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# Geological Controls on Radon Potential in Cochrane, Alberta. Understanding the Generation of Radon as Part of the Uranium 238 Decay Chain.

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## Summary

Soil samples from the Town of Cochrane, Alberta, were investigated for radon gas generation. X-Ray Fluorescence (XRF) was used for elemental analysis and a RAD7 radon detector was used to determine radon gas generation. This paper explores processes that take place during weathering of soils that potentially contribute to higher or lower soil gas radon, due to fractionation in the Uranium decay chain.

## Introduction

The focus of this study is to better understand the generation of radon gas, resulting from the Uranium 238 decay processes, in soils collected in Cochrane, Alberta. In a University of Calgary study conducted by Goodarzi (2016) , homes in and around the Calgary area were tested for radon over a 3 month period, via Radon West Company. The results show Cochrane to have some of the highest radon gas levels. Canada has set 200 $Bq.m^{-3}$ as the guideline for indoor radon concentrations (Health Canada 2012). In recent years, the concentration of radon found in the air of buildings has been of growing concern as radon gas is the second leading cause of lung cancer in Canada and accounts for about 16 per cent of lung cancer deaths (Canadian Lung Association, 2015). The low air pressure within a building causes a pressure difference that draws radon in from the surrounding soil; it can enter homes through crawl spaces, cracks in foundations, sump pumps, etc. One method of assessing the radon hazard in an area is through measurements of the amount of radon in soil gas. A soil gas survey was conducted in the Cochrane area using a Durridge Company RAD7 radon detector and soil samples were collected for radiometric and XRF analysis. Radon is a naturally occurring radioactive gas that is produced by both the uranium and thorium decay series. Uranium and thorium decay systems can become disturbed as a result of chemical weathering and/or groundwater influence, resulting in fractionation of daughter products. Ultimately, if fractionation occurs, isotopic equilibrium is not maintained and radioactive daughter products can be enhanced or depleted. The use of these results will help in understanding the complex role of uranium fractionation and the processes leading to high radon levels in soils.

## Theory and/or Method

*2.1 Theory*

Fractionation of Uranium 238 (U238) and Uranium 234 (U234) during chemical weathering is well established (Gawad and Ibrahim 2016). However, fractionation of other daughter products such as Thorium 230 (Th230) or Radium 226 (Ra226) is not. There are three potential scenarios for radon generation depending on the behavior of these daughter products:

1. If the radon is generated from unweathered rock, the U238 decay series will be at isotopic equilibria and the amount of radon generated from a sample is controlled by the amount of U238 through the decay series to Radon 222 (Rn222). (~12,440 Bq of radon per gram U)

2. If the U238 decay series is not at isotopic equilibria, as a result of preferential removal of daughter products during weathering, the generation of radon in the sample will be less than that indicated by the amount of U238. (<12,440 Bq of radon per gram U)

3. If the U238 decay series is not at isotopic equilibria as a result of preferential uptake of daughter products produced during weathering, such as on clays or other material in the soil, the generation of radon in the sample will be greater than that indicated by the amount of U238. (>12,440 Bq radon per gram U)

*2.2 Methods*

A RAD 7 radon detector (Durridge radon instrumentation company USA) was employed to conduct a Radon soil gas survey in the Town of Cochrane. At each sampling location, a hollow steal probe with sampling holes near the tip was inserted to depths of 30, 60, and 90 cm. Each test was run for 5 min and was repeated 8 times, totaling a 40-minute test for each sample location.

Soil samples weighing between 400 to 900 grams were collected at depths of 0, 30, 60, 90, and 120 centimeters from three locations in Cochrane, AB. Locations of high (Gleneagles), medium (Dog Park), and low (Cochrane Ranch) radon soil gas Radon concentrations were selected from the soil gas survey based on field measurements. The samples were dried at 105C for 48 hours and then transferred to one litre mason jars and sealed for soil testing. Each jar was tested with the RAD7 each week for a period of 6 weeks to determine the amount of radon generated by the soil.

