Paragenesis and composition of tourmaline types along the P2 fault and McArthur River uranium deposit, Athabasca Basin, Canada

Erin E. Adlakha and Keiko Hattori

Department of Earth Science, University of Ottawa, Ottawa, ON, K1N6N5, Canada. E-mail: eadla028@uottawa.ca

ABSTRACT

The P2 fault, a 13 km long steeply dipping reverse fault, is the main structural control of the McArthur River uranium deposit in the eastern Athabasca Basin, northern Saskatchewan, Canada. Three types of tourmaline were observed in the metasedimentary basement rocks along the P2 fault: early oxy-schorl $[(\square_{0.37}Na_{0.47}Ca_{0.16})(Mg_{0.72}Fe^{2+}_{1.30}Ti_{0.07}Al_{0.91})Al_{6}(Si_{5.79}Al_{0.21}O_{18})(BO_{3})_{3}OH_{3}(F_{0.08}OH_{0.29}O_{0.63})$, where $\square$ = vacancy] of magmatic origin, and hydrothermal oxy-dravite $[(\square_{0.18}Na_{0.57}Ca_{0.23}K_{0.02})(Mg_{1.93}Fe^{2+}_{0.62}Ti_{0.15}Al_{0.29})Al_{6}(Si_{5.93}Al_{0.07}O_{18})(BO_{3})_{3}OH_{3}(F_{0.20}OH_{0.23}O_{0.57})]$ and magnesio-foitite $[(\square_{0.77}Na_{0.20}Ca_{0.02}K_{0.01})(Mg_{1.99}Fe^{3+}_{0.07}Al_{0.92})Al_{6.00}(Si_{6.00}O_{18})(BO_{3})_{3}(OH_{3})(F_{0.04}OH_{0.71}O_{0.25})]$. Oxy-schorl formed in granitic pegmatites, a partial melt product of the metasediments during their peak metamorphism. Oxy-dravite formed from hydrothermal fluids after the peak metamorphism but before deposition of the Athabasca sandstones, whereas magnesio-foitite is a product of later, low temperature hydrothermal activity. Both oxy-schorl and oxy-dravite are coarse-grained (from 500 µm, up to 1 cm), whereas magnesio-foitite occurs as radial aggregates of fine, prismatic crystals (<15 µm in width). Magnesio-foitite crystallized together with sudoite, illite and "APS" minerals (alunite-supergroup LREE-rich aluminum phosphate-sulphate minerals) along the entire studied length (~ 7km) of the P2 fault and is abundant in proximity to the Zone 2 ore body of the McArthur River deposit. In the ore zone, the assemblage occurs with uraninite and is partially overprinted by late, remobilized uraninite and sudoite. Therefore, magnesio-foitite is likely contemporaneous with the main stage of uranium mineralization. It is characterized by a high vacancy in its X-site (0.70 – 0.85 *apfu*) and high Al in its Y-site (0.70 – 1.12 *apfu*), suggesting that magnesio-foitite likely replaced pre-existing high Al phases, such as kaolin and sudoite. The occurrence of magnesio-foitite along the entire P2 fault, in areas of mineralization and apparently barren areas, suggests similar fluids travelled along the entire P2 fault, but only produced ore in localized areas.

Keywords: tourmaline, oxy-schorl, oxy-dravite, magnesio-foitite, unconformity-type uranium deposits, hydrothermal ore deposits, alteration

INTRODUCTION

The Athabasca Basin hosts world-class unconformity-type uranium deposits, including the McArthur River deposit. Prevalent models for uranium mineralization invoke an oxidizing, highly saline brine (25 – 35 wt% NaCl equiv.), with a marine component, generated during basin development (*e.g.*, Hoeve & Sibbald 1978, Kotzer & Kyser 1995; Alexandre *et al*. 2005, Derome *et al.* 2005, Richard *et al.* 2011, Mercadier *et al.* 2012). Quartz-hosted fluid inclusions in ore breccias indicate that two types of fluids were present during mineralization, i) an earlier, acidic, NaCl-rich, uranium-bearing brine and ii) an evolved $CaCl_2$-rich brine assumed to have formed by the interaction of the earlier brine with basement rocks (Derome *et al.* 2005, Richard *et al.* 2010, Richard *et al.* 2011, Richard *et al.* 2012). Uranium deposition was caused by the reduction of U^{6+} to U^{4+} in the fluids. Proposed reductants include minerals (e.g., graphite, Fe^{2+}-bearing chlorite and