Hydroxyl contents of deep mantle minerals coexisting with CH4-rich fluids: Implications for the focusing of fluids in the upper mantle by redox processes

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The high solubility of hydroxyl in nominally anhydrous minerals such as olivine and wadsleyite at high pressures has been used to argue that they may be important hosts for H_2O in the mantle. However, volatiles in the Earths's interior are more accurately described in the system C-O-H where the activity of H_2O is a function of the oxygen fugacity. The oxygen fugacities in the lower regions of the upper mantle and in the transition zone and lower mantle are likely to be quite low and at least 4 log units below the FMQ oxygen buffer. Calculations show that at these conditions a C-O-H fluid will be CH_4-rich. The lower activity of H_2O in the fluid should lower the equilibrium OH^- content of coexisting nominally anhydrous minerals such as wadsleyite. Experiments have been performed to study the properties of such reduced fluid phases and examine if they influence the OH^- contents of nominally anhydrous mantle minerals at high pressure.

The experiments used a standard double capsule technique with an outer capsule containing a redox buffer (Mo-MoO_2 or Co-CoO) plus H_2O and an inner Pt capsule containing San Carlos olivine or garnet compositions in a graphite liner. Samples were equilibrated between 10 and 15 GPa in a 5000 tonne multianvil press. Results show that at plausible mantle oxygen fugacities minerals such as wadsleyite have H_2O contents over ten times lower than those reported at H_2O saturation. CH_4-rich fluids do not show evidence of having a significant dissolved silicate component. These reduced, low-density fluids should have a tendency to rise out of the deeper mantle and be oxidised to H_2O and CO_2 in the shallow upper mantle. This mechanism may tend to concentrate C-O-H volatiles in the upper mantle, leaving the deeper mantle dryer and with a higher viscosity.

Building Lost City: Serpentinization, mass transfer and life in a peridotite-hosted hydrothermal system

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The Lost City Hydrothermal Field (LCHF; Atlantis Massif, Mid-Atlantic Ridge, 30°N) is the product of reactions between seawater and ultramafic rocks that produce high alkaline (pH 10 to 11), 40 to 90°C fluids that form up to 60m tall carbonate-brucite towers. The fluids are enriched in H_2, CH_4 and other hydrocarbons, produced abiotically through Fischer-Tropsch type reactions, and support dense microbial communities that include anaerobic CH_4- and S-cycling thermophiles. We present an overview of multidisciplinary investigations of the LCHF and highlight the complex interplay between deformation, fluid flow, mass transfer and microbial activity that occur within this long-lived, peridotite-hosted hydrothermal system and the chemical and biological impacts of such off-axis systems on the global ridge system.

Textures and bulk rock chemistries of the harzburgitic serpentinites reflect formation and uplift of a heterogeneous lithosphere in a magma-starved spreading environment, with progressive serpentinization, talc-amphibole metasomatism and veining. Seawater-peridotite interaction at 150-250°C and high fluid-rock ratios (>100 and up to 10^6) produced enrichments in B, U and light REE, systematic changes in Sr- and Nd-isotope ratios towards seawater values, and highly depleted bulk rock O-, H-, and B-isotopic compositions in the basement. B-isotope analyses of the fluids and hydrothermal precipitates indicate that brucite is a significant, temporally variable, reservoir for Mg and B in these systems.

High fluid fluxes have important implications for S- and C-cycles: sulfur geochemistry indicates a loss of primary sulfide, an uptake of seawater sulfate, and local microbial remediated sulfate reduction and sulfide oxidation in the basement. Our studies show that the total carbon stored in the serpentinites is dominated by hydrocarbons and suggest that serpentinites may represent an important, as yet unidentified, reservoir for dissolved organic carbon from seawater. We conclude that high seawater fluxes and the interaction with both variably fresh peridotites and pervasively serpentinized peridotites is crucial to the formation of volatile-rich Lost City-type systems and that transform-related normal faulting and mass wasting in the south of the massif facilitates seawater penetration necessary to sustain hydrothermal activity over tens of thousands of years.