LITHIUM BRINE POTENTIAL OF NORTH DAKOTA: RESULTS FROM THE 2025 SAMPLING PROGRAM

by

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On the Cover:
Left: Pumping unit at a produced-water sampling location in western North Dakota. Right: Examples of produced fluids at an oil well, showing visible separation between the brine and oil phases.

ABSTRACT

Lithium (Li), classified as a critical mineral and key in energy storage applications because of its high energy density, faces unprecedented demand. This has driven interest in unconventional sources of Li, especially brines from sedimentary basins. Accordingly, the spatial distribution of basinal brine-hosted Li resources across North America is becoming better defined, including the Williston Basin underlying Saskatchewan, Canada. This has led to growing investment and exploration by industry throughout the 2020s; however, despite this interest, the Li potential of basinal brines of the Williston Basin in North Dakota remain underexplored. This work presents the results from the 2025 joint brine sampling campaign between the North Dakota Geological Survey, the United States Geological Survey (USGS), and The University of Texas at Austin. Twenty-seven fluid samples were collected from producing oil and water source wells from eight stratigraphic intervals across western North Dakota and analyzed for major cation and anion concentrations. Similar to southeastern Saskatchewan, the highest Li concentrations were identified in the Devonian Duperow Formation, with concentrations up to 179 mg/L being observed in a well commingled between the Duperow and Red River Formations. Some samples from the overlying Birdbear Formation exceeded 75 mg/L, whereas Li concentrations were lower in the Madison Group (33-44 mg/L) and the Three Forks (50 mg/L), Dawson Bay (43 mg/L), Winnipegosis (23 mg/L), and Red River (40.0 mg/L) Formations. This work indicates Li resource potential exists across the Williston Basin and advances our understanding of the Li distribution in basinal brines which could provide a new domestic source of this critical mineral.

INTRODUCTION

Lithium (Li) has the highest energy density among elements on the periodic table (Tomascak et al., 2016), making it essential in modern energy storage applications such as electric vehicles and grid storage (Gielen and Lyons, 2022). As the adoption of these technologies grow, the associated demand may result in global supply shortages (International Energy Agency, 2024), a factor leading to its inclusion on the 2025 List of Critical Minerals (U.S. Geological Survey, 2025). While Li has traditionally been produced from hard-rock pegmatite and salar deposits, current projects may be unable to meet future demand; as such, there is growing interest in new and unconventional deposit types, such as brines from sedimentary basins (Gardiner et al., 2024). Although these basinal brines are not suitable for traditional evaporation-precipitation processing methods used for extracting Li from salar deposits, advances in direct lithium extraction (DLE) technology are bringing recovery from these lower-grade sources closer to economic viability (Yang et al., 2024). Potentially economic Li concentrations have been discovered in formation waters from sedimentary basins across North America (Phan et al., 2016; Darvari et al., 2024; Knierim et al., 2024; McDevitt et al., 2024; Bishop and Robbins, 2025), which has spurred exploration and the discovery of significant mineral resources, including those in the Williston Basin of Saskatchewan (e.g., Arizona Lithium, 2023; EMP Metals, 2025).

The Li potential of basinal brines of southeastern Saskatchewan has been the focus of numerous studies since the early 2010s (Jensen, 2011; Jensen, 2012; Jensen, 2015; Jensen, 2016; Jensen and Rostron, 2017; Jensen and Rostron, 2018; Bishop et al., 2024). Through this work, elevated (>100 mg/L) Li concentrations have been identified in the Devonian Duperow Formation, while further industry exploration has discovered concentrations >250 mg/L (EMP Metals, 2025). Despite this growing research, Li concentration data for Paleozoic aquifers of North Dakota are limited and are primarily focused on the Bakken and Three Forks Formations (Gallegos et al., 2021; Henderson et al., 2026), with sparse data from the Duperow Formation derived from either historical reports from the 1960s (Nesheim, 2022) or university theses focusing on formation water geochemistry (Iampen, 2003). Moreover, the spatial distribution, stratigraphic variability, and mechanisms underpinning Li enrichment in basinal brines remain poorly constrained.

This study presents data from the 2025 sampling campaign, the first dedicated program to assess the Li potential of Paleozoic formation waters in North Dakota. A total of 27 wellhead and separator fluid samples from eight stratigraphic units across western North Dakota were collected and analyzed for their cation and anion concentrations. This study contributes to ongoing efforts to better understand the origin, distribution, and geochemical controls on Li in formation waters and highlights that brine-hosted Li potential exists in North Dakota.

