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Compositional variation and timing of aluminum phosphate-sulfate minerals in the basement rocks along the P2 fault and in association with the McArthur River uranium deposit, Athabasca Basin, Saskatchewan, Canada†

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Abstract

The Athabasca Basin hosts world class uranium deposits, such as the McArthur River deposit. This paper presents the occurrence of aluminum phosphate-sulfate (APS) minerals in the metasedimentary rocks along the P2 fault, the main ore-hosting fault of the McArthur River deposit. It compares the APS minerals along the P2 fault with those outside the fault, examined in this study, and those from other deposits of the Athabasca Basin and from other Paleo- to Mesoproterozoic basins worldwide.

APS minerals are common along the P2 fault but rare outside of the P2 fault zone in the basement and along the unconformity between the Athabasca sandstones and the basement. The APS minerals along the P2 fault occur with sudoite (± illite, magnesiofoitite) and are zoned with Sr-, Ca-, and S-rich cores (solid solution between svanbergite, crandallite, and goyazite) and LREE- and P-rich rims (close to florencite composition). APS minerals in the Bleached Zone (altered rocks along the unconformity consisting predominantly of kaolin and illite) are Sr-, Ca-, and S-rich (high svanbergite component) and occur with kaolin. APS minerals in the Red-Green Zone (mingled red hematitic and green chloritic basement rocks below the Bleached Zone) occur with sudoite and clinochlore. They contain relict cores of LREE- and As-rich arsenoflorencite-(Ce) and rims of svanbergite-goyazite-crandallite solid solution.

The occurrence of svanbergite-crandallite-goyazite along the unconformity suggests their formation by relatively oxidizing fluids during diagenesis of the overlying sandstones. The relict cores of arsenoflorencite-(Ce) in the Red-Green Zone are interpreted to be the product of paleo-weathering before the deposition of the Athabasca sandstones. Florencitic APS minerals are found along the entire studied strike length (7 km) of the P2 fault, including the ore zone and non-mineralized areas, but are absent outside the fault zone. The florencitic APS minerals contain low SO_4^{2-} in the ore zone, suggesting relatively reducing conditions during their crystallization. Zoned APS minerals (with svanbergitic cores and florencitic rims) proximal to ore contain elevated U (up to 16 ppm). These features suggest that diagenetic, oxidizing, and uranium-bearing fluids traveled along the P2 fault and became relatively reduced, especially within the ore zone. It also suggests florencitic APS minerals are contemporaneous with uranium mineralization. The restricted occurrence of florencitic APS mineral along the P2 fault in the basement suggests their use in identifying fertile basement structures associated with uranium mineralization.

Keywords: Hydrothermal alteration, APS, uranium mineralization, florencite, svanbergite, arsenoflorencite, diagenesis, paleo-weathering, unconformity-type uranium deposits

Introduction

The Athabasca Basin hosts numerous large uranium deposits (Fig. 1), which are classified as unconformity-related uranium deposits. The prevalent model for mineralization was first proposed by Hoeve and Sibbald (1978) and modified later by many researchers (e.g., Alexandre et al. 2005; Derome et al. 2005; Richard et al. 2011; Mercadier et al. 2012). This model suggests that sea-water derived, uranium-bearing oxidizing brines (25–35 wt% eq. NaCl) precipitated uranium ore at the unconformity when it reacted with a reducing fluid of currently unknown origin. Many deposits occur in the proximity of deformation zones in the basement and it is suggested that re-activated basement faults served as conduits for uranium-bearing fluids (Jefferson et al. 2007) or reducing basement fluids to reach the unconformity (McGill et al. 1993). The McArthur River deposit, the largest discovered high-grade (average grade of 16.46% U_3O_8; Bronkhorst et al. 2012) uranium deposit on Earth, is situated along the P2 fault, a 13 km long reverse fault constrained to graphitic metapelite below the Athabasca Basin. Although geophysical and structural studies have been carried out on the P2 fault (e.g., Hajnal et al. 2010), the exact role of the fault in the mineralization remains uncertain.

In the Athabasca and Thelon basins of Canada, aluminum phosphate-sulfate (APS) minerals (also known as alumino-phosphate sulfate) spatially associated with uranium deposits have been reported (Quirt et al. 1991; Gall and Donaldson 2006;

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† Special collection papers can be found on GSW at http://ammin.geoscienceworld.org/site/misc/specialissuelist.xhtml.

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