

# Exploring the Potential for Natural Hydrogen in Alberta: A Preliminary Assessment

Dayal B. Wijayarathne, Tiago A. Morais, Aprami Jaggi, John J. Gibson, Paul Eby, Martin Huard

InnoTech Alberta

## Summary

Natural hydrogen, often referred to as "white hydrogen", has recently emerged as a sustainable and cost-effective energy resource candidate due to its potential low-carbon footprint and ability to contribute significantly to a clean energy transition [1]. Unlike manufactured hydrogen, natural hydrogen is generated through geological processes such as radiolysis [2], hydrocarbon decomposition [3], serpentinization [4], water-rock interactions [5], organic pyrolysis [6] and mantle degassing [7]. Research on natural hydrogen systems is still in its infancy, with relatively few studies conducted globally [8-14]. This study represents Alberta's first systematic effort to evaluate natural hydrogen potential in the province using publicly available geological and geospatial datasets along with hydrogen concentration data from natural gas analysis tests. Natural hydrogen supports Canada's and Alberta's net-zero goals by providing a low-carbon energy alternative [15-17]. The production of natural hydrogen can also diversify Alberta's economy while leveraging its geological and oil and gas production expertise, positioning the province as a leader in clean energy innovation.

This research identifies high-potential zones for natural hydrogen occurrence and accumulation in Alberta's Western Canadian Sedimentary Basin (WCSB) by overlaying hydrogen concentration data from natural gas tests [8,18] with geological features such as lithostratigraphy, formations, faults, shear zones, and kimberlites, among others. This approach minimizes the occurrence of false positives and negatives from the hydrogen concentration data. Initial findings suggest that Alberta has the potential for both natural hydrogen generation and storage, but more detailed investigations are required to confirm the region's commercial hydrogen potential. This initial assessment also establishes a foundation for more comprehensive investigations utilizing machine learning techniques, stable isotopes of hydrogen ( $^2\text{H}/^1\text{H}$ ), and other geochemical analyses to confirm this potential and the origin of hydrogen present in natural gas samples in the province.

## Theory / Method / Workflow

The methodology employed in this study was designed to identify areas with high potential for natural hydrogen occurrence and accumulation while also pinpointing regions that require more comprehensive investigation. Integrating publicly available datasets [19], including geological, geospatial, and hydrogen concentration data, is crucial for assessing the geological suitability of areas for natural hydrogen exploration in Alberta. This approach is particularly critical for identifying areas where further research is needed, especially about natural hydrogen generation, migration, and trapping mechanisms. The following key steps were undertaken:

1. **Geological Mapping:** Formations favourable for hydrogen generation (e.g., radiolysis and hydrocarbon decomposition) and storage (e.g., porous reservoirs and impermeable

cap rocks) were identified using the Alberta Table of Formations, which outlines the province's geological formations across eight geological regions [20].

2. **Spatial Overlay Analysis:** Geological and geospatial datasets, including basement rocks, formations, faults, kimberlite, shear zones and existing hydrogen concentration data were integrated to characterize zones with higher hydrogen potential.
3. **Natural Gas Concentration Analysis:** Hydrogen concentration data from natural gas tests in the province [21] were used to identify energy wells with hydrogen concentrations exceeding 0.1%, a threshold aligning with global studies [18].
4. **Mapping Framework:** Weighted overlay techniques were applied in ArcGIS to rank and prioritize regions based on geological and structural characteristics.

## Results, Observations, Conclusions

Preliminary findings through the integration of geological, geospatial, and hydrogen concentration data from natural gas tests suggest the possibility of natural hydrogen occurrences in Alberta. This approach identified key regions with favorable geological conditions that could support hydrogen generation, migration, and accumulation (Figure 1).

High-potential regions for hydrogen accumulation in Alberta's WCSB include the Southern, East-Central, and the West-Central Plains, which are characterized by favorable conditions for natural hydrogen generation through hydrocarbon decomposition and radiolysis, along with effective cap rocks. Moderate-potential regions, such as the Northwest and Northeast Plains, as well as the Mountains and Foothills, show only localized hydrogen indicators, but further validation is required, particularly in faulted zones and potential source rocks.

