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Implications of laboratory velocity measurements for seismic imaging of faults in anisotropic media

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Laboratory measurements of velocity and velocity anisotropy of fault zone rocks can contribute to a greater understanding of seismic imaging of fault zones at the crustal scale. Knowledge of fault zones at depth is vital to identify seismic hazard and characterize crustal structure and seismic investigations are often used to image fault zones at depth. Fault zones commonly occur within phyllosilicate-rich rocks. The anisotropic fabric of these rocks gives rise to seismic velocity anisotropy, which in turn will influence seismic imaging. However, anisotropy is not always taken into account in seismic imaging and the extent of the anisotropy is often unknown. We use laboratory measurements of velocity anisotropy to quantify the extent of anisotropy that may be expected in crustal fault zones. The results have implications for seismic imaging of anisotropic fault zones.
The Carboneras fault is a left-lateral strike-slip fault in SE Spain that cuts through phyllosilicate micaschist. Laboratory measurements of the velocity and velocity anisotropy indicate 10% P-wave velocity anisotropy in the gouge of the Carboneras fault and 30% anisotropy in the schist protolith. Cyclic loading of the protolith, designed to replicate and quantify the fracture damage in fault zones, reveal only small changes in measured velocities due to the influence of microcracks. Greater differences in velocity are observed between the fast and slow directions in the mica-schist rock (5500 - 3500 m/s at 25 MPa), than between the gouge and the slow direction of the rock (3500-3000 m/s at 25 MPa). This implies that the orientation of the anisotropy with respect to the fault is key to imaging the fault seismically. If the slow direction is oriented perpendicular to the fault, then waves travelling in the same direction will see little velocity contrast and the reflectivity of the fault will be low. A guided wave travelling along the fault, however, would see a strong velocity contrast. If the slow direction is oriented parallel to the fault, the opposite of the above will be true. This highlights the importance of considering the orientation (or potential range of orientations) of the foliation in design and interpretation of seismic experiments of faults in anisotropic media.