Overview of potential lithium sources in the WCSB

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Summary

Lithium has the highest energy density among all elements and is therefore crucial in battery applications where size and weight are important considerations, specifically in electric vehicles (EVs). Since decarbonizing the transportation sector is an important climate change goal of many nations, governments around the world have introduced policies mandating the transition to EVs which will require a substantial increase in global Li production. Indeed, global production increased 21% from 2021 to 2022 (US Geological Survey, 2023), and the price of Li has increased nearly seven times in the last three years, with projections that Li demand will continue to grow by up to 13 times by 2040 (Uji et al., 2023). To meet this increase in demand, there has been significant interest in developing new sources of Li, including deep subsurface brines from sedimentary basins. Elevated concentrations of Li have been identified in brines from Devonian-aged formations in both Alberta and Saskatchewan which has led to significant interest from government, industry, and academia in the past decade. While the Frasnian-aged Leduc, Nisku, and Duperow Formations are well known to have the highest Li concentrations in the WCSB, the source of the Li remains enigmatic. This work explores the proposed sources of Li in the WCSB and other sedimentary-hosted Li deposits to identify possible geological conditions that may result in anomalous concentrations of Li in these formations. Understanding the source of Li is crucial for better informing exploration efforts and identifying locations with the highest economic potential for Li recovery.

Proposed Li Sources in the WCSB

Lithium concentrations by formation from previously published reports and theses for the Alberta and Williston Basins are shown in Figure 1 which indicates brines from Frasnian-aged formations (the Winterburn and Woodbend groups which host the Nisku and Leduc formations, respectively, and the Beaverhill Lake Group of the Alberta Basin and the Duperow Formation of the Williston Basin) are most enriched in Li.

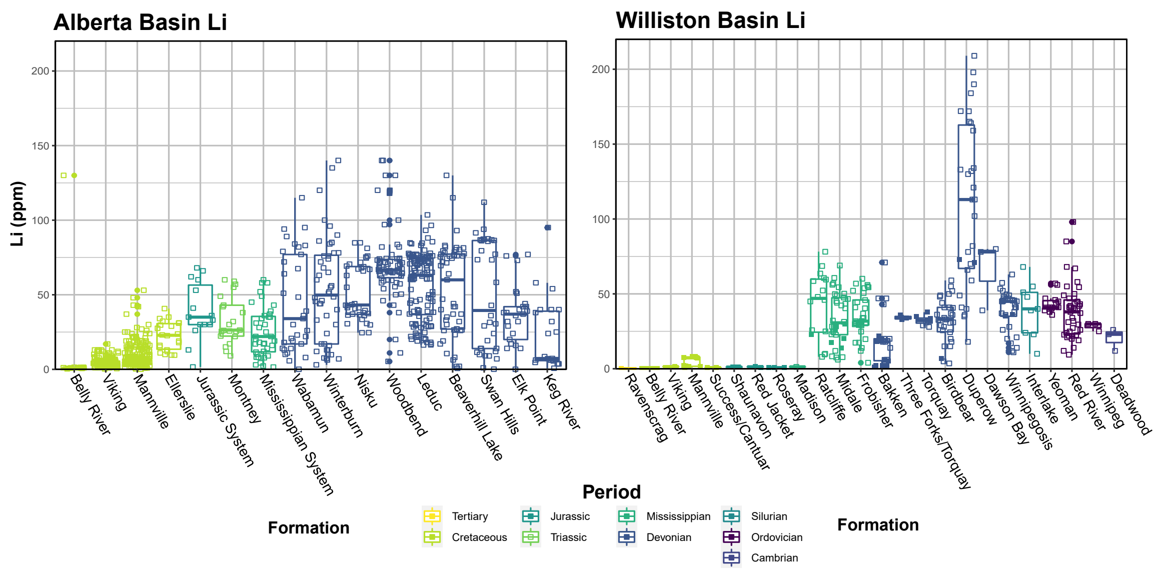

Figure 1 Li concentrations by formation across the Alberta and Williston Basins. Data from the Alberta and Saskatchewan geological surveys and graduate theses.

A map showing the distribution of Li in Frasnian formations in the WCSB is shown in Figure 2. The highest concentrations have been observed in the North Dakota portion of the Williston Basin which can exceed 200 ppm. However, the economic cutoff for Li concentration has been proposed to be approximately 75 ppm, therefore economic abundances are found across the WCSB, and this consistency in elevated concentrations indicates a regional, as opposed to localized, source of Li.

