Metabolic Cartography in Basalt Hosted Systems

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The geophysics of the cooling Earth – mantle dynamics and the chemistries it motivates and repositions – produces a diversity of rock compositions along mid-ocean ridge (MOR) spreading centers. These MOR basalts, tortured as they are by the invasion of seawater along propagating cracks and fissures, gestate some of the most energetically diverse ecosystems on Earth. The hot, reduced, rock equilibrated vent fluids, and the cold, relatively oxidized seawater, provide a wide range of electron donors and acceptors that support the energy demands of a diverse assortment of bacterial and archael clades occupying the same real estate.

In this study we calculated energy supplies to organisms using any one of 1400 different redox reactions as vent fluids and seawater mix. This process was carried out for 465 basalt compositions identified as the average for their perspective ridge segments by Gale et al., 2013, resulting in over 65,000 energy calculations.

Each model calculation is completed in two stages. Stage 1, consists of a reaction path calculation in which an increasing amount of basalt is reacted with a fixed amount of seawater, beginning at 2°C (pure bottom seawater), and ending at 350°C, whereupon a total of 1 kg of basalt has been reacted with a total of 1 kg of seawater. The resulting equilibrium assemblage includes a solid component (precipitates) and an aqueous component (model vent fluid). In stage 2 the redox reactions are evaluated by mixing the vent fluid – sans precipitates – back into seawater to an eventual ratio of 100:1 seawater to vent fluid. By inhibiting the transfer of elections among donors and acceptors, such mixing calculations yield maximum energy supplies.

Given the pervasiveness of life, which exists as a relaxation pathway for redox disequilibria, environmental reaction rates are sufficiently slow such that the rate of mixing is faster than the abiotic rates of reactions. Each source of energy derived in this was can be mapped onto the ridge systems of the Earth to visualize the maximum energy landscape.

These results are the first global assessment of the energetic landscape depicting how MOR hydrothermal systems support life. And although not a description of what *does* exists in vent systems, it is nonetheless a description of what *can* exist, given model constraints. It is as a cartographic map to a real environment, a simplified yet accurate image of energetic topology.

A. Gale, C. A. Dalton, C. H. Langmuir, Y. Su, J.-G. Schilling, *Geochem. Geophys. Geosyst.* **14**, 489–518 (2013).