GEOLOGICAL SETTING

The Williston Basin is an elliptical intracratonic basin encompassing portions of North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba and has been the subject of hydrocarbon exploration for more than 75 years (Figure 1; Gerhard et al., 1990). The basin was formed during the Late Cambrian and Early Ordovician with sedimentary cover reaching thicknesses of up to 16,000 feet (ft; ~4,900 m) in western North Dakota, capturing almost the complete sequence of Phanerozoic strata (Gerhard et al., 1982; Peterman et al., 2017). Despite experiencing relatively mild tectonic activity throughout much of the Phanerozoic, there are several prominent structural trends such as the Nesson, Billings, and Cedar Creek anticlines which have played a key role in hydrocarbon entrapment (Gerhard et al., 1982, 1990).

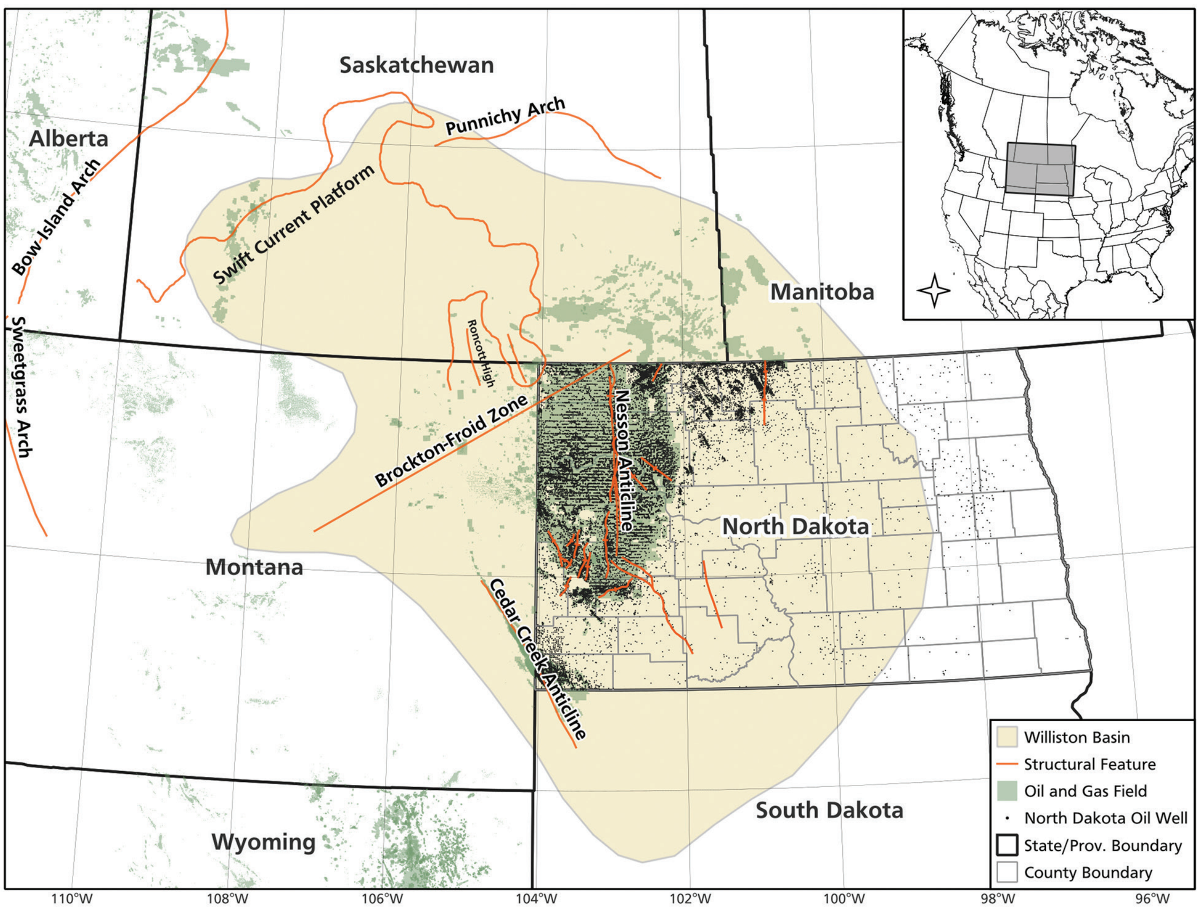


FIGURE 1. Geographic extent of the Williston Basin including structural features and producing oil wells in North Dakota. Prov – Province.

