OVERVIEW OF HIKURANGI MARGIN SUBDUCTION TECTONICS AND MEGATHRUST SLIP BEHAVIOR

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Acknowledgements

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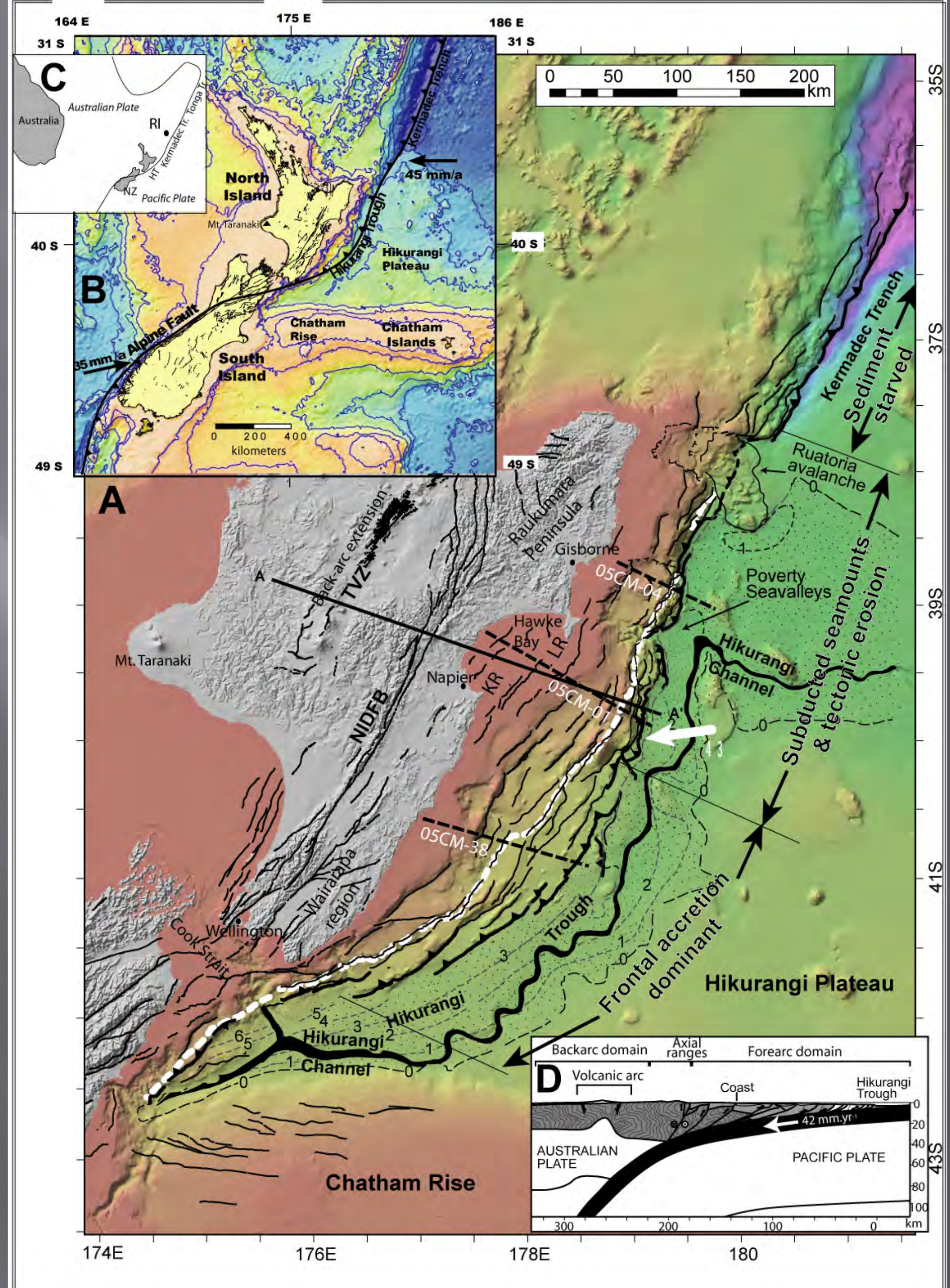
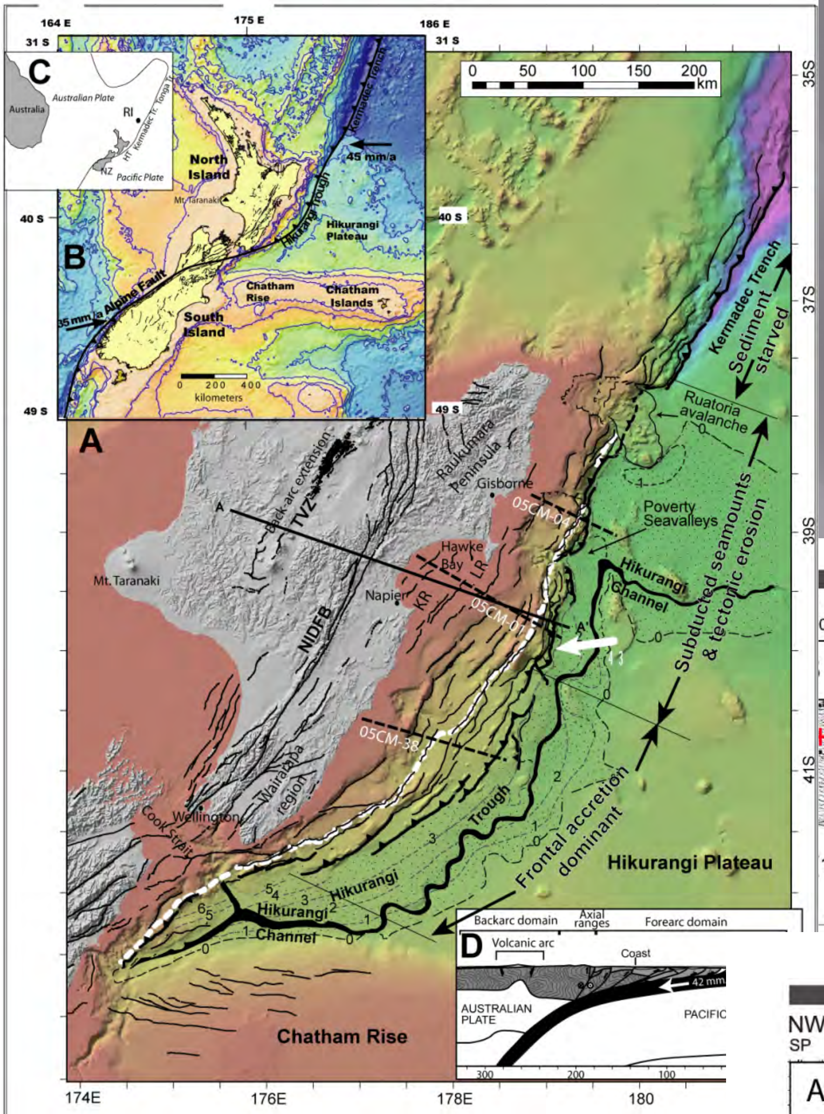
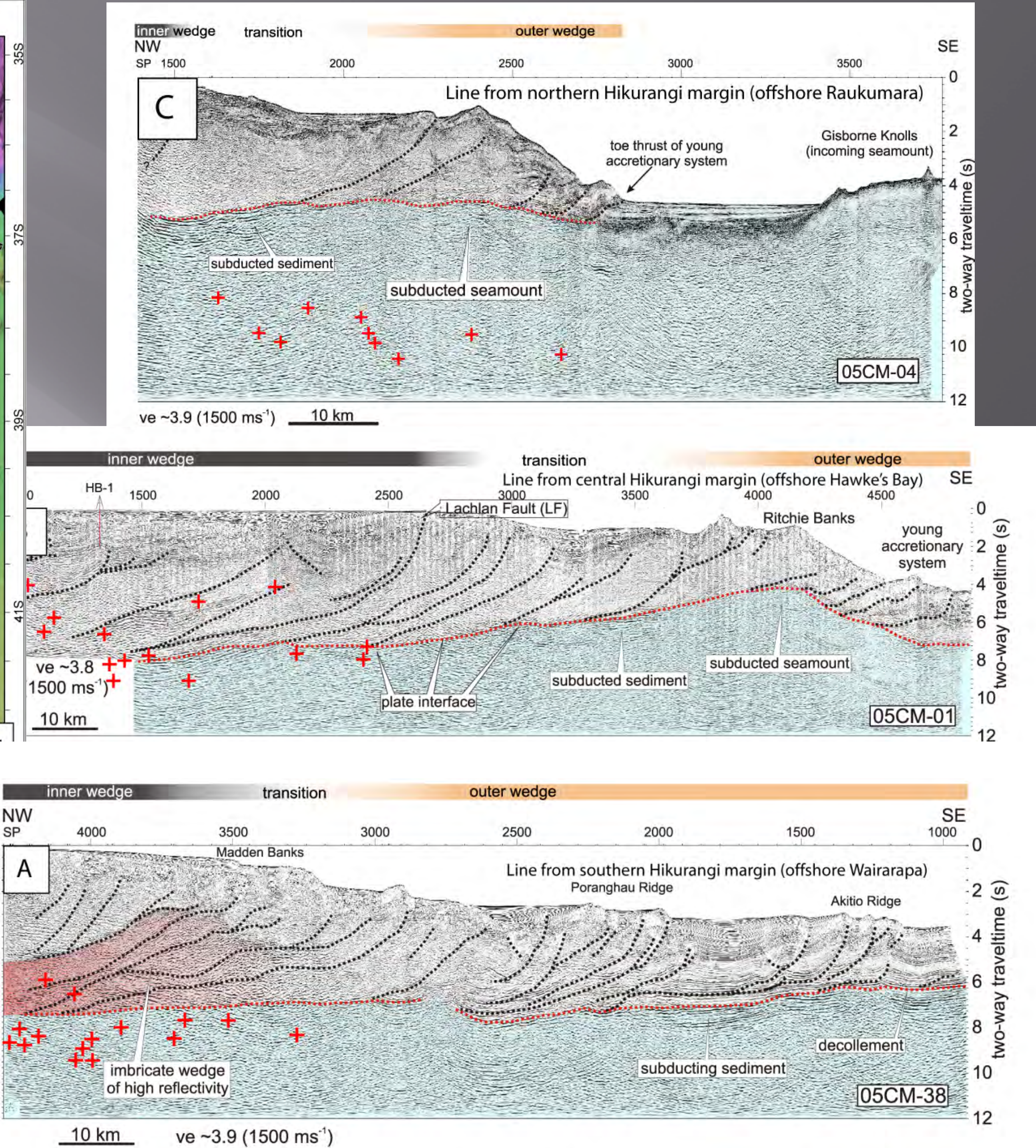
The Hikurangi subduction margin

- The Hikurangi Plateau (a Cretaceous oceanic Plateau) is being subducted at the Hikurangi Trough
- Plate motion is oblique, and is partitioned all along the margin via strike-slip faults and clockwise rotation of the margin. Rotation leads to a northward increase in convergence rates.
- Active back-arc rifting occurs in the central North Island (in the Taupo Volcanic Zone)
- The southern Hikurangi margin has a well-developed accretionary wedge, while the northern portion of the margin is dominated by tectonic erosion and seamount subduction.
- The sediments on the lower plate are much thicker at the southern Hikurangi margin, due to sedimentation being funnelled along the Hikurangi channel from the South Island

