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# Relationships between olivine LPO and deformation parameters in naturally deformed rocks and implications for mantle seismic anisotropy

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Laboratory experiments suggest that water contents and stress magnitudes primarily control olivine lattice preferred orientation (LPO) and associated upper mantle seismic anisotropy. Several natural and experimental datasets, however, suggest that olivine LPO may also be sensitive to pressure, temperature, deformation mechanism, strain geometry, strain magnitude, and/or strain history, and it is unclear to what extent simple water-stress relationships can be extrapolated to nature. We use 65 peridotites deformed by dislocation creep under temperatures ranging from 600-1250°C, and sourced from a wide range of global tectonic settings (62 xenoliths, 2 ophiolitic massifs, 10 continental massifs), to investigate correlations between physical deformation parameters and olivine LPO in natural rocks. Olivine, orthopyroxene, and clinopyroxene water contents were measured using Secondary Ion Mass Spectrometry, and ranged from <1-157 (n = 39), 11-322 (n = 29), and 53-1733 (n = 29) ppm wt%, respectively. Grain transects and comparisons of measured water with published partition coefficients suggest pyroxenes are in equilibrium while olivine likely lost hydrogen during ascent/exhumation; we therefore use pyroxene to approximate olivine $H_2O$. The equilibrium pyroxene contents, and the lack of microstructural annealing or evidence for post-deformation metasomatism, lead us to assume that water in pyroxene reflects the water present during deformation. Stress magnitudes measured using paleopiezometry ranged from 11 to 87 MPa. LPOs measured using electron backscatter diffraction exhibit the full range of fabric types: 35% preserved A-type LPO, 10% B-type, 6% C-type, 8% D-type, 27% E-type, and 15% AG-type. These new data, along with an extensive compilation of published measurements (445 samples from 48 studies), suggest the following:
1. Naturally deformed peridotites rarely follow the experimentally derived relationships of water, stress, and LPO, with two exceptions: a) A-type samples always exhibit less than 26 ppm wt% (420 ppm H/10ˆ6Si) water content; and b) the only samples with calculated olivine water contents greater than 90 ppm wt% (1500 ppm H/10ˆ6Si) were C-type samples.
2. We find a moderate correlation between olivine LPO and spinel shape constrained using CT-scanning, suggesting an influence of strain geometry.
3. No other systematic trends were observed for LPO types as a function of water, stress, temperature, pressure (i.e. spinel vs. garnet), modal percent, microstructure, olivine aspect ratios, fabric strength, or tectonic setting.
4. 30% of localities preserve three or more different LPO types deformed at the same general conditions, and 20% of localities preserve LPO types in which the olivine seismically fast axes (a-axes) are oriented up to 90 degrees to each other.
Collectively, these observations suggest that at the moderate to low stresses preserved in these naturally deformed peridotites (<100 MPa), the strengths of individual olivine slip systems are not as sensitive to changes in external variables as observed in experiments. Instead, the data suggest that olivine LPO in the lithosphere may be more sensitive to strain memory (absent in most experiments) and/or strain magnitude or geometry. These data are consistent with the relative complexity of shear wave splitting measurements observed beneath continental regions where strain memory and strain perturbations are expected to be common.