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Olivine LPO in Abyssal Peridotites: Does the Presence of Melt During Deformation Determine the Seismic Anisotropy of the Oceanic Lithosphere?

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Seismic anisotropy in the oceanic lithosphere is determined largely by deformation-controlled lattice-preferred orientation (LPO) in olivine and can thus be used to assess deformation conditions in the upper mantle during lithospheric accretion. Here we present an electron backscatter diffraction (EBSD) study of LPO in abyssal peridotites from four mid-ocean ridges representing the global range of spreading rates. The peridotites preserve three distinct olivine LPOs. The common Type-A LPO, recording olivine slip in the (010)[100] system, was observed in samples from the Mid-Atlantic Ridge (15˚39'N, full spreading rate ∼2.6 cm/yr) and the Atlantis II Fracture Zone on the Southwest Indian Ridge (57˚E, full spreading rate ∼1.4 cm/year). This LPO is interpreted to form during "normal" mantle upwelling and deformation. The Type-E LPO, recording slip in the (001)[100] system, was observed at Hess Deep on the East Pacific Rise (2˚N, full spreading rate ∼12.3 cm/year) and most likely developed during deformation in the presence of abundant interstitial melt. The third type of LPO, an [010]-fiber pattern termed here Type-F, preserves slip on the olivine (010) plane with girdles of (100) and (001) in the plane of the foliation. This LPO was recorded at the Gakkel Ridge (84˚38'N, 4˚13'E, full spreading rate ∼1.2 cm/year) and may result from mantle deformation in the presence of melt that has not been effectively segregated into channels. We suggest that different olivine LPOs are caused by variations in the amount of melt present in the mantle during lithospheric accretion, a parameter controlled in part by spreading rate. These differing LPOs will result in markedly different azimuthal P-wave anisotropy in the upper mantle assuming an approximately horizontal foliation within the oceanic lithosphere. With Type-E LPOs, the plane containing the maximum and minimum seismic velocities, and hence the maximum anisotropy of the rock, lies parallel to foliation, and can thus be observed with measurements of azimuthal P-wave anisotropy; our samples record absolute and azimuthal P-wave anisotropies of ∼10%. For Type-A LPOs, the seismic fast direction remains parallel to lineation but the seismic slow direction is perpendicular to the foliation plane, and azimuthal P-wave anisotropy will be reduced relative to the absolute anisotropy of the rock. In these samples absolute P-wave anisotropy ranges from 5.8–8.6%, while azimuthal P-wave anisotropy is 3.2–6.4%. For Type-F LPOs, azimuthal anisotropy will be even further reduced because, while the seismic slow direction is oriented perpendicular to the foliation plane, the seismic fast direction is girdled within the plane of the foliation. Our sample preserves absolute P-wave anisotropy of 6.8% and azimuthal P-wave anisotropy of only 2.4%. These results suggest that the oceanic lithosphere may preserve peridotites with a variety of LPO patterns, and that azimuthal seismic anisotropy may be strongly affected by the amount of melt present during the latest stages of deformation in the oceanic mantle.