Brine-hosted Li exploration in the Williston Basin has primarily focused on Paleozoic carbonate-evaporite successions which cover the Tippecanoe (Ordovician – Silurian) and Kaskaskia sequences (Devonian – Mississippian). Within the Tippecanoe sequence, the Ordovician Red River Formation consists of carbonate–evaporite cycles deposited in subtidal open- to restricted-marine environments transitioning upward into salina and peritidal settings (Husinec, 2016). The primary targets of the

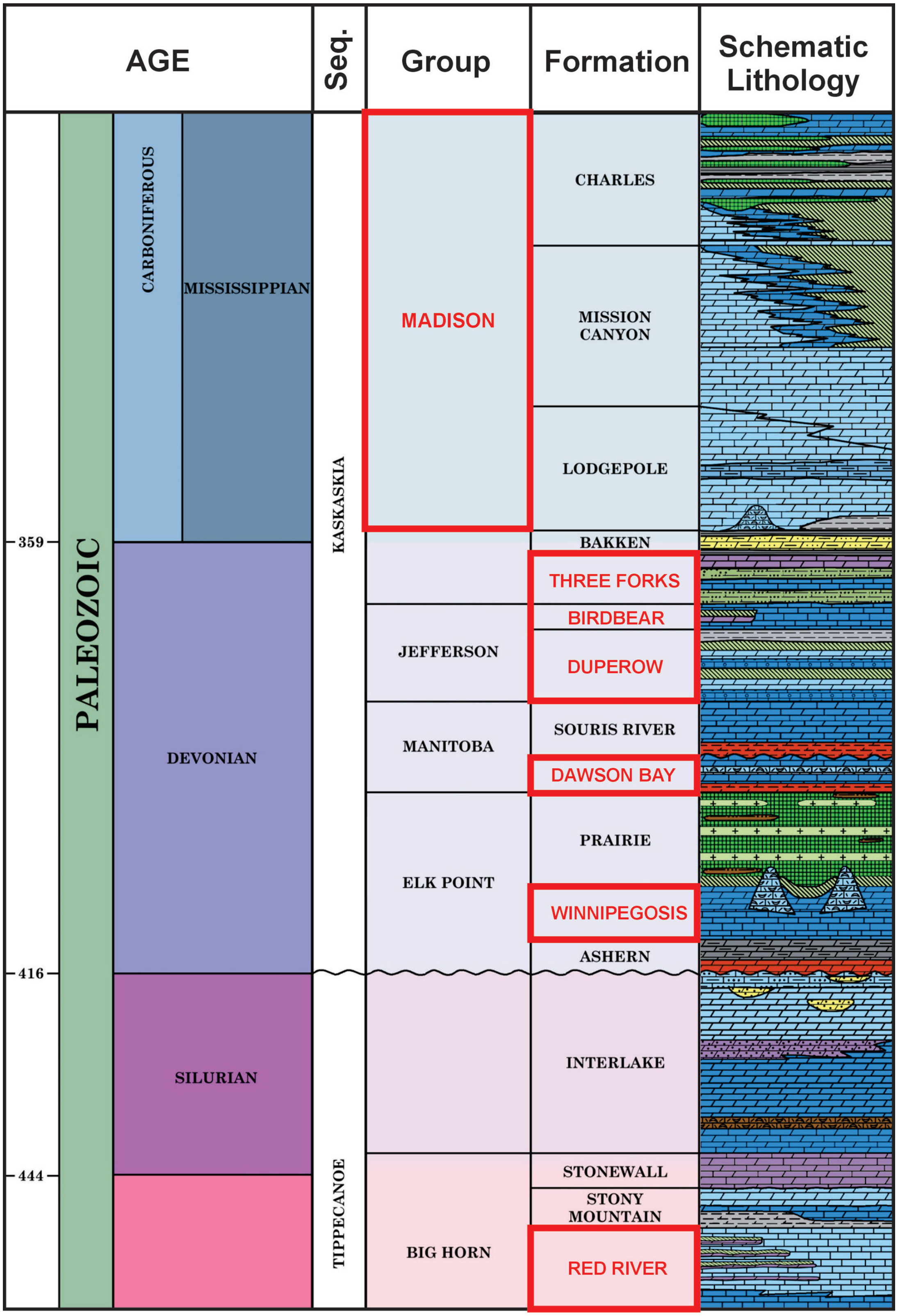
Kaskaskia sequence include the Devonian Winnipegosis, Dawson Bay, and Birdbear Formations, the Late Devonian to Early Mississippian Bakken Formation, and the Mississippian Madison Group. However, the most promising target for brine-hosted Li exploration is the Late Devonian Duperow Formation, an extensive cyclic carbonate-evaporite package deposited in an inner platform environment including subtidal, intertidal, and supratidal deposits (Wilson, 1967; Yang, 2015). Generally, the subtidal deposits are composed of brachiopod-crinoid wackestone overlain by laminated lime mudstone deposited in the intertidal zone which was then capped by supratidal bedded anhydrite and fine-grained dolostone (Pilatzke et al., 1987). In Saskatchewan, the Duperow Formation has been subdivided into, in ascending order, the Saskatoon, Wymark, and Seward Members (Dunn, 1975) with the highest Li concentrations being observed in the Wymark Member (Arizona Lithium 2023; EMP Metals, 2025). The Duperow Formation is stratigraphically equivalent to the Leduc Formation, a prominent target for brine-hosted Li exploration in Alberta.