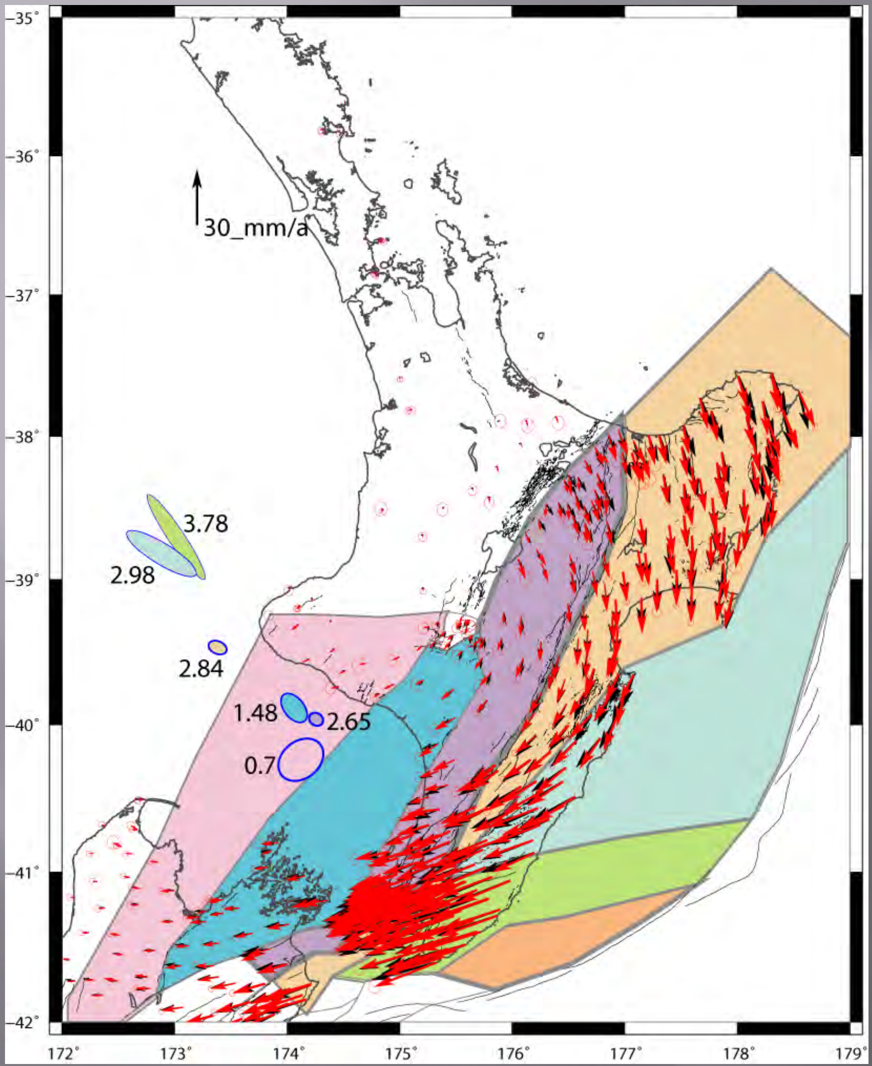






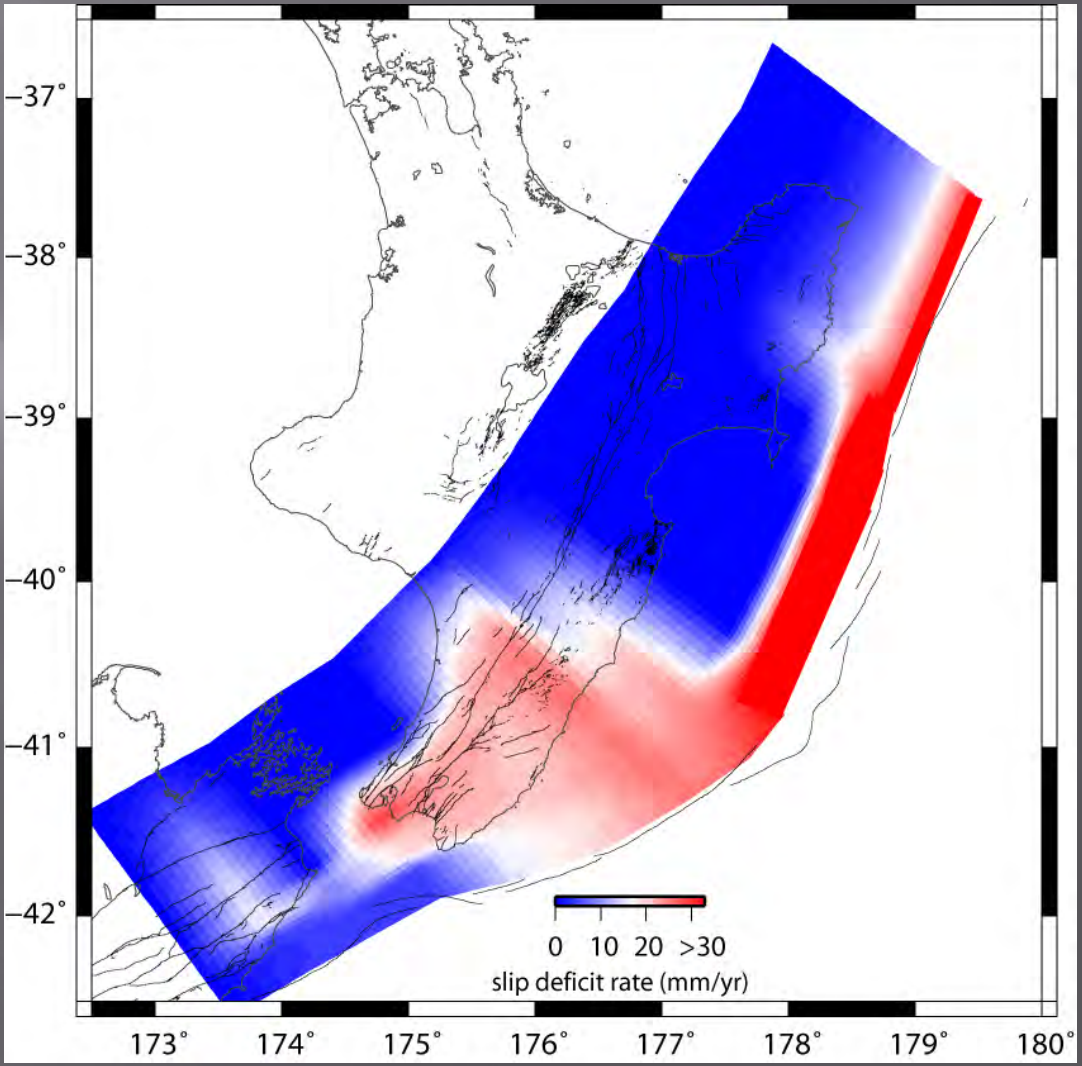
Seismic reflection lines from Barker et al., 2009 (G-cubed)

Campaign GPS used to assess interseismic coupling on the subduction interface



GPS data also reflect long-term tectonic rotation of the forearc

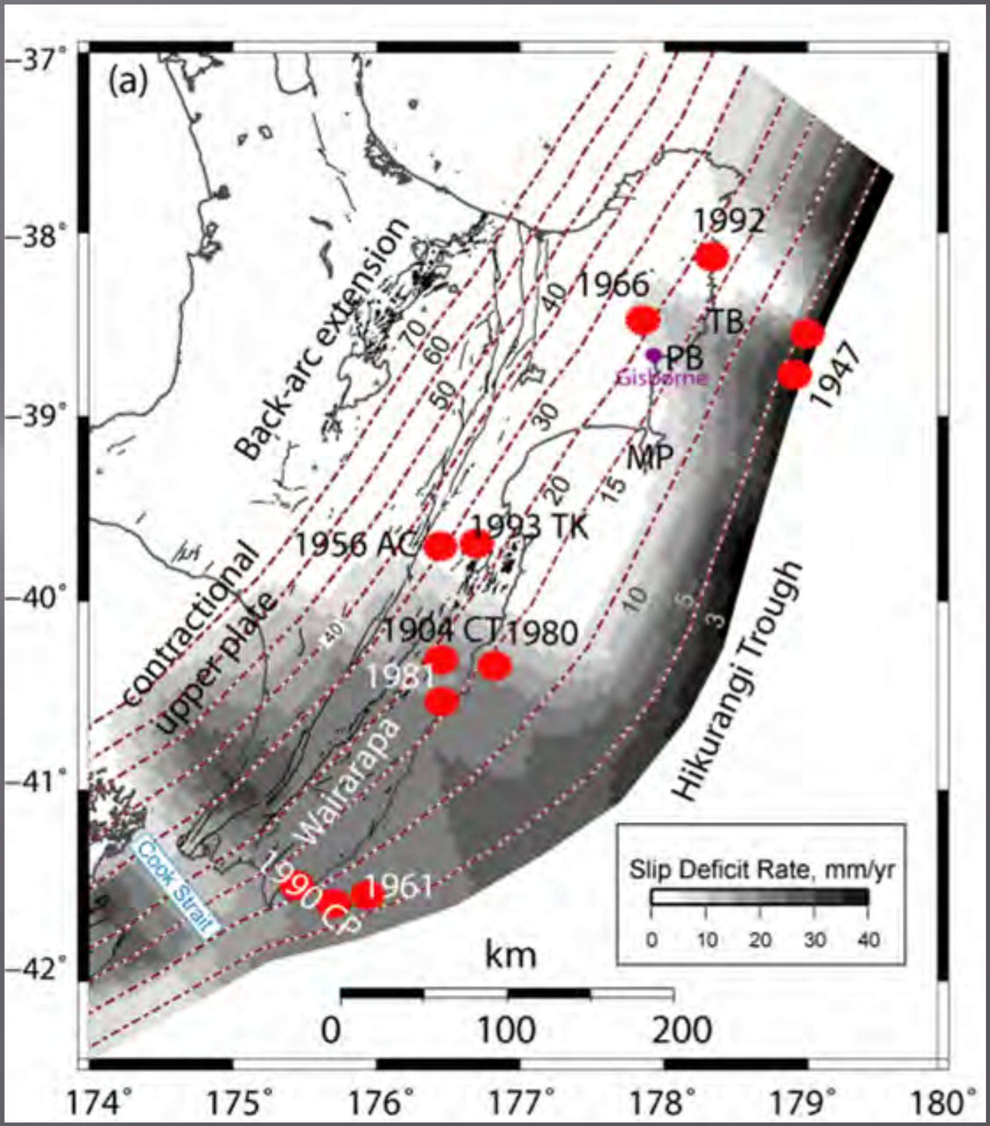
Interseismic coupling (in terms of slip deficit rate)



