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A STUDY OF THE MIGRATION OF RADIONUCLIDES, MAJOR, TRACE AND RARE-EARTH ELEMENTS ALONG DEEP FRACTURES IN THE LAC DU BONNET BATHOLITH, MANITOBA

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ABSTRACT

The history of actinide and trace element mobility in deep fractures (>1 km) in the Lac du Bonnet batholith, Manitoba, has been studied in support of the Canadian Nuclear Fuel Waste Management Program. The objective of this study was to date the sequence of hydrogeochemical disturbances that occurred in deep zones of the granite, and to determine their significance to element mobility. Borehole core samples were collected from brecciated zones (1170-m depth) containing highly saline groundwater. Samples obtained as 1-cm-wide sections in alteration haloes surrounding two fractures were investigated mineralogically, chemically and isotopically.

Several overprinted alteration events, from high-temperature deuteric effects to low-temperature hydrothermal alteration, were identified. K-feldspar and, more recently, clay minerals (mainly Fe-Mg- or Mg-rich chlorites, illite and then kaolinite) crystallized in brecciated zones; a subsequent circulation of oxidizing fluids produced alteration of Fe-Mg-rich chlorite to hydrous iron oxides. In one of the fractures a loss of Ca and Na as a result of plagioclase breakdown was observed in altered samples, whereas a sharp increase in K, Mg, U, Th and rare earth elements (REE) was observed closer to the fracture surfaces, associated with the presence of illite. Pronounced disequilibria of $^{234}U/^{238}U$ **(<0.5)**, $^{230}Th/^{234}U$ (-0.70) and $^{226}Ra/^{230}Th$ **(-0.90)** exist only in the illitic clay fraction, indicating ^{234}U, ^{230}Th and ^{226}Ra loss to groundwater within the last 1 Ma. This loss is essentially due to a direct alpha-recoil effect after U adsorption on clay mineral surfaces. The isotopes ejected into the groundwater have migrated toward the brecciated zones, resulting in **deposition** over different distances: ^{230}Th was retained in the immediate vicinity of the clay; ^{226}Ra deposited in kaolinite-rich samples collected in the breccia (-5 cm from the fractures surface); and ^{234}U migrated over longer distances and deposited at some distance (-15 cm) from the fracture.

These two fracture zones provide examples of a multistage history of water-rock interactions along the fractures. Some evidence of U and REE migration was observed in the alteration halo of the brecciated zone. This mobilization occurred during brecciation of the rock. Uranium-series disequilibria measurements indicate that the major disturbances occurred on the fracture surfaces, as deep as 1170 m in the granite, within the last 1 Ma. These disturbances are confined to migration of ^{234}U, ^{226}Ra and to some extent ^{230}Th isotopes via direct alpha-recoil effect after deposition of U on clay mineral surfaces.

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