Hydrogen concentrations from natural gas tests also provided valuable insights into the province's hydrogen potential. A review of publicly available data identified 40,424 tests from 22,636 wells, with 89.6% of the energy wells containing at least one hydrogen concentration. Of the measured hydrogen concentrations, 92.3% were below 0.1%. However, 2,643 analyses from 2,292 wells indicated concentrations greater than 0.1%, 430 analyses from 374 wells exceeded 1.0%, and 50 analyses from 46 energy wells showed concentrations above 10%.

This preliminary investigation identified areas with potential for natural hydrogen occurrence and accumulation in Alberta's WCSB. However, this study is still in its early stages, and further research is required to confirm our findings. To enhance our understanding, a more detailed investigation of basement rocks is required, incorporating aeromagnetic and gravity survey data to assess their potential contributions as source rocks. Hydrogen concentration data must be interpreted carefully due to biases, as the dataset used is primarily based on analysis with helium concentrations greater than 0.1%, and the geographical distribution is not ideal for natural hydrogen exploration. Additionally, as indicated by previous studies [8, 22-23], the hydrogen detected in these tests could also be a result of drilling operations, microbial activities, and/or metal corrosion, leading to false positives. Furthermore, well completion factors and the preferential accumulation of hydrogen in the top of the well casing headspace may also contribute to the occurrence of elevated concentrations. Therefore, key challenges for future investigations include verifying whether the detected hydrogen concentrations in wells represent true anomalies

and distinguishing between natural and anthropogenic (non-natural) sources through extensive field sampling and stable isotope analyses for validation.

