Goldschmidt 2025 Abstract
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$$\mathit{Olivine} + \mathit{Water} = \mathit{Serpentine} + \mathit{Brucite} + \mathit{Magnetite} + \mathit{Hydrogen}$$
$$Mg_{1.82}Fe_{0.18} + wH_2O = 0.5(Mg,Fe^{II},Fe^{III})_3(Si,Fe^{III})_2)O_5(OH)_5 + x(Mg,Fe)(OH)_2 + yFe_3O_4 + zH_2 \quad (1)$$

# Magnetic & Helium Isotope Monitoring of Serpentinization

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Natural hydrogen could be an important net zero natural resource; however, the kinetics and controls of geological hydrogen production remain poorly understood [1]. Serpentinization sources between 55 and 80% of hydrogen generated in continental settings [2]. (Equation 1)

Efforts to better constrain the reaction rates of serpentinization, both in the lab and in the field, are often hampered by slow reaction rates and the technical challenges associated with direct measurement of hydrogen production.

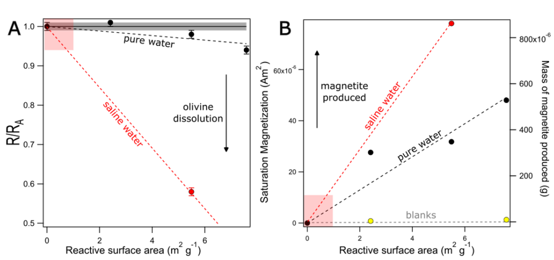
Here, we explore two novel methods to monitor serpentinization kinetics. In a series of gold capsule experiments with water or 4 Molal NaCl solution, and Aheim dunite of varying grain size fractions (38-30, 30-20, 20-10 µm), we track the precipitation of magnetite, one of the reaction products. Using a superconducting rock magnetometer with a sensitivity of $1 \times 10^{-12}$ $Am^2$, it is possible to detect changes as little as $1 \times 10^{-8}$g magnetite without opening the capsule or disturbing the ongoing reaction. This provides a cheap and high-resolution method to constrain serpentinization.

Secondly, we investigate the use of helium isotopes as a tracer for the consumption of olivine. Radiogenic helium ($^4He$) generated by U-Th decay within olivine remains trapped in the crystal lattice. During the dissolution of the mineral He is released resulting in a reduced $^3He/^4He$ signature. Upon termination of the experiments and piercing of the capsule, the $^3He/^4He$ signature was measured on a Helix SFT multi-collector mass spectrometer and provided a detectable signature even at the low extents of reaction (<14%) achieved. Further work will build on these techniques to facilitate an ongoing investigation into the kinetics of serpentinization and the optimal geological conditions for $H_2$ generation by varying parameters such as salinity, fugacity, pH and minor mineral phases.

References

[1] Zgonnik, V. (2020) Earth Science Reviews 203, 103-140

[2] Lollar, B. S. et al. (2014) Nature 516, 379-382




Pilot data obtained after 936hrs of reaction between olivine and water/saline fluid at 300°C and 500bar. Experiments conducted with pure water are shown with black markers, whilst red markers show a capsule with 4Molal NaCl. Grey shading in Figure A. indicates range where measurement uncertainty is within atmospheric values. Red shading indicates range of values that could be expected after 936hrs of reaction in a system with geologically plausible surface areas (<$1m^2g^{-1}$).