Structure and Triggered Sealing in a Subduction Interface from Earthquake-Reflection Imaging

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http://www.seismo.unr.edu/ftp/pub/louie/weber/

1990 Weber Sequence, Hikurangi Margin

**Location and Setting:** Earthquake seismic images show three-dimensional spatial and temporal properties of a subduction fault interface.

A seismograph array recorded an unambiguous forward-scattered P-P phase from the interface of the Hikurangi subduction zone in New Zealand. P-P scattering was most prominent within days of the Feb. 19, 1990 Weber I M6.2 earthquake in the lower plate below the 20-km-deep interface, and less prominent three months later.

S-P phase conversion at the sediment-laden interface was absent although it had been widely prominent previously.

Locating Multi-Mode Reflectivity in Time

![Image of location and setting](http://www.seismo.unr.edu/ftp/pub/louie/weber/)

**Figure 1:** a) Along the east side of New Zealand's North Island the oceanic Pacific tectonic plate subducts below a continental fragment on the Australian plate at the Hikurangi Trough.

b) Data for reflectivity imaging arises from the 500 "passive" sources of the Weber I and II intraplate earthquake sequences (with Robinson's focal mechanisms). The Weber I aftershocks (grey diamonds) located below the 20 km deep plate-subduction interface, illuminating it from below with forward-scattered seismic energy. The Weber II event and its aftershocks (yellow squares) are above the interface, illuminating it from above with back-scattered energy. The interface dips 5 degrees northwest. Portable seismographs (red triangles) along with the New Zealand Network provided vertical-component seismograms for reflectivity imaging.

The inset e) shows example seismograms from a small Weber I aftershock at two stations, both in the dilatational quadrant of the normal-fault mechanism. The blue downward first P-wave motions are followed by a simple pulse, then by scattered P-P, P-S, and S-P energy to the onset of the S arrival. The arrivals recorded at TEU did not pass through the bright spot.

Plate Interface Structure & Properties

**Figure 2:** a) Images of back-scattered reflectivity using the Weber II events above the interface, along the dip section of fig. 1. Blue colours show negative, red, and white low reflectivity. P-P reflectivity is strong and shows structural details of the plate interface. The upward-curving migration artifacts appear in areas with poor reflection-point coverage and can be ignored. The rms amplitudes of the P-P and S-S images are similar; the S-P image has about half the amplitude of the P-P, and the P-S is an order of magnitude lower. Superimposed are northeastward views of relocated aftershock hypocenters, and into each mainshock's focal mechanism.

b) Forward-scattering reflectivity from Weber I aftershocks below the plate interface. P-P forward scattering is prominent. An order of magnitude less S-S or P-S forward scattering takes place. The S-P scattering magnitude is about half that of the P-P. P-P scattering is strongest in a wedge above and northwest of the Weber I sequence, in the headwall of the NW-dipping normal fault.

c) and d) show the most prominent P-P scattering arises in a 10-20 km area at 21-22 km depth, west of the Weber I normal fault as defined by Robinson's aftershock relocations.

d) Forward-scattering reflectivity from Weber II events above the interface, along the dip section of fig. 1. Blue colours show positive, red, and white high reflectivity. P-P reflectivity is strong and shows structural details of the plate interface. The upward-curving migration artifacts appear in areas with poor reflection-point coverage and can be ignored. The rms amplitudes of the P-P and S-S images are similar; the S-P image has about half the amplitude of the P-P, and the P-S is an order of magnitude lower. Superimposed are northeastward views of relocated aftershock hypocenters, and into each mainshock's focal mechanism.

**Figure 3:** Three-dimensional views of migrated reflectivity volumes from Weber seismograms.

a) through c) show the Weber II back-scattered P-P reflectivity volume. The volumes start 10 km below the surface, extend to 30 km depth, and are 25 km on a side (white box in fig. 1).

e) through f) show the Weber I forward scattered P-P reflectivity volume.

Warm colours indicate large-magnitude positive or negative reflectivity; cool colours (and transparency in d) indicate low reflectivity. The views are all toward the northeast along the strike of the subduction interface.

Topographic and Tectonic Implications

**Figure 4:** Regional map of topography and bathymetry related to subduction processes on the Hikurangi margin. East of the dotted line the bathymetry shows the thrust ridges and trench-slope basins of the accretionary wedge. The indentation "n" in the shelf off Cape Tumagoni suggests erosion of the wedge by seamount impact as is seen northeasward along the margin off East Cape.

The high topography of the Puketui Range "M" shows the local thickening of the upper plate, just west of the Weber I fault. This high allows the Manawatu River "M" to breach the summit of the Rimutaka, Taranana, and Ruahine Ranges that form the main thrust backstop "B" to the subduction wedge, and flow through them west to the Tasman Sea instead of east to the Pacific.

Conclusions: We suggest that dilatation of fluid-filled pores by the M6.2 Weber I normal-faulting earthquake caused mineral precipitation by depressurisation. The minerals sealed thin cracks to yield more spherical pores, lowering Poisson’s ratio in the interface for at least a week after the February 19, 1990 Weber I event. The forward-scattering arose in a wedge of sediment, 3-5 km thick, bulbous into the interface by a subducted fault offset. Activation of a duplex thrust by the temporary sealing and locking of the interface may have triggered a second earthquake, the May 13, 1990 Weber II M6.4 event, within the upper plate.