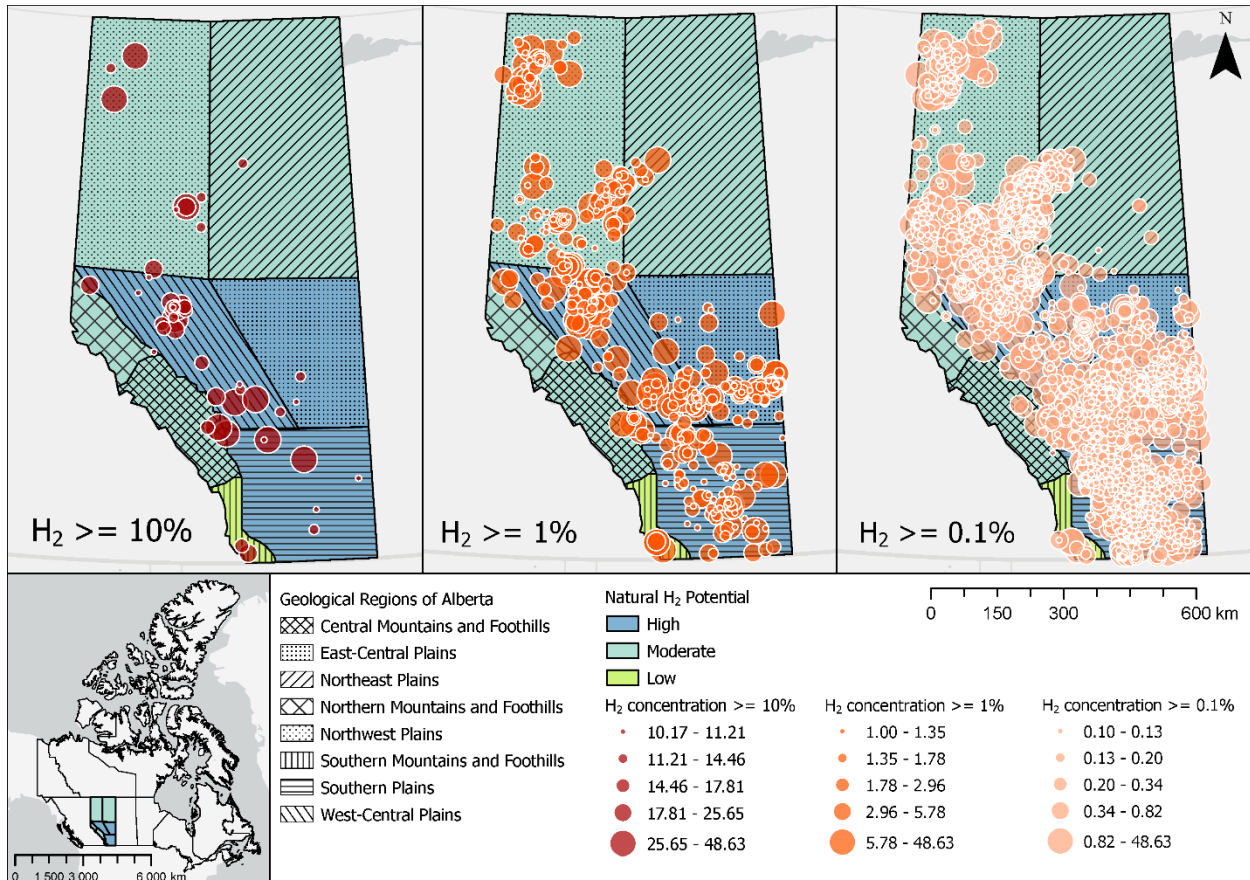


Figure 1. Geospatial analysis of natural hydrogen potential in the Western Canadian Sedimentary Basin (WCSB) in Alberta, based on publicly available geological and geospatial data.

### Novel/Additive Information

This study presents a novel approach to assessing natural hydrogen potential in Alberta's WCSB using only publicly available data. Integrating publicly available datasets from various sources provides a preliminary comprehensive framework for understanding Alberta's hydrogen potential. Importantly, the integration of machine learning and stable isotope analyses in future studies could help address current challenges, such as improving mapping accuracy, differentiating natural vs anthropogenic hydrogen sources and commercial production viability. This research contributes to Alberta's participation in global efforts to explore natural hydrogen and may help inform future hydrogen-specific exploration approaches tailored to the province's unique geological context.

