Seismic evidence for fault-bound anisotropy and its implications on fault structure in the northern Hikurangi subduction zone

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We present a three-dimensional anisotropic P-wave velocity model in the northern Hikurangi subduction zone offshore Gisborne, New Zealand, constructed by a tomographic inversion using over 380,000 travel times of refracted seismic waves from the NZ3D seismic experiment. The study area covers a region with active slow slip events at the shallow plate boundary (Wallace et al., 2016) and provides an ideal location to understand the relationship between the structural and hydrogeologic properties along the megathrust faults and shallow slow earthquakes. The obtained P-wave velocity model reveals a ~30-km-wide low-velocity (P-wave velocity of 1.8-4.0 km/s) accretionary wedge in the frontal part of the overriding plate, in which the previous multi-channel seismic reflection study suggests that several active thrust faults branching from the plate interface are developed (Barker et al., 2018). We found some locations with large azimuthal anisotropy over 4% spatially correlate with the distribution of the backstop interface, branching faults and deformation front. The fast axes of the P-wave anisotropy are mostly oriented to the trench-normal direction (i.e., plate convergence direction) within the accretionary prism, but become trench-parallel on the seaward side of the trough and within the landward old backstop crust.

Seismic anisotropy around the shallow plate interface is often interpreted to be caused by preferentially-oriented cracks in a compressional stress regime associated with plate subduction. Our findings suggest that the anisotropic features are not ubiquitous and homogeneous within the overriding plate but more localized along the active thrust faults. We also found that the magnitude of anisotropy is roughly equivalent to the values reported in the spreading centers where the ridge-perpendicular extensional stress regime is dominant and thus aligned fractures, or cracks, are primary controls on crustal anisotropy (e.g. Dunn, 2015). In the case of subduction zones, the porosity along the faults is not expected to increase significantly due to the compressional stress regime as implied by the core samples from the splay fault in our study area (Fagereng et al., 2019). These considerations may indicate that both the orientation of cracks and the foliation structure, related to fault slip, contribute to seismic anisotropy.

Keywords: Subduction zone, Seismic anisotropy, Fault structure

