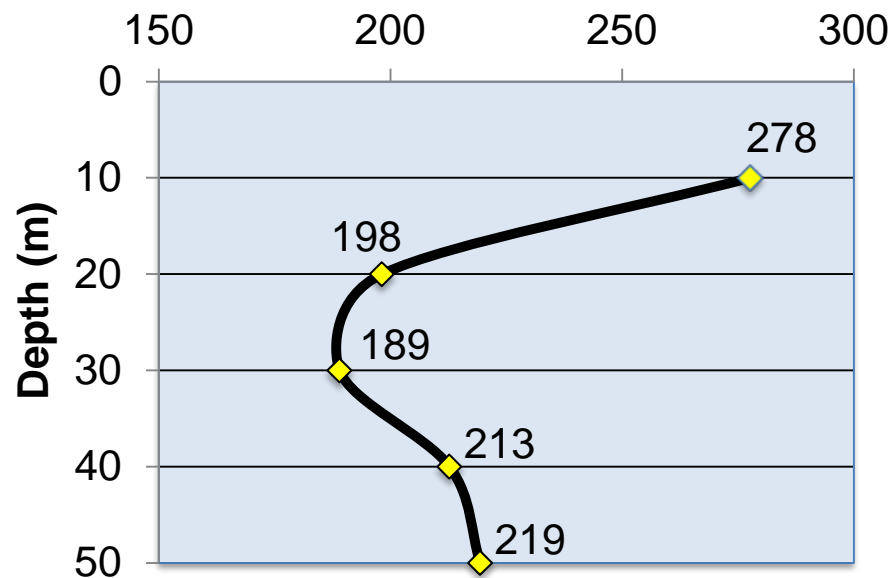
## 4. Uranium along drill hole walls

- Drilling of mineralized holes may leave residual uranium along drill hole walls.
  - Measured total uranium in groundwater compared to Rn
  - Overall low U concentration with a range of Rn concentrations

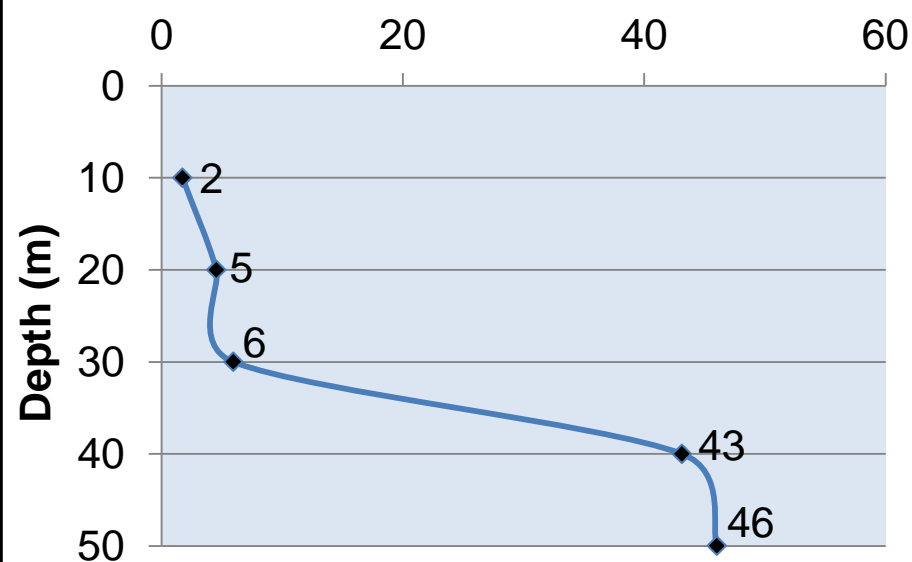


# Depth profiles of DDH CX-40

**Radon (Bq/L)**



**U (ppb)**



Radon and uranium do not correlate with depth.

# Summary

- Three sampling techniques and two measuring techniques yielded comparable results.
- All samples show detectable activities in the area of 1 km x 1.5 km.
- Rn was high at the borehole above the deposit.
- A depth profile (10-50m) showed high Rn at 10 m depth and low at 30 m.
- The variation in Rn activity does not correlate with pH, conductivity, and halogen contents.
- There are several possible sources of Rn
  - Residual U along drill hole walls does not appear to be a source.

# References

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# Questions?

