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.

Ministry of Economic Development Manatū Ōhanga

Te Whare Wānanga o Te Ūpoko o Te Ika a Māui Victoria University of Wellington

ministry of science + innovation Te Pūnaha Hiringa Whakaea

GNS Science Te Pū Ao

Earthquake Research Institute, The University of Tokyo

USC University of Southern California

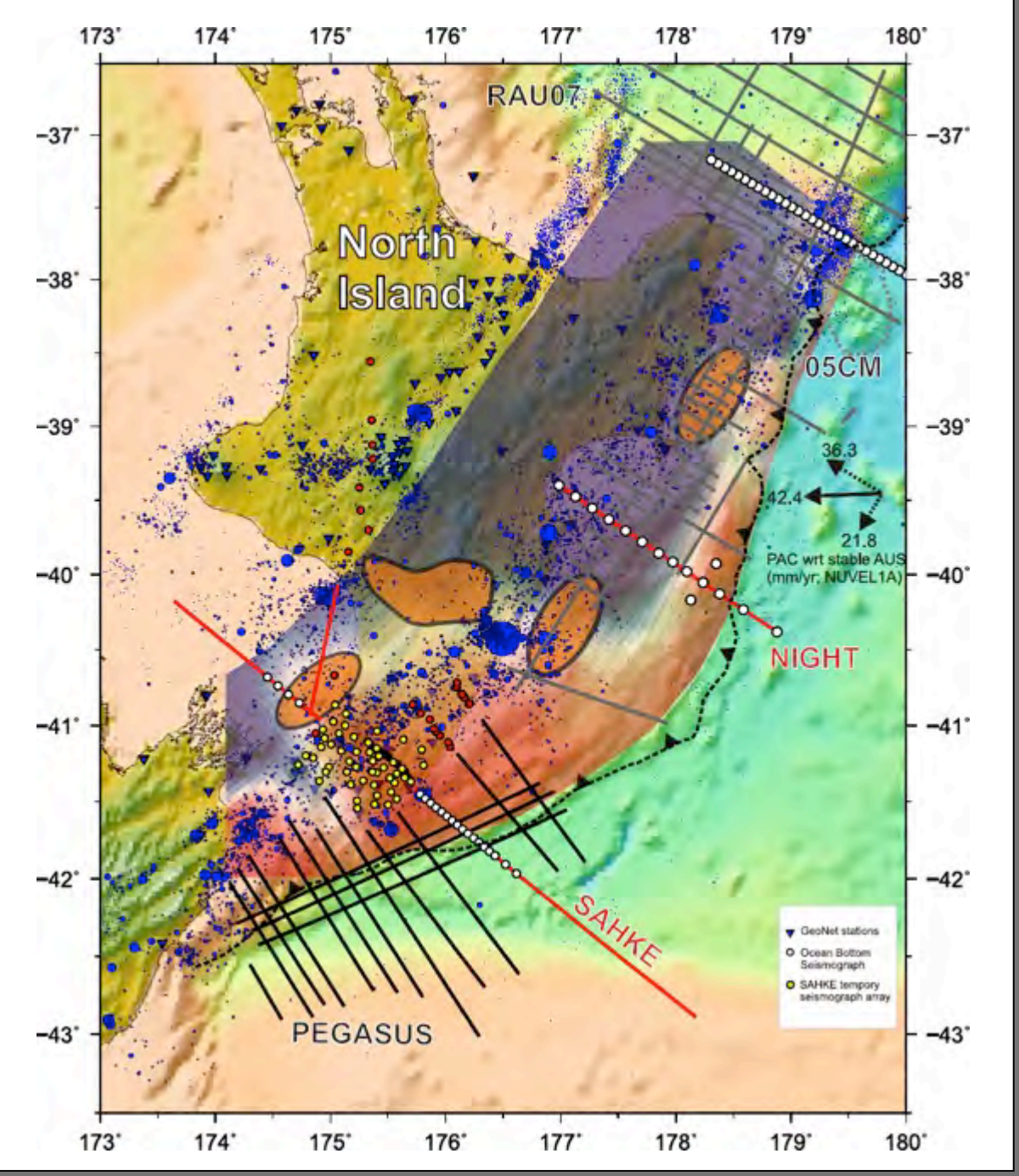
EQC Earthquake Commission

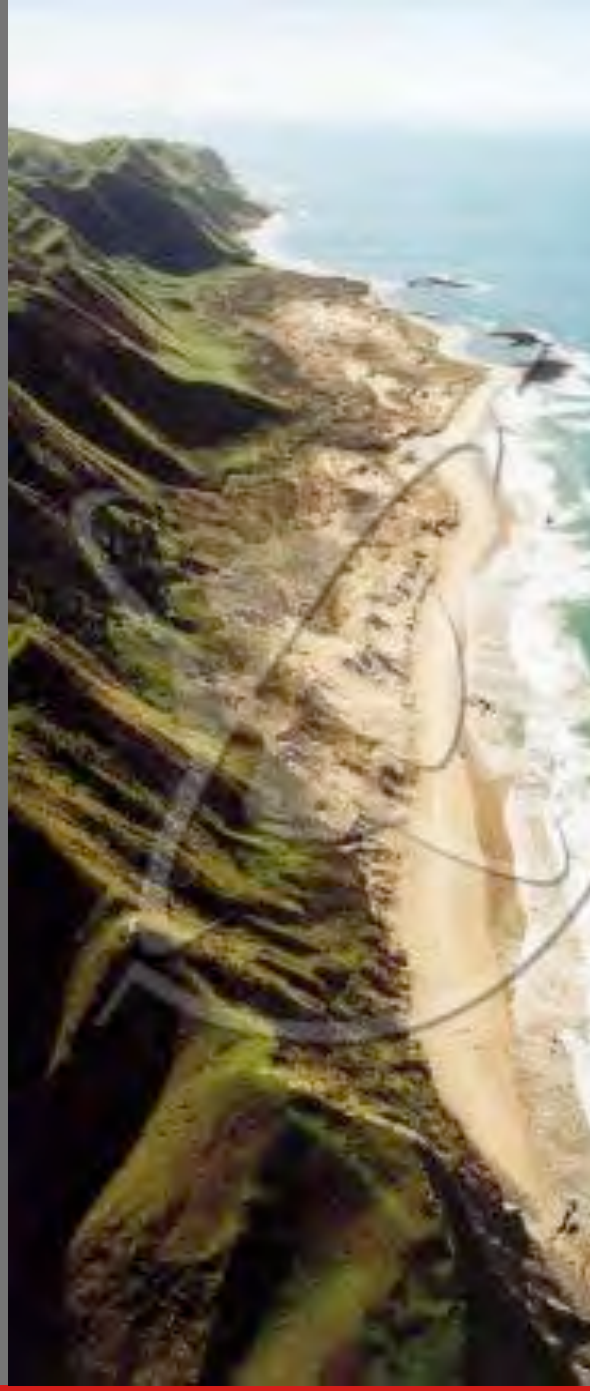
NSF

Seismic Array HiKurangi Experiment: SAHKE