METHODS

Formation water samples were collected in August 2025 from 24 unique hydrocarbon producing wells and one water source well. Sampling focused primarily on Paleozoic units, specifically the Duperow Formation as it has been found to host the highest fluid Li concentrations in the Williston Basin to date. Formation waters were also collected from the Mississippian Madison Group and Devonian Three Forks, Birdbear, Dawson Bay, and Winnipegosis Formations and the Ordovician Red River Formation (Figure 2). One sample (ND25-22) from a water source well producing from the Cretaceous Inyan Kara Formation of the Dakota Group was also collected to assess potential mixing and dilution as some wells were either under water-flood or were regularly treated with freshwater. Some samples were from wells that had co-mingled production between two formations. Additional information regarding formation and fluid production can be found in Appendix 1.

Fluid collection and analyses were carried out following previously established protocols by the United States Geological Survey (USGS; Engle et al., 2020; Blondes et al., 2020; Jubb et al., 2024). Briefly, samples were collected at the wellhead (with the exception of ND25-24 from the separator) into 20-liter (five-gallon) high density polyethylene (HDPE) carboys. Fluid temperature was measured on-site with an infrared thermometer. Madison Group samples contained H2S and were purged with nitrogen gas prior to further processing. The hydrocarbon and water fractions were allowed to density separate, and the water was drawn from a spigot through silicone tubing using a peristaltic pump. An in-line fibreglass filter was used to remove residual hydrocarbon compounds prior to field parameter (pH, conductivity) measurements. For cation and anion analysis, fluids were passed through 0.45 µm Geotech Versapor membrane filters into HDPE bottles. Cation samples were subsequently acidified to pH <2 with trace metal grade nitric acid. Samples were shipped on ice to the USGS Brine Research Instrumentation and Experimental (BRInE) laboratory in Reston, VA and stored at 4°C prior to further analysis.

Total dissolved solids (TDS) were measured by evaporation at 180°C using the EPA Method 160.1, while specific gravity was determined using the ASTM Method D-1429B. Major cation (B, Ba, Ca, Fe, K, Li, Mg, Mn, Na, Si, and Sr) concentrations were analyzed via inductively coupled plasma optical emission spectrometry (ICP-OES) using a Horiba Ultimate Expert instrument. ICP-OES was selected as it has advantages over traditional mass spectrometry approaches due to higher salinity tolerances, and therefore lower dilution requirements (Jubb et al., 2020). Anion (Cl, Br, and SO4) concentrations were measured with a Thermo Scientific Dionex ICS-2100 ion chromatograph (IC). Analytical QA/QC followed USGS protocols and field and procedural blanks and replicate samples (ND25-06 & ND25-07 and ND25-21 & ND25-23) were collected and analyzed.



(Modified from Murphy et al., 2009)

FIGURE 2. Stratigraphic column of Paleozoic strata of North Dakota. Sampled intervals are highlighted in red. Seq. – Sequence.