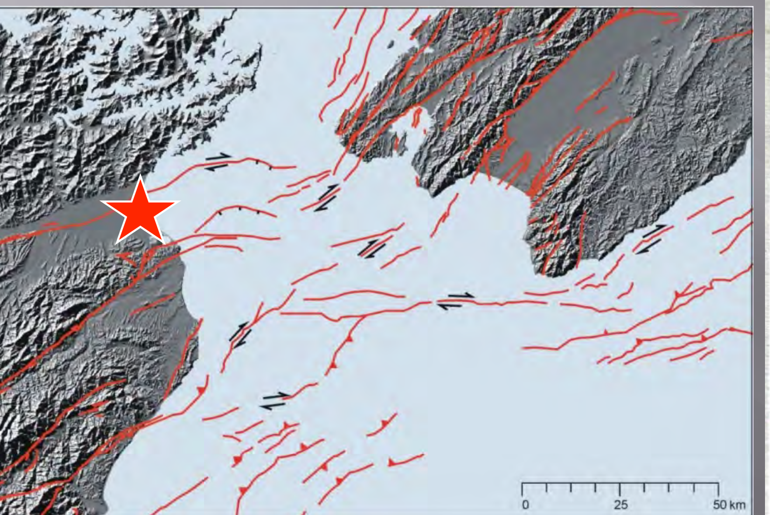
Wallace et al., 2004 (JGR)

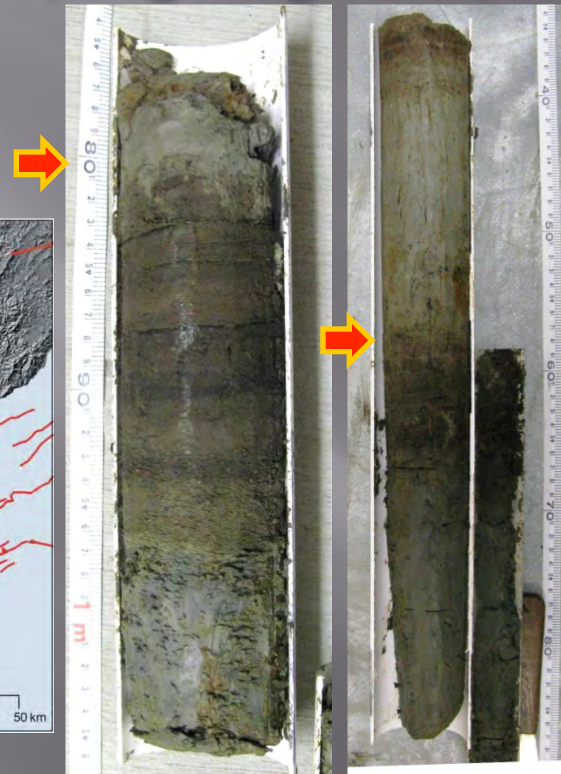
Historical earthquakes on the subduction interface

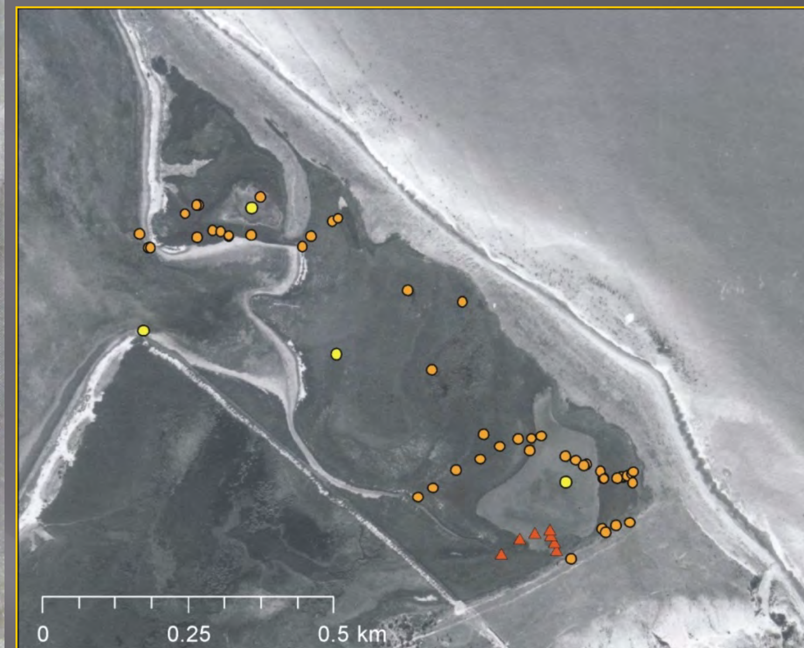
- No Great (Mw > 8.0) subduction thrust events have occurred on the Hikurangi interface in historical times (e.g., last 170 years)
- Moderate magnitude (Mw < 7.2) historical interface earthquakes occur on the edges of the deeply coupled portion of the interface, or in the region of shallow interseismic coupling
- If the southern portion of the margin ruptures in events with 6-10 m of slip, it could produce Mw >8-8.5 events. BUT, we have NO idea if such events occur here.
- If the whole margin goes in a single event, we could be looking at Mw > 9.0



New paleoseismic evidence for rupture of the southern Hikurangi margin, Big Lagoon (northern South Island)





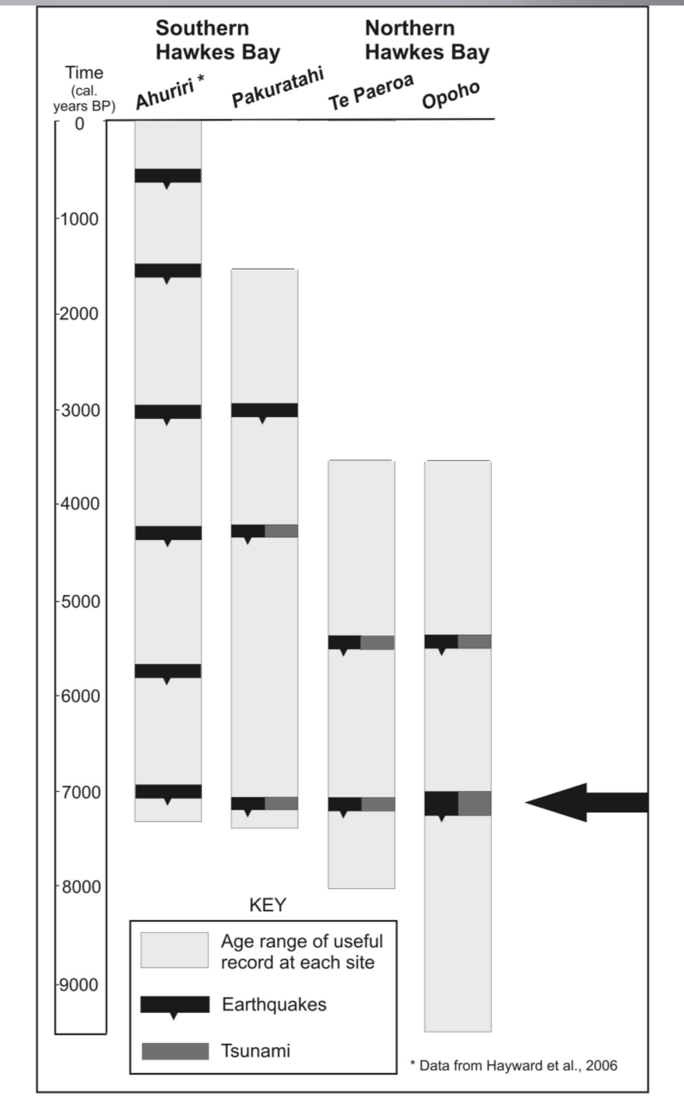


Kate Clark, unpublished data

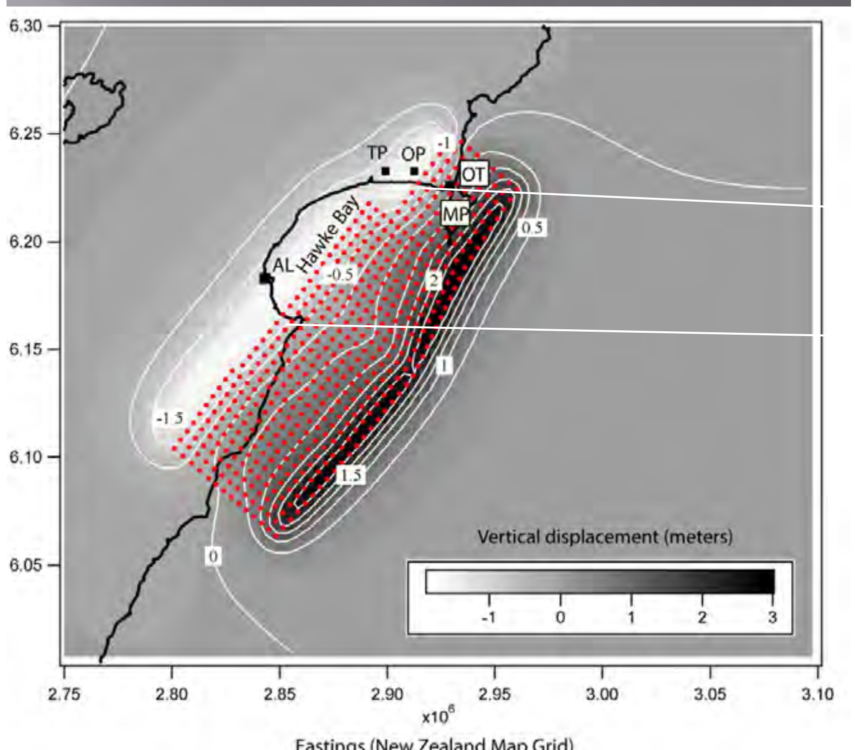
- Widespread organic-rich clay to peat unit, 10-15 cm thick
- Overlain by homogenous grey clay.
- Transition from peat to clay marks a sudden rise in relative sea level = a coseismic subsidence event?

