Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37767

Banded Iron Formations: A Significant Source of Natural Hydrogen?

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Natural hydrogen could be an important net zero natural resource [e.g. 1]. Field observations and recent experimental studies suggest maghemitization in Banded Iron Formations (BIFs), may source geological H_2 by the oxidation of Fe(II) in magnetite (Eq. 1) [e.g. 2,3]. Considering magnetite is a substantial reservoir of Fe(II) (24wt%), BIFs could have the capacity to generate large volumes of hydrogen.

Quantifying maghemitization kinetics remains challenging due to slow reaction rates and the technical difficulties associated with direct measurement of H_2 generation. Magnetite (Fe_3O_4, reactant) and maghemite (γ-Fe_2O_3, product) differ in crystal lattice parameter by only 1%, making the application of many traditional techniques to discern reaction extent difficult.

We use changes in a samples magnetic properties to monitor maghemitization. Batch reactions were conducted in borosilicate vials with anoxic water and either natural or synthetic magnetite of varying grain size fractions (125-90, 90-63, 63-45, 45-38, 0.2µm). Reaction progress was quantified using the loss of Saturation Isothermal Remnant Magnetism (SIRM) during low temperature (77k) cooling and rewarming, exploiting differences in the magnetic behaviour of magnetite and maghemite.

Over 47 days, 23% reaction progress was achieved in the 0.2µm magnetite, whilst 4% was achieved in the 45-38µm fraction. Reaction extent remained below detection limits in coarser grain size fractions. Preliminary data indicates H_2 production was limited with a maximum yield of 36.6 $\mu mol\ H_2/\ kg\ rock$ in the 0.2µm fraction. Ongoing work will build on these techniques to investigate a wider range of BIF mineralogies and evaluate the influence of temperature and fluid composition on hydrogen generation.

References:

[1] Ballentine et al., (2025), *Nature Reviews Earth and Environment*, Natural hydrogen resource accumulation in the continental crust

[2] Geymond et al., (2023), *Frontiers Media*, Reassessing the role of magnetite during natural hydrogen generation

[3] Geymond et al., (2022), *Minerals,* Can Weathering of Banded Iron Formations Generate Natural Hydrogen? Evidence from Australia, Brazil and South Africa

$$Magnetite + H_2O \rightarrow Maghemite + H_2$$
$$2(\propto Fe_3O_4) + H_2O \rightarrow 3(\gamma Fe_2O_3) + H_2$$