RESULTS

Sample locations are shown on Figure 3 and geochemical data are presented in Table 1. Additional data, including analytical error and sampling information can be found in Tables SI1 and SI2 (formatted for machine readability) and in the companion USGS data release (Herzberg et al. 2025)

All Paleozoic samples were classified as brines with TDS values >35,000 mg/L (Kharaka and Hanor, 2014). The lone Dakota Group sample had the lowest TDS and Li concentrations, consistent with the stratigraphically equivalent Mannville Group of Saskatchewan (Bishop et al., 2024). Three Duperow Formation wells which had been treated with freshwater (ND25-01, 26, 27), had anomalously low TDS values relative to the other Duperow Formation samples collected in this study and those from southeastern Saskatchewan (Bishop and Robbins, 2025). To assess the influence of dilution, binary mixing models of TDS, Br, and Cl, using the Dakota Group (ND25-22) and Duperow Formation (ND25-19) fluids as endmembers, indicated these samples had a significant freshwater fraction and were therefore deemed not representative of Duperow Formation waters.

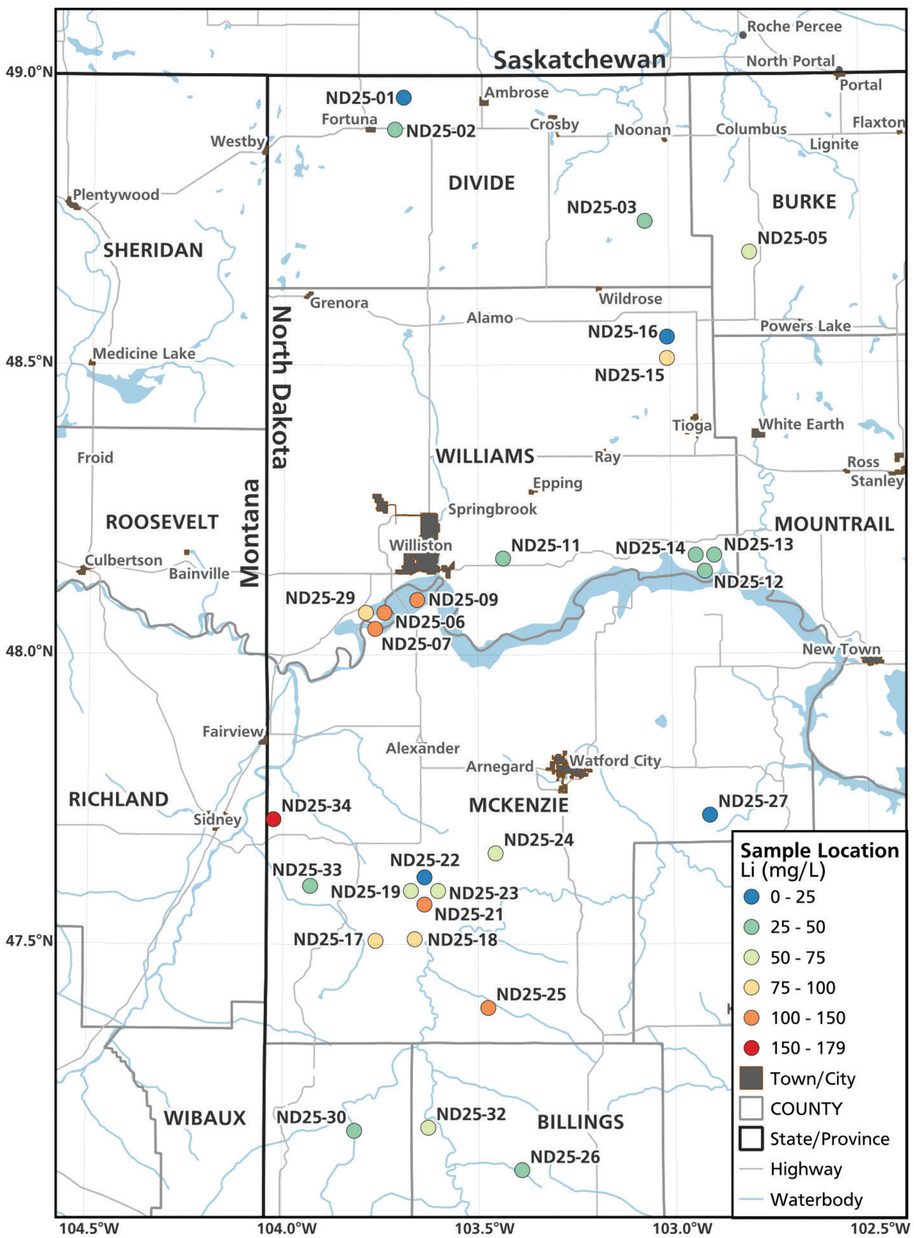


FIGURE 3. Formation water sample names and locations for the 2025 field program. Circle color denotes Li concentration.

