



## Mineralogical and chemical records of melt-rock and fluid-rock interaction in abyssal peridotites from the Mid-Atlantic Ridge (ODP Leg 209)

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At slow- and ultraslow-spreading mid-ocean ridges, abyssal peridotites are commonly exposed at the seafloor. They are chemically influenced by interaction with both gabbroic/plagiogranitic melts and seawater-derived fluids. Shear zones crosscutting the peridotites are marked by talc- and/or chlorite-bearing lithologies, which are often referred to as "fault schists". For some cases it has been proposed that these rock types form due to hydrous alteration of an ultramafic protolith at high fluid-to-rock ratios. In contrast, other studies suggest a lithological inhomogeneity to be the source of fault schist formation, e. g. at gabbroic melt impregnation veins. As enhanced fluid flow seems to be a characteristic of fault schist zones, unraveling the primary cause of fault schist formation is of importance for building up a comprehensive picture of the lithological and hydrological processes within the oceanic lithosphere.

We examined drillcore samples of strongly serpentinized harzburgites from the Mid-Atlantic Ridge (ODP Leg 209, Site 1270), which show evidence for both melt-rock and fluid-rock interaction. The sample location is south of the prominent 15°20'N Fracture Zone, close to the active ultramafic-hosted Logatchev black smoker field. Here, abyssal peridotite is exposed along low-angle detachment faults. At Site 1270 of Leg 209, four holes were drilled near the top of an exposed long-lived normal fault. The strongly serpentinized peridotites contain abundant gabbroic intrusions and intensely deformed shear zones. The latter are generally associated with chlorite and amphibole (magnesiohornblende and retrograde actinolite/tremolite) assemblages, with zircon and apatite as accessory mineral phases. From its distinct mineralogy, trace element chemistry and textural occurrence, the chlorite-amphibole-bearing veins are interpreted as strongly altered melt impregnations. The host serpentinites consist mainly of serpentine minerals in mesh (after olivine) and bastite textures (after orthopyroxene). Relics of olivine, orthopyroxene and spinel occur only in minor amounts. Apparently, brucite is not present as a secondary mineral phase after olivine, demonstrated by means of XRD, optical and electron microscopy.

Titanium-in-zircon thermometry for the chlorite-amphibole veins indicates temperatures of ca. 820 °C for crystallization of the precursor melt, which are therefore interpreted as former plagiogranitic melt impregnations. This interpretation is consistent with results from reaction path modeling, which indicate that a mechanical mixture of host peridotite and plagiogranite is the likely protolith for the vein mineralogy, with the adjacent serpentine being part of the equilibrium mineral assemblage. Reaction path models also indicate that the elevated aSiO<sub>2</sub> in serpentinites adjacent to plagiogranite veins inhibits brucite formation.

Geochemical analyses and mass balance calculations of serpentinites directly adjacent to evolved melt impregnations reveal an enrichment in rare earth elements, potassium and strontium compared to an unaltered harzburgite. In contrast, cobalt and nickel apparently were lost. These chemical changes can be explained by a combination of mechanical mixing of an ultramafic protolith with an evolved melt impregnation and an enhanced fluid flow in the shear zone. The latter is evidenced by extremely low  $\delta^{18}\text{O}$  of altered plagiogranite veins (+3.0–4.2 per mil SMOW) and adjacent serpentinites (+2.6–3.7 per mil SMOW), which indicate that the examined detachment fault represents a major pathway for seawater-derived fluids. The uniform oxygen isotope data indicate that fluid flow in the detachment fault system affected veins and directly adjacent host serpentinites likewise. This is confirmed by reports of higher  $\delta^{18}\text{O}$  values in serpentinites more distal to melt impregnation veins.

The co-occurrence of former plagiogranite melt impregnations and shear zones crosscutting the peridotites suggests

that seawater-related fluids hydrate the oceanic crust along detachment faults. At greater depths, where temperatures are high, fluids may lower the solidus of gabbros, leading to hydrous partial melting. This effect might be promoted by the still increased temperatures of recent gabbroic intrusions. The crystallized evolved melts break down during cooling to form a chlorite-bearing assemblage at temperatures where olivine of the surrounding harzburgite is still stable ( $T \approx 400\text{--}500\text{ }^{\circ}\text{C}$ ). Strain localization in the shear zone may thus be restricted to chlorite-rich rock portions, which therefore represent major fluid pathways that can facilitate serpentinization of the surrounding peridotites during further cooling.