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Alteration and deformation of amphibole and calcite from an oceanic detachment fault: Implications for rheological weakening and strain localization during mantle exhumation

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Hydrothermal fluid circulation along oceanic detachment faults (ODFs) leads to alteration and rheological weakening that enables strain localization and facilitates mantle exhumation. These metasomatic reactions depend on the interplay between fluid pathways, modulated by tectonic processes, as well as depth, temperature, and lithologic heterogeneity. Hence, the direct sampling of in-situ mantle sections is necessary to decipher the spatial extent and feedbacks between these processes. We analyze samples from IODP Expedition 402 Site U1614C, which recovered a heterogeneous exhumed mantle section from an ODF at a young Continent-Ocean Transition in the Tyrrhenian backarc basin. To investigate the feedback between fluid flux, alteration, and deformation we conducted a microstructural and petrographic investigation coupled with EPMA and EBSD data on amphibole and calcite in altered protomylonitic and mylonitic peridotite samples.

The protomylonitic peridotite contains amphibole and serpentine with minor calcite in the matrix along with amphibole and serpentine veins. Primary pyroxene is replaced by amphibole, and olivine has been entirely calcified or serpentinized. Amphibole grains show static growth along the foliation planes and exhibit a core to rim transition from pargasite to tremolite, suggesting a polyphase metasomatic reaction sequence initiating at high temperatures followed by lower temperature hydrothermal alteration (400-500°C). The mylonitic peridotite contains amphibole, serpentine, secondary diopside, and minor calcite in the matrix, along with calcite and serpentine veins. Olivine is replaced by calcite and serpentine, whereas pyroxene is replaced by amphibole suggesting extensive metasomatism. Amphibole grains preserve minor pargasite cores but are largely altered to tremolite and show evidence of intracrystalline deformation with strong shape and crystal preferred orientations. The transition from pargasite to tremolite with evidence of dynamic crystallization might suggest syn-kinematic and fluid-mediated deformation. Mixed brittle-viscous deformation is also evident in calcite veins, which show evidence of intracrystalline deformation with twinning, bulging, and subgrains.

Preliminary data suggest that the extensive cross-cutting vein networks of calcite, serpentine, and amphibole represent multiple stages of deformation and alteration throughout exhumation. Static amphibole growth in the protomylonite, along with intracrystalline deformation in the mylonite suggest that mylonitic fabrics may further localize hydrothermal alteration and fluid-driven deformation processes during the lifetime of the detachment.