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Mapping the Continental Hydrogen Kitchen

Supervisors

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Research Group

Solid Earth–Fluid Earth Interactions (SoEFEI) Group (https://freddrichards.github.io/team/)

Project Summary

Natural (or "geological") hydrogen (H_2) represents a potentially transformative carbon-free energy resource, yet fundamental questions remain about the rate at which it is generated in different tectonic settings, and where—if they exist at all—significant reservoirs might lie in the subsurface. Recent discoveries in Mali, Albania, and Australia show that appreciable quantities of hydrogen are emitted from the subsurface in certain locations, but we still lack a rigorous framework for quantifying geological hydrogen resources at large scales. In particular, while we know that radiolytic splitting of water (Sherwood-Lollar et al., 2014, *Nature*) and serpentinization of ultramafic rocks (Zgonnik et al., 2019, *AJG*) are the dominant source of natural hydrogen, we do not have a good idea of where the rock types and thermodynamic conditions needed for these processes to operate reside in Earth's continental crust.

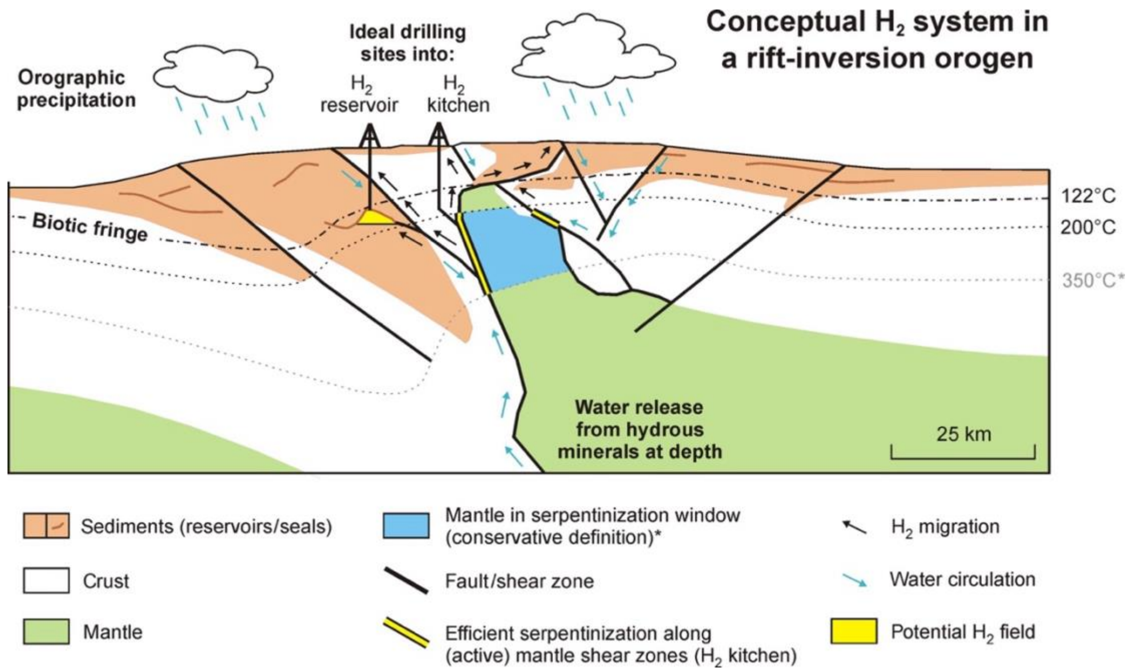

Figure 1: *Conceptual model of a natural hydrogen system in a rift-inversion orogen (i.e., a mountain belt created by compressing rifted lithosphere). Redrawn from Zwaan et al. (2025, Science Advances).*

This project will address these knowledge gaps by integrating geophysical, thermodynamic, and geodynamic methods to develop the first global-scale map of the continental "hydrogen kitchen" (i.e., the subsurface regions capable of generating H_2). By establishing which parts of the continents are most prospective for natural hydrogen, this work will place the successful applicant at the forefront of global efforts to determine the economic viability of this potential clean energy source. Obtaining this understanding is critical to the effective planning and realisation of humanity's increasingly urgent transition to carbon-free energy sources.

