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Phase transformation induced strain localization in mantle pyroxenite from the Ronda Peridotite Massif (Betic Cordillera, Southern Spain)

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The deformation of rocks in response to forces in Earth's interior is governed by rock rheology, which varies as a function of a number of constitutive and environmental aspects including mineralogy, fluid content and chemistry, melt fraction, temperature, pressure, differential stress conditions and mineral grain size. Extensive studies of mantle xenoliths, peridotite massifs and ophiolites indicate that deformation of the shallow lithospheric mantle is dominantly acquired by dislocation creep but the occurrence of mylonitic-ultramylonitic shear zones, especially in large exposures of ophiolites and peridotite massifs, suggests that strain localization may also play an important role during the thinning of the lithospheric mantle. It has been suggested that strain localization in peridotites occurs due to either grain-size sensitive creep of dynamically recrystallized fine-grained olivines or to melt/rock or solid state reactions accompanying the deformation. Synkinematic net-transfer metamorphic reactions can result in fine-grained reaction products promoting positive feed-back between deformation and reaction, thus reaction-enhanced softening is a well recognized mechanism fostering strain localization. It has been also shown that strain can be localized into fine-grained aggregate of plagioclase, olivine and chromian spinel formed by the phase transformation reaction from spinel lherzolite to plagioclase lherzolite. This phase transformation is primarily controlled by the P-T conditions and the bulk chemistry, where plagioclase is stable at higher pressure in a fertile, than in a refractory peridotite. Although it is expected that in clinopyroxenite this phase transformation occurs at higher pressure than in a peridotitic lithology, the role of phase transformation in localizing strain in pyroxenites has not been proved yet.

Here we report the study of strain localization in mantle pyroxenite during the spinel to plagioclase (sp-pl) websterite transition in the Ronda peridotite (S Spain) that occurs at the transition between coarse-grained peridotite to plagioclase-lherzolite tectonic domains of this massif. Mapping shows that shear zones are systematically associated with thinned pyroxenites in this area. We have studied a unique outcrop of sp-pl websterite where a cm-sized fine-grained ultramylonitic shear zone occurs within coarse-granular pyroxenite defined by an abrupt decrease of grain size (down to 10-50 μm) in the pyroxenite layer. It is also correlated with the modal increase of metamorphic plagioclase around spinel in the coarse granular pyroxenite with decreasing distance to the shear zone, as well as in the fine-grained mylonitic shear zone itself. We propose that weakening at the sp-pl transition in pyroxenite may cause early nucleation of shear zones that can propagate deformation into mantle lithospheric scale anastomosing shear zones in further thinning and decompression.