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Deformation in a shallow partially-molten mantle: constraints from natural systems

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This study analyses the effect percolating melts may have on the upper mantle deformation. I performed detailed (mm-m sampling) microstructural studies of two mantle sections in different geodynamic settings. The first part of the study concerns the uppermost mantle section of the Oman Ophiolite - an ‘end member’ situation where partially-molten peridotites, upwelling beneath a fast spreading ridge, are forced sideways as they attain the base of the lithosphere, as their positive buoyancy exceeds the spreading rate. The features that characterize this 100m section of the Moho Transition Zone (MTZ) include notably the compositional layering on the cm-m scale parallel to the deformation fabric, the strong crystal preferred orientation of all mineral phases, and the change in the olivine crystal preferred orientation pattern, from axial-[100] in the layers with <70% modal olivine to axial-[010] in the more gabbroic layers (<50% olivine). This study analyses the effect percolating melts may have on the upper mantle deformation. I performed detailed (mm-m sampling) microstructural studies of two mantle sections in different geodynamic settings. The first part of the study concerns the uppermost mantle section of the Oman Ophiolite - an ‘end member’ situation where partially-molten peridotites, upwelling beneath a fast spreading ridge, are forced sideways as they attain the base of the lithosphere, as their positive buoyancy exceeds the spreading rate. The features that characterize this 100m section of the Moho Transition zone (MTZ) include notably the compositional layering on the cm-m scale parallel to the deformation fabric, the strong crystal preferred orientation of all mineral phases, and the change in the olivine crystal preferred orientation pattern (CPO), from axial-[100] in the layers with <70% modal olivine to axial-[010] in the more gabbroic layers (<50% olivine). This change from axial-[100] to axial-[010] occuring over quite a narrow compositional range and can be observed on a mm scale (between two layers) providing strong evidence for occurring due to deformation of a partially molten mantle. The second part of our study focuses on the deformation of plagioclase-rich lherzolites from the Lanzo peridotite massif (Alps), which have been previously interpreted as recording an evolution from a thinned continental plate to incipient oceanization. These lherzolites also display a compositional layering, though more diffuse than observed in the Oman MTZ, with the plagioclase-rich layers usually forming an anastomozed network. The olivine CPO is orthorhombic, but [010] maximum concentrations are always slightly stronger than [100] ones. As in Oman, all major phases (except the clinopyroxene) in Lanzo peridotites are well oriented, independent of the layer composition. This implies that both sections record percolation of relatively low instantaneous melt fractions (the solid matrix disruption threshold was not attained), despite the evidence for high cumulative melt fractions, especially in Oman. Finally, the compositional changes, and the orientation of the melt-rich bands are parallel to the foliation, implying their orientation is controlled by the deformation. The new CPO results from Oman and Lanzo contrasts with observations in massifs like Lherz and Ronda, where evidence of deformation the in presence of melt is associated with CPO dispersion. In conclusion, the present data show that in a deforming partially molten mantle melts tends to concentrate in bands aligned parallel to the shear plane. Shear-controlled compositional layering potentially creates a mechanical anisotropy, with a directional reduction of the shear viscosity parallel to the bands. Olivine CPO formed during deformation in presence of melt also differ from those formed in dry conditions and, by consequence, the relationship between deformation and seismic anisotropy is also changed.