
Deciphering uranium mobilities in unconformity-related uranium deposit: the Waterfound case study

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Résumé

The Athabasca Basin in Saskatchewan, Canada, is a world-class metallogenic province for uranium, hosting the highest-grade uranium deposits worldwide. These deposits, named unconformity-related, formed due to complex processes at the interface between the Archean-Paleoproterozoic basement and the Paleo-Mesoproterozoic sedimentary basin. Fluid circulations and mixing, active between 1.6 and 1.0 Ga and spatially associated with basement-hosted graphite-rich structures, created extensive hydrothermal halos and precipitating large uranium deposits. Multiple tectonic and hydrothermal events potentially favored the precipitation of uranium oxides and/or their alteration, complicating the understanding of (i) the critical events for U cycle and of (ii) uranium mobility over time in this geological context. This study focuses on the Waterfound U occurrence in northeastern Athabasca Basin. This zone gathers all the typical markers of unconformity-related uranium deposits but has a relatively limited size, which favored a preservation of the structural, mineralogical and geochemical contexts linked to uranium oxides (UO). The goal is to propose a framework of the physico-chemical and geochronological evolutions of the uranium oxides through an integrated approach combining structural, mineralogical and geochemical analyses focused on uranium oxides. The results indicate that uranium oxides primarily formed in the basin at 1360 ± 5 Ma in the different veins and fault cores regardless of their orientations, in association with clay minerals (illite and a first generation of chlorite). These oxides subsequently experienced three main alteration phases: (i) localized brecciation at ~ 1263 Ma, associated with Co-Ni sulfo-arsenide precipitation; (ii) alteration around 1050 Ma, involving clay formation, partial UO dissolution, Pb loss, and element gains (Si, Ca, Fe); (iii) a near-recent (< 100 Ma) circulation of meteoric water leading to oxidation, Pb loss and Si, Ca, Fe, LREE

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enrichments, and the formation of new uranium oxides. The study highlights the necessity of integrating structural, mineralogical, and geochemical data to accurately reconstruct uranium deposit formation and post-crystallization alteration throughout the long geological history of the Athabasca Basin and related Canadian Shield. Such approach would be highly beneficial in other types of uranium deposits.

Mots-Clés: Uranium veins, Athabasca Basin, U/Pb Geochronology, Unconformity, Related Uranium deposits (URU), LA, ICP, MS, Trace element geochemistry