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Mixing of Sodic and Calcic Brines and Uranium Deposition at McArthur River, Saskatchewan, Canada: A Raman and Laser-Induced Breakdown Spectroscopic Study of Fluid Inclusions

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Abstract

The richest U deposit in Saskatchewan, Canada, occurs in the McArthur River area, in the vicinity of the unconformity between the Athabasaca sandstones and an Archean to lower Proterozoic basement. Paleofluids related to the silicification of the sandstones and the formation of pre- and postore cements in breccias were studied using microthermometry, Raman microspectroscopy, and laser induced breakdown spectroscopy (LIBS) on individual fluid inclusions. A detailed reconstruction of the fluid composition in the system Na-Ca-Mg-Cl shows that two types of brines are responsible for the main quartz cements: an NaCl-rich brine (25 wt % NaCl, up to 14 wt % $CaCl_2$, and up to 1 wt % $MgCl_2$), which is interpreted as a primary formation water that was expelled from bedded evaporites; and a $CaCl_2$-rich brine (5–8 wt % NaCl, 20 wt % $CaCl_2$, and up to 11 wt % $MgCl_2$), which is considered to have formed during the interaction between the NaCl-rich brine and Ca-rich minerals in the basement and was introduced into the fault system and mixed with the NaCl-rich brine during the critical stage of U deposition. The pressure-temperature conditions of formation of the quartz cements are estimated to be 1,200 to1,400 bars and 190° to 235°C for the silicification events during the preore stage, and 500 to 900 bars after a pressure decrease from lithostatic conditions and slightly lower temperatures due to the mixing of the NaCl-rich brine with the cooler (approx 140°C) $CaCl_2$-rich brine during the main stage of breccia sealing. Temperature and pressure drops combined with the effects of brine mixing appear to be key factors for the main stages of quartz cementation and U deposition at the McArthur deposit.

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