

Contrasting Hydrogen (H₂) Production Potentials of Continental and Deep-Sea Weathering and Hydrothermal Environments

NURI PARK AND EVERETT L SHOCK

Arizona State University

Presenting Author: npark13@asu.edu

As a carbon-free energy source, H₂ is one of the promising candidates for replacing fossil fuels. Furthermore, H₂ is an energy source for chemosynthetic microbial communities that may have existed since shortly after the origin of life on Earth. It follows that H₂ production is central to evaluating the habitability of reactive water-rock systems across the Solar system. Therefore, deciphering the factors that facilitate H₂ production in natural settings benefits both industry and the scientific community. Natural H₂ is produced in environments where water is in physical contact with rocks, which allows reactions where the iron (Fe(II) or Fe(metal)) in rocks reduces water to H₂ and forms oxidized iron (Fe(III)). The extent of H₂ production through water-rock interaction varies with differences in rock and fluid compositions. To explore the H₂ production potential of terrestrial systems, we apply thermodynamic equilibrium calculations that simulate more than 40,000 systems. We use 9,414 rock compositions that encompass a spectrum of terrestrial rocks ranging from mafic to ultramafic (MgO content: 3wt% to 50wt%). We model reactions with rainwater and seawater at various temperatures to simulate continental and deep-sea weathering and hydrothermal systems. Our major findings are that 1) hydrogen production depends highly on rock compositions at low temperatures where the difference spans more than eight orders of magnitude, and converges as temperature ascends owing to common stabilization of Fe(III)-bearing minerals (e.g., epidote and serpentine), 2) deep-sea hydrothermal models generally show less H₂ production potential than continental hydrothermal models because reduction of oxidants in seawater to form sulfides and methane consumes some of the H₂ produced from iron oxidation, and 3) the effects of differences in fluid composition on hydrogen production of ultramafic rocks (>40 wt% MgO) are less significant due to their intrinsic compositions that precipitate serpentine and garnet during weathering or hydrothermal alteration. In summary, the H₂ potential of a water-rock system is the highest when the rocks meet precipitation-derived continental fluids at elevated temperatures (>200°C).