Elemental and Isotope Geochemistry of Lithium-Rich Brines in the Northern Gulf of Mexico Basin: Implications for Fluid Mixing and Water-Rock Interaction

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Geochemical data reveal the extent and nature of fluid mixing and water-rock interaction accompanying the migration of brines in sedimentary basins. Sedimentary brines may contain economic quantities of lithium, bromide, and other elements that are strategically important. This study investigates the origin, geochemical characteristics, and migration of lithium-rich brines within the Upper Jurassic Smackover Formation in the Northern Gulf of Mexico Basin through elemental and isotopic analyses and numerical modeling. Major ion analysis displays Na-Cl-Ca dominated hydrochemical facies and a depletion in sulfate relative to seawater. Lower sulfate concentrations, coupled with appearance of high H_2S levels in some brines, suggest sulfate removal mechanisms such as bacterial sulfate reduction. Low Cl/Br and Na/Br ratios of brines indicates their acquisition of salinity through the mixing of meteoric water with evaporated seawater reaching halite saturation, rather than halite dissolution. Isotopic trends of $\delta^{18}O$ and $\delta^{2}H$ also suggest a mixture of meteoric water with remnant evaporated seawater reaching gypsum and halite saturation. The $^{87}Sr/^{86}Sr$ ratios of the brines range from 0.707403-0.710026, higher than that of Jurassic seawater (0.7071). The non-linear relationship between $^{87}Sr/^{86}Sr$ and 1000/Sr suggests alteration of brine geochemistry by water-rock interaction and input from ^{87}Sr-riched fluids. Correlation among $^{87}Sr/^{86}Sr$, Li, and H_2S indicate their common deep geologic sources. Geochemical modeling predicts a Cl-Mg facies of evaporated seawater that reaches halite saturation, contrasting with the observed Cl-Ca dominance in the Smackover Formation brines. Water-rock interaction such as dolomitization, cation-exchange, and albitization may account for enrichment of Ca and depletion of Na and Mg in brines. The fault zones created by the diapirism of Louann Salt may provide potential migration pathways for the brine to travel upward into the shallower Smackover Formation under the influence of overpressure or thermohaline convection driving forces in the Gulf of Mexico Basin.