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Insights from an enriched lithium basinal brine source: A geochemical comparison of brines from the Smackover and Cotton Valley Formations of southern Arkansas and northern Louisiana

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The Jurassic Smackover and Cotton Valley Formations are two prolific petroleum-producing units within a thick and laterally extensive Mesozoic sedimentary sequence of the Gulf Coast region. Substantial attention has focused on the high lithium (>100 mg/L) concentrations of Smackover Formation brines, which recent studies suggest may contain between 5 to 19 million tons of dissolved lithium. These brines are being explored by industry to determine their commodity potential via direct lithium extraction technologies. Many outstanding questions exist regarding the behavior and natural enrichment mechanisms of lithium in Smackover and overlying Cotton Valley brines across the region.

To address these knowledge gaps and build upon historical brine geochemical records, the U.S. Geological Survey sampled 27 oil, gas, and brine wells across southern Arkansas in 2022, and 26 wells in northern Louisiana in 2024 with the majority of all wells producing from the Smackover and Cotton Valley Formations at depths ranging from 5,000-13,000 feet. Brines were analyzed for a suite of geochemical and physical parameters including total dissolved solids (TDS), major cations and anions, and isotopic measurements including d^7Li, $^{87}Sr/^{86}Sr$, and d^2H-H_2O/$d^{18}O$-H_2O, and $d^{34}S$-SO_4/$d^{18}O$-SO_4.

Across the Gulf Coast region, dissolved lithium concentrations (1-250 mg/L) covary with other concentrations of alkali elements, including potassium, and suggest sourcing from high-temperature (>150 °C) alteration of silicate minerals. Stable lithium isotope values from high-salinity (>250 g/L) Smackover brine samples in southern Arkansas (d^7Li_{LSVEC} = +14.0±1.2‰, N=16) are substantially heavier compared with high-salinity samples from northern Louisiana (d^7Li_{LSVEC} = +9.4±1.2‰, N=8) where the Smackover Formation is 3,000-4,000 feet deeper. Isotope mixing models suggest a greater contribution of lithium from the evaporation of paleoseawater (d^7Li_{LSVEC} > +20‰) in the shallower southern Arkansas Smackover brine samples. In contrast, deeper sections in northern Louisiana likely exhibit significant water-rock (d^7Li_{LSVEC} > 0-5‰) interaction and early loss of lithium from evaporated seawater due to meteoric flushing. We evaluate these data from brines of the Smackover and Cotton Valley Formations in a regional context and demonstrate the utility of isotope tools for understanding the complexity of lithium sources in northern Gulf Coast basinal brines.