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Evidence for deep seawater percolation and mantle hydration on oceanic transform faults

Prigent Cécile (1), Warren Jessica (1), Kohli Arjun (2), Wolfson-Schwehr Monica (3), and Teyssier Christian (4)
(1) University of Delaware, Geological Sciences, United States, (2) SLAC National Accelerator Laboratory, (3) Univeristy of Minnesota, Department of Geology and Geophysics, (4) Monterey Bay Aquarium Research Institute

To investigate the depth of hydrothermal fluid percolation, processes of fluid-mantle interaction, and their rheological consequences for oceanic transform fault (OTF) seismicity, we analyzed deformed mantle rocks dredged from the Shaka and Prince Edward OTFs, which offset segments of the Southwest Indian Ridge. We performed an integrated study on 16 samples (peridotite mylonites and deformed serpentinites) that encompass the range of mineralogy and deformation features observed in the dredges.
Based on mineral assemblages present in fractures and shear bands, combined with thermobarometric calculations, we identified three domains of deformation corresponding to different temperature conditions. The first domain is characterized by the presence of serpentine (± talc ± amphibole ± chlorite ± oxides) and reflects low temperature (LT) deformation at < 500-550°C. The second domain is marked by crystallization of chlorite and tremolitic amphibole at medium temperature (MT) conditions of ∼500-750°C. The high temperature (HT) domain is defined by crystallization of Mg-hornblende to pargasitic amphibole, indicating deformation at >750°C. Crystallization of chlorine-rich hydrous phases in each domain suggests circulation of seawater and reaction with peridotite - assisted deformation. In each domain, samples record evidence of deformation by both brittle and ductile mechanisms, with increasing fracturing and fluid-peridotite interaction leading to the progressive formation of LT, MT and HT mylonites. In those mylonites, plate motion was respectively accommodated by ductile flow of serpentine, amphibole (MT) and an amphibole-rich fine-grained peridotite aggregate. In HT mylonites, empirical thermometers suggest that brittle fracturing and amphibole crystallization occurred down to 1000°C indicating hydrothermal fluid percolation beyond the traditional ∼600°C limit of peridotite brittle failure.
To convert temperature constraints to depth, we modeled the fault zone thermal structure using a 3D finite element simulation. Results indicate that mantle serpentinisation occurred down to ∼11-13 km depths (to 550°C) and deep hydrothermal fluid percolation down to ∼25-30 km depths (to 1000°C).
The evolution in fault zone structure induced by deep fluid-rock interaction and progressive formation of LT, MT and HT mylonites on OTFs provides a mechanism which accounts for weakening and strain localization processes within the mantle.