## Examples

Measurement of soil gas Radon in the field is both difficult and time consuming. Data obtained from the same locations on different days and nearby locations on the same day vary significantly. For instance, data were collected at 60 cm depth from three locations within a 100 metre radius at Cochrane Ranch. Soil Radon values for 11 analyses vary from 475 to greater than 5,500 Bq/m$^3$; 3 analyses at 30 cm range from 300 to nearly 4000 Bq/m$^3$ (Figure 1A). Soil gas measurements from 60 cm depth at the GlenEagles location have values of 9,980 and 19,202 Bq/m$^3$ (Figure 1A). Soil gas Radon was measured on only one date for the 90 cm depth at Cochrane Ranch and for the 30 and 90 cm depths at GlenEagles. Soil gas Radon from the Cochrane dog park falls between these two data sets. While there may be a higher radon hazard at the GlenEagles location than at the Cochrane Ranch location, the variability of the data is bothersome. Therefore, a better method to determine the radon hazard is via the Radon generation potential of the soils.

It takes about 10 times the half-life of a daughter product to establish secular equilibrium; about 2 million years is required for the entire U238 decay series to reach equilibrium. If the daughter products of the U238 decay series are less or greater than the equilibrium value this indicates that a daughter product of Uranium has been disturbed and migrated within the last 1–2 Million years (Gawad and Ibrahim 2016). The preferential removal of U234 during chemical weathering has been well documented in literature. Damage to the host from energy released during the decay of U238 to Thorium 234 (Th234), Th234 to Proactinium 234 (Pa234), and Pa234 to U234 results in preferential removal of U234 in the host and an enrichment of U234 in water during chemical weathering. While similar processes are expected to occur during decay of U234 to Th230 and Th230 to Ra226, no literature was found to contain this information.

The fate of Th230 and Ra226 during chemical weathering in soils is important for explaining the soil radon gas generation, since Radon 222 is the direct daughter product of Ra226 in the Uranium decay series. Radium 226 has a half life (~1600 years) that is relavent to the length of time for soil development and therefore, could be generated from the decay of Th230 (Faure, Gunter 1977). It is likely that both Thorium and Radium are leached from the host in the soil zone; however, both have strong affinitiy for adsorption onto some clay minerals.The study question presented here is whether the Th230 and Ra226 are removed from the system in aqueous solution, retained through adsorption, or transported and concentrated at other depths.

Experimantal data for Radon gas generation in soils from 60 cm depth at three different Cochrane locations are shown in Figure 1 (B,C,D); the amount of Polonium 218 (in counts per second) is compared to theoretical Radon generation curves if the soil is in secular equilibrium for the U238 decay series.  The Radon generated in each of the Cochrane samples is clearly lower than the secular equilibrium value indicating that Ra226 is depleted in these soil samples.

