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Alteration Mineralogy and Stable Isotope Geochemistry of Paleoproterozoic Basement-Hosted Unconformity-Type Uranium Deposits in the Athabasca Basin, Canada

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Abstract

Unconformity-type uranium deposits are characterized by mineralization developed along the contact between younger sandstone cover and underlying crystalline basement rocks. Mineralization may extend up to 400 m into the underlying basement rocks. Whereas sandstone-hosted unconformity-type deposits have been well studied, deposits hosted primarily in the basement have not. This study examines the deposits at Rabbit Lake, Dawn Lake, and McArthur River, in the Athabasca basin of Canada, which are hosted by the metamorphic Archean and Early Paleoproterozoic rocks forming the basement to younger Late Paleoproterozoic sandstones. Alteration is similar in the three deposits and is characterized by three distinct paragenetic stages: (1) preore alteration involving illitization of plagioclase and amphibole, followed by chloritization of biotite and illite, which formed at ca. 230°C; (2) ore-stage alteration, characterized by uraninite and coarse-grained illite, which formed at ca. 240°C; (3) postore alteration comprising spherulitic dravite, vein chlorite, quartz, calcite, and Fe, Cu, Co, and Pb sulfides, which formed at ca. 135°C. Fluid circulation associated with emplacement of later Mackenzie dikes initiated partial recrystallization of uraninite. A later stage of alteration includes kaolinite and iron hydroxide precipitation formed at much lower temperatures of ca. 50°C.

Stable isotope compositions of the alteration minerals in conjunction with their paragenesis indicate that oxidized basinal fluids (δD = –43 to –21‰, $\delta^{18}O$ = 3–8‰) were derived primarily from evolved seawater and leached uranium from the overlying sandstones of the Athabasca Formation and transported it into the basement via infiltration along fracture zones associated with reverse faults. Graphitic units in the basement and preore alteration served as both physical (fractured zones) and chemical (reductants) traps for the uranium mineralization. The basinal fluids were responsible for the preore illite-chlorite, synore uraninite-illite, and the early postore alteration events; this differs from many other sandstone-hosted deposits, where both oxidized basinal and reduced basement-derived fluids were responsible for uranium precipitation.

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