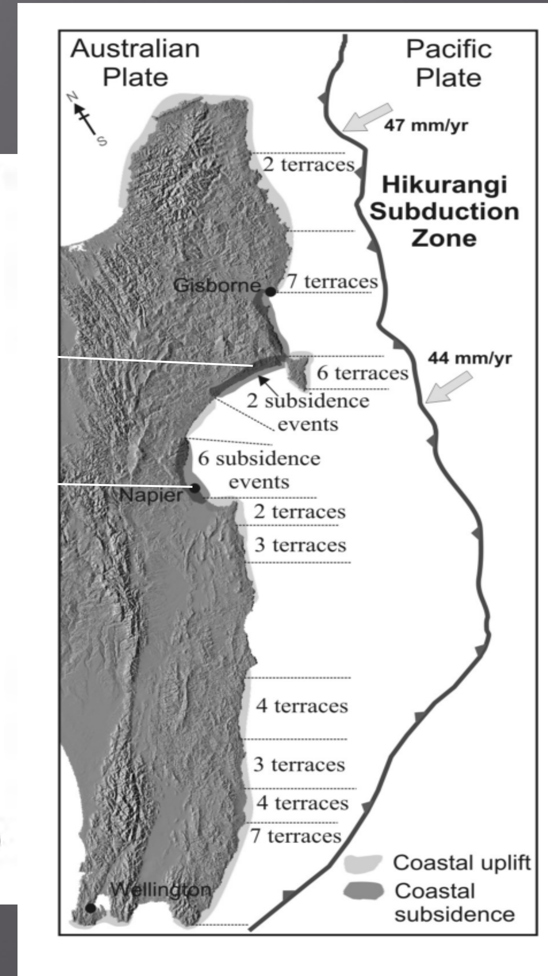
Peat layer dated at 800-600 BP, so we estimate subsidence event at ~600 ± 50 yrs BP. Foraminifera assemblages indicate ~0.5 m of subsidence

Paleoseismological studies show evidence for abrupt coastal subsidence events in the Hawke's Bay region, which could be generated by Great earthquakes



Cochran et al. (2006), Hayward et al. (2006)

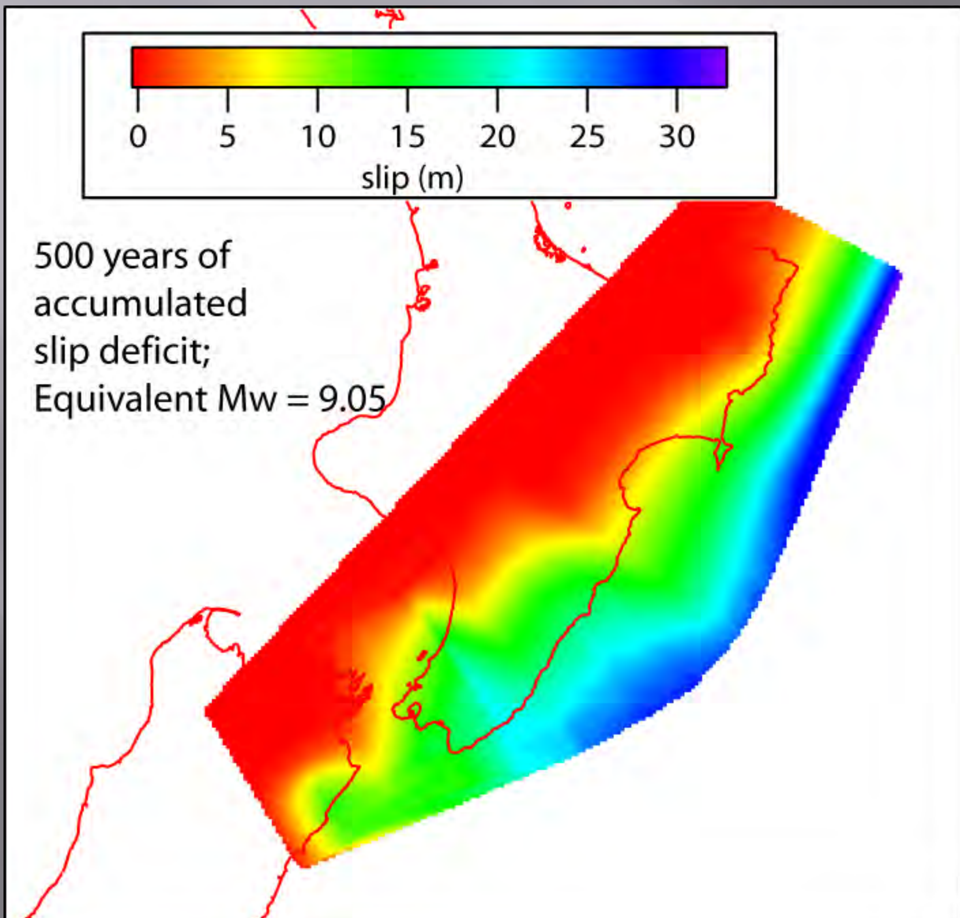


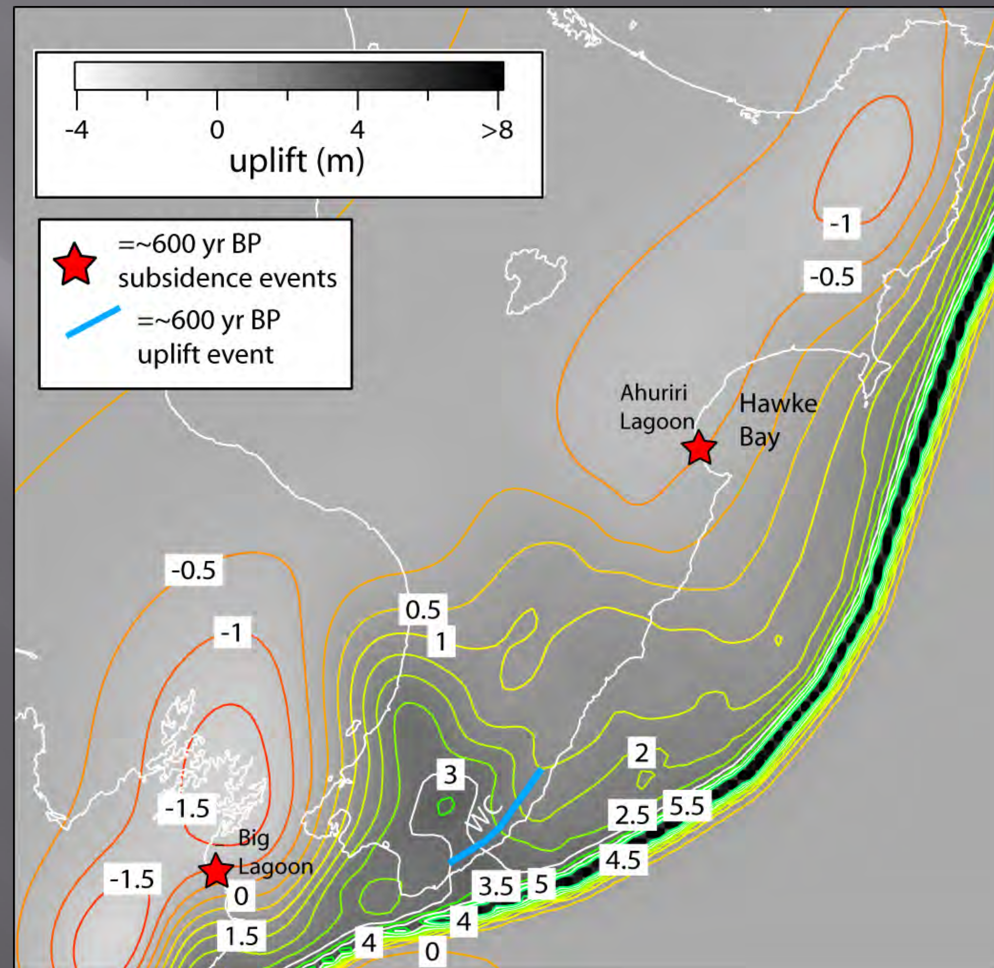


See also poster by Cochran et al., this meeting

Possible paleoseismic evidence for rupture of much of the Hikurangi margin ~600 years ago?

600 yr BP subsidence event in Big Lagoon correlates with ~600 yr BP uplift event along the Wairarapa coast (Berryman et al., 2011) & subsidence event in Ahuriri Lagoon (Hawkes Bay; Hayward et al., 2006)



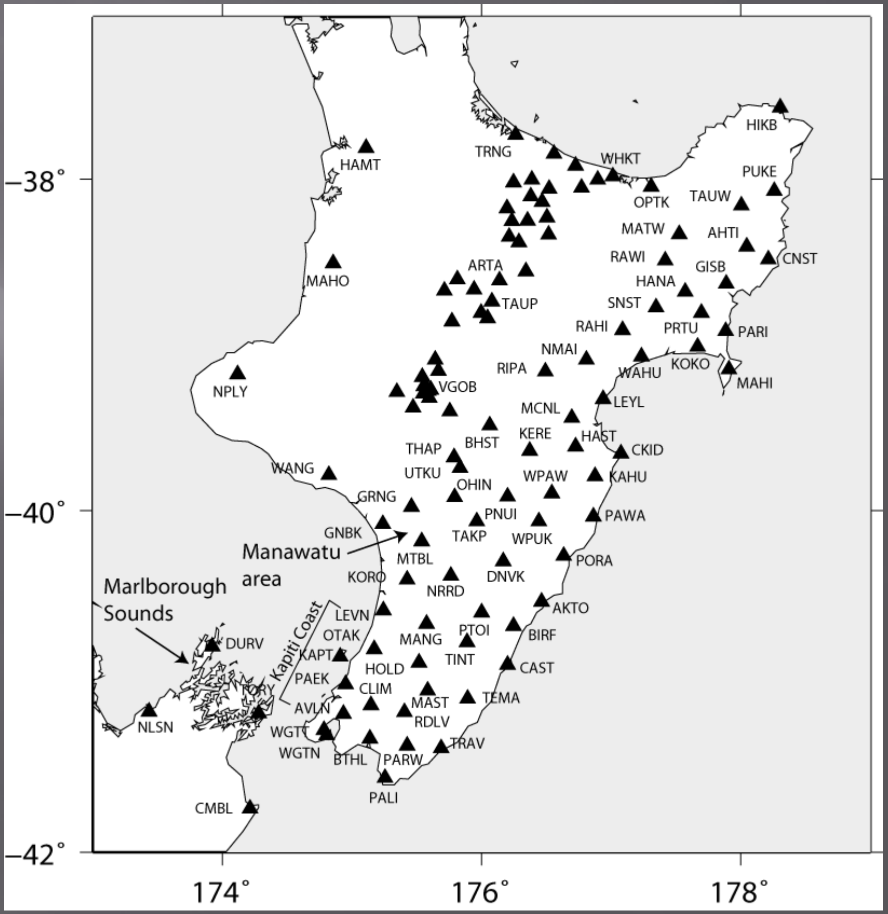


Kate Clark et al., in prep.