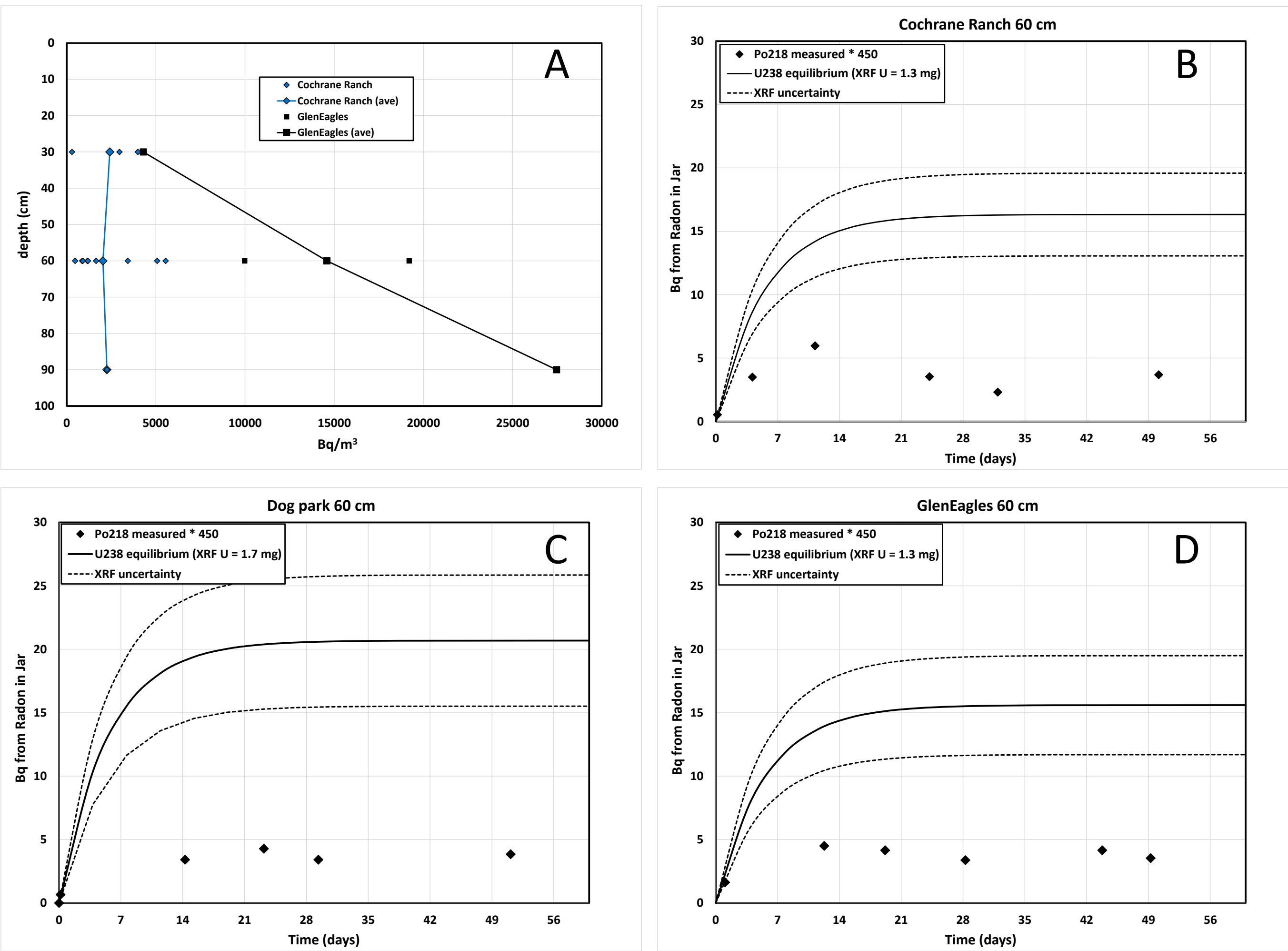


***Figure 1*** *A. Soil gas Radon values with depth collected from field measurements at Cochrane Ranch and Gleneagles, via the RAD 7 soil probe. B,C,D. Soil radon gas versus time profiles from Cochrane Ranch, Cochrane Dog Park, and Gleneagles soil jar samples. Graphical analysis of Polonium 218 (measure of Radon generation) from soils collected at 60 centimeters depth at Cochrane Ranch, Cochrane Dog Park and Glenn Eagles. Radon generated in all samples is lower than the secular equilibrium value.*

## Conclusions

Field measurements of soil gas Radon are time consuming and the data are quite variable; therefore, the measurement of radon gas from the jar experiments was seen to be a better approach to measuring the radon generation potential of soils. Three scenarious can result in regards to radon generation. The first scenario invlolves Radon 222 in secular equilibirum; meaning it is generated from unweathered rock and is controlled by the amount of U238. The second scenario is if the Radon 222 generated is greater than indicated by the amount of U238. The third scenario is if the Radon 222 is generating less than what is predicated by the amount of U238.

The fifteen jar experiments from Cochrane soil samples show that all of these have a similar Radon generation potential. The amount of Polonium 218 (measure of radon generation) is lower than indicated by the Uranium 238 content, indicating removal of Th230 and Ra226 from the system. This suggests that the Uranium daughter products have either been removed from the system and enriched in the aqueos phase; therefore, leaving the sediment depleted in daughter products, or the daughter products have been transported and are concentrated at greater depths than our equipment allowed us to reach.

While the amount of soil gas Radon generated from the soils appears to be sufficient to attain levels near that of the Cochrane Ranch soils, the much higher soil gas Radon at GlenEagles (and likely the Dog Park) require additional source(s). The very high soil gas Radon at GlenEagles appears to be the result of diffusion of Radon from depth. This source may be from the underlying bedrock or from daughter products leached from the soil and concentrated at depth. Additional work is needed in order to determine this.

Studying radon generation in soil is important as it can provide information on areas of high soil radon gas. When radon enters basements through surrounding soil,it can concentrate in high levels and pose health risks to the homeowners. Therefore, it is important to know the levels of soil radon gas surrounding homes and other buildings; however, because soil radon gas can vary so greatly over an area, it is advised that everyone should test their home regardless.

## References

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