Stress orientation variability along the Hikurangi Subduction Margin: Insights from borehole image logging

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The Hikurangi Subduction Margin (HSM) of New Zealand is well-known for its variable seismic behaviour along strike, and across the Pacific-Australian subduction interface. Pacific-Australian plate motion is accommodated by a combination of slow slip and normal seismic events. The mechanics of slow slip earthquakes and their relationship to normal earthquakes are not well constrained, and so they represent a challenge to the development of hazard models for this region of New Zealand. Variability in a number of aspects of the stress state along the HSM may play a role in controlling the observed spatially variable seismic behaviour. Here we present preliminary analysis of stress orientation information from borehole image logs acquired from oil and gas exploration wells, and scientific wells drilled as part IODP Expedition 372. Orientations of borehole breakouts (BOs) and drilling-induced tensile fractures (DITFs) from these image logs are used to determine orientations of the minimum and maximum horizontal stress directions respectively within the upper 3 km of the over-riding Australian Plate (hanging wall of the HSM subduction interface). Our analysis reveals that present day maximum horizontal compressive stress orientation (SHmax) within the subduction hangingwall varies along the HSM strike, from NE-SW (oblique to Pacific-Australian plate motion, parallel to HSM strike) in the northern HSM, to NW-SE (oblique to Pacific-Australian plate motion and HSM strike) in the southern HSM. Some deviation from this trend can be observed in both regions. At the frontal thrust in the northern HSM, SHmax is oriented N-S, and in the southern HSM one well shows a shallow E-W oriented SHmax. The borehole image log SHmax orientations in the northern HSM are consistent with SHmax orientations derived from shallow focal mechanism inversion. In contrast, borehole image logs SHmax orientations in the south of HSM are oblique to focal mechanisms derived shallow
SHmax orientations. Borehole SHmax orientations are compatible with the maximum horizontal contraction strain rate direction determined from campaign GPS surface velocities, though in the southern HSM multiple directions are determined from this technique. The difference in stress orientations along the HSM is consistent with the variation in seismic behaviour linked to changes in coupling at the subduction interface. Interestingly, it is the southern HSM, where the subduction interface is considered strongly coupled, that stress field orientations are not consistent with depth and show variability. In the northern HSM, where the subduction interface is considered to be weakly coupled, stress orientations appear broadly consistent with depth.