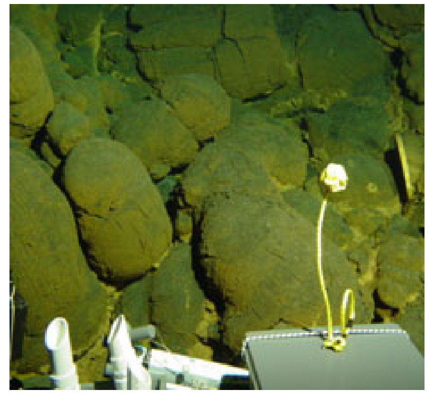
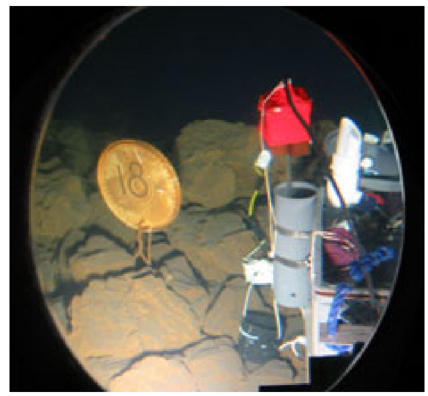
Microbial Life on the Seafloor: Where's the Energy?

During the past 10 years there has been a growing recognition that the vast expanse of bare, unsedimented rocks on the seafloor harbor abundant and diverse microbial communities. Surprisingly, biofilms rapidly develop as volcanic rocks are produced at the mid-ocean ridges and Seamounts, and these types of microbial biomes are relatively unexplored. Geochemists, oceanographers and microbiologist have all questioned the role of the microbial organisms in the breakdown and weathering of the ocean crust. In particular, the energy sources and metabolisms supporting this rock-hosted microbial biosphere are currently unknown. Since the majority of the cold, dark seafloor is not directly influenced by hydrothermal activity, nor receives large inputs of organic carbon from photosynthesis, do the rocks themselves provide the energy microorganisms need to grow?



Pillow basalts on the side of the volcano.



View of pillow basalts from inside the *Pisces V*.

Recently, an interdisciplinary team that included faculty, students and research scientists from the University of Colorado, Scripps Institution of Oceanography, Oregon Graduate Institute, Stanford Synchrotron Radiation Lightsource and Pacific Northwest National Laboratory conducted a microbial colonization experiment at Loihi Seamount, adjacent to the Big Island of Hawaii. Young basaltic glasses were collected by the deep-sea submersible *Pisces V* and the remote operated vehicle *Jason II* to determine whether or not extensive biofilm formation and rock weathered had occurred. The study was designed to test whether bacteria were catalyzing the release of Fe(II) and Mn(II) from basaltic glasses and oxidizing these metals by reaction with oxygen in seawater to gain energy for growth. To date, exploring rapid changes in the chemistry of natural rock surfaces has been difficult due to the small length scales over which the reactions occur and the need to achieve chemical sensitivity. The team solved this problem using synchrotron-based x-ray fluorescence microprobe mapping coupled with x-ray absorption spectroscopy at SSRL beam lines 2-3 and 11-2 to explore the micron-scale changes in Fe and Mn distribution and chemical speciation at

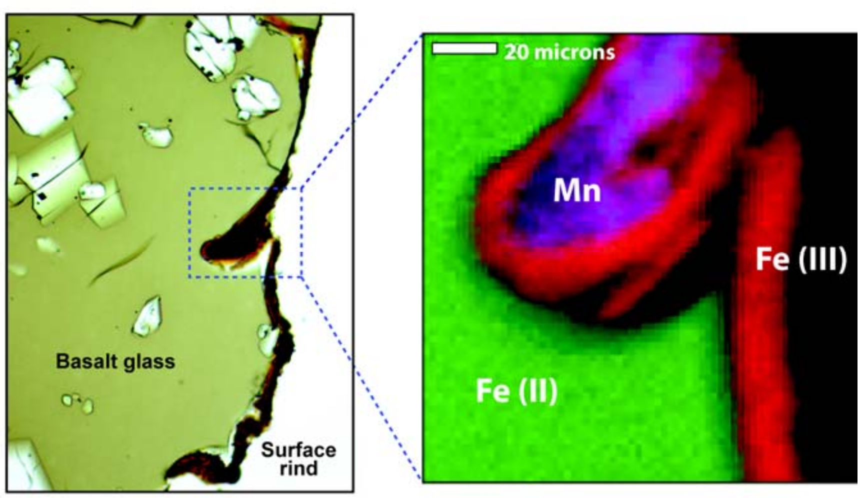


Figure 1

the rock/biofilm interface. The key measurements involved energy-difference mapping and the Fe K-edge to spatially resolve changes in the ratio of Fe(II) to Fe(III) across the reacted surfaces (see Figure 1).

The study, recently published in *Nature Geoscience* (Templeton et al., 2009), also used newly developed focused-ion-beam milling techniques to cut into the surface of colonized rocks and extract sections of the biofilm/mineral interfaces for high-resolution scanning and transmission electron microscopy. Together, the combined spectroscopic and imaging data surprisingly revealed that the microbial biofilms are not inducing rapid weathering of the colonized basalts, nor oxidizing the Fe and Mn derived from the surfaces. Instead, the biofilms are mediating the uptake and oxidation of dilute carbon, Fe and Mn from seawater and building mineral crusts dominated by Fe(III) and Mn(IV)-oxyhydroxides. These findings suggest that basalts may often not be the energy source for seafloor life, and that many microbial communities may instead rely upon the dispersion of hydrothermal fluids through the deep ocean. In addition, the biomineralization reactions within the microbial biofilms appear to generate critical micron-scale precursors of highly-reactive "ferromanganese crusts". Previously, the growth mechanisms for ferromanganese crusts have been relatively enigmatic. However, this study provides new insights into the genesis of ferromanganese crusts, which ultimately become ubiquitous across the Pacific seafloor and accumulate economic concentrations of trace metals over geological time scales.

Primary Citation:

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