TABLE 1. Geochemical data for formation water samples collected across North Dakota during the 2025 sampling program. QA/QC terms (i.e. ND, U, J, J+, H) can be found in the SI. Fm – Formation. Gr. – Group. TDS – total dissolved solids. * - commingled production between formations.

Sample ID	Geologic Unit	pH	mV	TDS	Br	Cl	SO4	B	Ba	Ca	Fe	K	Li	Mg	Mn	Na	Si	Sr
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ND25-01	Duperow Fm.	6.81	-3.6	67600	103	38700	465	42.6	1.4	2520	1.8	666	4.3	332	0.55	21600	8.63	88.4
ND25-02	Duperow Fm.	6.20	29.6	320000	548	188000	241	222	10	13100	10	3630	32	1550	0.53	101000	6.3	549
ND25-03	Dawson Bay Fm.	5.02	96.1	346000	478	215000	175	104	64.3	87700	218	29200	43.3	3060	67	14400	6.3	614
ND25-05	Three Forks Fm.	6.05	43.4	308000	882	177000	229	328	12	17400	156	5990	50.1	1510	7.2	86800	13	1120
ND25-06	Duperow/Birdbear Fm.*	5.68	59.7	275000	938	156000	157	432	34.8	28900	25	7100	108	2510	1	62200	15.4	1210
ND25-07	Duperow Fm.	5.69	59.0	275000	961	160000	162	437	39.6	29500	24	7120	109	2510	1	62600	15	1220
ND25-09	Duperow Fm.	6.00	41.7	201000	846	113000	170	296	27.6	28900	8.3	5400	126	2260	0.78	34600	9.8	1220
ND25-11	Madison Gr.	5.69	NA	290000	634	168000	220	367	1.3	13200	ND	5080	44	1430	0.34	83900	15	938
ND25-12	Madison Gr.	5.78	NA	284000	483	165000	267	250	1.1	13600	ND	4850	38.6	1590	0.34	83700	14	859
ND25-13	Madison Gr.	5.80	NA	295000	613	172000	242	299	0.79	15100	ND	4930	43.8	1750	<0.219	82900	14	942
ND25-14	Madison Gr.	5.82	NA	293000	620	166000	215	313	0.89	15200	ND	5160	37.3	1840	<0.219	82300	14	977
ND25-15	Duperow Fm.	5.89	56.1	273000	1180	166000	331	307	9	42700	21	7400	85.6	3270	1.4	49100	9.1	1600
ND25-16	Winnepegosis Fm.	5.52	74.6	320000	326	179000	183	92	38.1	18500	ND	3470	23	1340	2.1	91200	12	641
ND25-17	Birdbear Fm.	5.82	NA	319000	935	179000	196	508	53.6	27800	79.4	7830	84.2	2150	1.7	77000	16.6	1140
ND25-18	Birdbear Fm.	5.69	65.6	313000	914	173000	173	534	44.1	23900	59.6	7630	84.8	2050	1.4	79800	18.9	1180
ND25-19	Duperow/Birdbear Fm.*	5.42	NA	340000	1380	203000	156	574	29	41500	61.1	9690	148	2750	2.3	75500	17	1740
ND25-21	Birdbear Fm.	6.60	17.0	211000	594	122000	442	349	4.3	9530	51.6	5090	57.1	753	0.87	64000	26.6	417
ND25-22	Inyan Kara Fm. (Dakota Grp.)	8.28	-72.0	5160	1.73	1400	875	7.01	0.088	7	ND	<9 J	0.25	<1	0.023	2020	25	0.46
ND25-23	Duperow/Birdbear Fm.*	6.67	NA	212000	578	119000	427	352	13	9520	49.8	5050	56.5	760	0.89	63900	26.4	431
ND25-24	Duperow Fm.	5.59	70.0	313000	745	180000	177	476	24	19800	6.7	6060	66.7	1520	1.4	87700	3.4	1260
ND25-25	Duperow Fm.	5.33	62.0	298000	1230	173000	180	429	47.5	41700	172	8140	116	2960	4.2	57500	7.4	1740
ND25-26	Duperow Fm.	6.92	0.1	101000	368	60000	60.7	137	16.5	11100	68.1	2340	34.1	737	1.4	22300	10.4	471
ND25-27	Duperow Fm.	7.16	-12.4	58600	222	33200	480	81.4	1.5	7310	2.9	1500	23.2	527	0.4	12000	7.54	316
ND25-29	Duperow Fm.	5.51	54.1	230000	999	133000	165	283	36.4	35200	47.4	6260	94.7	2840	2.2	40200	7.5	<0.5
ND25-30	Birdbear Fm.	6.59	0.0	190000	475	113000	248	210	11	10300	ND	3330	31.2	946	1.9	58100	ND	483
ND25-32	Birdbear Fm.	5.92	32.4	273000	789	162000	186	338	29.7	20900	126	5740	50.3	2140	2.5	73100	8.2	678
ND25-33	Red River Fm.	5.67	45.5	207000	736	123000	264	61.5	16	27000	6.7	2470	40	2090	3.9	44300	14.1	974
ND25-34	Red River/Duperow Fm.*	4.95	81.4	342000	1520	202000	165	494	45.9	50400	42.8	8900	179	3850	2.2	63000	9.8	1850