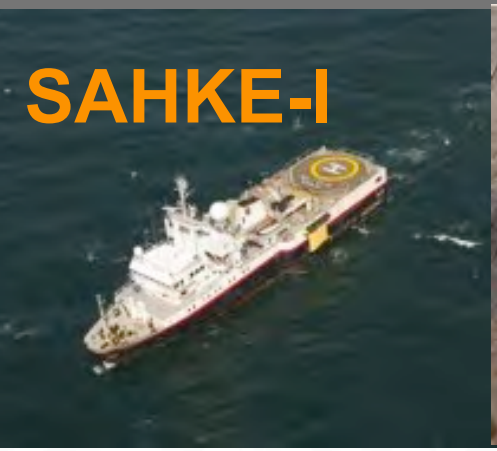
Question: What is the strength of the plate interface beneath Wellington? — Work in progress

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

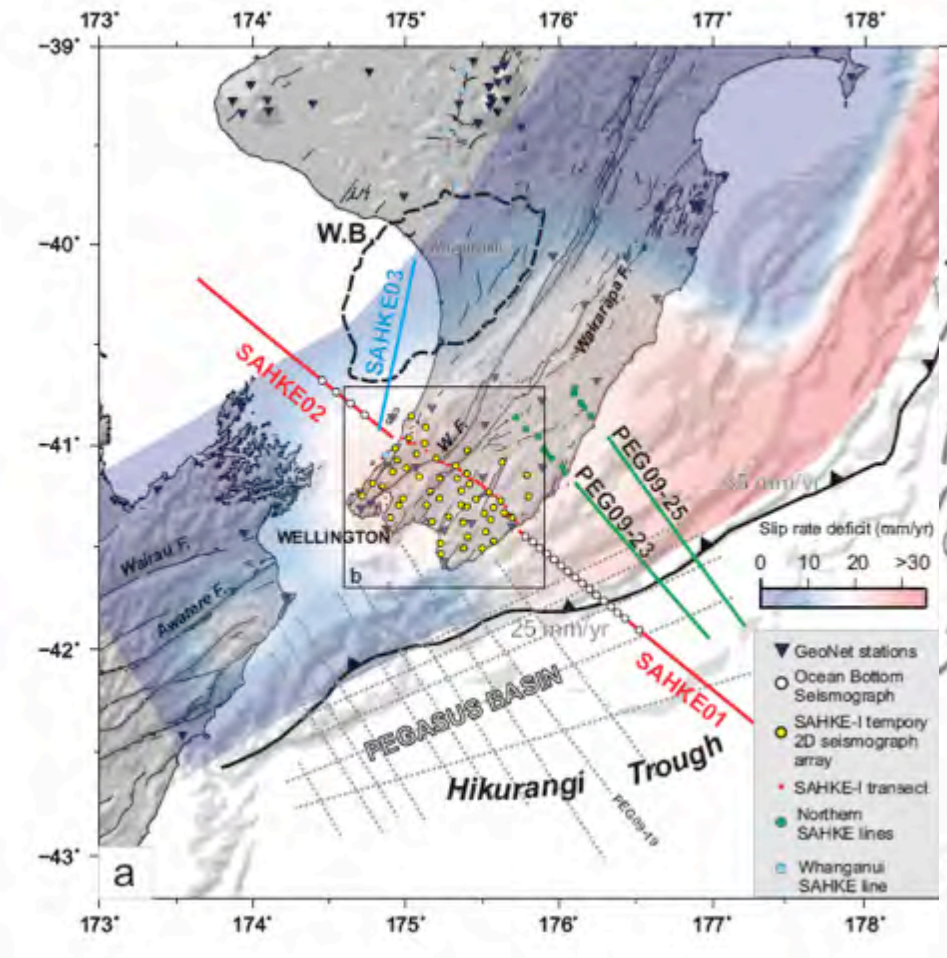

173°
174°
175°
176°
177°
178°
179°
180°
-37°
-38°
-39°
-40°
-41°
-42°
-43°
RAU07
North Island
05CM
36.3
42.4
21.8
PAC wrt stable AUS (mm/yr, NUVEL1A)
NIGHT
SAHKE
PEGASUS
GeoNet stations
Ocean Bottom Seismograph
SAHKE tempory seismograph array