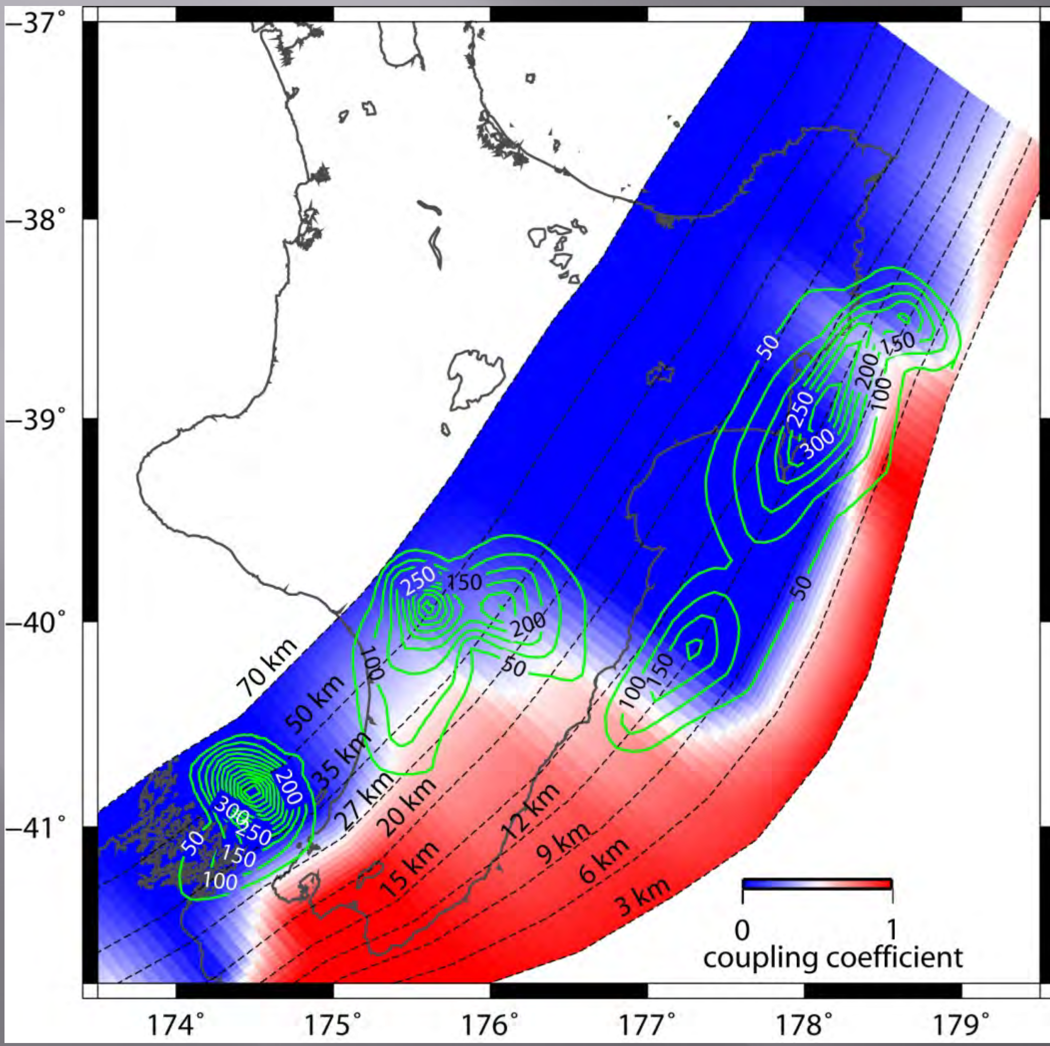
Operational continuous GPS sites: NZ GeoNet, www.geonet.org.nz

Since 2002, we have observed ~20 distinct slow slip events at CGPS sites in the North Island

Current CGPS network configuration



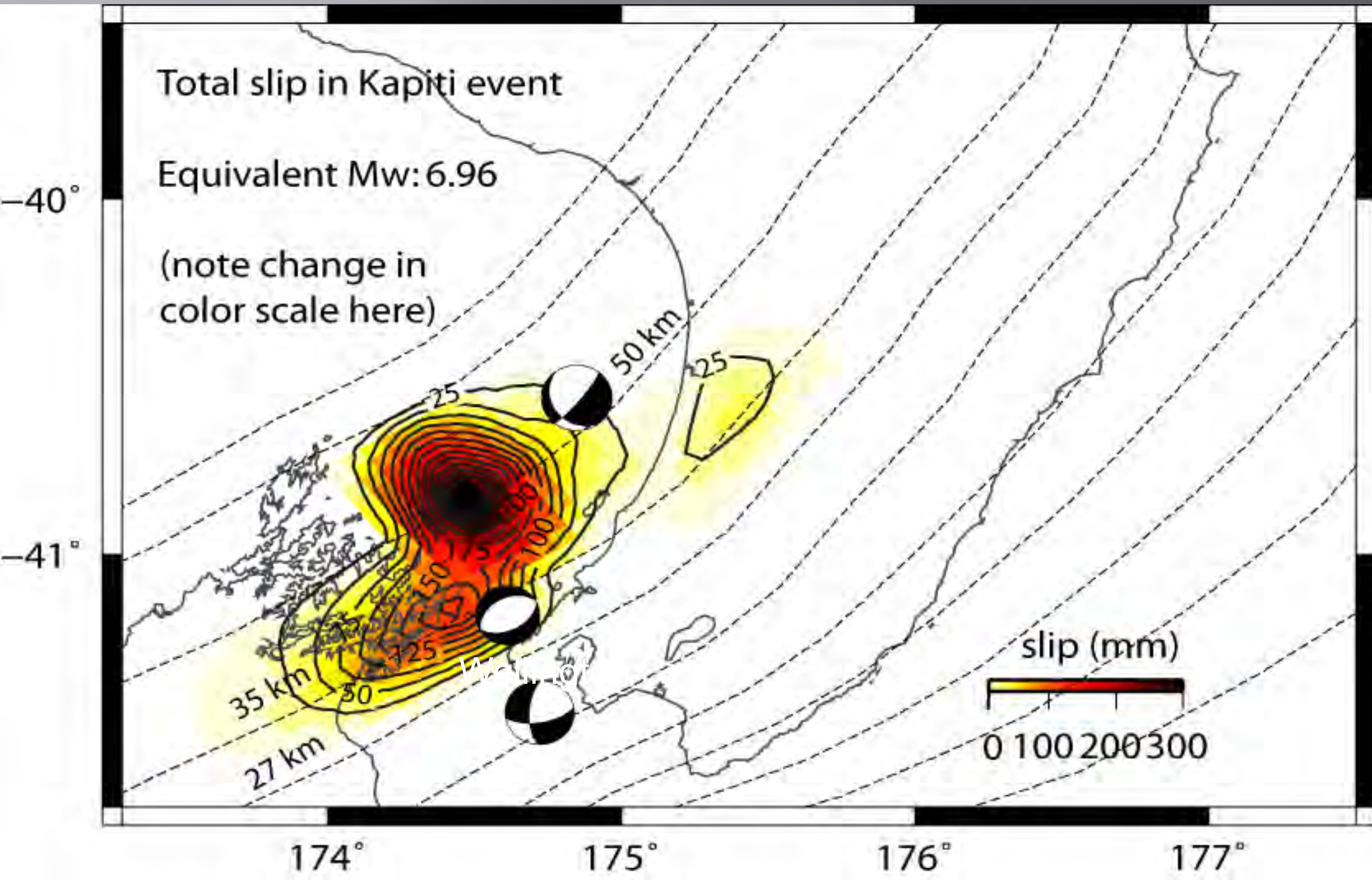
Slow slip events and their relationship to interseismic coupling at the Hikurangi margin



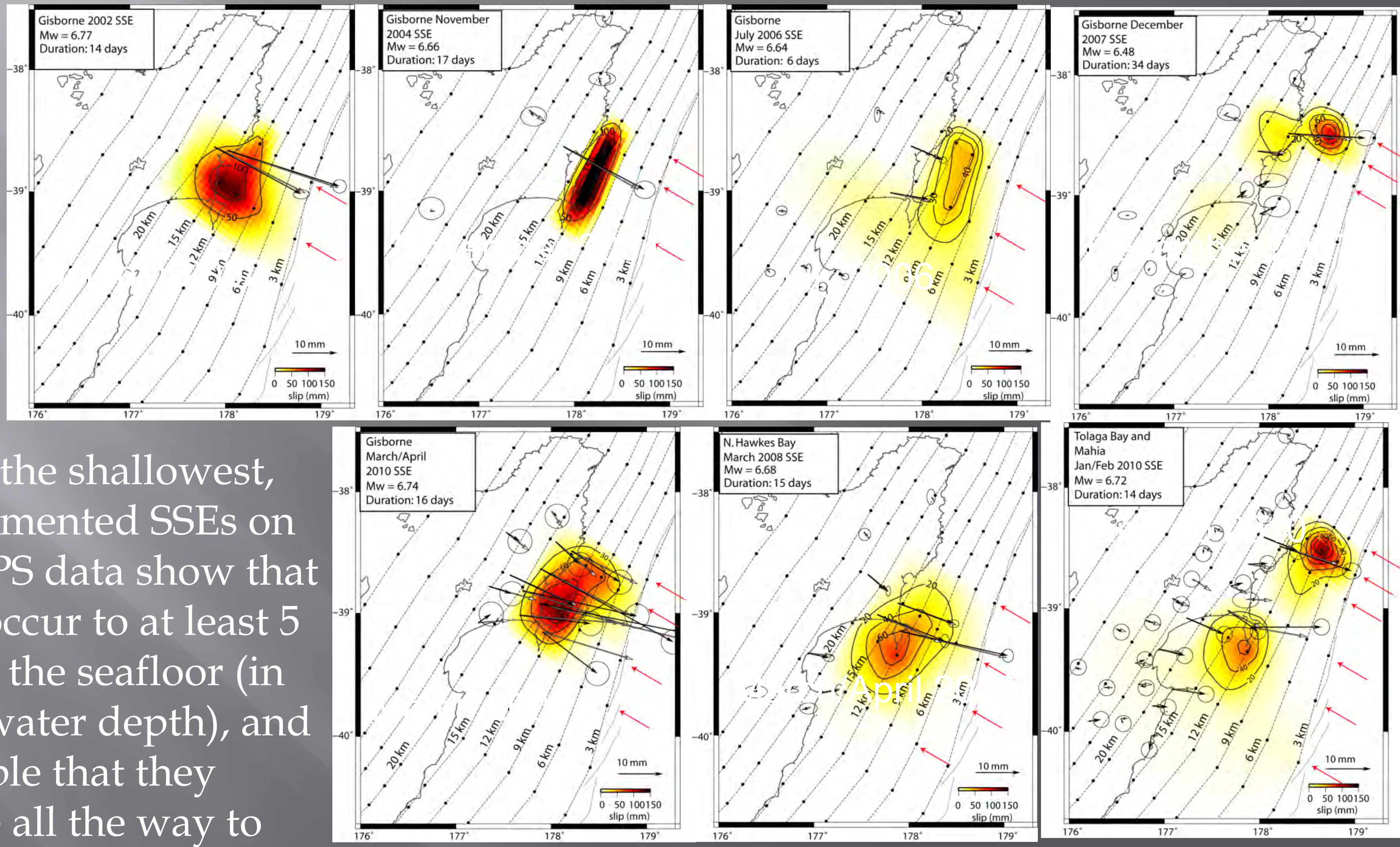
Slow slip events follow along the down-dip edges of interseismic coupling, similar to what is observed in Cascadia, southwest Japan, and other SSE localities

In the north, we see very shallow, short-lived, frequent slow slip events, in the south, we see larger, longer, and less frequent SSEs.