* commingled production between formations

Excluding these three samples (ND25-01, 26, 27), Li concentrations in Paleozoic units ranged from 23 mg/L to 179 mg/L (Figure 4). The four Madison Group samples (ND25-11, 12, 13, 14) collected in eastern Williams County occupied a narrow range of Li concentrations (37 to 44 mg/L), while the single Three Forks Formation sample (ND25-05) from Burke County to the north was slightly higher at 50 mg/L. Formation waters from the Birdbear Formation (ND25-17, 18, 30, 32) displayed a much higher range (31 to 85 mg/L) with no discernible geographic trends. Based on well reports, sample ND25-23 with 57 mg/L Li was from a commingled well with balanced fluid contributions from both the Birdbear and Duperow Formations. In contrast ND25-19, which also had commingled production, had a higher Li concentration (148 mg/L) and fluid contribution from the Duperow Formation. Of the samples solely from the Duperow Formation that were not interpreted to have been diluted with freshwater, Li concentrations ranged from 32 to 126 mg/L and were highest in McKenzie County, decreasing to the north and south. The highest concentration (179 mg/L), which is also the highest value observed from a producing oil well in the Williston Basin to date, was from a well with commingled production from the Duperow and Red River Formations (ND25-34) along the Montana border, also in McKenzie County. However, based upon the available historical well production records for this well (ND25-34), most of the commingled water is likely from the Duperow Formation. Fluids from the Dawson Bay, Winnipegosis, and Red River Formations were notably lower and, similar to the Madison Group samples, did not exceed 50 mg/L.

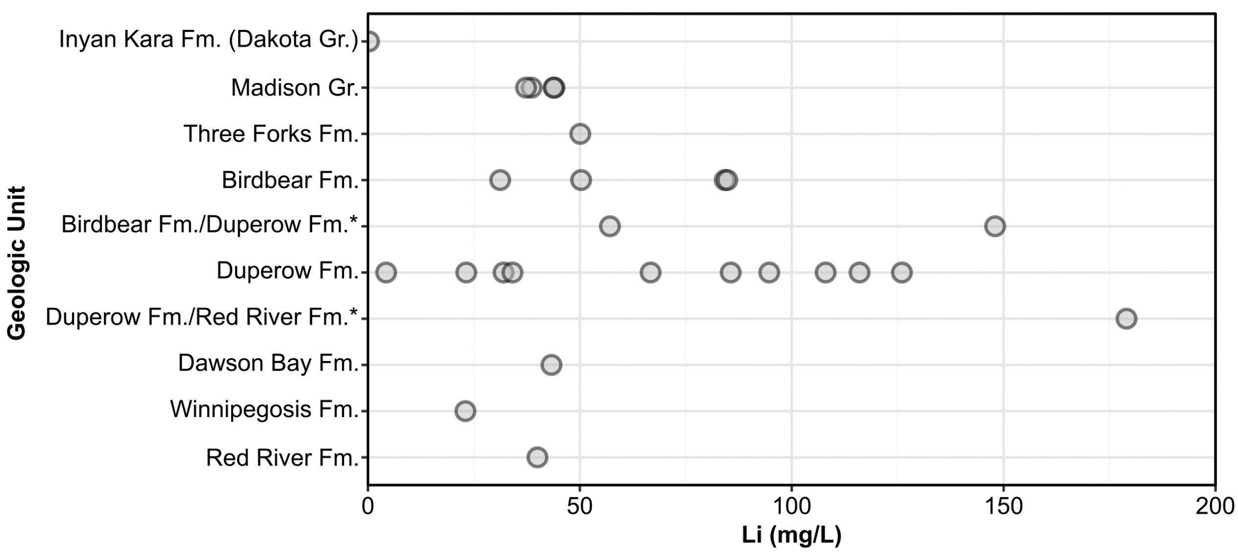


FIGURE 4. Lithium concentrations (mg/L) for the samples collected in 2025 grouped by geologic unit.

