Mobility of Uranium and Radon Associated with Uranium Roll Front Occurrences in the Horton Group of the Windsor Area, Nova Scotia, Canada[1]

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There are numerous uranium occurrences in the basin fill units of the Maritimes Basin and in the adjacent crystalline basement rocks in Atlantic Canada. The uranium occurrences in the Carboniferous Horton Group sedimentary strata are sandstone-hosted uranium roll fronts. Recent recognition of deeply weathered granitoids below the unconformity of the Horton Group on the Late Devonian South Mountain Batholith suggests a possible genetic link to regolith-related unconformity deposits as well. The roll fronts in the Horton Group sandstones are known primarily from drill core; however, there is an excellent exposure of mineralized sandstone at Green Street, near Windsor, Nova Scotia. The rate and quantity of uranium and radon contributed to surface and groundwater by mineralized outcrops has been poorly documented in the past. Leaching experiments were undertaken using the mineralized sandstones and siltstones from the Green Street occurrence. All of the samples revealed significant uptake of uranium and radon into both distilled water and in samples mixed with natural rain water. These leaching experiments have important implications for the mobility of these elements in the environment and dispersion patterns in regards to geochemical exploration. Although this paper deals primarily with uranium and radon from occurrences in the Windsor area of Nova Scotia, the regional nature of the Horton Group strata throughout eastern Canada would seem to imply that environmental issues related to the uranium mineralization might exist throughout the Maritimes Basin. This may be of particular note in areas that have elevated uranium occurrences within granitoid basement rocks adjacent to the Carboniferous basin fill.

Introduction

The rate and quantity of radon and uranium contributed to waters exposed to mineralized outcrops and the subsequent mobility of these elements in the present day environment has not been previously documented. This paper presents the results from leaching experiments carried out on uranium-enriched Horton Group sandstones in the Windsor area of Nova Scotia. Understanding of these processes is important both to environmental and exploration geochemistry.

General Geology

The rocks and saprolites referred to in this paper are located primarily in southern Nova Scotia (Fig. 1). Southern Nova Scotia forms the Meguma Terrane of the northern portion of the Appalachian Orogen (Williams 1995). The Meguma Terrane is made up primarily of Cambro-Ordovician metasedimentary rocks of the Meguma Group and approximately one third of the terrane has been intruded by Late Devonian granitoid batholiths, the largest of which is the South Mountain Batholith (MacDonald 2001). These basement rocks are overlain by the sedimentary rocks of the Maritimes Basin.

The general stratigraphy of the Maritimes Basin consists of a late Devonian redbed and volcanic sequence referred to as the Fountain Lake Group, Mississippian clastic fluvial-lacustrine rocks of the Horton Group, Mississippian marine evaporite, clastic-carbonate sequence of the Windsor Group,

[1]Contribution to the 24th International Applied Geochemistry Symposium, Fredericton, New Brunswick, June 1-4, 2009.
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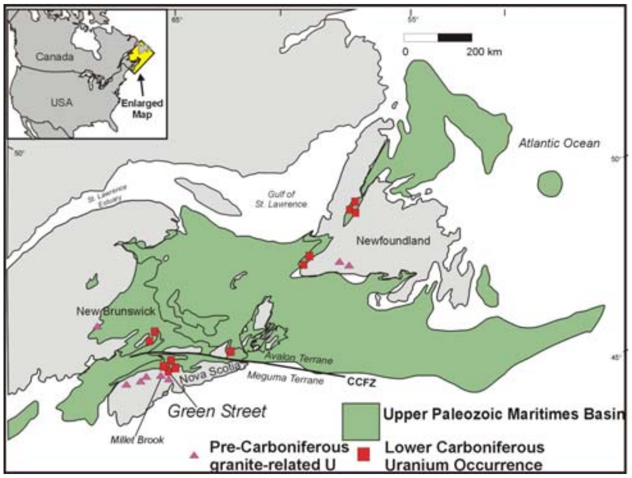

Figure 1. Location of uranium occurrences in granitoids and the Horton Group in Atlantic Canada.

the fine terrestrial clastics of the Mabou Group, the coal measures of the Cumberland Group, and the late Carboniferous to Permian redbeds of the Pictou Group (Bell 1929). In the area surrounding the Bay of Fundy, there was also a Jurassic-Triassic sedimentary basin (Fundy Group) developed in which sandstones, shales, basalts and minor limestone were deposited. During the Cretaceous fluvial quartz sands and kaolin of the Chaswood Formation were deposited throughout the Maritimes, but only a few outliers have been preserved (Stea and Pullan, 2001).

The Horton Group rocks of the Maritimes Basin are hosts to the best documented uranium occurrences (Quarch *et al*., 1981). The Horton Group can be divided into the upper arkosic Cheverie Formation and the lower Horton Bluff Formation.

Uranium Mineralization

The presence of anomalous levels of uranium, radium, and radon in the Carboniferous-aged Horton Group and underlying basement rocks of Atlantic Canada has been known for many years (Quarch *et al*., 1981; Fig. 1). The exploration model applied on the sandstone-hosted occurrences was that of a uranium roll-front similar to the deposits found in Texas and the western United States. However the recognition of deeply weathered granitoids below the unconformity of the Horton Group on the South Mountain Batholith suggests a genetic link to regolith-related unconformity deposits such as the Athabaska Basin of Saskatchewan may also be applicable.