Kapiti 2008 SSE lasted ~15 months, was equivalent to an Mw 7.0, and may have involved slip on the interface up to 35-40 cm



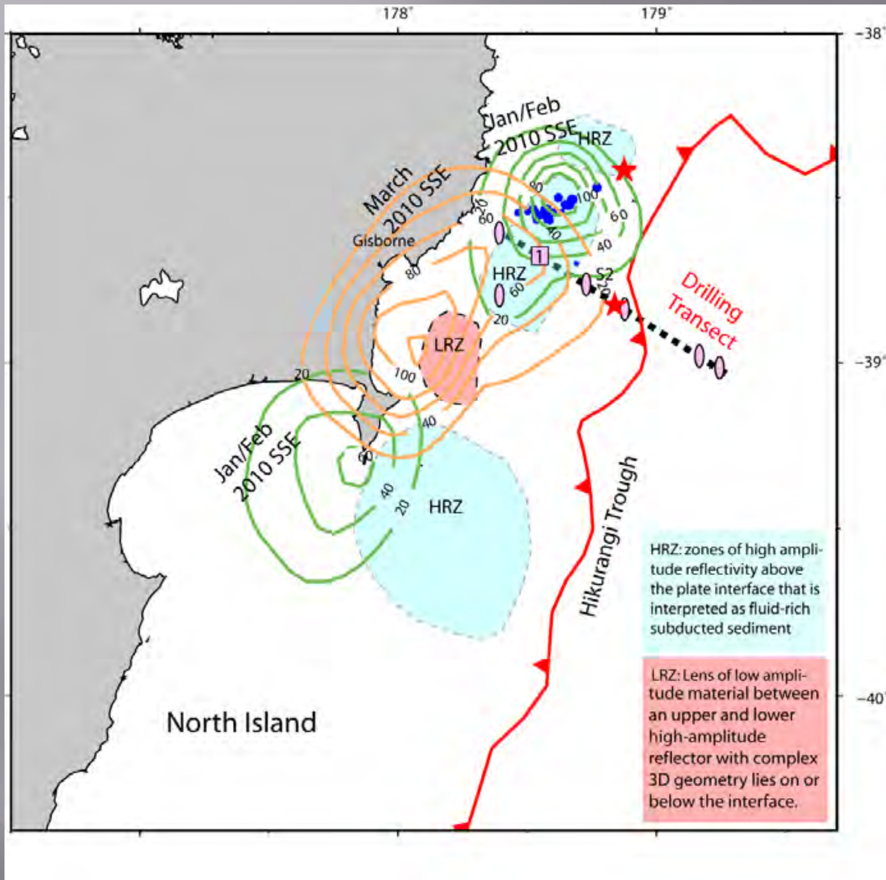
Shallow slow slip events (<5-15 km depth) on the subduction thrust at northern Hikurangi repeat every 1.5-2 years, and last for 1-2 weeks

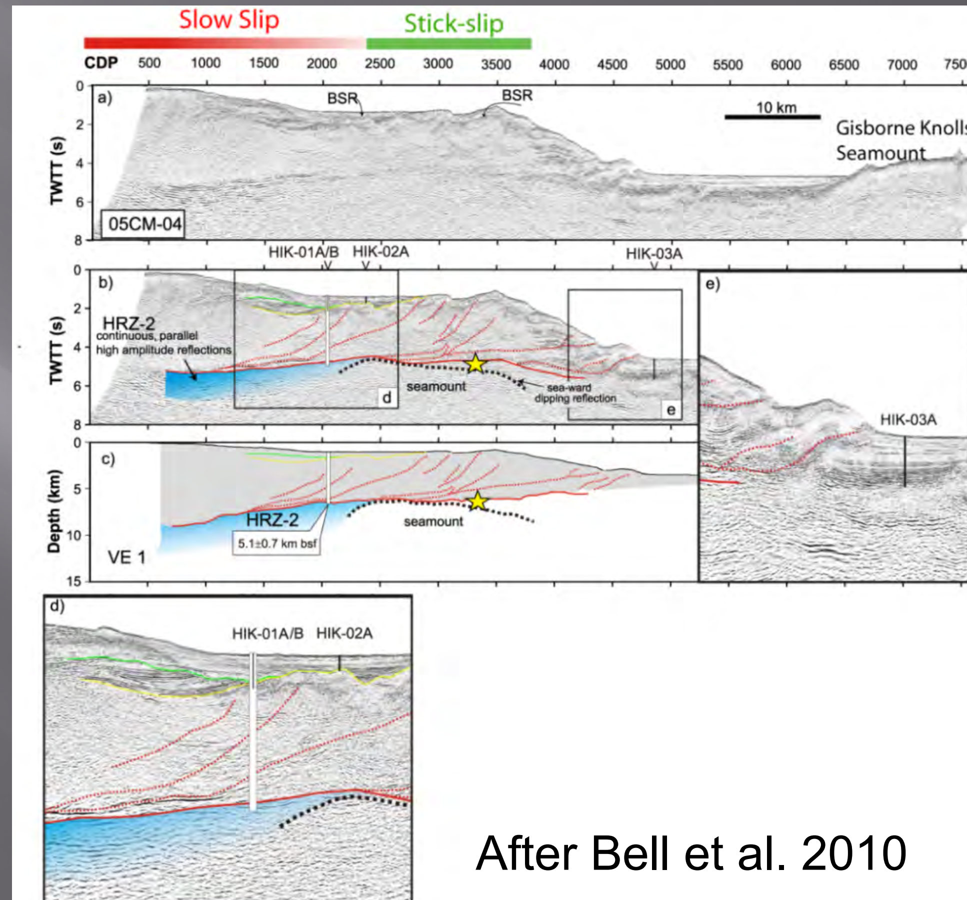


These are the shallowest, well-documented SSEs on Earth. cGPS data show that the SSEs occur to at least 5 km below the seafloor (in ~1000 m water depth), and it is possible that they propagate all the way to the trench

Wallace and Beavan, 2010, JGR

North Hikurangi slow slip events are associated with a zone of high-amplitude reflectivity at the interface, which may indicate abundant fluids at the SSE source

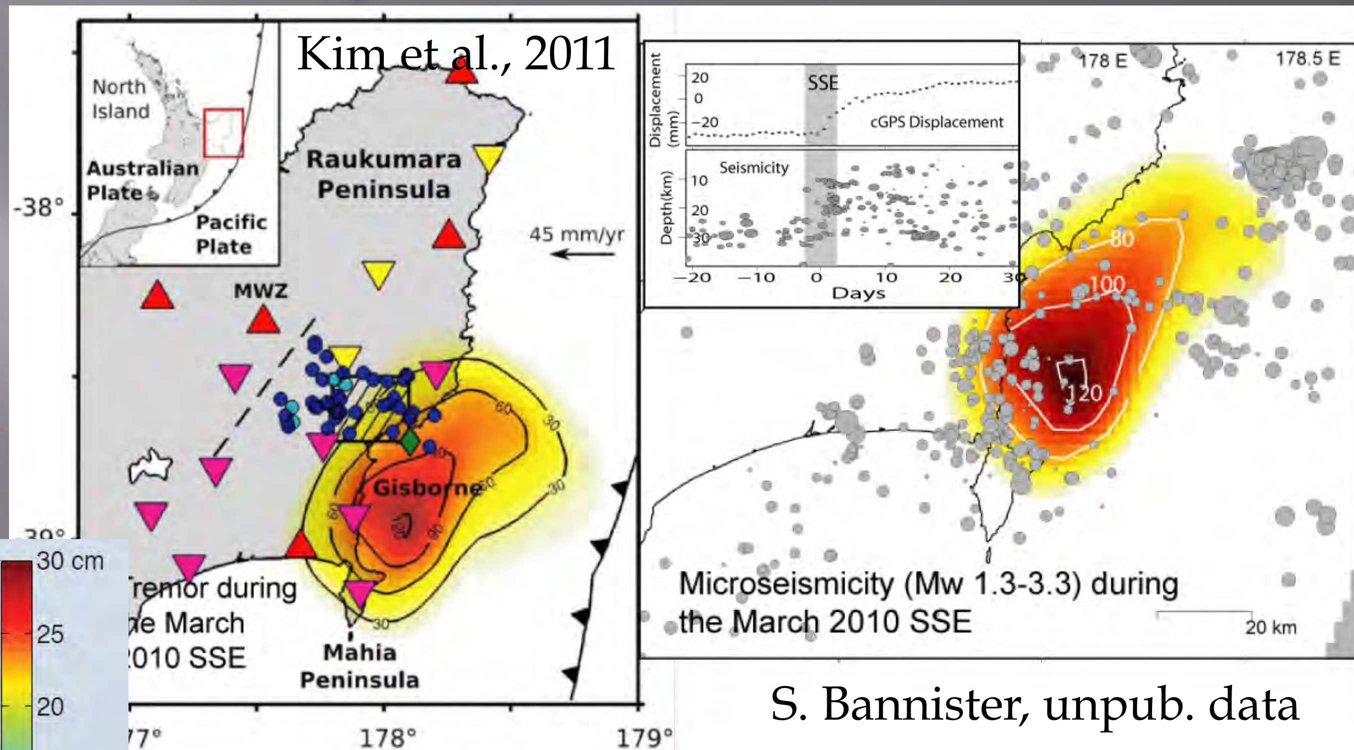


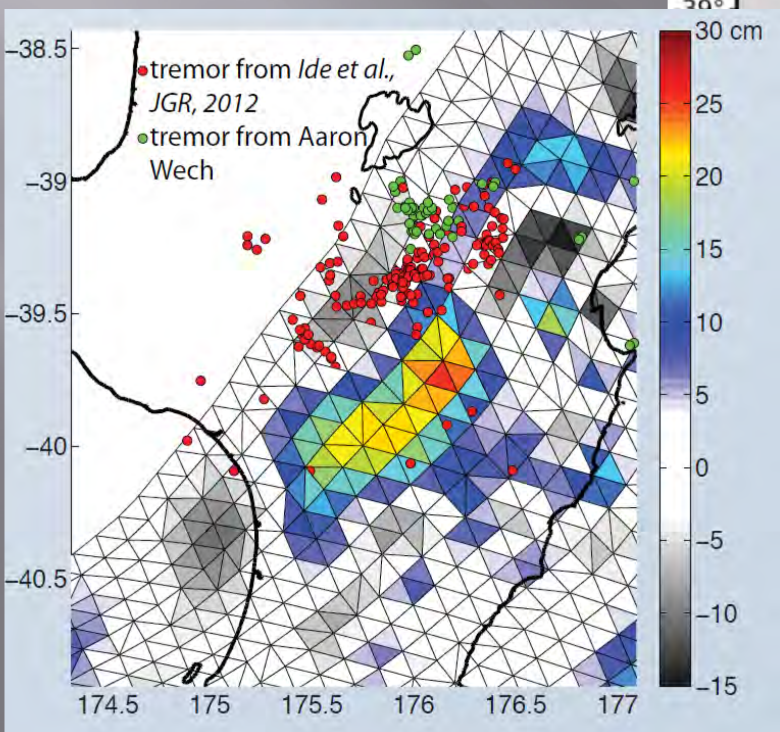


The high amplitude zone and the SSE source is the drilling target (~5 km below the seafloor, in 1 km water depth). After submitting a preproposal on the project in 2010, SSEP requested that we develop the project into a Multi-phase drilling project. We submitted the MDP and the proposal for the riserless drilling phase (781A-Full) in October 2011. The proposal for the riser phase (to intersect the source of SSEs at ~5 km bsf) was submitted on April 1, 2013.

