geoconvention
Calgary • Canada • June 17-19 2024

Mapping Lithium Brine Sweet Spots in Devonian Oil And Gas Reservoirs in Alberta

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Summary

The depletion of shallow mineral deposits [1], challenges in supply and demand of critical minerals [2] and growing environmental concerns [3] have led to substantial investments and advancements in deep ground mining in recent years [4]. However, alongside the inherent engineering challenges of mining at greater depths (>1000 m), exploration for deep critical mineral sources has also many other challenges.

Taking Lithium resources in Alberta deep formations as an example, our collected data indicate that host rocks act more as an environment for trapping or concentrating lithium in brines than as the origin of lithium. Furthermore, no single or simple combination of compositional or isotopic parameters can reliably indicate the presence and concentration of lithium, posing a significant exploration risk. A more complex indicator system is needed to identify the favorable geological environments that can enrich lithium above the economically exploitable grade.

Leveraging the decent collection of lithium-related geochemical data on produced water in Alberta over recent years, a prediction model has been established to locate lithium distributions exceeding three particular cutoffs (e.g., 35, 50 and 75 mg/L) for practically exploring the unconventional lithium brine contained in Alberta's Devonian strata.

Theory / Method / Workflow

Initially, we gathered geospatial and geochemical data on produced/flowback water samples from Devonian reservoirs across Alberta reported for 1980 to 2023. Following data wrangling, it was partitioned into three distinct subsets: (1) The training dataset (430 observations) with Li-contents measured before May 2022; (2) the validation dataset (102 observations) with Li-contents measured after May 2022; and (3) the target dataset (897 observations) without Li-contents measured collected from 1990 to 2019. Secondly, the overlapping geochemical characteristics of brines and their corresponding geospatial data for the abovementioned datasets were transformed into the probability domain by utilizing information obtained from the training dataset for model training, validation, and prediction purposes. Thirdly, the transformed training dataset underwent conditional random sampling to generate 729 realizations for each cutoff of Li concentration. For each realization, 80% of the data was allocated for training a deep-learning model, while other 20% was reserved for evaluating its performance. Fourth, the validation dataset was used to assess the performance of the method based on the prediction votes of the trained learning models across all realizations. Finally, the target data was input into the model for spotlighting the potential locations with Li concentration exceeding a predetermined cutoff in extended regions of Alberta where lithium content was not measured and/or reported in the historical produced/flowback water geochemical data.

Results, Observations, Conclusions

The model was successfully validated using a dataset collected and published after May 2022, demonstrating a minimum prediction accuracy of 84%. The results indicate that the most common parameters in water analysis (i.e., Na^+, K^+, Mg^{2+}, Ca^{2+}, and TDS) along with basic geospatial information (sample coordinates and formation) are sufficient for the proposed method to effectively label the lithium concentration level of brine in Devonian system formations, such as the Wabamun Group, Winterburn Group, Woodbend Group, Beaverhill Lake Group, and Elk Point Group. Moreover, there is no evidence that the method performance is affected by brine sampling points. Overall, the potential sweet spots identified based on the target dataset cover the industrially pursued areas and highlight several untouched areas that may warrant future investigation. In terms of limitations, it is important to note that the current vertical resolution of the model is only at the level of geological units due to the absence of precise sampling depth information in the database.

Novel/Additive Information

In contrast to the identification of indicators for lithium origins, this work employed a supervised learning model to directly investigate the lithium-enriched environments in Alberta and subsequently predict potentially high-grade locations for extracting lithium brines under various technological scenarios. This approach could accelerate the development of sustainable lithium recovery based the Direct Lithium Extraction (DLE) technology by narrowing down the exploration regions for unconventional lithium sources and obviating the need for extensive resampling/retesting of water samples. Although this study focuses on data collected from the Devonian system in Alberta, Canada, the method can be applied to other areas/formation systems.

Acknowledgements

The authors sincerely thank the Critical Minerals Geoscience and Data (CMGD) and GeoEnergy Programs of Natural Resources Canada for funding support.

The authors also express their gratitude to Dr. Andrew Kingston (now with AGAT Laboratories) for his kind support in technical discussions and assistance with data collection in the early stages of this research.

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