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Research Context and Objectives

Estimating the scale of the continental hydrogen kitchen requires several pieces of information that are currently lacking. First, accurate maps of where rock types capable of generating H_2 reside within the subsurface, i.e., ultramafic (or mafic) rocks for serpentinisation-derived H_2 and felsic crustal rocks with high radioisotope concentrations for radiolytic H_2. Second, knowledge of intracrustal temperature conditions and fluid pathways (e.g., fault planes), which control how much water can interact with these rocks and the resulting volume of H_2 produced. Third, constraints on when H_2 is likely to have been generated in a particular region, which governs the volume that may be trapped at depth and that is being fluxed from depth today.

This project will take advantage of recent advances in geophysical imaging, experimental thermodynamic databases, and geodynamic modelling to address each of these knowledge gaps, thereby generating the first comprehensive estimate of subsurface global hydrogen production. This will involve:

1) Combining new continent-scale high-resolution magnetotelluric, seismic, potential field, and heat flow datasets into a probabilistic inverse framework to produce global maps of lithospheric temperature structure, crustal radiogenic heat production, and ultramafic rocks within the serpentinization window (~200–350°C).
2) Joint geodynamic and thermodynamic modelling of radiolysis and serpentinisation in different end-member tectonic settings to determine the characteristic spatiotemporal evolution of hydrogen production, transport, and trapping in each case.
3) Integration of model output with tectonic reconstructions and present-day hydrogen kitchen maps to predict quantities of H_2 produced and trapped over lifetime of different hydrogen systems, with targeted fieldwork conducted to validate these estimates.

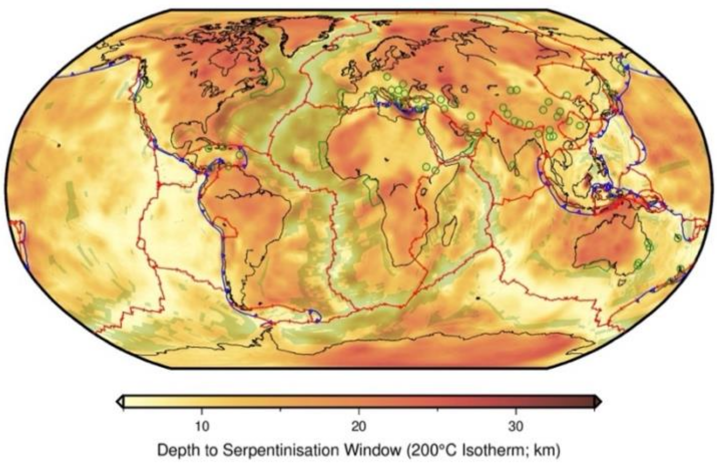

Figure 2: *Preliminary estimate of depth to top of the serpentinization window (i.e., 200 °C isothermal surface) predicted from joint inversion of seismological and rock mechanical data. Green symbols, lines and shading indicate regions where ultramafic rock is often exposed at the surface; shading = slow-spreading oceanic regions; circles = ophiolite complexes; polygons = hyper-extended continental margins. Blue lines = convergent plate boundaries; red lines = divergent and transform plate boundaries (Bird, 2003, G^3).*

Further reading:

Ballentine, C.J., Karolytė, R., Cheng, A., Sherwood Lollar, B., Gluyas, J.G. & Daly, M.C. (2025). Natural hydrogen resource accumulation in the continental crust. *Nature Reviews Earth & Environment*, **6**(5), 342-356.

The Royal Society (2025). Natural hydrogen: Future energy and resources – Policy Briefing, DES9148_1, *The Royal Society*, London. https:/royalsociety.org/natural-hydrogen.

Who are we looking for?

The successful applicant will be an Earth scientist, engineer, or physicist with some coding skills and an interest in interdisciplinary research at the interface between geophysics, geochemistry, and resource engineering. The candidate will have the opportunity to conduct fieldwork, to interact with industry partners, to raise their profile via international conference attendance, and to be supported throughout by a diverse and experienced supervisory team.