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Hydrogen generation during simulated earthquake faulting: its implication for subsurface microbial evolution

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Since the discovery of deep-sea hydrothermal vents in the late 1970s, the most ancient microbial ecosystems are considered to evolve at habitable environments in the vicinity of H2-rich hydrothermal fluids (e.g., Russell & Hall, 1997). In the modern ocean, the H2-rich hydrothermal fluids that are often observed along the slow-spreading Mid Ocean Ridges (MOR) are most likely to be provided by the ultramafic rock-water reaction (serpentinization) (e.g., Seyfried et al., 1979). However, such H2-rich fluids can be also found at the East Pacific Rise (EPR) where ultramafic rocks are not exposed. In this study, we hypothesized that the H2-rich fluids at the EPR are produced during the seismic events in basaltic rocks, and that the H2 generation associated with seismic faulting could contribute to sustaining the subsurface biological communities.

In order to confirm above hypotheses, we performed laboratory friction experiments on basalt, dunite and granite at normal stresses of 0.5-2 MPa, slip velocities, V, of 0.09-1.6 m/s (nearly coseismic slip rates) and displacements of up to 10 m using a rotary-shear apparatus. Slip on the simulated fault was conducted within a small pressure vessel that was filled with air. Hydrogen gas released during experiments was measured by a micro gas chromatograph which was directly connected to the pressure vessel. The main findings of our preliminary experimental work are: (1) the amount of H2 gas increased almost linearly with frictional work energy (e.g., normal stress and displacement). The amount of H2 generation in granite samples is a few times higher than that of basalt. (2) When a few drops of distilled water were added to the sliding surfaces, the H2 production was enhanced for all rock types. (3) When the wet basalt specimen was sheared at V of 1.6 m/s corresponding to a total mechanical work energy of ~2.8 kJ (calculated as shear stress multiplied by displacement), the H2 gas of ~3.2E-7 mol was released from the simulated fault.

In terms of frictional work energy during seismic faulting, the total work energy of several kJ applied on the simulated fault in our experiments corresponds to an earthquake moment magnitude, Mw of -5. Enormous number of such small earthquakes (Mw <1) currently occurs along the MORs (i.e., Bohnenstiehl et al., 2008). Based on the experimentally-determined correlation between H2 production and frictional work energy, estimated H2 release during an earthquake with Mw=1 is the order of mmol. Although further careful consideration is needed to evaluate the contribution of earthquake related H2 generation to the microbial ecosystems, our results imply that H2 generation due to seismic faulting could possibly affect the evolution of subsurface microbes.

Keywords: earthquake, fault, hydrogen, methanogen