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The Origin and Enrichment of Sedimentary Basin Lithium Brines: A case study from the Devonian oil field brines of the Alberta Basin, Canada

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Direct extraction of lithium from oil field brines is emerging as an economical and environmentally responsible alternative to conventional lithium resources. Oil field brines and produced waters present a promising and readily available domestic supply of lithium. Elevated lithium concentrations are known in hydrocarbon fields across North America, but the origin of these brines, the lithium sources, and lithium enrichment mechanisms are largely debated or unknown. We document the complexity of unraveling brine genesis and evolution by applying multiple isotope systems (δ^2H, $\delta^{18}O$, $^{87}Sr/^{86}Sr$, $\delta^{11}B$ and δ^7Li) to interrogate formation of the Devonian brines of the Alberta Basin, Canada. Competing hypotheses regarding brine origin, postformational brine modification, and lithium sources confound an understanding of the lithium resource homogeneity and longevity. Using brine-dissolved species and isotopic data, we show that the Devonian brines are regionally geochemically distinct across the Devonian reef complex reservoirs. We further subdivide the Devonian brines into geochemically distinct groups associated with four Devonian carbonate reef complexes (Redwater, Leduc, Chedderville, Bashaw). These reef trend aquifer brines show varying meteoric water dilution and brine modification due to interactions with basinal siliciclastic sediments that alter Li concentrations. Shallow reef complexes in hydraulic communication with the surrounding formations are unable to preserve high Li grades, and can be identified by depleted δ^2H, $\delta^{18}O$ values and low Li concentrations. Brines from structurally deeper reef complexes approaching the Rocky Mountain deformation front show evidence of greater rock-water interactions with marine shales (high B-K-Li concentrations, enriched $\delta^{18}O$ and radiogenic strontium, and depleted $\delta^{11}B$ and δ^7Li values), which may serve as a Li source to brines. This compositional heterogeneity has implications for lithium resource exploration, production, and valuation of the Alberta Basin Devonian brines and other sedimentary basin lithium brine resources.