SUBSURFACE INVESTIGATION OF THE COAST RANGE OPHIOLITE, NORTHERN CALIFORNIA: FIELD CAMPAIGN FINDINGS. D. Cardace and T.M. Hoehler, NASA Ames Research Center, MS 239-4, Moffett Field, CA 94035
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Introduction: Serpentinizing systems on Earth have attracted great interest for their potential as analogs to habitable environments on other planetary bodies and also as sites important for understanding the origin and evolution of life on Earth. The geological process of serpentinization, in which olivine minerals in ultramafic rocks react with water to produce serpentine minerals, brucite, iron oxyhydroxides, magnetites, and hydrogen, has been proposed to be capable of fueling a subsurface microbial ecosystem, to a possibly widespread (if not planetary) geographic extent. Terrestrial field campaigns offer diverse opportunities for ground-truthing and comparison in astrobiological research. We surveyed a block of the Coast Range Ophiolite in Northern California that is plumbed with groundwater monitoring wells (up to ~45 m deep), allowing access to the serpentinizing subsurface.

Geologic Setting:
The Coast Range Ophiolite, an uplifted section of middle Jurassic oceanic crust, comprises a series of ophiolite blocks aligned along the Coast Range fault from Elder Creek to Point Sal, in contact with underlying Franciscan Complex rocks [1]. Regional tectonics that control the emplacement of this ophiolite are complex, but indicate supra subduction zone formation, likely in an extensional forearc setting [1]. Ultramafic mantle peridotite blocks situated in a sheared serpentinite matrix have been studied in the vicinity, and are mainly refractory harzburgites [2], that is, relict parent minerals are mainly olivine and low-calcium pyroxene. At the McLaughlin Reserve near Lower Lake, CA, serpentinite mélange dominates, with variably serpentinized boulders of peridotite weathering out of the landscape.

Results:

Mineralogy of rock cores
Core logs from the well sites indicate greater and lesser extents of serpentinization in subsurface rocks, characterized by metaigneous rocks with an uppermost oxidized zone to ~15 m deep, underlain by variably sheared serpentinite with metaigneous breccia to ~40 m below soil surface. Inspection of selected, archived cores of serpentinite from nearby drill sites that bottom out ~110 meters below the surface reveals nearly completely serpentinized parent rock, with polished and massive serpentine, and prominent bastite (serpentinized pyroxene) grains. XRD data for core samples reveal variably serpentinized bedrock, with juxtaposed chrysotile and lizardite serpentine minerals and relict parent minerals, suggesting episodic and ongoing serpentinization. Also noteworthy is the magnetism of surface serpentine gravels, reflecting the presence of late stage magnetite in the serpentinization process.

Aqueous geochemistry
Well waters show consistently elevated pH (9.12-10.15) and Ca^{2+} concentrations (12-84 ppm), consistent with formation under serpentinizing conditions. In general, these formation fluids are depleted in major ions and enriched in Fe and Mn with respect to seawater. Hexavalent chromium is also present. Fluid concentrations of methane and hydrogen, are consistent with active serpentinization, in the ranges of 1 to 800 micromolar $CH_{4(aq)}$, and 30 nanomolar to 3 micromolar $H_{2(aq)}$. The organic geochemistry of these waters is so far unconstrained.

Modeling of metabolic feasibility
Geochemical modeling of these data constrains the free energy yields that could be accessed by H_2-consuming microbial metabolisms. Methanogenesis, sulfate reduction, nitrate reduction, and ferric iron reduction are all favored given the observed groundwater chemistries [3].

Environmental DNA extractions
Serpentinizing groundwaters were filtered with a clean, sterile 0.22 micron pore size water filter, and the resulting concentrated DNA was extracted from the filter using commercially available kits designed for waters (www.mobio.com, UltraClean® Water DNA Isolation Kit for small or large volume water samples). Quantitative PCR was used successfully to target functional genes and quantify eubacterial biomass (primers EUB 338f/EUB518r) and genes necessary for sulfate reduction (primers DSRP2060f/DSR4r), metal reduction (primers GEO494f/GEO825r), and methanogenesis (primers ME1/ME2).

Implications:
Heritage wells tapping serpentinizing groundwaters in the Coast Range Ophiolite in Northern California reveal high pH, high Ca^{2+} waters interacting with low temperature serpentinite. Predictions of the feasibility of selected microbial metabolic reactions are borne out

in functional gene probes from the environmental genome in this setting. Future work will clarify the diversity of carbon sources available to microbes, fine tune the gas geochemistry of the system, and allow for more comprehensive microbiological sampling and DNA sequencing.

References: [1] Shervais J.W. et al. (2004) International Geology Review, 46, 289-315. [2] Choi S.H. et al. (2008) Contributions to Mineralogy and Petrology, 156, 551-576. [3] Cardace D. and Hoehler T.M. (2008) Geochemical Characterization of Subsurface Microbial Habitat Produced by Serpentinization: Preliminary Results from Coast Range Ophiolite Formation Fluids. Fall 2008 Meeting of the American Geophysical Union (December 15-19, 2008), Abstract B53C-0511.