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# $H_2$ production during alteration of Fe-bearing igneous rocks: Lithological controls, microbial energy supplies, and Earth system oxygenation

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The aqueous alteration of igneous rocks produces volatiles ($H_2$, $CH_4$) that enable habitable environments and was key to maintaining a reduced and $O_2$-free atmosphere on the early Earth. Moreover, Fe-bearing igneous rocks are not unique to Earth, and thus are attractive for their potential to support life in other rocky bodies in our solar system.

Rock-hosted habitats have varying potentials to support different chemotrophic metabolisms and supply reduced volatiles into the atmosphere. In this work, we present results of a comprehensive survey of dissolved $H_2$ and $CH_4$ contents alongside outgassing rates in several active hyperalkaline spring sites in the Samail ophiolite in Oman. These sites are hosted in various lithological settings in the ophiolite and are accessible analogs for submarine hydrothermal vents at Earth's seafloor and rock-hosted environments elsewhere in our solar system. Outgassing rates are variable and corresponding water-rock reaction rates that can account for measured outgassing are consistent with those extrapolated from laboratory experiments. Variations in dissolved gas compositions in these sites yield variable potentials to support different chemotrophic strategies. For example, $H_2$-poor but sulfur- and $CH_4$-rich sites hosted in gabbroic rocks supply less energy for $H_2$ oxidizing microbes (hydrogenotrophs), but have higher potentials for other microbial strategies relative to $H_2$-rich ultramafic-hosted sites in the same ophiolite.

To account for compositional variations observed in our study sites and other rock-hosted systems on Earth, we investigate lithological controls on $H_2$ production during low-temperature water-rock interactions. Through extensive thermodynamic simulations encompassing >9,400 rock compositions taken from the GEOROC database, we provide an inclusive assessment of the $H_2$-generation potentials of Earth's Fe-bearing mafic and ultramafic igneous rocks. Alteration of ultramafic rocks (i.e., serpentinization) yields substantially higher $H_2$ relative to mafic rocks. We used these calculations to construct the global $H_2$ production and $O_2$ consumption rates via low-temperature rock alteration throughout Earth's history. Results show that on the early Earth, significant $H_2$ production during ultramafic alteration likely helped prevent atmospheric $O_2$ accumulation. This continued until the abundance of ultramafic rocks diminished by the end of the Archean and helped set the stage for the Great Oxidation Event.