***** - commingled production between geologic units.

DISCUSSION

Lithium concentrations in formation waters of North Dakota display substantial variability both stratigraphically and geographically. Lithium concentrations in fluids from the Madison Group, and Three Forks, Dawson Bay, Winnipegosis, and Red River Formations, were generally <50 mg/L (Figure 4), similar to the Bakken Formation (Bishop and Robbins, 2025; Henderson et al., 2026). Consistent with fluids from Saskatchewan, Li concentrations were highest in the Late Devonian Duperow Formation compared to the other formations sampled, reaching up to 179 mg/L, indicating brine-hosted Li potential also exists in the Duperow Formation of North Dakota.

While the main focus for brine-hosted Li resources in the Williston Basin has been on the Duperow Formation, there may also be Li potential in the Birdbear Formation which contains fluids with concentrations exceeding 75 mg/L, which is similar to concentrations being targeted for exploration in the Leduc Formation of Alberta (E3 Lithium, 2024; LithiumBank, 2024) and the Duperow Formation of west-central Saskatchewan (Grounded Lithium, 2023).

While proposed standalone projects in Saskatchewan and Alberta require dedicated infrastructure, specifically production and injection wells, the co-recovery of Li from oil and gas produced waters may support production from lower grade brines (Kumar et al., 2019). Indeed, despite the lower Li concentrations relative to the Duperow Formation (Bishop and Robbins, 2025; Henderson et al., 2026) there is interest in extracting Li from co-produced Bakken Formation fluids (Jakaria et al., 2025). Accordingly, based on the data available here, other stratigraphic units within the Williston Basin such as the Madison Group and Three Forks, Dawson Bay, Winnipegosis, and Red River Formations may also have potential for co-recovery as a by-product of oil and gas production. However, this will ultimately depend on economic and technological factors including advancements in DLE technologies.

Despite an increasing volume of sedimentary basin formation water data (i.e., USGS National Produced Waters Geochemical Database, Blondes et al., 2023), there is still a lack of data which constrains our understanding of the distribution of brine-hosted Li resources in sedimentary basins, including in the Williston Basin. Therefore, additional sampling can help to further delineate Li concentrations in formation waters across North Dakota. Further complicating our knowledge of subsurface brine chemistry is that sample collection is limited to producing oil and water source wells, leaving the Li potential of other areas without hydrocarbon production virtually unknown. Moreover, many wells were affected by mixing with other fluids through either water-flooding or freshwater treatment which can influence the brine chemistry and Li concentrations. Since Li in the Duperow Formation has significant vertical variability, even within a single well (EMP Metals, 2025), it is possible that mixing between different members occurs, or that the well was not completed in the unit which hosts the highest Li concentration and was therefore not captured in this sampling. Additional research may constrain Li variability within and between different units of the Williston Basin and the effects of mixing with exogenous fluids. Similarly, further geochemical and isotopic studies can help to identify the processes which generate Li-rich brines in sedimentary basins, crucial for identifying new exploration targets in the absence of a fluid sample.

CONCLUSIONS

This work presented formation water geochemical data for Paleozoic intervals of North Dakota with a focus on Li. The highest Li concentrations (up to 179 mg/L) were discovered in the Late Devonian Duperow Formation, consistent with the Williston Basin of Saskatchewan, indicating that brine-hosted Li potential exists in North Dakota. Fluids from the overlying Birdbear Formation have similar concentrations to those of the Leduc Formation of Alberta which has recently been the focus of brine-hosted Li exploration. Although lower in the Madison Group and Three Forks, Dawson Bay, Winnipegosis, and Red River Formations, Li concentrations may be sufficient to support co-production with hydrocarbon resources. Regardless, the economic feasibility of either standalone or co-production will ultimately depend on market conditions and the development of suitable DLE technologies for brines from the Williston Basin. While formation water sampling has generally been a necessity for determining Li potential of formation waters, future work to constrain the distribution and the processes which govern the development of this new type of mineral deposit can aid in the exploration of new basinal brine-hosted Li resources.

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