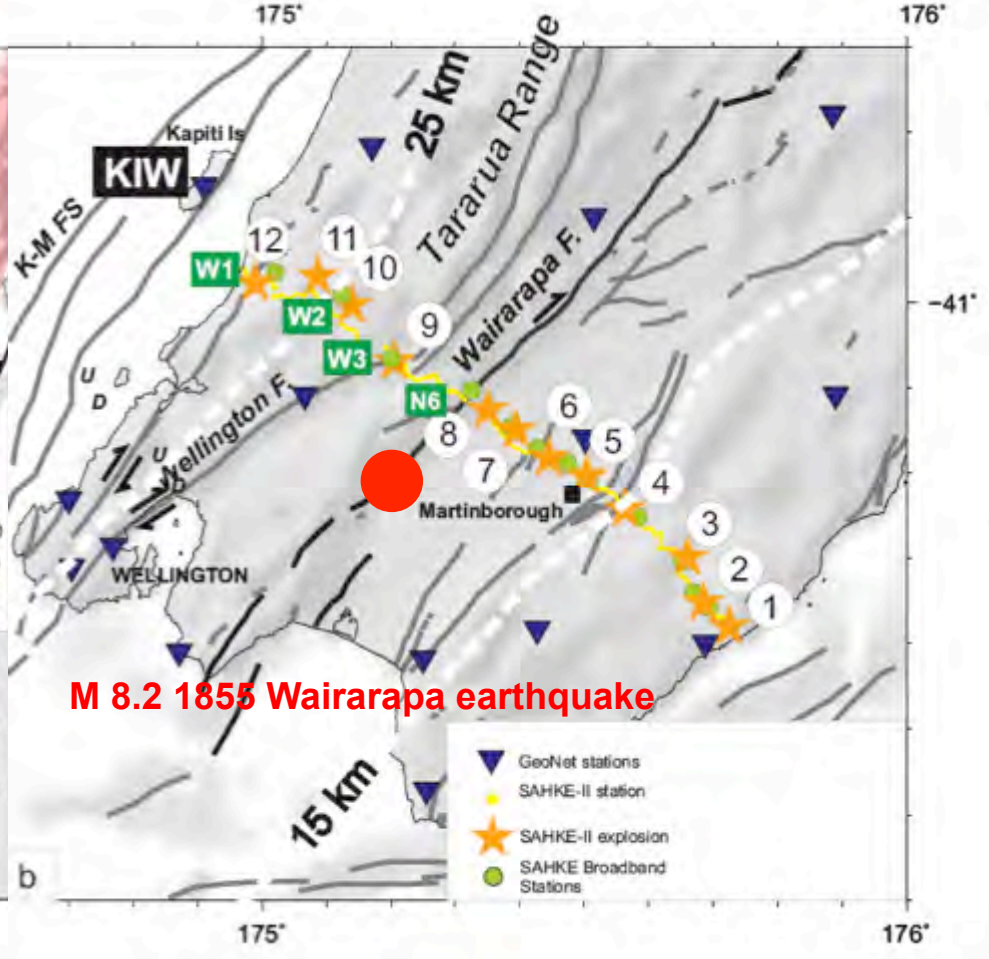


SAHKE-I



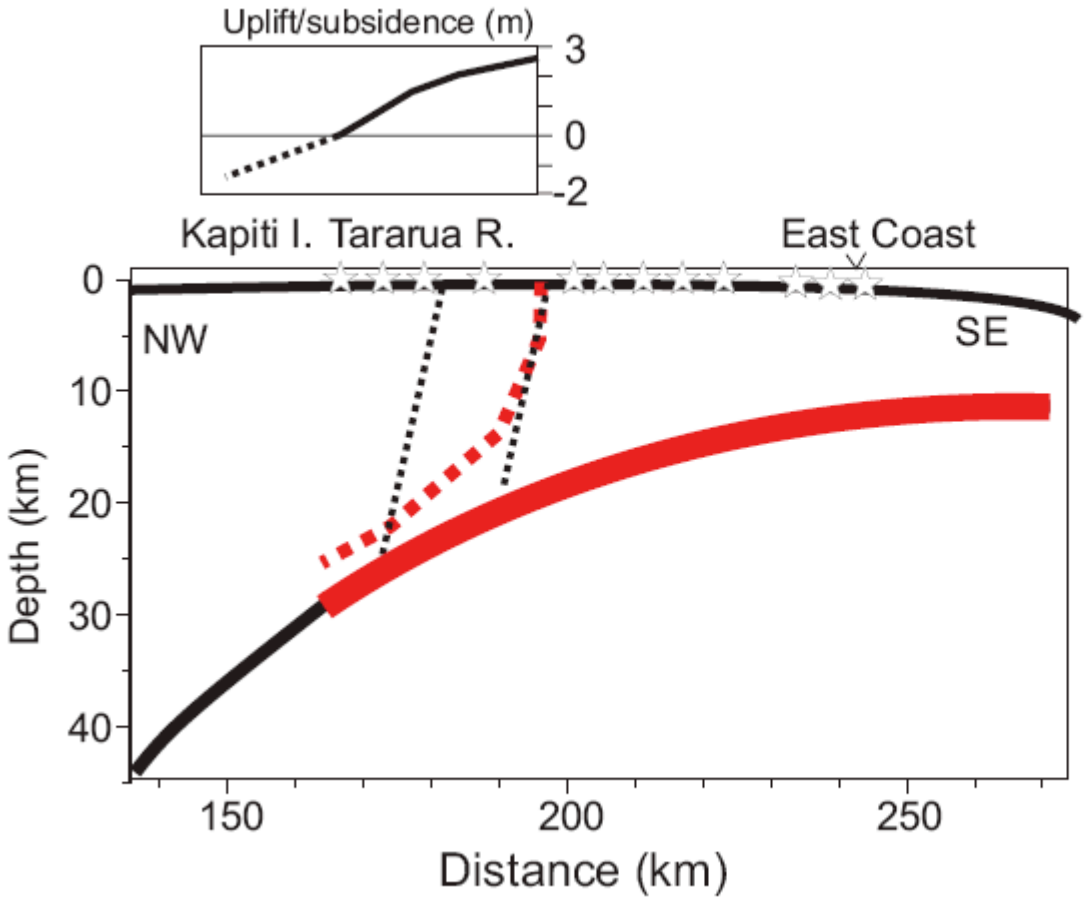
SAHKE-II



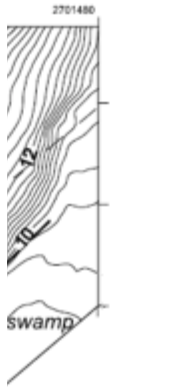


Wairarapa Fault: M8.2 1855 Earthquake

