Structure and deformation of the overlying plate in the New Zealand Hikurangi subduction system: the SHIRE project

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The Hikurangi subduction system accommodates westward subduction of the Pacific Plate beneath the North Island, New Zealand, portion of the Australian Plate. As an overlying plate, North Island's structure and recent deformation are evidence of this plate boundary's subduction processes. Significant along-strike variations exist in convergence rate, slab dip, frontal accretion and tectonic erosion, slab heterogeneity (buoyancy) and fluid supply. A well-developing backarc rift exists in northern North Island. The northern segment of the subduction interface is presently creeping (steadily, and/or episodically in SSEs), whereas the southern segment is mostly locked and appears capable of generating great earthquakes. Inboard of the trench within the overlying plate and running the length of North Island are the Axial Ranges, a narrow belt of uplift associated with trans-island dextral faulting. Geophysical surveys have revealed the subsurface characteristics of the Hikurangi slab in central and southern North Island (e.g., NIGHT and SAHKE projects; Henrys et al., 2006, 2013).

In northern North Island, the NZ-USA-Japan "SHIRE" (Seismogenesis at Hikurangi Integrated Research Experiment) project combines paleoseismology, morphotectonics, seismology, and geodynamical modeling in order to investigate subduction slip behavior, mass fluxes, and long-term plate-boundary mechanics. This project's large-scale goals are to understand a subduction system that integrates forearc uplift, sediment transport and underplating, plate boundary strength, and seismogenesis. The seismology component of SHIRE collected new data using marine airgun, land explosion and local earthquake sources all recorded into temporary OBS and land recorders; MCS profiling was also carried out. In addition we assembled a catalogue of all local earthquakes that appeared within our seismic data.

Here we present results of the SHIRE along-dip seismic transect. Tomographic inversion of wide-angle phases from active sources and newly detected earthquakes was used to construct a 400-km long, 50 km deep VP model which captures the incoming plate, accretionary prism, subduction interface, slab, overriding crust and backarc. Geometries are confirmed by the reflection profiling and 3D propagation phases of our detected local earthquakes. The incoming Pacific plate has a slab dip of 7-12 degrees, oceanic crustal thickness of 10 km, and velocities between 2.5-7.0 km. The accretionary prism is significantly folded and dissected by frontal backthrusts, as observed in MCS profiles and low seismic velocities. Upper crustal velocities are higher in the western portion of the overlying plate, representing a transition from Neogene aged allochthonous units above Cretaceous basement formations. Wide-angle reflections and refractions show a crustal thickness of 30 km for the overlying Australian plate where Moho is present.

A unique feature in our results is a subsurface region of low velocities (~5.5 km/s) in the overlying plate lower crust where our SHIRE transect crosses the northern Axial Ranges. This feature is positioned at a depth near the intersection of the overlying plate Moho and subducting slab, is filled with strong seismic reflections, and is associated with a lack of internal seismicity. We interpret this feature as deep underplated sediments. Similar geophysical signatures are found beneath other portions of the Axial

Ranges along much of the overlying North Island. A spatial correlation of deep sediments beneath the Axial Ranges suggests two differing causal relationships. First, subducted sediments would have lower velocities and larger relative buoyance than surrounding lower crust, thus driving uplift of the Axial Ranges. Second, externally caused uplift of the Axial Ranges could enable basal infilling of such crustal material. Further data analyses using attenuation information and SHIRE team geodynamical modeling will help test these interpretations.

Keywords: subduction, New Zealand, overlying plate structure, seismic imaging, physical properties

