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A Possible Role for Detrital Silicates in Generating Li-enriched Oilfield Brines: A Case Study from the Bakken Formation, Williston Basin, North Dakota

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Abstract

Some oilfield brines have elevated concentrations of lithium in North America, notably the Jurassic Smackover Formation (median Li concentration 103 mg/L; range 35 to 223 mg/L; 16th to 84th percentiles), the Middle Devonian Marcellus Formation (median Li concentration 67 mg/L; range 45 to 229 mg/L) and the Late Devonian Bakken Formation (median Li concentration 47 mg/L; range 32 to 70 mg/L). Other oilfield brines, however, contain much less Li. These include the Permian-aged Wolfcamp Shale (median Li concentration 13 mg/L; range 9 to 20 mg/L) and several formations within the Western Canadian Sedimentary Basins, such as the Keg River Formation (median Li concentration 14.1 mg/L; range 8.6 to 27 mg/L), the Ellerslie Member (median Li concentration 18 mg/L; range 6.1 to 24.3 mg/L) and the Mannville Group (median Li concentration 6.5 mg/L; 3 to 11.7 mg/L). The reasons why some oilfield brines are enriched in lithium, and other are relatively depleted in this metal are poorly understood. Three processes have been proposed to explain the elevated lithium concentration in some oilfield brines: evaporation of seawater, dissolution of Li-enriched evaporite sequences, and fluid-rock interaction with silicates. However, these processes have not been tested rigorously and appear to have several weaknesses. Many brines contain more Li than could be concentrated through the evaporation of seawater, which has a very low initial Li content (0.1 mg/L). Similarly, it is unlikely that end-stage evaporites (e.g., potash) could host enough Li to be a viable source of Li for oilfield brines. Of the three processes, the leaching of Li from silicate minerals appears to be the most plausible. However, the mechanism(s) by which this may occur have not been determined. This study presents new oilfield brine and whole-rock compositional data from the Bakken Formation (Williston basin, North Dakota), which suggest that the brines and shales are geochemically related. We show that there is a decrease in the Li content of the shales from the margins (~100 ppm Li) towards the deeper portions of the basin (~70 ppm), which we infer relates to the burial temperature. Two distributions of shale composition with similar Li contents have been identified based on the concentration of incompatible elements (e.g., Zr, Rb, Ta, Nb and Cs). We propose that the higher concentrations of incompatible elements represent detrital material sourced from a highly fractionated granitic hinterland, which would have had a greater Li content at the onset of deposition. Lithium was leached from the detrital minerals during diagenesis, particularly at higher temperatures during deep burial and partitioned into the brine.