NORTHEASTERN BRITISH COLUMBIA LITHIUM FORMATION-WATER DATABASE PROJECT

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Introduction

Lithium has garnered significant interest in recent years as an essential constituent in lithium-ion batteries—a necessary component in the plan to decarbonize energy infrastructure in the coming decades. Having been deemed a critical mineral necessary for the future clean energy economy (Natural Resources Canada, 2021), it has grown increasingly important to catalogue prospective lithium resources and explore possible synergies with existing oil and gas operations to position Canada for the forthcoming electrified economy. Formation waters collected from oil and gas wells have previously only been tested for lithium content at a handful of sites in British Columbia with lithium data remaining quite limited in the public domain (BC; Eccles and Jean, 2010). This compares to the more than 2000 and 200 brine analyses in Alberta and Saskatchewan, respectively (*Figure 1*; Eccles and Jean, 2010; Jensen, 2012, 2016; Jensen and Rostron, 2017). This data scarcity in the lithium brine dataset in BC requires additional sampling and analysis to improve the understanding of these prospective resources in the province and the geological mechanisms driving such enrichments.

This study, which is a joint venture between Canadian Discovery Ltd. (CDL) and Matrix Solutions Inc. (Matrix), aims to deliver a preliminary inventory dataset of lithium and other dissolved-metal brine data in northeastern BC through a large-scale sampling program. The study which commenced in the fall of 2021 aims to collect and analyse formation water samples from approximately 300 active oil and gas wells throughout northeastern BC (NEBC) (*Figure 2*). To date, various challenges have reduced this number to less than 200 active wells as of the end of 2022 and provide important learnings for future initiatives.

Defining current lithium concentrations and quantities in subsurface brines enables the evaluation of novel resource potential, which will use existing infrastructure and expertise in current operations, while supporting job creation and development in an emerging industry.

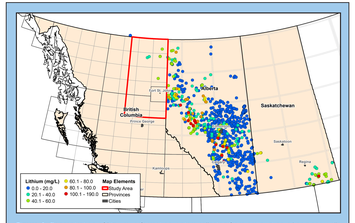

Figure 1. Concentration of lithium in formation waters collected from pre-existing oil and gas wells throughout the Western Canada Sedimentary Basin. Currently, only a handful of lithium data points exist in the study area in northeastern British Columbia (outlined in red; data from Eccles and Jean, 2010), as compared to more than 1600 in Alberta and Saskatchewan (data from Eccles and Jean, 2010; Jensen, 2012, 2016; Jensen and Rostron, 2017).

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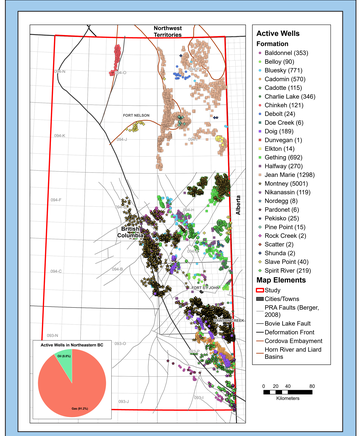

Figure 2. Active oil and gas wells by group/formation/member in northeastern British Columbia (BC; well data supplied by geoLOGIC systems ltd. © 2021). Inset shows breakdown between oil and gas producers, this highlights the dominance of gas wells within the study area.

Geological criteria for potential lithium enrichment *(modified from Bradley et al., 2013)*	Criteria present in BC?	Examples identified in northeastern BC
Tectonically driven subsidence	✓	Multiple subsidence episodes and tectonic settings, including intracratonic and intraoceanic basins, rifting and continental margins (Nelson and Colpron, 2007)
Associated igneous, volcanic or geothermal activity	✓	High geothermal gradient, generally higher than Alberta and Saskatchewan
Interactions with basement-derived hydrothermal fluids along basement conduit features	✓	Basement structural features such as the Peace River Arch and the Hay River fault zone, the latter of which was the conduit for fluids that led to significant mineralization at the Pine Point Mississippi Valley-type deposit (Nelson and Colpron, 2007)
Proximal felsic bedrock and volcanic terranes weathering into sedimentary basins	✓	Various volcanic and plutonic events exist in northeastern BC through accreted terranes and igneous intrusions (Goodfellow et al., 1995; Nelson and Colpron, 2007)
Periods of restricted basin conditions and and to semi-arid paleoclimates where evaporation exceeds precipitation, often recorded by evaporite deposits, which display cyclic brining-upward sequences concentrating lithium into remaining brine fractions	✓	Restricted basin conditions were present during the deposition of the Muskeg Formation; cyclic intervals are noted and thickening is observed along the Hay River fault zone and other subsiding blocks along strike-slip faults (Petrel Robertson Ltd., 2003)
Presence of adequate aquifer units	✓	Significant reservoir enhancements through hydrothermal dolomitization and solution brecciation (Petrel Robertson Ltd., 2003)
Sufficient time to allow concentration	✓	Geological history in northeastern BC spans 1.8 Ga, including various potential Phanerozoic reservoirs that range in age from Middle Devonian to Late Cretaceous