Seismicity and SSEs

North and central Hikurangi: Abundant microseismicity and some tremor





Some tremor (triggered and ambient) in region just downdip of Manawatu SSEs

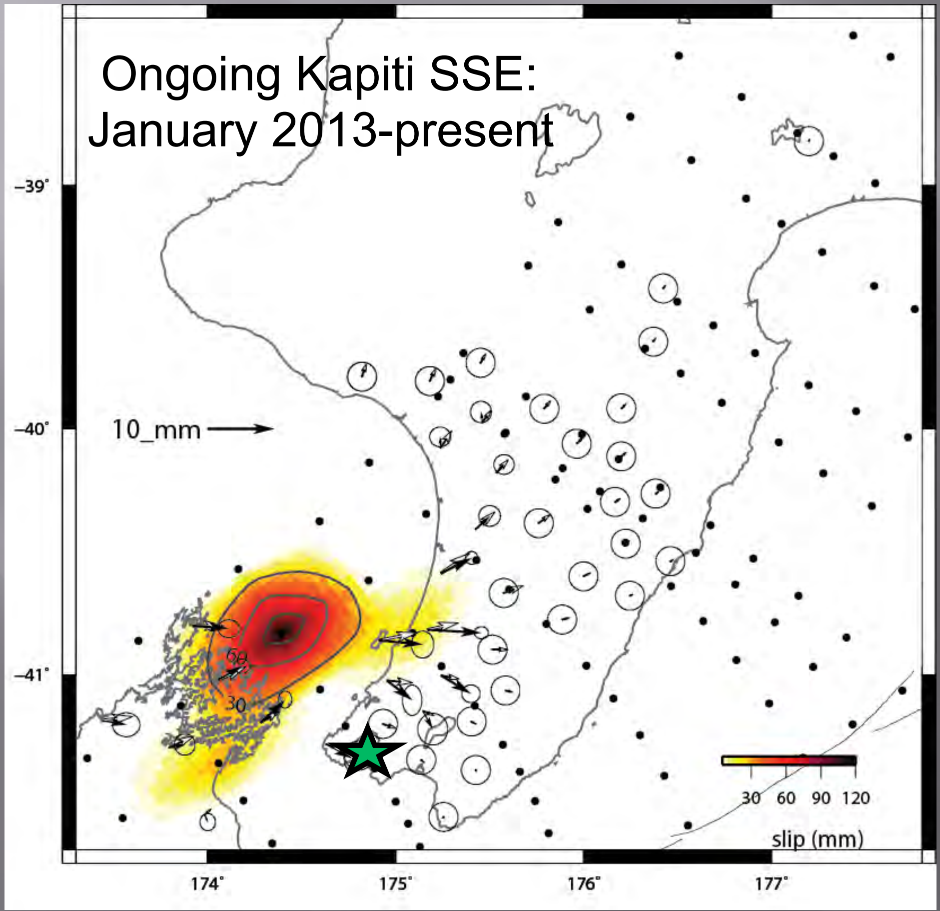
See also talk tomorrow by Bill Fry

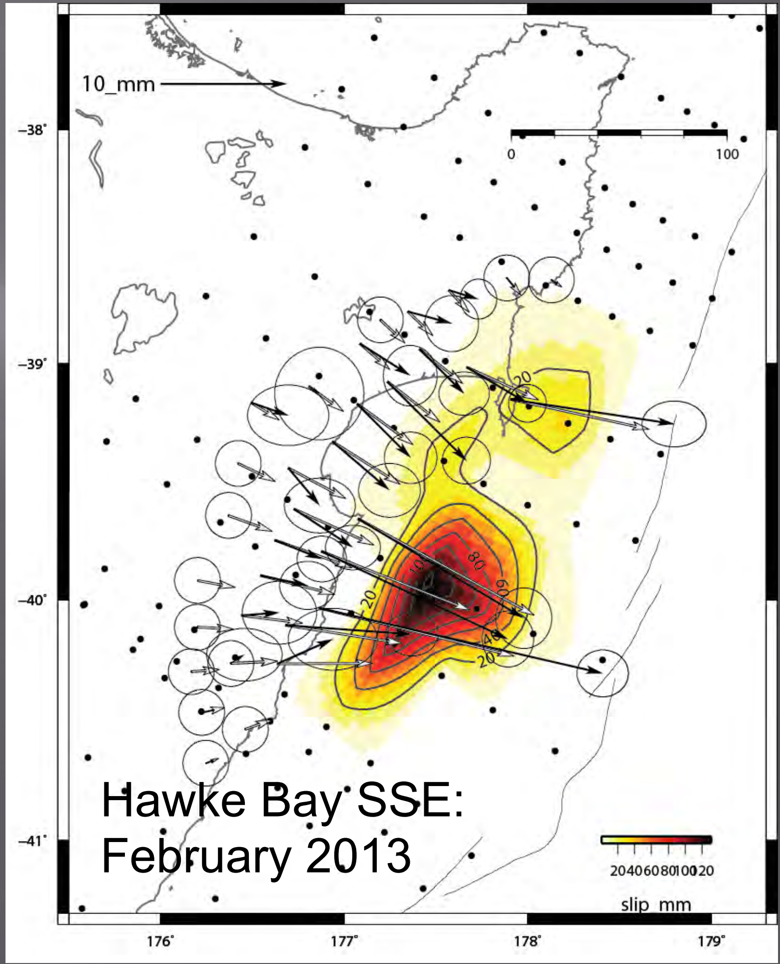
Tremor not as ubiquitous at Hikurangi— microseismicity is more important

Two major SSEs have occurred so far this year (2013)

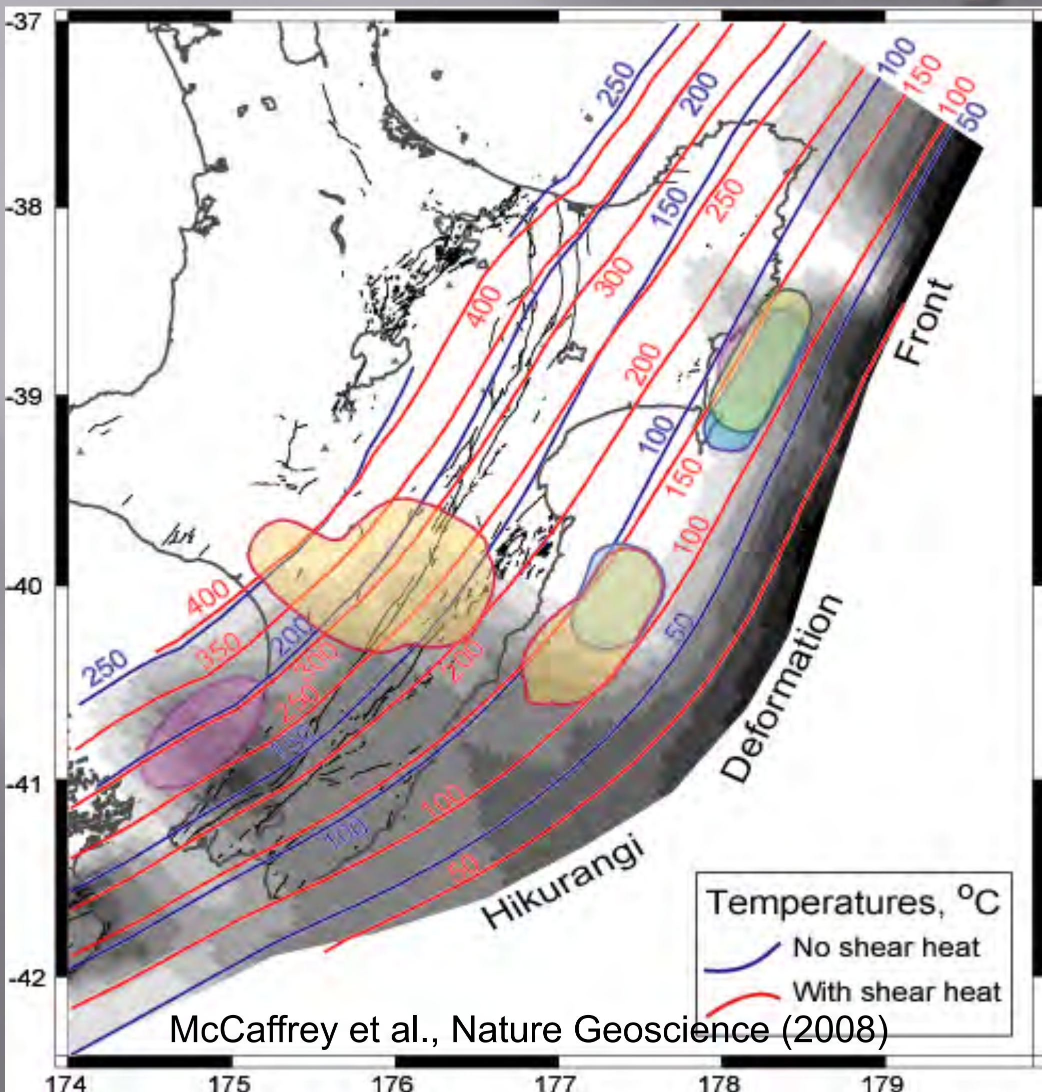
(1) The deep, long-term Kapiti SSE (west of Wellington) has started back up since January (the last occurrence was in 2008) . Equivalent Mw so far ~6.8

(2) A large, shallow east coast SSE beneath Hawkes Bay in February: equivalent Mw ~ 6.8





What controls the seismogenic zone geometry and location of slow slip at the Hikurangi margin?

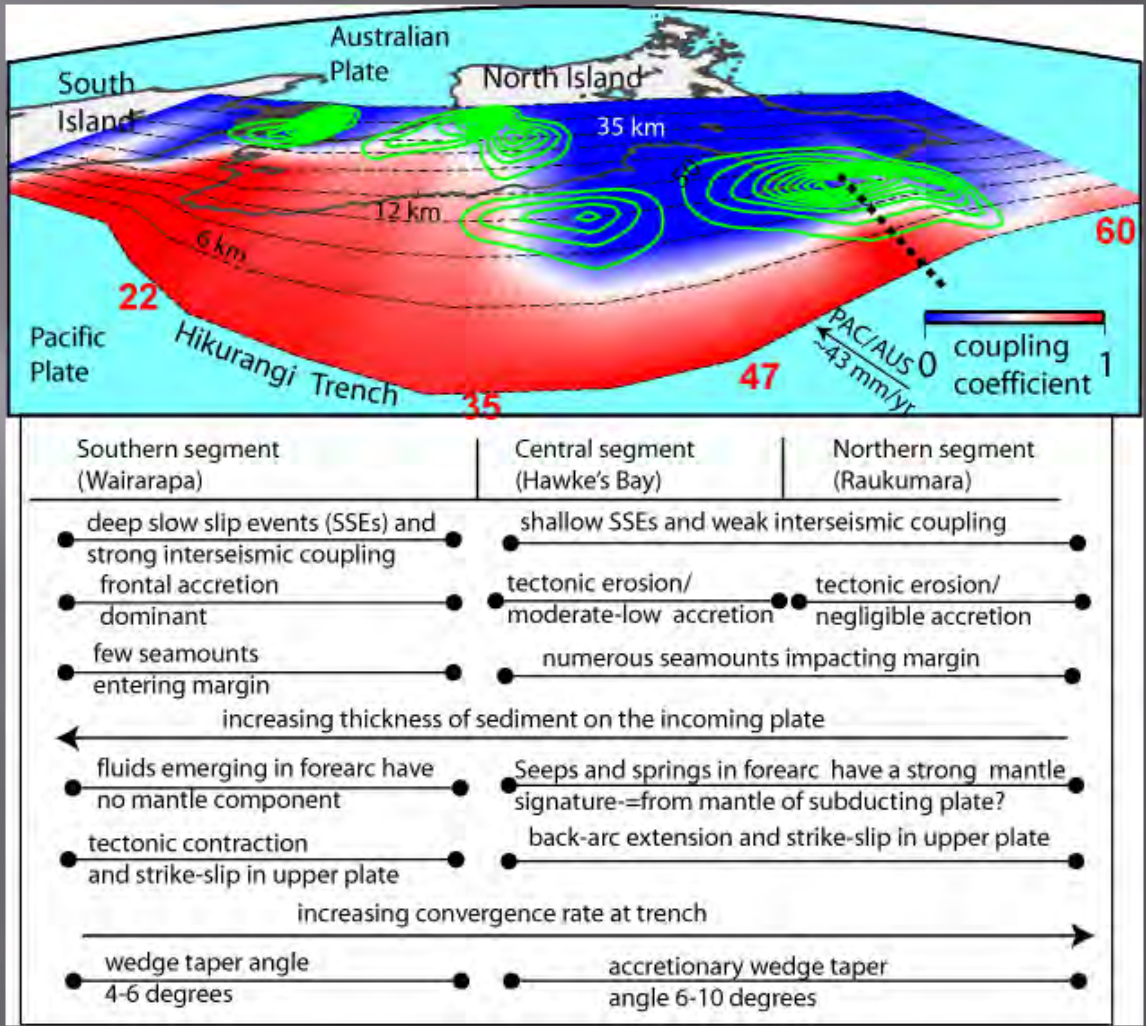


Hikurangi interseismic coupling distribution (and SSE locations) CANNOT follow a simple temperature-based model, due to along-strike changes we observe in the depth to the down-dip limit of coupling and SSEs

What parameters might control the abrupt change in depth of the down-dip limit of the seismogenic zone that we observe?