and Little 2005

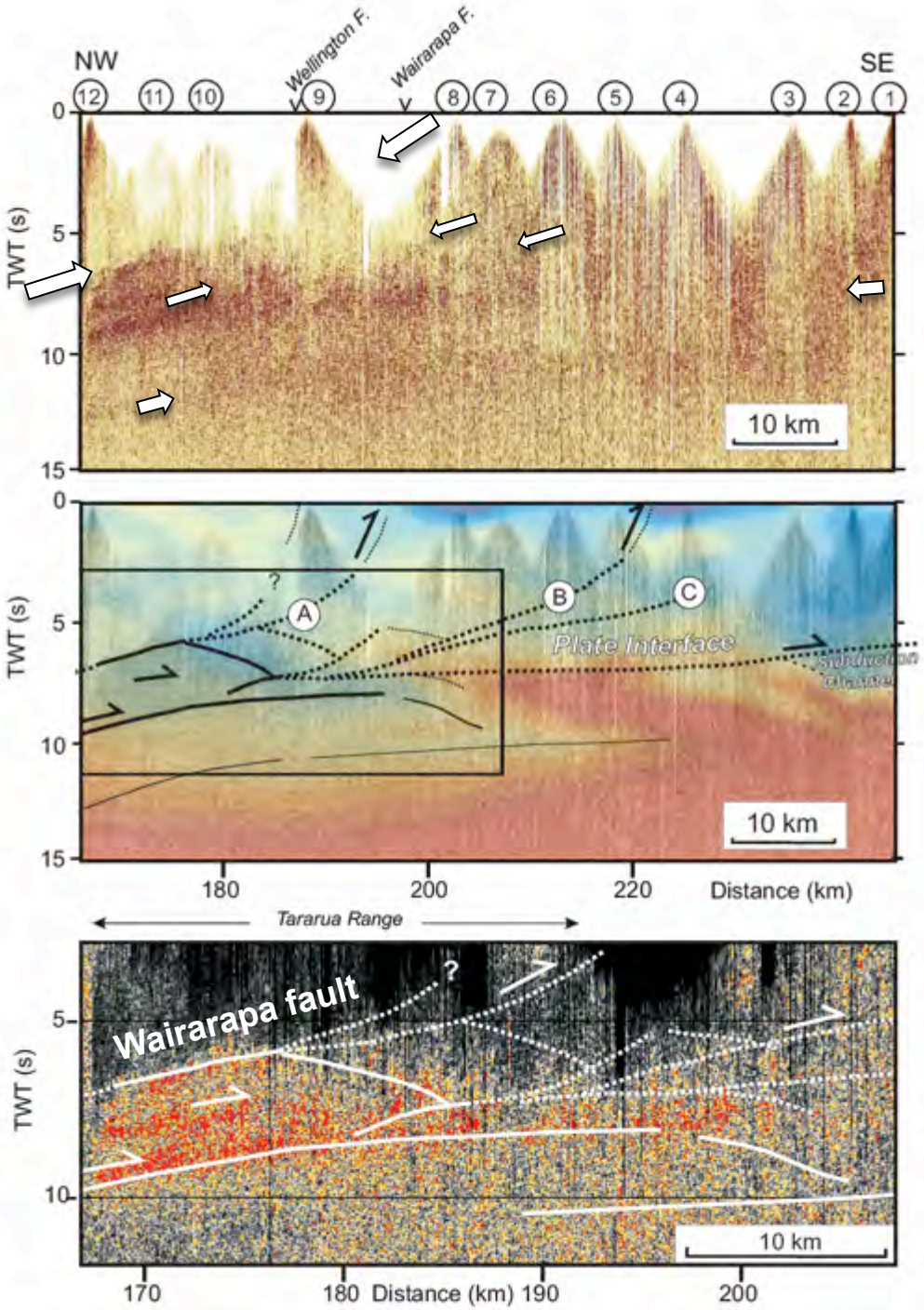


GPS observations can be explained by 100% coupling on the plate interface to ~30 km depth.