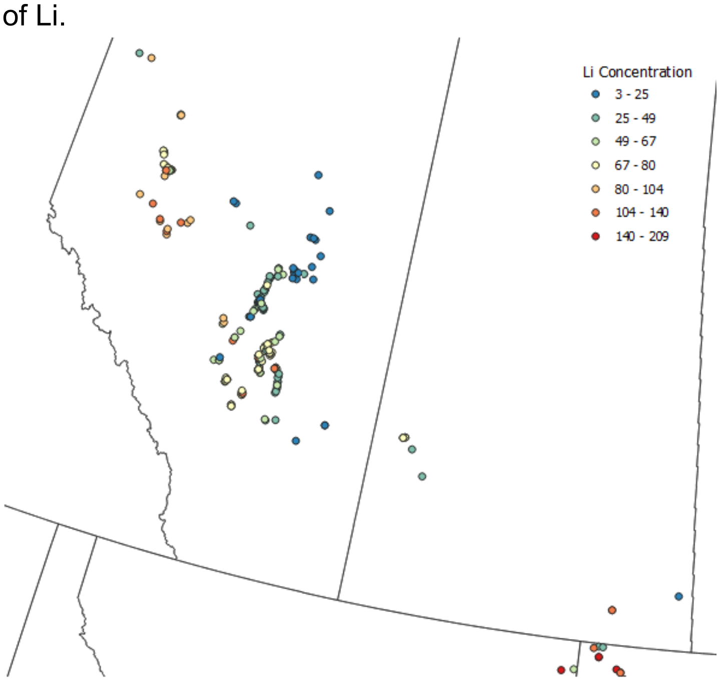

Figure 2 Lithium concentrations in Frasnian formations across the WCSB.

Evaporation of seawater has been proposed as a mechanism which leads to the enrichment of Li, since Na-Cl-Br systematics indicate that Li-enriched brines in the WCSB typically derive their salinity from seawater evaporation (e.g. Rostron et al., 2022; Figure 2). However, some samples with high Li concentrations plot in the evaporite dissolution field (upper right). Furthermore, past research has indicated that these elevated Li concentrations would require evapoconcentration in excess of 600x modern seawater (Huff, 2016) and seawater evaporation can only realistically concentrate Li to a maximum concentration of approximately 25 ppm (Dugamin et al., 2021). Therefore, seawater evaporation alone cannot account for the anomalous concentrations of Li observed in western Canadian brines (e.g. Bishop et al., 2022).

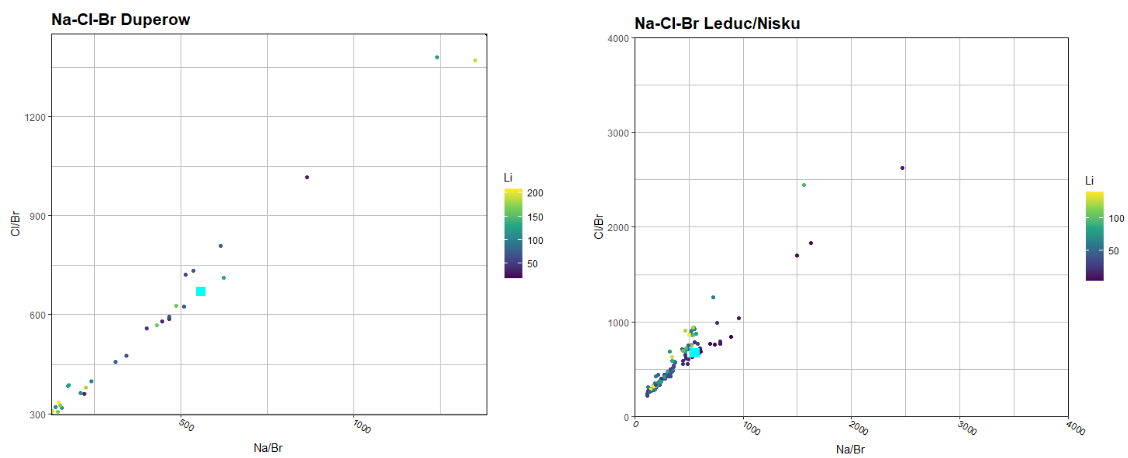

Figure 3 Na-Cl-Br systematics (Seawater represented by blue triangle).

Dissolution of late stage evaporite minerals concentrated in Li, likely within the Prairie Evaporite Formation, followed by fluid migration induced by tectonism has been proposed to account for high Li concentrations in the Leduc and Nisku formations (Huff, 2016). However, since Li behaves conservatively during evaporation and is not significantly incorporated into evaporite minerals (Dugamin et al., 2021; Mertineit & Schramm, 2019), it is extremely unlikely that this mechanism could concentrate Li to observed levels. It would also be expected that other formations adjacent to the Prairie Evaporite Formation would also be Li enriched if this were the case. A further hypothesis posited that, based on geochemical indicators of interaction with silicates, migration of fluids which were either derived from, or interacted with, the Precambrian basement led to Li enrichments in these formations (Eccles & Berhane, 2011). Again, for this mechanism, it would be expected there would be elevated Li concentrations in strata between the Frasnian formations and the Precambrian basement, while the fluids would likely need to traverse the impermeable Prairie Evaporite Formation. Alternatively, here, we propose that water-rock interactions which occur within these formations could be the dominant source of Li, which is supported by the data from Eccles and Berhane (2011) as well as observations from Li-rich brines and clays of South America, Nevada, China, and Germany. However, this hypothesis requires additional analytical work to further verify the source of Li as being internal to the formation in addition to identifying a mechanism that could account for a widespread, temporally constrained regional source. One potential control worthy of further investigation is the influence of widespread volcanism either prior to or during the Devonian which led to the emplacement of a Li-rich source. By constraining the source of Li and coupling this to knowledge of the subsurface in western Canada, intervals and locations that could host the highest concentration of Li and therefore present the best target for Li extraction may be predicted. The extraction of Li from brines in western Canada could be an important component of the energy transition by providing jobs and the necessary materials to decarbonize the economy.

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