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Geochemical controls on the lithium enrichment of brine in the Late Devonian Bakken Formation, Williston Basin

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Oilfield brines commonly have elevated lithium concentrations compared with fresh water and seawater, yet the processes driving this enrichment are poorly understood. Two main enrichment mechanisms have been proposed, namely fluid-rock interaction and the dissolution of lithium-bearing evaporites. Direct evidence linking lithium mobilization to specific lithologies is poorly documented. This study investigates the origin of the brines in the Late Devonian Bakken Formation, and their pathways to lithium enrichment in the Williston Basin, by relating the brine chemistry to the host rock lithogeochemistry.

We analyzed major and trace element concentrations in samples from the Lower, Middle, and Upper members of the Bakken Formation, as well as the underlying Three Forks Formation. These data were used to evaluate spatial and temporal trends in lithium distribution across the Bakken Formation.

Lithium concentrations in the Bakken brines range (16th to 84th percentiles) from 41.9 to 58.1 mg/L with a median of 50.3 mg/L and increase systematically towards the basin centre. In contrast, lithium concentrations in the shales decrease from the margins (~100 ppm) towards the basin centre (~60 ppm). Weakening correlations among Li, Al and K with increasing thermal maturity suggest that detrital aluminosilicates were the principal source of lithium and that burial-induced temperature changes drove lithium mobilisation into the brine.

The brine chemistry is characterised by Sr and Ca enrichment coupled with Mg-depletion, due likely to dolomitisation, whereas the K and B distributions point to feldspar dissolution and limited illitisation. The Middle Devonian Prairie Evaporite Formation, a proposed source for lithium in correlative units in Alberta (Canada), contains negligible lithium, ruling out evaporite dissolution as a major contributor of lithium.

Our findings suggest that post-depositional diagenetic alteration of detrital clays and feldspar dissolution were responsible for the observed lithium enrichment in the Bakken brines rather than evaporative concentration or external lithium input. Spatial variations in brine lithium concentrations correspond to lateral changes in shale geochemistry, reinforcing a temperature-controlled fluid-rock interaction model. These findings enhance our understanding of lithium mobility in sedimentary basins and offer valuable guidelines for conducting lithium brine exploration in subsurface geological formations.