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Understanding the source of magnetic and seismic anisotropy in peridotites

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Peridotite, a rock consisting of more than 90% olivine, orthopyroxene and clinopyroxene, is the dominant component in the Earth's upper mantle. Olivine, which is more abundant than pyroxene in general, and rheologically weaker, controls the deformation behavior and seismic anisotropy of the Earth's upper mantle. The majority of naturally deformed peridotites develop a [100](010) olivine fabric, and this fabric is the major contributor to physical anisotropies in these rocks. Seismic anisotropy is often determined from the crystallographic-preferred orientation (CPO) of olivine and its intrinsic anisotropy in elastic properties. The relationship of the anisotropy of magnetic susceptibility (AMS), determined in low field (LF), to deformation fabrics in peridotites is more coplicated. This is due to the presence of ferromagnetic minerals that may form late in the deformation history. The isolated paramagnetic fabric, however, is controlled by the texture of the paramagnetic minerals, olivine and pyroxene. We have studied the texture, as determined by EBSD or X-ray texture goniometry, and relate this to magnetic and seismic anisotropy in a series of peridotites from Norway and northern Italy. Our peridotite samples show different olivine fabrics, e.g., weakly deformed and strongly sheared peridotites develop [100](010) and [001](010) fabrics, respectively. The LF-AMS, which is controlled by ferromagnetic minerals, is often not significant. The paramagnetic anisotropy, which is isolated using high-field torque magnetometry, shows a well–defined magnetic fabric. Often the paramagnetic anisotropy agrees with the olivine texture. When more than one mineral phase contributes to the AMS, interpretation becomes more complicated, because of the different orientation of the AMS principal axes of the intrinsic minerals with respect to their crystallographic axes. The AMS of olivine has the maximum susceptibility (k1) parallel to the c-crystallographic axis, whereas the orientation of the intermediate (k2) and minimum (k3) axes is dependent on the mineral composition; i.e. k3 is along the a-axis and k2 along the b-axis for 3 to 5 wt% FeO, but with higher iron oxide content, 7 to 9 wt%, k3 is along the b-axis. For clinopyroxene, k2 lies close to the b-crystallographic axis, independent of composition, and the k1 and k3 axes lie slightly off the a-c-plane. The orientation of the principal axes of the AMS in orthopyroxene is strongly dependent on composition; e.g., enstatite has a triaxial anisotropy with k1 along the crystallographic c-axis, k2 along the a-axis and k3 along the b-axis. Therefore contributions from different phases may weaken the net magnetic fabric. We compare magnetic anisotropy that is calculated from the CPO of the major mineral constituents in the peridotites with the measured anisotropy to gain a better understanding of the factors that control magnetic anisotropy. Further, we use the CPO of the samples together with the elastic properties of constituent minerals in a rock to calculate the seismic anisotropy. It is also possible to show under what conditions the magnetic anisotropy can be related to seismic anisotropy. Results from this work will help improve our understanding about in situ deformation mechanisms and physical fabrics of the upper mantle.