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Serpentinization rates in low-temperature, continental, ultramafic environments: Clues from H_2 and CH_4 outgassing rates in the Samail ophiolite, Oman

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Low-temperature (<50 °C), hyperalkaline (pH >11), and reduced (H_2- and CH_4-rich) fluids are products of subsurface reactions accompanying the serpentinization of ultramafic rocks. H_2 and CH_4 generated through serpentinization can fuel chemotrophic microbial communities and thus, have profound implications on the habitability of Earth's ultramafic aquifers as well as in Ocean Worlds where ultramafic minerals are believed to be present in contact with water. The rate at which these reduced volatiles are delivered to the surface as well as the rate of reactions that generate these volatiles at low temperature conditions are poorly known. In this work, we measured H_2 and CH_4 outgassing rates in seven hyperalkaline spring sites in the Samail ophiolite, Oman. Gas bubbling was observed in all but one site. H_2/CH_4 ratios of outgassing gas ranges from 0.3 to 30, consistent with published gas data from Oman. Outgassing rates per bubbling point source are also variable ranging from 0.1-4.2 and 0.1-45 µmol sec^{-1} for CH_4 and H_2, respectively. The highest outgassing rates are associated with warmer fluids and imply deeper sources that are less modified by shallow processes. These warmer spring sites often have 20-50 individual bubbling sources and thus, total outgassing rates for these sites would amount to 80-200 and 900-2,250 µmol sec^{-1} for CH_4 and H_2, respectively. Serpentinization rates that can account for these volatile fluxes were estimated using thermodynamic simulations of active subsurface water-ultramafic rock interactions. Using results of simulations, we estimate times to complete 1% serpentinization of a given volume of subsurface rock ranging from 10^4 to 10^6 years. The former is close to low-temperature rates extrapolated from high-temperature laboratory experiments. In contrast, the latter timescale can be decreased if contributions from volatiles released from fluid inclusions, which requires ~1,000-10,000 times larger rock volumes to account for similar volatile fluxes are considered. These findings show that low-temperature serpentinization on geologically short timescales can account for observed flux of reduced volatiles in continental hyperalkaline environments.