



Contributions of microstructure and crystallographic preferred orientation to seismic anisotropy in the lower continental crust

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Various seismic data indicate that lower continental crust is highly anisotropic, although the origin of this anisotropy is debated. This debate presents an exciting area of research, but also limits our understanding of the dynamics of lower crust. It is, however, generally agreed upon that the state of the lower crust directly influences the behavior and dynamics of the entire continental lithosphere. The anisotropy is often attributed to a mineralogical source, such as significant amounts of mica (i.e. biotite) and amphibole that develop strong crystallographic preferred orientation (CPO) during ductile deformation. However, there are several other factors that exert control on seismic anisotropy. Seismic anisotropy is governed by intrinsic and extrinsic factors related to composition and structure of rocks. The intrinsic factors that contribute to anisotropy concerns the minerals and microfabric of the rock, and includes information on for example crystallographic preferred orientation (CPO) and shape preferred orientation (SPO). The extrinsic factors considered here include micro-cracks, fractures and layering. Although the wavelength of a seismic wave is orders of magnitude larger than the intrinsic scale of minerals and microstructures, the interpretation of seismic data is critically dependent on our understanding and quantification of these microscopic constituents. The contribution of texture and microstructure must be considered when evaluating seismic anisotropy in rocks. In addition to laboratory measurements on rock samples, the current prediction of seismic anisotropy is, nevertheless, based mainly on calculations that consider mineral composition and their respective CPO. CPO is recognized as a primary source for seismic anisotropy in parts of the crust where ductile deformation dominates. In addition, the relatively large variety in mineral composition in middle and lower continental crust, introduces a potential uncertainty on the source of seismic anisotropy. This uncertainty is accentuated by the general lack of mineral elastic data for crustal minerals at middle and lower crustal pressure and temperature conditions.

Recent developments in modeling efforts and analytical techniques allow us to consider additional microstructural parameters, including grain shape, grain-scale layering or banding and elastic interaction between grains and/or minerals. These parameters have generally been neglected or under-emphasized, but they can be of considerable importance. Compositional banding, as an example, may be important in lower crustal settings. Two contrasting scenarios are presented to exemplify the potential role of compositional banding: 1) garnet-pyroxene-plagioclase from arc lower crust in New Zealand and 2) strongly foliated plagioclase-amphibole from the deformed middle crust in the central Scandinavian Caledonides. Compositional banding affects both the symmetry and degree of anisotropy in the lower crustal rocks from New Zealand, whereas it does not appear to play an important role in the banded amphibolites from the Scandinavian Caledonides. It is therefore not always evident in which case compositional banding is an important factor in contributing to seismic anisotropy. The new modelling methods that have become available invite for detailed investigations to better constrain how rock microstructure influences seismic anisotropy. Such constraints are paramount to improve our understanding of the structure, rheological properties and composition of lower crust in continents.