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Are seismic wave velocities and anisotropies reliable proxies for partial melts?

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Partial melts and their segregation weaken mineral crystallographic alignment, resulting in a decrease in seismic anisotropy (AV). Furthermore, introduction of melt induces a drop in seismic wave velocities, especially for shear (Vs) but also compressional (Vp) waves, although some solid-state processes can also lead to velocity drops. Thus, decreases in AV and/or V are often used to infer the presence and even the amount of melt in both the crust and mantle, for example via the Vp/Vs ratio. However, evidence is accumulating that the relationship between melt fraction and seismic properties is not straight-forward.

We consider how varying melt fraction (f) might affect crustal seismic properties. Our modelling approach is based on electron backscattered diffraction (EBSD) analysis of crystallographic preferred orientation (CPO) patterns from granulite facies sheared migmatites. The CPO data are used to model the seismic properties of rocks with different solid/melt proportions. Subsequently, melt was simulated via an isotropic elastic stiffness matrix and combined mathematically with the CPO-derived seismic properties, and seismic properties then recalculated to take into account the presence of melt. These melt models, therefore, predict changes in seismic properties at different f. The models show that low (c. $f < 0.15$) and high ($0.7 < f < 1$) values affect seismic properties much more than the ‘crystal mush’ part ($0.1 < f < 0.7$): velocities (V) and anisotropies (AV) for both low and high f drop rapidly but ‘plateau’ at intermediate f. Our results imply that V and, especially, AV may not be reliable proxies for the amount of crustal melt present. Seismic wave behaviour in crystal-supported ($0.1 < f < 0.7$) material may be controlled by the solid rather than the melt phase.