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Feedback of fluids on ductile strain localization in the upper mantle

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Here we report microstructural evidence for fluid-assisted ductile strain localization in mylonitic to ultramylonitic peridotite and pyroxenite shear zones that have been formed during exhumation of the subcontinental lithospheric mantle (Ronda Peridotite massif, Betic Cordillera, S-Spain). Geothermobarometry and thermodynamic modeling indicate that strain localization took place at low pressure (<0.8 GPa) and moderate temperature (700-1000°C). Pyroxenite shear zones occur as thin (below 10 cm) and discontinuous bands, whereas the width of peridotite shear zones varies along their length from dozens of meters to a few cm. In either cases strain localization is associated with a marked decrease of grain size of both olivine and pyroxenes, but in the pyroxenite shear zones with increasing volume fractions of plagioclase and amphibole too, as a result of a spinel to plagioclase phase transformation reaction during decompression. This reaction fostered hydrogen extraction ('dehydroxylation') from clinopyroxene producing effective fluid saturation that catalyzed the synkinematic net-transfer reaction. As a result, fine-grained, wet olivine and plagioclase were produced, allowing the onset of grain-size sensitive creep and further strain localization in these pyroxenite bands, however it has led to a weak Crystal Preferred Orientation (CPO) and a nearly random fabric of the shear zone. Strain localization in peridotite shear zones is associated with redistribution of orthopyroxene in the finest grained microstructural domains (ultramylonites), where it forms trails of fine grains with interstitial shapes, perfectly intermixed with fine-grained olivine and, in many cases, still preserving a spatial relation to the coarse-grained porphyroclasts inherited from the protolith. In the mylonitic domains of the peridotite shear zones, olivine shows a CPO coherent with dominant (001)[100] glide, probably due to the presence of interstitial fluids during deformation. In the ultramylonites, however, olivine CPO is weak to very weak, consistently with a decreasing contribution of dislocation creep to deformation. Nevertheless, fine-grained orthopyroxene in both mylonites and ultramylonites display a clear CPO characterized by a [001] maximum normal to the foliation, which is not consistent with dislocation glide in any known slip system for orthopyroxene. Microstructural observations in the ultramylonites are coherent with alternating dissolution and precipitation of olivine and orthopyroxene, which may be explained by changes in Si molality of the percolating fluid (disequilibrium at scales > mm). We therefore suggest that focusing of aqueous fluids in the peridotite shear zone favored the activation of dissolution-precipitation creep and we interpret orthopyroxene CPO as formed by oriented crystallization during this process. We propose that this deformation mechanism may be important in intermediate temperature domains (delimited by the stability of hydrous phases and the wet melting reactions) of subduction zones, where it may lead to feedbacks between strain localization and fluid transport.