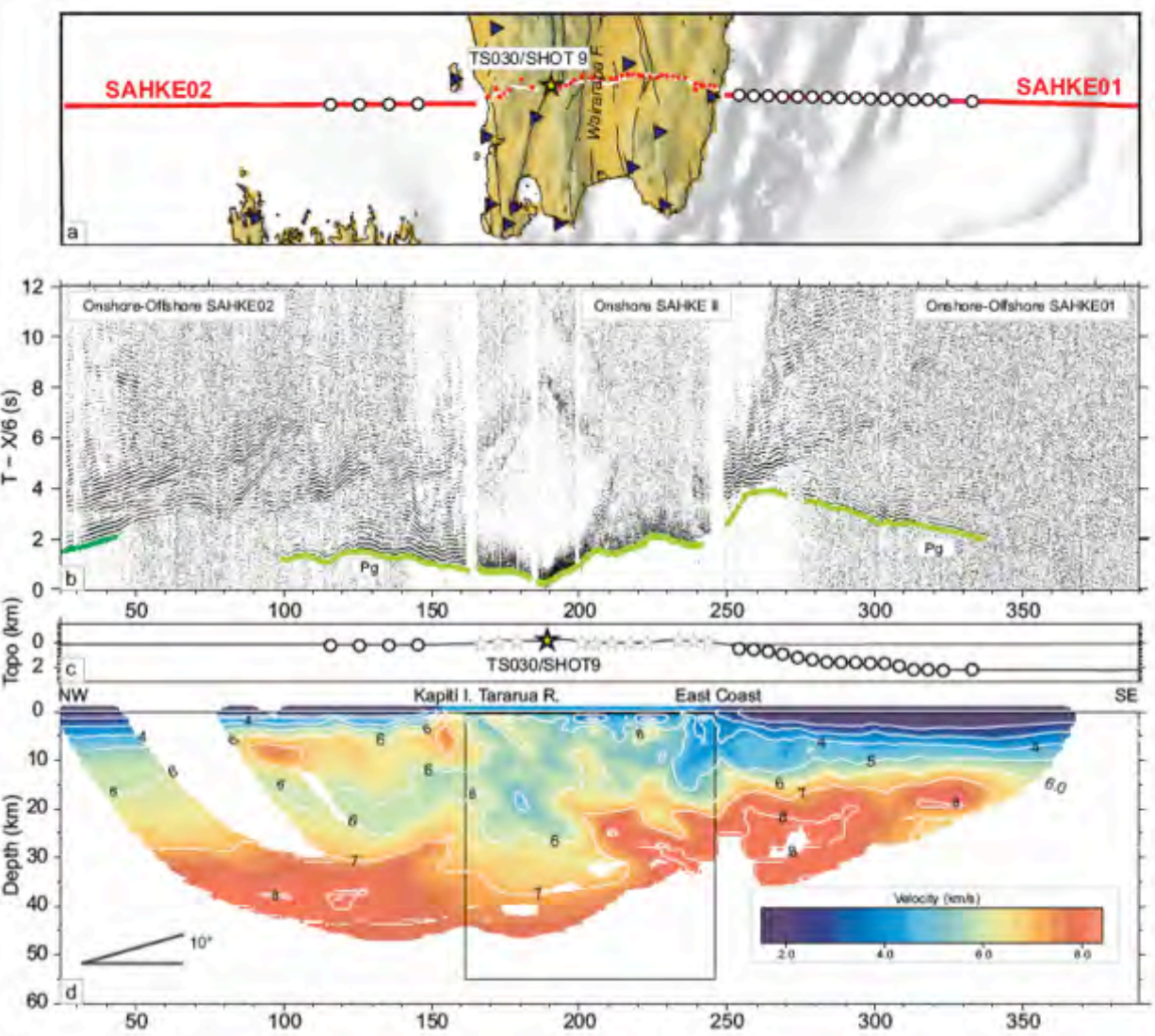


horizontally.

Darby and Beanland 1992 Darby and Beavan 2000


NW
SE
Wellington F.
Wairarapa F.
12
11
10
9
8
7
6
5
4
3
2
1
TWT (s)
0
5
10
15
10 km
A
B
C
Plate Interface
180
200
220
Distance (km)
Tararua Range
Wairarapa fault
?
170
180
190
200


