# Leveraging Geochemical Techniques to Unravel Lithium Sourcing and Enrichment in Low-Temperature Geothermal Brines

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## Summary

Deep saline aquifers are emerging as economically competitive and environmentally responsible resources for Direct Lithium Extraction (DLE), offering an alternative to hard-rock and salar-style lithium production. Low-temperature geothermal lithium brines, in particular, present a promising and readily available domestic supply of lithium. Elevated lithium concentrations (>50 mg/L) have been documented in hydrocarbon fields across North America; however, the origins of these brines, lithium sources, and enrichment mechanisms remain subjects of debate.

Using the Upper Devonian Leduc Formation (Alberta Basin, Canada) as a case study, this presentation highlights the geochemical techniques employed to unravel the complex genesis of these brines and their lithium enrichment. Key methods include inductively coupled plasma optical emission spectroscopy (ICP-OES) and mass spectrometry (ICP-MS) for precise lithium concentration measurements, along with isotopic analyses of lithium ($\delta^7$Li), oxygen and deuterium ($\delta^{18}$O/$\delta$D), and strontium ($^{87}$Sr/$^{86}$Sr). Major and trace element characterization further complements these approaches.

Geochemical datasets reveal significant spatial heterogeneity in lithium concentrations across reef complexes. Isotopic findings and Cl/Br ratios suggest that the brines are derived from evaporatively concentrated seawater (primary brines) and the dissolution of evaporite sequences (secondary brines). These fluids have been modified by processes such as mixing, diagenesis, mineralization, and rock-water interactions. Oxygen and deuterium isotopes ($\delta^{18}$O/$\delta$D) provide insights into brine origins and post-formational modifications, including mixing and dilution processes. Strontium isotopes ($^{87}$Sr/$^{86}$Sr) trace fluid evolution by documenting interactions between brines and basinal rocks, basinal fluids, or dolomitizing fluids. Lithium isotopes ($\delta^7$Li) uniquely identify Devonian shale pore waters as a critical lithium source and reveal mechanisms of lithium enrichment.

These findings highlight the critical role of integrated geochemical techniques in understanding lithium sourcing and enrichment processes. Understanding the regional variability in brine composition and lithium concentrations is crucial for optimizing resource development strategies. By integrating geochemical analyses with depositional history and reservoir characterization, lithium resource estimates can be refined, enabling more sustainable extraction methods and facilitating the discovery and exploration of new resources in unconventional lithium reservoirs.

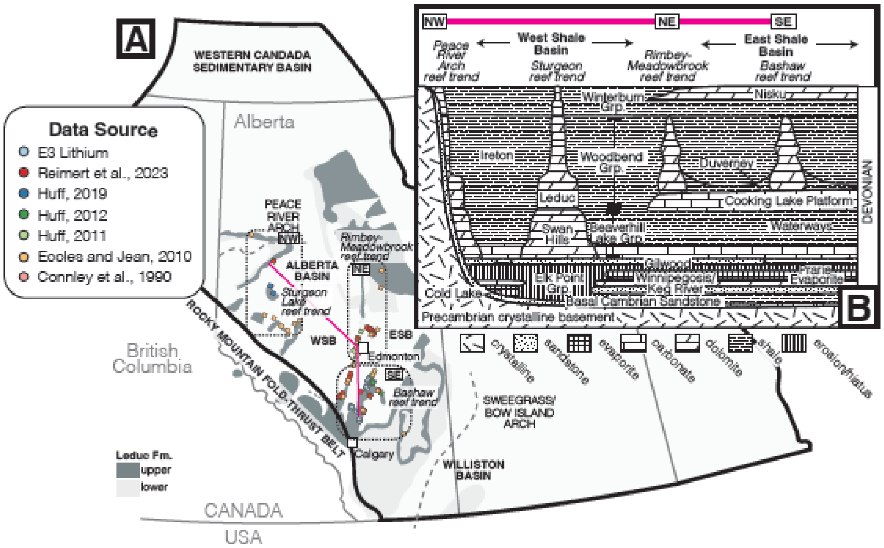


*Figure 1: (A) Study area map showing the Leduc brine wells, study regions (NW - northwest, NE - northeast, SE - southeast), key reef trends (Peace River Arch, Sturgeon Lake, Rimbey-Meadowbrook, Bashaw), basins and sub-basins (Western Canada Sedimentary, Alberta, Williston, WSB: Western Shale Basin, ESB: Eastern Shale Basin), regional structures (Rocky Mountain fold-thrust belt, Peace River Arch, Sweetgrass/Bow Island Arch). Modified from Huff, 2019. (B) Schematic Devonian-Precambrian stratigraphy along NW-NE-SE line Modified from Stacey et al., 2020.*

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