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Abyssal peridotite constraints on hydrothermal fluid circulation

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Alteration mineral assemblages in abyssal peridotites provide insights into hydrothermal fluid circulation in mid-ocean ridges and transform faults. We evaluate the long-term chemical changes produced in the oceanic lithosphere through petrographic and compositional analyses of peridotites from the Gakkel ridge and Tonga trench, and peridotite mylonites from oceanic transform faults.

To explore the extent of hydrothermal alteration in typical oceanic lithospheric mantle, we characterized peridotites petrographically on a scale from 1 (unaltered) to 5 (altered) based on the extent of serpentinization [1]. High extents of serpentinization do not affect mineral parameters such as olivine forsterite number or spinel ferric ratio. While serpentinization is a redox reaction that leaves behind an oxidized residue, the oxygen fugacity recorded by mantle minerals is unaffected by nearby serpentinization [1]. In addition, the presence of serpentine limits the temperature of peridotite-seawater interaction to <500 °C. However, our samples contain additional alteration minerals that imply hydrothermal fluid-rock interaction at higher temperatures – and thus greater depths – than serpentine stability.

Among Gakkel samples, we found that 20% of samples contain tremolite, talc, and chlorite [2]. Pseudosection modeling with Perple_X indicates that pyroxene reacts to form these minerals at temperatures >500 °C, assuming closed-system behavior [2]. In peridotite mylonites (rocks that underwent high-strain, ductile deformation), high-temperature, syn-deformational fluid flow is recorded by the formation of new minerals: chlorite and tremolitic amphibole at ~500–750 °C, and magnesio-hornblende amphibole at ~850–875 °C or higher [3]. The occurrence of similar amphibole compositions in fractures and ductile shear bands suggests that fluid-rock interaction modifies fault rheology, leading to weakening and strain localization [3].

Our observations indicate that hydrothermal circulation occurs deep into the lithosphere at ridges and transform faults. Comparison to thermal models implies that seawater circulates below 20 km depth at ultraslow spreading rates. The formation of amphibole, chlorite, and talc, in addition to serpentine, suggests that the lithosphere is a larger reservoir for volatiles than estimates based on serpentine alone.

[1] Birner et al. (2016), *Geology* 44, 535-538; [2] Patterson et al. (2021), *Lithos* 392-393, 106107; [3] Prigent et al. (2020), *EPSL* 532, 115988.