Wairarapa fault



1st arrival tomography

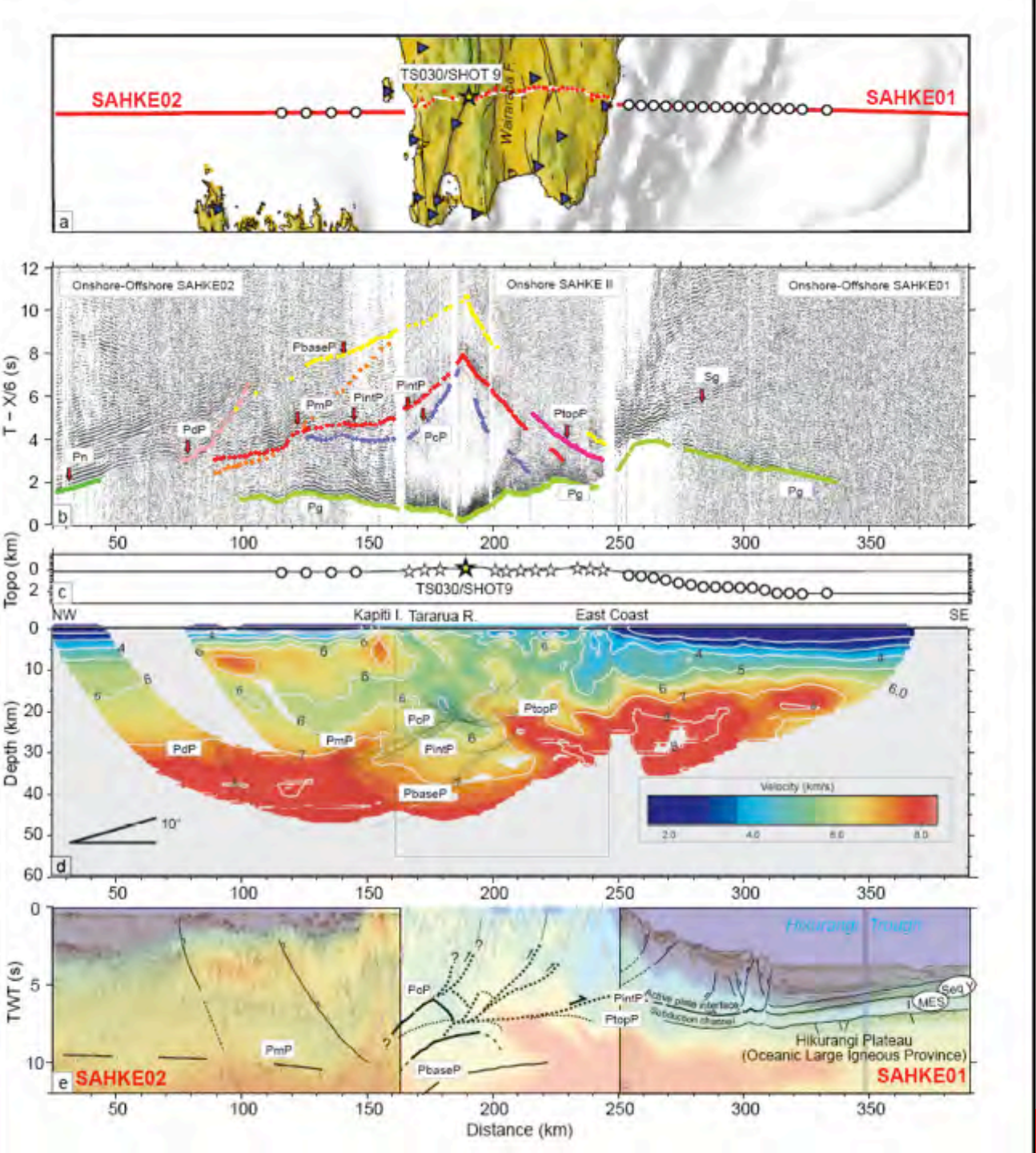
of 18000 picks

