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Submarine water-rock interactions and microbial life: a theoretical approach

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Mass and energy balances coupled with thermodynamic calculations indicate that a large amount of energy in the form of chemical work (about 100 Petajoule/yr) is transported to the seafloor by hydrothermal vent fluids. A similar amount of energy is tied to the affinity of reduced components in seafloor rocks and minerals for oxidation. Chemolithoautotrophic microorganisms harness an unknown fraction of that energy to produce primary biomass in the deep sea.

The specific magmatic and fluid-rock interaction processes taking place within the geological system control what metabolic reactions can support chemolithoautotrophy-based microbial ecosystems at the seafloor. It turns out that basement composition, magmatic degassing, and subseafloor mineralization impose a first-order control on vent fluid chemistry.

We used thermodynamic calculations to assess how much energy hot rocks can provide in different geotectonic setting to support biomass production by chemolithoautotrophic microorganisms. The dominant energy source varies greatly between vents in different submarine settings, from hydrogen sulfide in basalt-hosted systems to dihydrogen and methane in peridotite-hosted systems to Fe and S in felsic rock systesm in island arcs. The dihydrogen fluxes related to serpentinization are at least one order of magnitude greater than those related to global magmatism, and hydrogen consumption could be one of the most important catabolic reactions in deep-sea chemolithoautotrophy.

In one example we show that peridotite-water interactions release quantities of hydrogen that are sufficient for methanogens and sulfate reducers to thrive under a range of temperature and fluid flux conditions. In contrast, hydrogen production within basaltic aquifers is barely enough under the best of circumstances to allow for growth of methanogens and sulfate reducers. This prediction appears to be corroborated by sulfur isotope compositions of hydrothermally altered peridotites and basalts, where only the former show a distinct mode centered around light (microbial) isotopic ratios.