The 2009-11 SAHKE Experiment: 2D velocity imaging across the interseismically locked southern Hikurangi margin, Wellington, New Zealand

Stuart A. Henrys; Aaron Wech; Hiroshi Sato; David A. Okaya; Takaya Iwasaki; Tim A. Stern; Martha K. Savage; Kimihiro Mochizuki; Eiji Kurashimo; Rupert Sutherland.
Seismic Array HiKurangi Experiment: SAHKE

**Question:** What is the strength of the plate interface beneath Wellington?

- The role of upper crust faults controlling crustal structure, topography, and tectonics across the lower North Island
- The mechanical conditions on, and adjacent to the plate interface
- Compare and contrast processes along the margin
- Are there lessons for other subduction zones

**Work in progress**

- Yes
- Yes perhaps
- Yes
- Perhaps
SAHKE-I

SAHKE-II

M 8.2 1855 Wairarapa earthquake
Movement along at least 140 kilometres of the Wairarapa Fault, along the eastern edge of the Rimutaka Range.

About 5,000 square kilometres of land west of the fault was lifted up and tilted.

The southern end of the Rimutaka Range rose by ~3 metres.

Land also shifted over 18 metres horizontally.

GPS observations can be explained by 100% coupling on the plate interface to ~30 km depth.
1st arrival tomography of 18000 picks

After 18 iterations RMS travel time residual was reduced from 0.45 s to 0.04 s

Checkerboard analysis
Shallow structure is well resolved in the upper crust down to about 10-20 km depth
At greater depths, poorer resolution, but broad scale (35 x 20 km) structure is recovered.
Reflections

Plate Interface
PintP

Top of Oceanic Crust
PtopP

Base of the Oceanic Crust
PbaseP

Australian Crust Moho
PmP, PdP

Upper Crust
PcP
Data from Savage et al. 2007

\[ V_p/V_s = 1.78 \]

\[ V_p/V_s = 1.7 \]
Subducting Sediment Channel and Underplating

Underplated and stacked imbricated sheets of sedimentary material from the top of the Hikurangi Plateau, on the overriding Pacific plate, into the footwall of the Wairarapa fault, driving uplift of the Tararua Range, and may be acting as a seal trapping fluid in the oceanic crust.
Wairarapa Fault

Reflections from the Wairarapa fault show it is a steeply dipping listric fault that appears to bound the upper surface of reflective low-velocity underplated sediment, and sole into where the plate interface intersects Australian Plate Moho at about 32 km depth and near the downdip end of the strongly locked coupled zone.
Relationship to locking
Suggest that increase in dip to angles defines the transition from locked areas of the plate interface to unlocked and partitions stable and unstable slip regimes. As a result mechanical behaviour and seismic hazard of the subduction interface may also be spatially correlated with this along-strike change of interface geometry.
Conclusions

1. We have developed a 2D P-wave velocity model across a 350 km long transect of the Hikurangi margin subduction zone with the aim of determining properties of the locked subduction thrust.

2. Imaged stacked imbricated sheets of sedimentary material from the top of the Hikurangi Plateau, into the footwall of the Wairarapa fault, driving uplift of the Tararua Range, and may be acting as a seal trapping fluid in the oceanic crust.
Conclusions

3. Suggest that increase in dip to angles greater than 8° defines the transition from locked areas of the plate interface to unlocked and partitions stable and unstable slip regimes.

4. Abrupt slab-dip changes are inferred to have implications for seismicity where bending points may act as barriers to rupture propagation.
Complimentary seismic and MT observations

- Reoccupying the temporary SAHKE transect stations
- Augmenting this 2D array with small 3D (100 m spacing) and large regional (10 km spacing) arrays;
- Instrument some SAHKE shot holes with borehole seismographs;
- Collect lines perpendicular to the subduction margin
- Acquire high-resolution seismic reflection lines across accessible parts of the lower North Island that cross Wellington and Wairarapa Faults.
Wikipedia: Itsukushima Shrine
North Island
New Zealand

SW Japan

Wallace et al 2012