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Relationship Between Far Field Stresses, Fluid Flow and High-Pressure Deserpentinization in Subducting Slabs: a Case Study From the Almirez Ultramafic Massif

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Serpentinite dehydration during prograde metamorphism plays a crucial role in subduction dynamics. Observations from exhumed paleo-subduction metamorphic terranes suggest that the discharge of deserpentinization fluids from the subducting slab takes place along different pathways and mechanisms [e.g. 1–3]. Analysis of intermediate-depth focal solutions in active subduction zones indicates that slabs are subjected to different principal stress fields characterized primarily by downdip compression and downdip tension [4]. Although it is well known that far field stresses play a crucial role on fluid flow channeling, their potential impact on the kinetics of serpentinite dehydration and subsequent fluid escape in subducting slabs is still poorly understood.
Here, we present a detailed structural and microstructural study to investigate the relationships between far field stresses, fluid flow and high-pressure deserpentinization in the Almirez ultramafic massif (Betic Cordillera, SE Spain) [1, 2]. This massif preserves the high-pressure breakdown of antigorite (Atg-) serpentinite to prograde chlorite (Chl-) harzburgite, which are separated by a sharp isograd [2, 5]. The Chl-harzburgite reaction products show either a granofels or spinifex-like texture indicating crystallization under different overstepping of the Atg-out reaction. The two different textural types of Chl-harzburgite occur below the Atg-out isograd as alternating, meter-wide lenses with either a granofels or spinifex texture. From field measurements, we infer that during antigorite dehydration the minimum compressive stress was subnormal to the dehydration front and the paleo-slab surface. This stress field is consistent with subduction zones with slabs under downdip compression at intermediate depths [4]. The detailed microstructural study —combining μ-CT and EBSD-SEM [6]— of Chl-harzburgite across a c. 15 m wide lens reveals that the SPO and CPO of olivines with contrasting textures are strongly correlated with the inferred paleo-stress. The SPO of opaque phases and that of granofelsic olivine are aligned and have a single maximum in each sample. Across the studied lens these maxima are distributed along a plane that corresponds to the average orientation of Atg-serpentinite foliation in a nearby outcrop, and they show a strong maximum close to the intermediate compressive stress axis. Spinifex olivines form tablet-like crystals that are elongated parallel to [001]-axes in a plane perpendicular to their [100]-axes. These growth planes are oriented at high angle to the least compressional stress axis, and the olivine growth directions (i.e. [001]-axes) are dominantly oriented at the acute angle between the maximum and intermediate compressive stress axes. These results indicate that formation of spinifex crystals is preferred at enhanced reaction rates and it occurred along hydrofractures that opened as controlled by the stress field. Our data show that overpressured fluids escaped along the slab surface towards the maximum compression direction. We therefore propose that at periods of high fluid flux due to hydrofracturing in a dehydrating slab, the development of fluid network channels strongly depends on the principal stress field.

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