

**Coupled Geochemical and Biological Processes in Low-Temperature Serpentinizing Systems** A. S. Templeton<sup>1</sup>, H. M. Miller<sup>1</sup>, L.E. Mayhew<sup>1</sup>, K. Rempfert<sup>1</sup>, E. Ellison<sup>1</sup>, J.M. Matter<sup>2</sup>, P. Kelemen<sup>2</sup>, <sup>1</sup>Department of Geological Sciences, UCB 399, University of Colorado, Boulder CO 80309 ([alexis.templeton@colorado.edu](mailto:alexis.templeton@colorado.edu); [hannah.miller-1@colorado.edu](mailto:hannah.miller-1@colorado.edu); [lisa.mayhew@colorado.edu](mailto:lisa.mayhew@colorado.edu); [kaitlin.rempfert@colorado.edu](mailto:kaitlin.rempfert@colorado.edu); [eric.ellison@colorado.edu](mailto:eric.ellison@colorado.edu)), <sup>2</sup>Lamont Doherty Earth Observatory, Columbia University, 211 Corner, 61 Route 9W, PO Box 1000, Palisades NY 10964-8000 ([peterk@ldeo.columbia.edu](mailto:peterk@ldeo.columbia.edu); [jmatter@ldeo.columbia.edu](mailto:jmatter@ldeo.columbia.edu)).

**Introduction:** Minerals such as olivine and pyroxene are abundant components within peridotite rocks throughout our solar system; these minerals are highly reactive in the presence of fluids, resulting in the formation of secondary minerals such as (Mg,Fe)-serpentine, hydroxides, carbonates, and oxides. During peridotite hydration, the simultaneous reduction of water and CO<sub>2</sub> also commonly occurs, thereby generating H<sub>2</sub>, CH<sub>4</sub> and small molecular weight hydrocarbons that can power biological systems.

Although there exist numerous thermodynamic predictions, field studies and experimental investigations to constrain the dominant serpentinization reaction products that form at high-temperatures and pressures, little experimental or observational data exists for low-temperature serpentinization processes that may be prevalent on many moons and planets, including Europa and Mars. Thus we seek to define the operative reaction pathways and products of peridotite hydration that occur within a temperature regime where it should be possible to support in-situ life activity. In particular we ask whether the rates of H<sub>2</sub> generation and C flux are sufficient to sustain metabolism in low-temperature serpentinizing rocks? Is there a detectable biosphere hosted within actively serpentinizing subsurface rocks on the modern Earth? Is it possible to experimentally investigate the coupling between low-temperature serpentinization processes and direct microbial utilization of the products of such water/rock reactions?

**New insights from Experimental Studies:** We will provide a synthesis of existing peridotite hydration experiments conducted at 100°C and below, and provide a hypothesis for the dominant controls on H<sub>2</sub> generation in low-temperature systems (e.g. Mayhew et al. 2013 and unpublished data). We propose that the extent of low temperature H<sub>2</sub> generation is often dependent on the catalytic properties of the rocks, such as the presence of conductive mineral interfaces that promote electron transfer. In addition, we will demonstrate that the rate and extent of hydrogen generation and CO<sub>2</sub> reduction during water/rock interaction can be strongly modulated by the extent of prior serpentinization, as observed through experimental studies of peridotite alteration using rocks recovered from the Samail Ophiolite in Oman. Our detailed characterization of the redox processes occurring during low-temperature

serpentinization relies upon several analytical approaches to interrogate the distribution and speciation of Fe during progressive rock alteration (e.g. Raman, EPMA, synchrotron-based micro-XRF and micro-XANES mapping) (Miller et al., 2013 and unpublished data), which then reveals the degree to which Fe is oxidized and distributed into serpentine vs. magnetite secondary minerals in low-temperature systems.

**New insights from the deep subsurface biosphere in serpentinizing rocks:** We will also present new 16S rRNA data on microbial communities detected in deep serpentinite-hosted fluids from Oman. Our team has collected hyperalkaline, H<sub>2</sub>- and CH<sub>4</sub>-rich fluids (<40°C) from hundreds of meters below the surface in partially-serpentinized peridotite aquifers in the Oman. We are conducting an integrated analysis of the well fluid chemistry, mineralogy, dissolved H<sub>2</sub>, CH<sub>4</sub>, CO concentrations, isotopic composition of the fluids and gases and and microbial community composition, to determine the operative water/rock reaction pathways, identify the dominant organisms and infer putative metabolisms. In particular, we note strong geochemical controls on the distribution of methane with highly enriched  $\delta^{13}\text{C}$  CH<sub>4</sub> values; this phenomenon can also be reproduced under laboratory conditions with recently cultivated consortia of methanogens, sulfate reducers and iron reducers from Oman fluids (Miller et al 2014 and unpublished data).

**Conclusions:** In our laboratory and field-based work, we can demonstrate that H<sub>2</sub> generation and active methanogenesis do measurably occur in low-temperature serpentinizing systems. The coupling of C reduction pathways (e.g. to formate and methane), and the biogeochemical cycling of Fe are currently enigmatic but may produce distinctive methane C isotope systematics and Fe mineralogy that could emerge as examples of biosignature for serpentinite-hosted life.

**References:** [1] Mayhew, L.E., Ellison, E., McCollom, T.M., Trainor, T.P., and Templeton, A.S. (2013) *Nature Geosciences*, 6, 478-484. [2] Miller, H.M., Mayhew, L.E., and Templeton, A.S. (2013) *AGU Abstract MR33B-2322*. [3] Miller, H.M., Ellison, E., Kelemen, P., Matter, J.M., and Templeton, A.S. (2014) *AGU Abstract V53A-4830*.