Lithium Anomalies as Indicators of Fault-Driven Brine Migration in Gulf Coast Basin Aquifers

Growing global demand for lithium necessitates improved understanding of lithium distribution and mobilization in sedimentary basin environments. This study evaluates groundwater geochemistry from the U.S. Gulf Coast, particularly within Texas aquifers, to investigate lithium enrichment processes and the role of fault-driven brine migration. Utilizing publicly available groundwater datasets from the Texas Water Development Board (TWDB) and the USGS National Water Information System (NWIS) and produced waters database (PWDB), geochemical and spatial analyses were conducted to identify and characterize lithium anomalies associated with structural features.

High-resolution geochemical mapping demonstrates clear correlations between elevated lithium concentrations and major fault systems, suggesting active brine migration along structural pathways. These elevated lithium concentrations near faults indicate that lithium is either directly co-transported within migrating brines or released into solution from clay minerals via brine interactions, both proposed mechanisms directly resulting from brine migration processes. Key geochemical indicators—including lithium-to-magnesium (Li/Mg), sodium-to-potassium (Na/K), and chloride-to-bromide (Cl/Br) ratios—effectively differentiate between local groundwater chemistry influenced by in-situ water-rock interactions and anomalous lithium-enriched brines sourced from deeper formations. Statistical analyses, supported by Principal Component Analysis (PCA), reinforce the structural control of lithium distribution, particularly in regions intersected by significant faults such as the Mexia-Talco fault zone and the Fort Worth Basin.

This study provides critical insights into aquifer regions experiencing increased salinity from brine migration, which is vital for forecasting future groundwater availability in Texas. Additionally, identifying and characterizing regional brine profiles allows researchers to better understand the potential distribution and recoverability of lithium and other critical minerals. Improved brine profiles contribute significantly to strategic planning for resource exploration and sustainable groundwater management. Future research should expand on these findings by incorporating isotopic analyses and additional geochemical tracers to further elucidate brine origins and migration pathways, particularly in identifying if these lithium anomalies are brine or clay sourced.

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