Table 1. Geological criteria identified for lithium-enriched brine deposits with examples from northeastern British Columbia (BC).

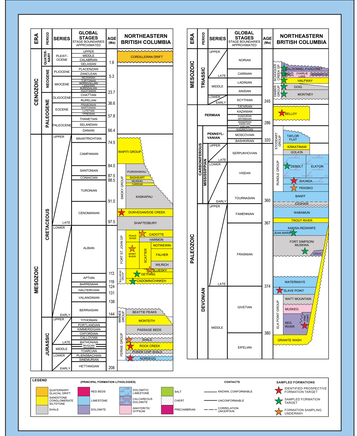

Figure 3. Stratigraphy of northeastern British Columbia (modified and reproduced with permission from Core Laboratories Petroleum Services, 2017). Targeted groups/formations/members are indicated with a star.

Background

Lithium occurs naturally in a variety of rock types, brines and groundwater; however, most concentrations are not economic. The content of lithium in the Earth's upper crust has been estimated to be between 20 and 70 ppm by weight (Kamienski et al., 2004). Lithium enrichment occurs in felsic continental crust, with particular approaciations in highly differentiated granites and pegmatites. Lithium brine deposits by contrast are saline groundwater accumulations that are enriched in dissolved lithium, often orders of magnitude higher than background oceanic concentrations of approximately 0.1 ppm. Globally these are present in a variety of settings, such as the Andean salar brines in South America, and various formation waters (wastewater) produced during oil and gas or geothermal operations.

The mechanism of lithium enrichment in brines is not fully understood, but a variety of sources and processes for enrichment have been identified and proposed. These are derived in part from the physical characteristics of lithium, which is exceptionally mobile and has a strong affinity to remain in solution in either magmatic or brine systems during fluid/rock interactions (Teng et al., 2004). Geological criteria have been identified for various lithium-enriched brine deposits and these criteria are evident in NEBC, as outlined in *Table 1*. These criteria were considered to inform stratigraphic targets identified for sampling in NEBC (*Figure 3*). *Figure 4* illustrates some of the potential geological criteria for mobilization of lithium in a Devonian carbonate reservoir in western Alberta which shares similar geological elements as those in NEBC.

Project Design and Progress

This project represents the first regional brine sampling program of its kind in NEBC and is developed in a three-phased approach slated to take place over approximately 24 months.

The three project phases include:

1. Design and scoping (Completed: Q2 2022)
   a. project co-ordination, logistics and safety standards
   b. prospective formation review and high-level scoping of wells to be sampled
   c. operator engagement, access negotiations and field logistics
2. Field sampling and data analysis (Target end date: end of Q2 2023)
   a. field sampling program
   b. laboratory analysis
   c. data processing, quality assurance–quality control (QA-QC) and analysis
3. Geological interpretation and lithium potential (final report) (Target end date: TBD)
   a. incorporate data into the broader geological and hydrogeological framework
   b. advance the understanding of geological controls and natural variability of lithium in formation waters
   c. preliminary assessment of aquifer volumes, deliverability and economic viability of lithium extraction

Metadata Collection

Metadata parameters are considered those which are not explicitly analyzed but collected prior to and as part of the program activities. These parameters are organized into three main categories corresponding to their order of collection.

1. Pre-field metadata
2. Field collected metadata
3. Post-field quality check and assurance data

The full list of metadata parameters is displayed in *Table 2*.