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

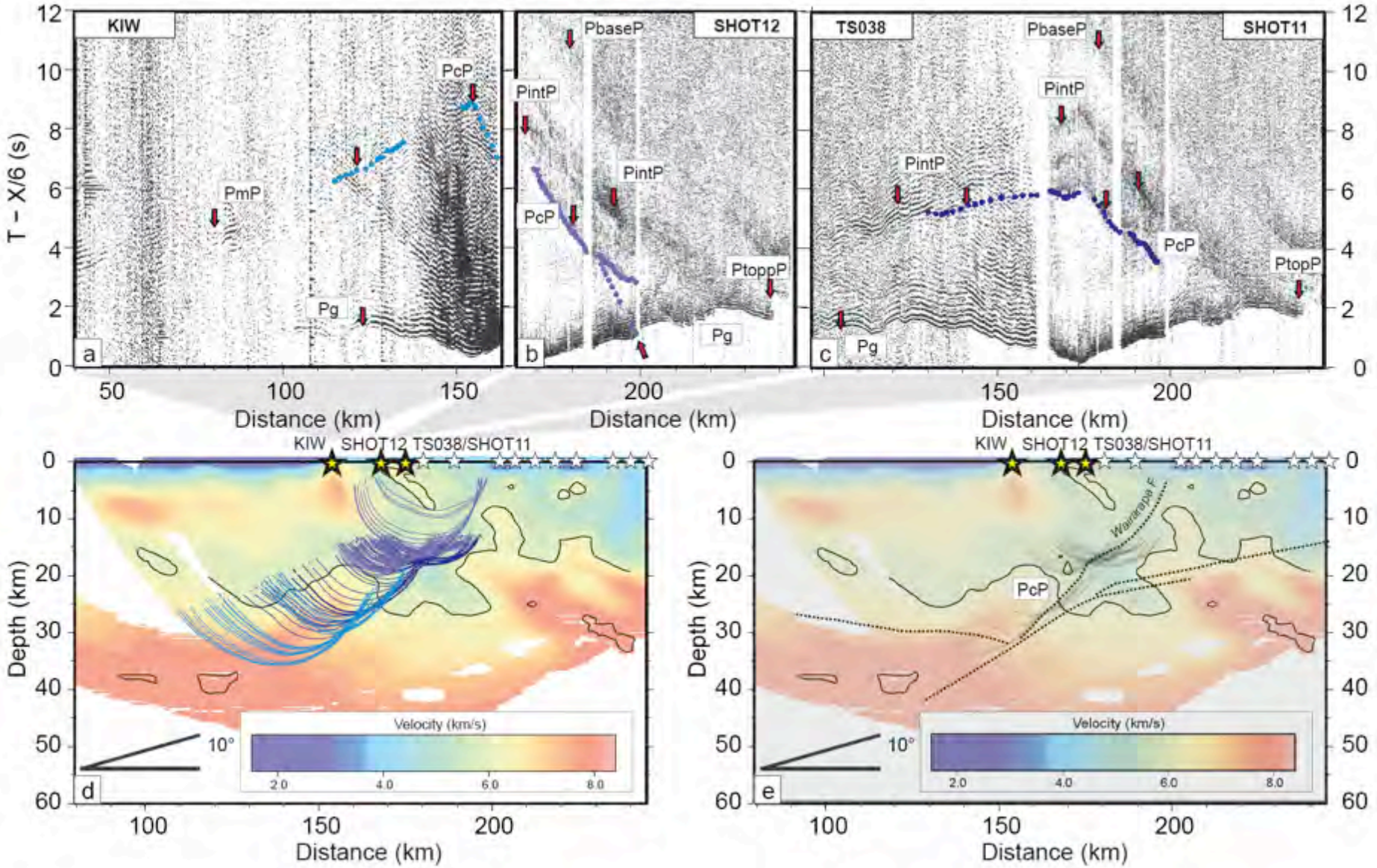
PbaseP

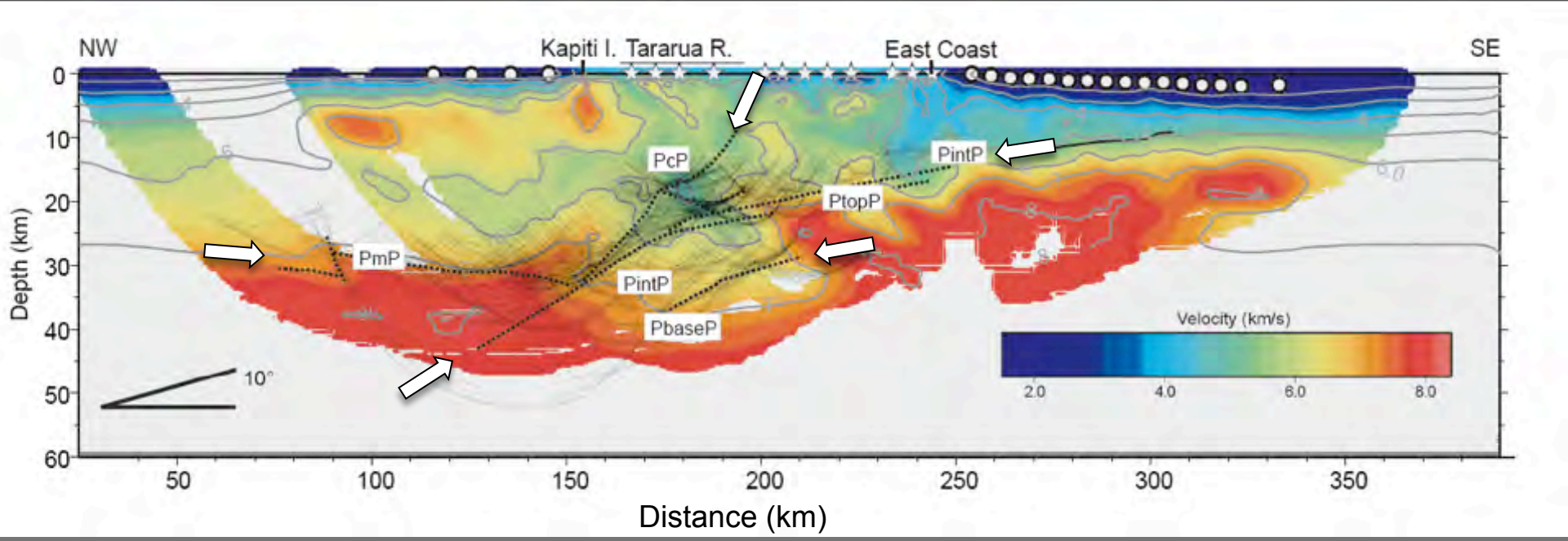
