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Imaging The Shallow Velocity Structure Of The Hikurangi Megathrust Using Full-Waveform Inversion

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The Hikurangi margin, offshore North Island, New Zealand, exhibits a number of different slip behaviours, including shallow slow slip events (SSEs) (<2km to 15 km). There is also a strong contrast in geodetic coupling along the margin. Although the shallow structure is clearly imaged with seismic reflection data, these data provide only limited information about physical properties across the megathrust. A large earthquake may be imminent, given there have been no large ruptures along the megathrust in the last 200 years, hence, an in depth understanding of subduction zone properties is important for risk assessment in the region.

Full-waveform inversion (FWI) is an imaging technique which incorporates the full seismic wavefield rather than just first-arrival travel times. In FWI a synthetic source wavelet is propagated through a smooth starting velocity model, and a residual is calculated between the synthetic and true seismic data. A back-propagated residual is used to update the velocity model so that the match between the real and synthetic waveforms improves. In this way, we can resolve high-resolution physical property variations which influence the seismic wavefield. In this study, FWI was used to resolve the P-wave velocity structure at the Hikurangi megathrust up to 2km depth below the sea-bed.

Information on lithologies and possible fluid conduits is a primary aim of the FWI inversions, and can be used to investigate how upper-plate structure may influence plate boundary slip behaviour. The recovered velocity model provides a good match between synthetic and real data, and small scale features are well resolved in the upper plate. The velocity model correlates well with the structure in reflection seismic section. In particular, several faults interpreted from the reflection seismic data produce low P-wave velocities near the frontal thrust. We interpret these faults as possible fluid conduits.

As the dataset was not collected specifically for FWI, the results show promise in resolving more information at depth. As such, both a 3D seismic survey and two drilling expeditions have been carried out. The new seismic survey recorded data at long offsets, allowing imaging of the fault boundary, which is not possible with the current 2D streamer data. The cores and LWD results will provide direct geological evidence which can be used alongside with the velocity model to further discern lithology and structure across the 3D area. The current result identifies the existence of overpressure and was used in drilling safety when collecting these cores. In conjunction with the new IODP cores, well-logs, and the 3D seismic survey, the FWI model will improve understanding of properties of the shallow structure of the megathrust.