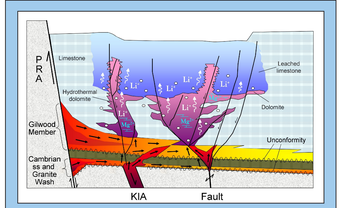

Figure 4. Schematic diagram illustrating various potential mechanisms for lithium enrichment in formation waters (Eccles and Berhane, 2011). Geological criteria favourable for enrichment include: associated igneous, volcanic or geothermal activity; interactions with basement derived hydrothermal fluids; proximity to felsic bedrock and volcanic terranes; periods of restricted basin conditions and presence of evaporite deposits; presence of adequate aquifer units.

Phase	Data type	Metadata Parameter
Pre-Field Metadata and Confirmation	Location	UWI
		GPS coordinates easting
		GPS coordinates northing
		Ground elevation (masl)
		Operator company
	Formation	Producing field name
		Formation sampled (formation name)
		Formation member name (if available)
		Geological age (eg. Devonian)
		GeoScout downhole temperature (°C)
		Production zone, if known
	Well & Infrastructure	Well type: Oil / Gas
		Well Safety: Sweet or sour?
		Well type comment: Fracked well, flowback or other condition of produced water
	Completion	Well completion depth top (elev masl)
		Well completion depth base (elev masl)
		Most recent well intervention type and date - workover, frac, etc.
	Production & Fluids	Certainty of singular prod zone (ranked: 1-low to 10-high)
		Water Cut (percentage if known ex: 75%)
		Additives - yes/no
		Additive information - concentration, location added, type (descaler, oxygen scavenger, biocide, unknown, proprietary, etc.)
		Pressure of producing well?
Field Collected	Sampling & Infrastructure	Sample ID(s) (Pre-populated; coincides with COC)
		Confirm if sample is sour (Y/N)
		Operator Company
		Collecting operator: last name, first name
		Collection date, time
		Number of sample bottles
		Infrastructure type sampled (ex: separator, wellhead ect.)
		Infrastructure additional comment (single or multi-well, in test condition and running time)
		Degree of emulsification (appx. Percentage ex.: 10%)
		Description of sample - clear/cloudy, colour, emulsion, product, smell, gassy, turbid, etc.
		Field note / additional comments
		COC number
Post Field Metadata Quality Checks	Collection and Transmittal Details	(1) Matrix collected, (2) operator collected + handoff, (3) operator collected and shipped
		Date shipped
		Transit time
		Lab arrival date & time
		Date sample processed and analyzed
		Observations about sample when analyzed, if applicable

Table 2. Metadata collection parameters for sampling program.

Preliminary Sampling Results and Outcomes

- 22 formations considered prospective, 19 are slated to be sampled by conclusion of project
- 15 additional samples to be collected and analyzed in Q2 2023
- Timeline has been extended to accommodate for challenges encountered during the sampling program
- *Table 3* and *Figure 3* highlight the current and future formations being sampled
- Additional prospective units may be sampled depending on timing and operator agreements
- 118 samples collected and analyzed as of Q1 2023 (19 different formations/members)
- *Figure 5* illustrates the approximate sample areas as of Q4 2022
- Higher concentration samples are deemed to be within the range for Direct Lithium Extraction (DLE technologies (Grant, 2022)
- Many of the elevated lithium concentrations encountered differ in character and distribution than other lithium enriched brines in the western Canada basin and may indicate a deviation in enrichment mechanisms in this part of the basin.

Conclusion & Future Work

Characterizing the formation water chemistry in NEBC is an important first step to:

- Inform regulatory policy considerations,
- De-risk early exploration activities to incent investment and development,
- Support academic advancement of knowledge on resource prospects such as geothermal and dissolved mineral production, particularly for critical minerals/metals.

Sub-surface brine resource exploration is accelerating in North America as the demand outlook for critical minerals points to shortfalls before the end of the decade. Currently a window of opportunity exists to evaluate and identify the potential to develop these new resources. The fluid database from this project will assist in these activities and help support the development of a broader critical minerals/metals industry in British Columbia, and Canada. The fluid database will be accompanied by a final report that interprets and maps the final outcomes of the project for the public domain.

