



Quantitative assessment of hydrogen and helium production from the basement of the Western Canada Sedimentary Basin

Daniel Coutts – Geological Survey of Canada - Calgary

Omid H. Ardakani – Geological Survey of Canada – Calgary

Dinu Pana - Retired

Oliver Warr – University of Ottawa

Barbara Sherwood Lollar – University of Toronto, IPGP, Paris

Summary

Naturally occurring hydrogen represents a novel source of hydrogen for use in electricity generation and industrial processes (e.g., ammonia, fertilizer, steel)(IEA, 2024). Although naturally occurring hydrogen is theoretically produced in the crystalline basement of many basins through radiolysis and serpentinization (Lin et al., 2005; Sherwood Lollar et al., 2014), awareness of the global extent of hydrogen trapped in the Earth's subsurface has been seemingly restricted to researchers focused on deep subsurface microbiology and planetary sciences. As a new resource for humanity, understanding of the natural hydrogen system has been much less well developed (Prinzhofer et al., 2018; Maiga et al., 2023).

Here, we use a Bayesian Monte Carlo simulation (Warr et al., 2023) to estimate the production rate of hydrogen and cogenetic helium via radiolysis in the basement of the Western Canada Sedimentary Basin (WCSB). This model is informed by new and historic litho-geochemical samples of the basement of the Western Canada Sedimentary Basin. This modeling approach accounts for variance in sample rock properties (density, porosity, geochemistry) to calculate a probabilistic range of production values. Here, we show that high production rates of hydrogen and helium broadly correlate with mapped areas of high heat flow, indicating that radiolysis is likely the dominant source of hydrogen in the basin.

Lastly, we demonstrate the use of this model in an online web application format developed here, which can be easily used to compare geochemical results for use in a hydrogen system modeling approach.

Theory / Method / Workflow

Hydrogen is created through two dominant processes in the subsurface, serpentinization and radiolysis. Serpentinization is the process of hydration and metamorphic transformation of iron-rich minerals such as olivine, pyroxene, and magnetite. This dominantly occurs in mafic and ultramafic rocks but can also occur in banded iron formations (Geymond et al., 2022). Water in the hydration reaction is used to oxidize iron in these minerals, liberating hydrogen from the water (Coveney et al., 1987). The process of radiolysis, however, involves the generation of alpha particles (He^{2+}) from radiogenic isotopes of uranium and thorium in dominantly felsic rocks. Collisions between the ejected alpha particles and water in porosity can cause water to split into hydrogen and oxygen gas (Lin et al., 2005; Ballentine and Burnard, 2002).



The basement of the Western Canada Sedimentary Basins is composed of a wide variety of rock types (Burwash et al., 1994), some which would be dominated by H₂ production via radiolysis (e.g., granites) while other more iron-rich lithologies would favour serpentinization (e.g., kimberlites, greenstone belts). Here, for simplicity and to generate a conservative estimate of production, we only consider radiolysis. This provides a minimum estimate for total hydrogen production but is also consistent with the more felsic to intermediate igneous rocks typical of the WCSB basement.

The Monte Carlo approach follows the equations of Warr et al. (2023), incorporating ranges for rock geochemistry (uranium and thorium concentrations), rock properties (rock density and porosity), and fluid properties (fluid density). Rock geochemistry are taken from core samples that have undergone whole rock and trace element analysis. Porosity of the rock is taken from the Canadian Rock Physical Property Database (Enkin, 2018) based on lithology. This approach is programmed in R to handle a large number of sample inputs. In addition to this, this model has also been developed into a web application, which will be highlighted in the presentation (Figure 1). This allows for more streamlined, user-friendly application of the method to H₂ and He exploration problems.

Results, Observations, Conclusions

Calculated hydrogen and helium production is heterogenous across the basement of the Western Canada Sedimentary Basin, where production rates can vary over an order of magnitude within kilometers. Initial results show some correlations between high hydrogen production rates calculated here and basement heat flow highs (e.g., Burwash et al., 1994; Majorowicz, 2018).

Novel/Additive Information

We present a novel application of radiolysis equations (Warr et al., 2023) to the Western Canada Sedimentary Basin to better characterize the source of hydrogen in the basin and inform exploration strategies for the gas. This represents a first attempt to map the *source rock* of a hydrogen system in Canada and in a world class basin. As a direct output of this project the development of a user-friendly model, exploration models, and plays can now be more readily constructed.

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H₂/He production app

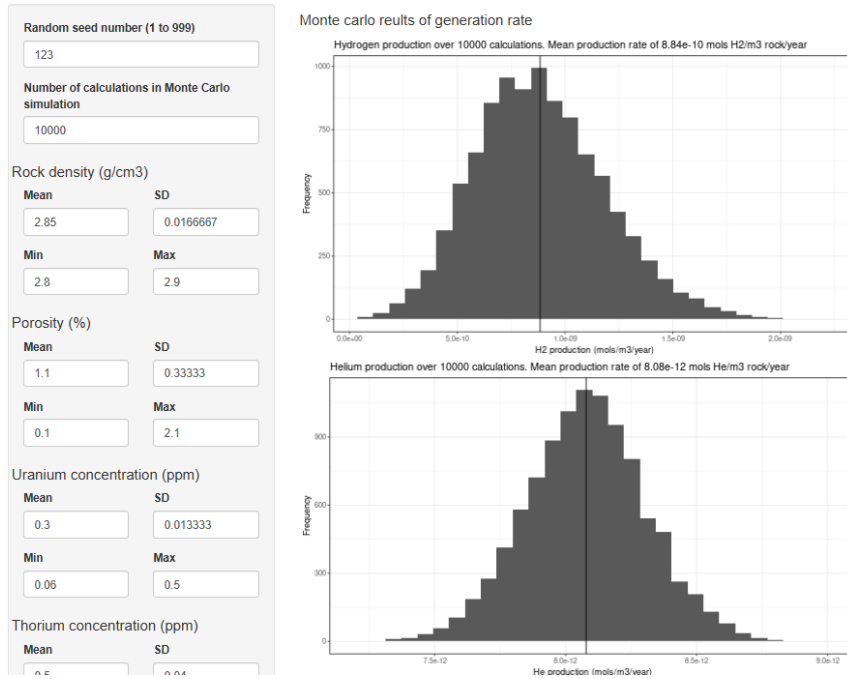


Figure 1 – Screen shot of the hydrogen and helium Monte Carlo application