There is no doubt of the presence of roll fronts in the Horton Group sandstones, however the source of the uranium within the system may be related to the weathered horizons beneath the Horton Group rocks and not exclusively the result of diagenetic change within the sandstones (Ryan and O’Beirne-Ryan, 2007).

The granitoid rocks of the South Mountain Batholith in Nova Scotia contain numerous uranium deposits and occurrences. These deposits are interpreted as having been formed due to fluid migration in the late stages of the granitoid emplacement and occur within shear and fracture zones of altered rocks either within the granitoids or as peribatholithic occurrences in the metasedimentary Meguma Group country rocks (Chatterjee 1983). These occurrences exhibit mineralogical evidence that they have been deeply weathered (Chatterjee 1983).

The uranium liberated by weathering of the granitic region must have been incorporated in the surface water and subsequently entered, as uranium-enriched groundwater, into the permeable sandstone and conglomerate aquifers of the Horton Group. Upon entering the sandstones of the Horton Group, the uranium-enriched oxygenated waters caused diagenetic reddening of the sandstone therefore liberating additional uranium into the water that travelled down dip until it reached a reduction-oxidation boundary where the uranium was deposited.

Uranium mineralization in the Windsor area is a typical sandstone roll-front type. The Green Street occurrence that is the focus of this study occurs in thick arkosic sandstones, siltstones, and pebbly conglomerates of the Cheverie Formation (Fig. 2). The occurrence is a remnant tail of a uranium roll front that has subsequently migrated down dip from the outcropping (Ryan and O’Beirne-Ryan, 2007).

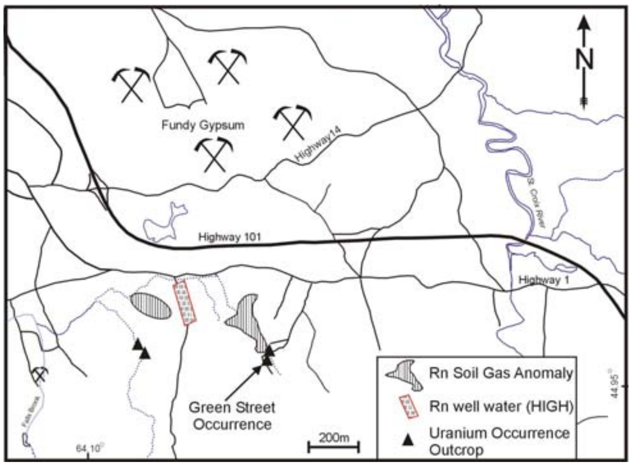

Figure 2. Location of Green Street Occurrence and related radon soil gas and well water anomalies.

Mobility of Uranium and Radon

The initial exploration and subsequent drilling in the Windsor area was sparked by the discovery of radon anomalies in the soil gas and well waters in the area (Quarch *et al*., 1981; Fig. 2). In addition, uranium and radium in well waters were weakly anomalous in the area. It is therefore not difficult to infer that these geochemical techniques are useful exploration tools for deposits of this type and that there are environmental issues related to uranium occurrences in the Horton Group.

A series of leaching experiments were carried out on mineralized sandstone and siltstone from the Green Street Occurrence (Parsons 2007). The samples were poorly consolidated and easily broken apart by hand and placed into the waters. The samples were placed in distilled water, stream water, and rain water at temperatures ranging from 5 to 20°C. In addition to unshaken samples, duplicate samples were agitated at regular intervals for varying lengths of time and subsequently analyzed for uranium and radon. All of the samples demonstrated significant uptake of uranium into the water (Table 1; Parsons 2007). The uranium content of the water from the siltstone sample exceeded the Canadian Drinking Water Quality Guidelines of 20 µg/L. There are no guidelines for Radon in drinking water however the concentrations in the waters exceeded 1,000,000 Bq/m3 (Table 2; Finlayson 2008). Whereas the radon and uranium can easily be incorporated into the surface and groundwater and transported down slope (to the north) the anomalous radon in soil and well waters in the area can be attributed to the mineralized outcrops (Fig. 2).

Table 1. Total uranium in water analyses, leaching experiments using rainwater, Green Street Occurrence, near Windsor Nova Scotia (after Parsons, 2007).

Sample AP06-01	Sample AP06-04
Mineralized Sandstone	Mineralized Siltstone
16 µg/L Uranium	24 µg/L Uranium

Table 2. Radon uptake in unshaken distilled water at 20^{0}C from mineralized Green Street samples (after Finlayson 2008).

Time	**Mineralized sandstone**	**Mineralized siltstone**
8 days	83,000 Bq/m^3	422,000 Bq/m^3
10 days	796,000 Bq/m^3	558,000 Bq/m^3
12 days	>1,000,000 Bq/m^3	>1,000,000 Bq/m^3

Although this paper deals primarily with uranium and radon from occurrences in the Windsor area of Nova Scotia, the areal extent of the Horton Group strata throughout eastern Canada would seem to imply that environmental issues related to the Horton Group uranium mineralization might exist throughout the Maritimes Basin.

Acknowledgments

Funding for this project was provided by the Nova Scotia Department of the Environment and Labour and the Nova Scotia Department of Natural Resources.

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