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Hydrofracturing in the cold top-slab mantle wedge: insights from field and microstructural observations

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Before attaining the mantle wedge, where they trigger partial melting, volatiles released from dehydration reactions in the slab have to migrate across a relatively cold (<750ºC), peridotite-layer above the incoming slab. To unravel the mechanisms allowing for this initial stage of fluid transport, we performed a detailed field and microstructural study of prograde peridotites in the Cerro del Almirez ultramafic massif (Betic Cordillera, Spain), where one of the most important dehydration reactions in subduction zones, the high-pressure antigorite breakdown (P=1.6-1.9 GPa and $T\approx$680ºC), can be mapped in the field [1,2]. This reaction led to arborescent growth of centimeter-size olivine and orthopyroxene, producing a chlorite-harzburgite with a spinifex-like texture. Microstructural observations and crystal preferred orientations (CPO) mapping show no evidences of solid-state deformation during the prograde growth of olivine and orthopyroxene at the expenses of antigorite. However, a few tens to a hundred meters away from the reaction front, the metamorphic texture is partially obliterated by grain-size reduction zones (GSRZ), a few mm to meters wide, which form roughly planar conjugate structures. GSRZ are characterized by (1) sharp contacts with undeformed spinifex-like texture domains, (2) an important reduction of the olivine grain size (60-250 μm), (3) olivine color change (from brownish to colorless), (4) decrease in the modal amount of orthopyroxene, and (5) at the mm- to cm-scale, irregular shapes and abrupt terminations. Field and microstructural observations rule out relative displacement across these GSRZ. Changes in modal composition imply reactions with fluids undersaturated in silica. Analysis of olivine crystal-preferred orientations (CPO) in GSRZ shows similar patterns, but a higher dispersion than in neighboring spinifex-like domains. It also reveals mm- to cm-scale discrete domains with rather homogeneous crystallographic orientations suggesting inheritance from the preexisting spinifex-like olivines in the host peridotite. Misorientation angles between neighboring grains in the GSRZ show peaks at $\sim$5-10º and $\sim$20º, but the rotations are not crystallographically controlled. Based on these observations we propose that hydrofracturing is the main mechanism accounting for grain size reduction in the Cerro del Almirez chlorite-harzburgites. The flux of an overpressure fluid through the GSRZ is also supported by substantial reduction of the orthopyroxene modal content compared with the spinifex textured domains. Development of the GSRZ network was probably linked to the fluid release during the antigorite dehydration. Microcraking may allow for the formation of high permeability channelways for overpressured fluids in an otherwise almost impermeable and cold (680-710ºC) peridotite. We suggest that this high-pressure hydrofracturing may be an essential mechanism in the first stages of fluid flow through the coldest parts of top-slab mantle in subduction zones, before the fluids attain the hotter parts of the mantle wedge where their migration may be assisted by viscoplastic deformation processes. The near-lithostatic pressures associated with this process will produce transient low seismic velocities, high Poisson ratios, and high attenuation zones, similar to those associated with episodic tremor and slip attenuation zones.

[1] Trommsdorff, López Sánchez-Vizcaíno, Gómez-Pugnaire & Müntener (1998), *Contrib Mineral Petr* **132** 139-148.

[2] Padrón-Navarta, Hermann, Garrido, López Sánchez-Vizcaíno, Gómez-Pugnaire (2010), *Contrib Mineral Petr* **159**, 25-42.