There are a number of margin characteristics that vary in concert with megathrust behavior

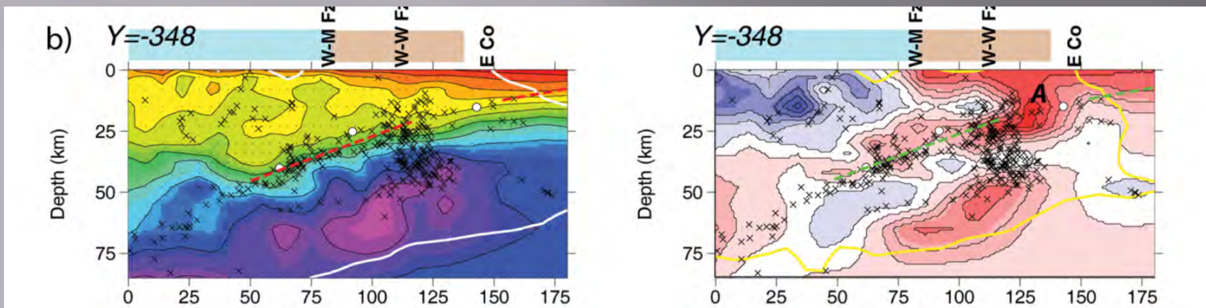
These include:
(1) a shift from an accretionary to erosional offshore margin
(2) A northward decrease in thickness of sediment on the incoming plate
(3) A larger number of seamounts protruding above the sedimentary cover in the north vs. south
(4) An along-strike change from back-arc rifting to upper plate contraction
(5) Major change in the geochemistry and volume of fluids emerging at the onshore forearc
(6) Northward increase in convergence rate
(7) Change in Vp/Vs and Qp in the upper plate and near the interface



What are the most important mechanisms that produce these along-strike variations, and what are the feedbacks between the operative processes?

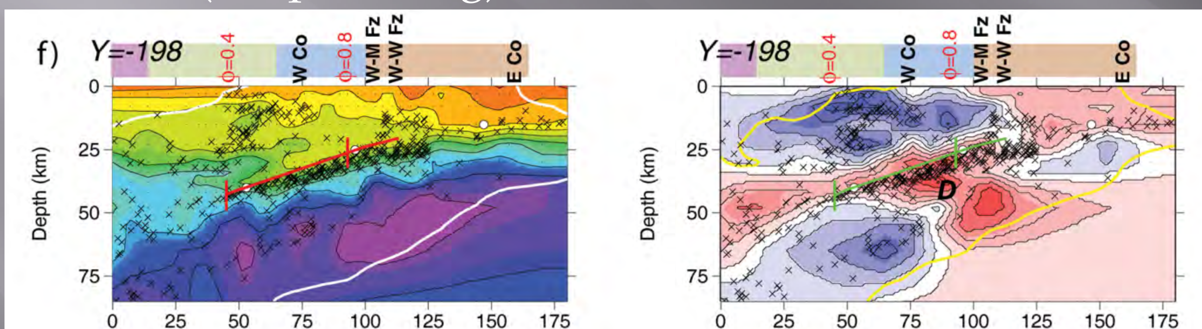
Seismic tomography and geochemical studies also show intriguing along-strike changes

NORTH (slow slip)

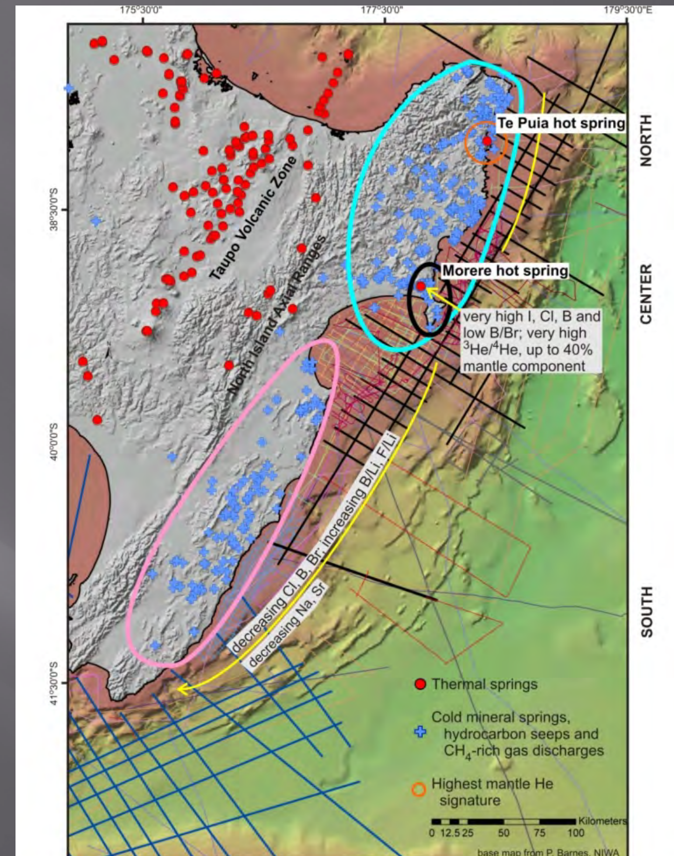


SOUTH (deep locking)

Eberhart Phillips and Reyners, 2012



There is a sharper gradient in Vp/Vs near the plate interface in the region of deep interseismic coupling vs. the region where the interface is dominated by slow slip. This may be telling us something about the distribution of fluids near the subduction interface and within the upper plate between the two areas.



Distribution of hot springs and cold springs, hydrocarbon seeps and gas vents in the Hikurangi emergent forearc, North Island Axial Ranges and the Taupo Volcanic Zone. General fluid chemical and isotopic compositional trends are shown for the Hikurangi forearc. The northern, central and southern sectors of the forearc are encircled (Reyes in prep.).

Geochemistry of fluids emerging at the surface in seeps and springs also show compelling along-strike variations (Agnes Reyes-see talk tomorrow).

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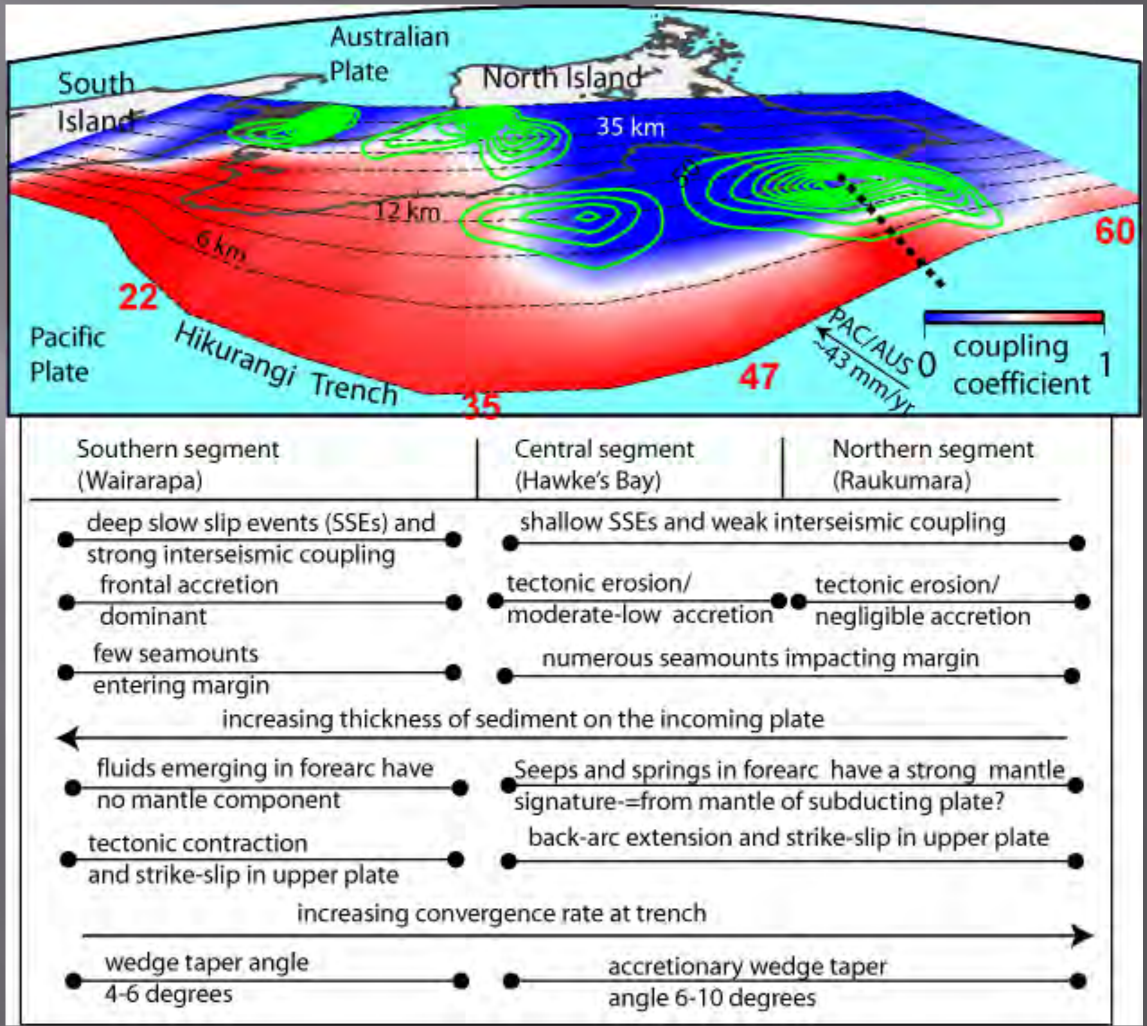

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