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Relationship among petrofabric, magnetic anisotropy and seismic anisotropy in dunite

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Physical anisotropies in rocks arise from the preferred alignment of the rock's constituents, which include mineral grains, organic matter or pore space. Different physical properties will be affected to a greater or lesser extent by these various factors. The anisotropy of magnetic susceptibility (AMS) is dependent on mineral orientation, particularly of minerals with high susceptibility and strong intrinsic anisotropy. Seismic anisotropy will also be controlled predominantly by mineral texture for rocks deformed at high pressure, where pore space or cracks are closed. During high-temperature ductile flow of the upper mantle, peridotite will develop a permanent deformation texture, which will be responsible for its physical anisotropies. Olivine develops characteristic crystal-preferred orientations (CPO) under different thermal-mechanical conditions. In this study we examine the relationship among mineral texture, magnetic anisotropy and seismic anisotropy of dunites from the Western Gneiss Region, Norway. Because dunite consists of > 90% olivine, the intrinsic magnetic anisotropy of single crystals of olivine is also investigated. AMS was measured with a high-field torsion magnetometer at room temperature and 77 K, in order to separate the paramagnetic sub-fabric from the total anisotropy. Our results indicate that olivine has a prolate anisotropy, in which the minimum, intermediate, and maximum axes of susceptibility correspond to the [010], [100] and [001] axes of olivine, respectively; this is partially contrary to an earlier investigation by Belley et al. (2009, EPSL, 284, 516-526). The degree of anisotropy increases by a factor of 7.1 – 8.2 at 77 K, and the shape becomes more triaxial. The CPO of olivine was measured using electron backscatter diffraction technique or X-ray texture goniometry. Although olivine grains in the samples develop two fabric types, namely [100](010) or [001](010), there is the same very good agreement between the orientation of the principal axes of the AMS ellipsoid and the texture ellipsoid of olivine. The minimum axes of the AMS ellipsoid are coaxial with the [010] axes in all samples, and maximum axes are coaxial with [001] in all but two samples; for these the intermediate axes are along the [100] direction of olivine. In addition, the degree of AMS increases with increasing texture strength. Seismic velocities and anisotropy are determined from the orientation distribution function and elastic constants of olivine, using the method described by Mainprice (1990, Comput. Geosci., 16, 385-393). A significant linear correlation is found between the degree of P- and S-wave anisotropies and AMS degree. Our results indicate that AMS can be used to infer the petrofabric and seismic anisotropy of olivine-rich rocks.