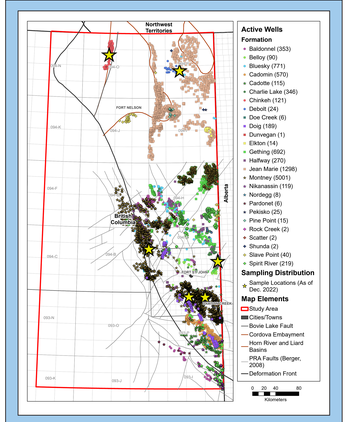

Figure 5. Active oil and gas wells by group/formation/member in northeastern British Columbia (BC; well data supplied by geoLOGIC systems ltd. ©2021). The yellow stars represent the approximate location of sampling programs completed in 2022.

Formation	Samples collected to date (sample numbers)	Sampling Underway (sample numbers)	Confirmed Target Sample Totals	Sampling access restricted** - ongoing efforts to secure sampling (X-denotes restricted access)
K_Dunvegan				X
K_Cadotte				X
K_Dunlevy	2		2	
K_Spirit River/Notikewin				X
K_Bluesky				X
K_Gething	2		2	
K_Cadomin/Chinkeh	2		2	
K_Nikanassin				X
J_Rock Creek				X
J_Nordegg				X
TR_Baldonnel/Pardonet	9		9	
TR_Charlie Lake	8		8	
TR_Coplin	4		4	
TR_Cecil	2		2	
TR_Sphinx	1		1	
TR_Boundary Lake	8		8	
TR_Halfway	21		21	
TR_Doig	6		6	
TR_Montney	4		4	
TR_Montney_U	21	13	34	
TR_Montney_M	7	2	9	
P_Belloy	7		7	
M_Debolt	3		3	
M_Shunda				X
M_Pekisko				X
D_Jean Marie	5		5	
D_Fort Simpson/Muskwa	3		3	
D_Slave Point	3		3	
D_Pine Point				X
	118	**15**	**133**	
		Total samples based on final detail confirmations:	**133**	

*** restrictions exist due to numerous potential sampling challenges including operator well availability, operator capacity, infrastructure configurations and schedule limitaons*

Table 3. Sampling progress by formation as of Q1 2023.

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References

Core Laboratories Petroleum Services (2017): Stratigraphic correlation chart; Core Laboratories Petroleum Services, Geological Sciences Department, 1 p., URL <https://www.ipac2000.net/downloads/Zone2/Part.pdf> [March 2021].

Eccles, D.R. and Berhane, H. (2011): Geological introduction to lithium-rich formation water with emphasis on the Fox Creek area of west-central Alberta (NTS 83F and 83M); Energy Resources Conservation Board, ERCB/AGS Report 2011-10, 28 p.

Eccles, D.R. and Jean, G.M. (2010): Lithium groundwater and formation-water geochemical data (tabular data, tab delimited format); Alberta Energy Regulator, AER/AGS, Digital Data 2010-0001, URL <https://ags.aer.ca/publication/dig-2010-0001> [March 2021].

Jensen, G.K.S. (2012): Initial results of a brine sampling project: investigating the mineral potential of brines in southeastern Saskatchewan; in Summary of Investigations 2012, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2012-4.1, Paper A-8, 8 p.

Jensen, G.K.S. (2016): Results from the 2016 field season for the brine sampling project: investigating the mineral potential of brines in Saskatchewan; in Summary of Investigations 2016, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2016-4.1, Paper A-3, 7 p.

Jensen, G.K.S. and Rostron, B. (2017): Investigating the mineral potential of brines in Saskatchewan: results from the 2017 field season for the brine sampling project; in Summary of Investigations 2017, Volume 1, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2017-4.1, Paper A-1, 6 p.

Kamienski, C.W., McDonald, D.P., Stark, M.W. and Papcun, J.R. (2004): Lithium and lithium compounds; in Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley and Sons, p. 1-21.

Natural Resources Canada (2021): Canada announces critical minerals list; Natural Resources Canada, news release, March 11, 2021, URL <https://www.canada.ca/en/natural-resources-canada/news/2021/03/canada-announces-critical-minerals-list.html> [May 2021].

Teng, F.Z., McDonough, W.F., Rudnick, R.L., Dalpé, C., Tomascak, P.B., Chappell, B.W. and Gao, S. (2004): Lithium isotopic composition and concentration of the upper continental crust; Geochimica et Cosmochimica Acta, v. 68, p. 4167–4178.