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## References

- [1] Hidden hydrogen: Earth may hold vast stores of a renewable, carbon-free fuel. Available at: <https://www.science.org/content/article/hidden-hydrogen-earth-may-hold-vast-stores-renewable-carbon-free-fuel> (accessed January 21, 2025).
- [2] Wang L, Jin Z, Chen X, Su Y, Huang X. The Origin and Occurrence of Natural Hydrogen. *Energies* 2023;16:2400. <https://doi.org/10.3390/en16052400>.
- [3] Apps JA, van de Kamp PC. Energy gases of abiogenic origin in the Earth's crust. U.S. Geol Survey Professional Paper 1993;1570.
- [4] Zgonnik V. The occurrence and geoscience of natural hydrogen: A comprehensive review. *Earth-Science Reviews* 2020; 203:103140. <https://doi.org/10.1016/j.earscirev.2020.103140>.
- [5] Mayhew LE, Ellison ET, McCollom TM, Trainor TP, Templeton AS. Hydrogen generation from low-temperature water-rock reactions. *Nature Geoscience* 2013; 6:478–84. <https://doi.org/10.1038/ngeo1825>.
- [6] Seewald JS. Aqueous geochemistry of low molecular weight hydrocarbons at elevated temperatures and pressures: constraints from mineral-buffered laboratory experiments. *Geochimica et Cosmochimica Acta* 2001; 65:1641–1649. [https://doi.org/10.1016/S0016-7037\(01\)00544-0](https://doi.org/10.1016/S0016-7037(01)00544-0).
- [7] Carstens I. The genesis of natural hydrogen exploration. *GeoExpro* 2024. Available at: <https://geoexpro.com/the-genesis-of-natural-hydrogen-exploration/> (accessed January 21, 2025).
- [8] Séjourné S, Comeau F-A, Moreira dos Santos ML, Bordeleau G, Claproot M, Mouge P, et al. Potential for natural hydrogen in Quebec (Canada): a first review. *Frontiers in Geochemistry* 2024; 2. <https://doi.org/10.3389/fgeoc.2024.1351631>.
- [9] Lemieux A, Shkarupin A, Sharp K. Geologic feasibility of underground hydrogen storage in Canada. *International Journal of Hydrogen Energy* 2020;45:32243–32259. <https://doi.org/10.1016/j.ijhydene.2020.08.244>.
- [10] Epelle I, Obande W, Udourioh GA, Afolabi IC, Desongu KS, Orivri U, et al. Perspectives and prospects of underground hydrogen storage and natural hydrogen. *Sustainable Energy & Fuels* 2022;6:3324–3343. <https://doi.org/10.1039/D2SE00618A>.
- [11] Lévy D, Roche V, Pasquet G, Combaudon V, Geymond U, Loiseau K, et al. Natural H<sub>2</sub> exploration: tools and workflows to characterize a play. *Science and Technology of Energy Transitions* 2023;78:27. <https://doi.org/10.2516/stet/2023021>.
- [12] Prinzhofer A, Rigollet C, Lefevre N, Françolin J, Valadão de Miranda PE. Maricá (Brazil), the new natural hydrogen play which changes the paradigm of hydrogen exploration. *International Journal of Hydrogen Energy* 2024; 62:91–98. <https://doi.org/10.1016/j.ijhydene.2024.02.263>.
- [13] Evaluating the natural hydrogen system in Ampana Basin, Central Sulawesi: An implication for natural hydrogen exploration in Indonesia. *Jurnal Geologi dan Sumberdaya Mineral*. Available at: <https://jgsm.geologi.esdm.go.id/index.php/JGSM/article/view/896> (accessed January 21, 2025).
- [14] Davies K, Frey E, Giwelli A, Esteban L, Keshavarz A, Iglauer S. A natural hydrogen seep in Western Australia: Observed characteristics and controls. *Science and Technology of Energy Transitions* 2024; 79:48. <https://doi.org/10.2516/stet/2024043>.
- [15] Canada NR. Hydrogen Strategy for Canada: Progress Report 2024. Available at: <https://natural-resources.canada.ca/climate-change/canadas-green-future/the-hydrogen-strategy/hydrogen-strategy-for-canada-progress-report/25678> (accessed January 21, 2025).
- [16] Canada NR. The Hydrogen Strategy 2020. Available at: <https://natural-resources.canada.ca/climate-change/canadas-green-future/the-hydrogen-strategy/23080> (accessed January 21, 2025).
- [17] Emerging Resources - Hydrogen. Alberta Energy Regulator. Available at: <https://www.aer.ca/data-and-performance-reports/statistical-reports/alberta-energy-outlook-st98/emerging-resources/emerging-resources-hydrogen> (accessed January 21, 2025).
- [18] Milkov AV. Molecular hydrogen in surface and subsurface natural gases: Abundance, origins and ideas for deliberate exploration. *Earth-Science Reviews* 2022; 230:104063. <https://doi.org/10.1016/j.earscirev.2022.104063>.
- [19] Alberta Geological Survey. Available at: <https://ags.aer.ca/> (accessed January 21, 2025).

- [20] Alberta Table of Formations. Alberta Geological Survey. Available at: <https://ags.aer.ca/publications/allpublications/alberta-table-formations> (accessed January 21, 2025).
- [21] Helium concentrations from natural gas analysis tests in Alberta. Alberta Geological Survey. Available at: <https://ags.aer.ca/publications/all-publications/dig-2023-0029> (accessed December 13, 2024).
- [22] Guelard J, Beaumont V, Rouchon V, Guyot F, Pillot D, Jézéquel D, et al. Natural H<sub>2</sub> in Kansas: deep or shallow origin? *Geochemistry, Geophysics, Geosystems* 2017;18:1841–1865. <https://doi.org/10.1002/2016GC006544>.
- [23] Erzinger J, Wiersberg T, Zimmer M. Real-time mud gas logging and sampling during drilling. *Geofluids* 2006; 6:225–233. <https://doi.org/10.1111/j.1468-8123.2006.00152.x>.