Australian Crust Moho

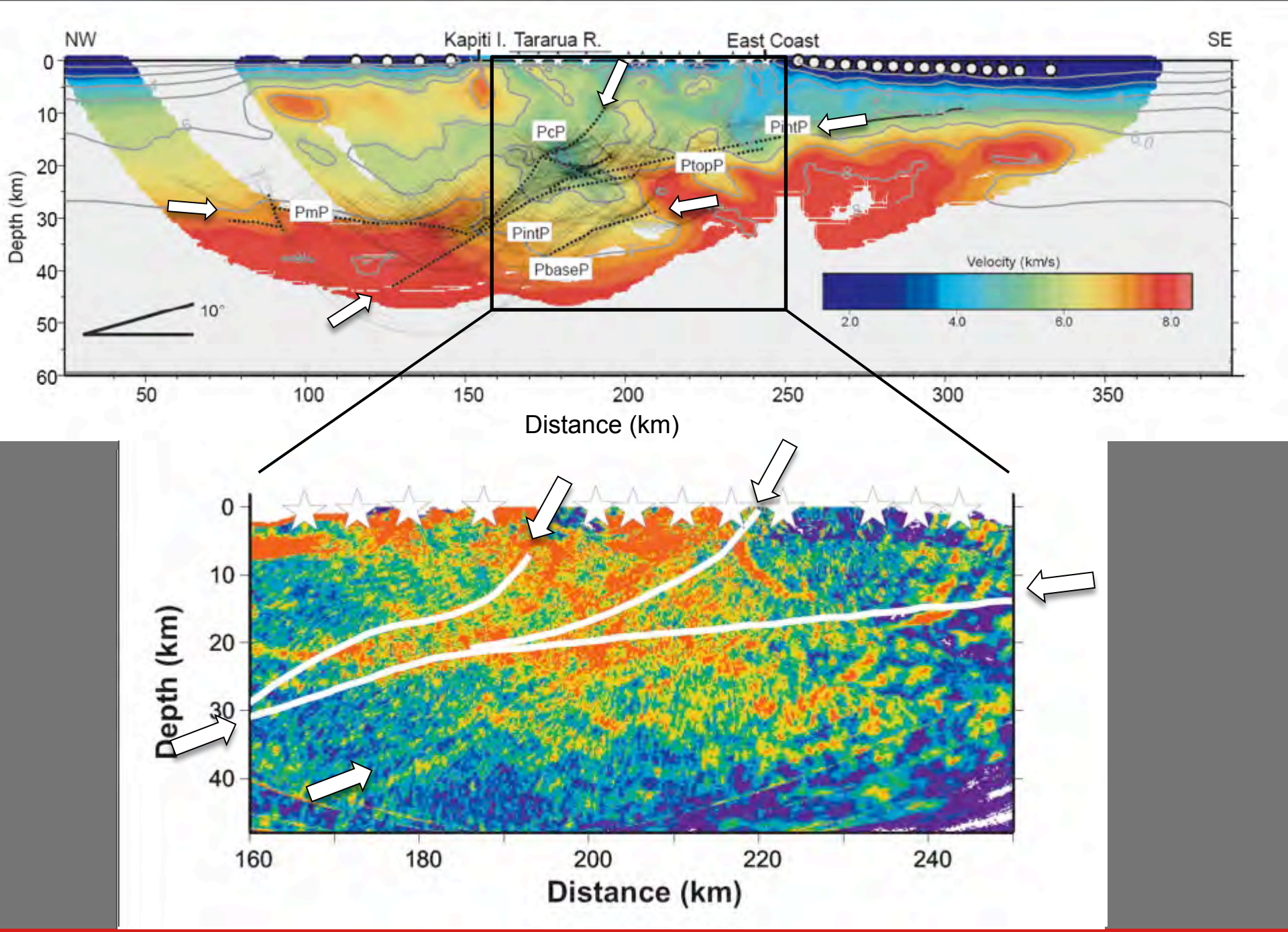
PmP, PdP

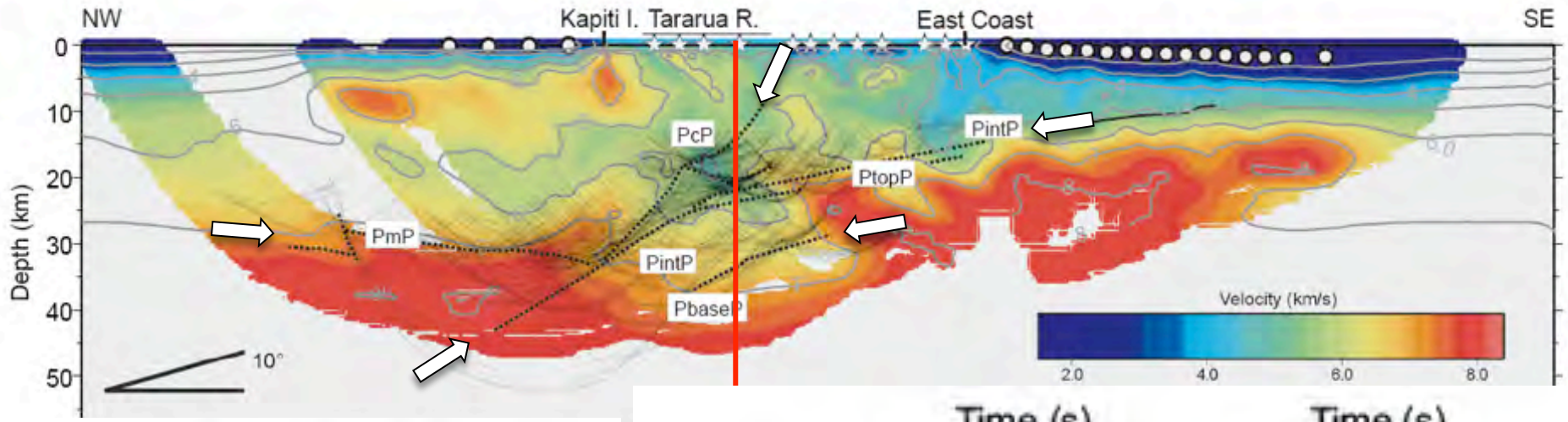
Upper Crust

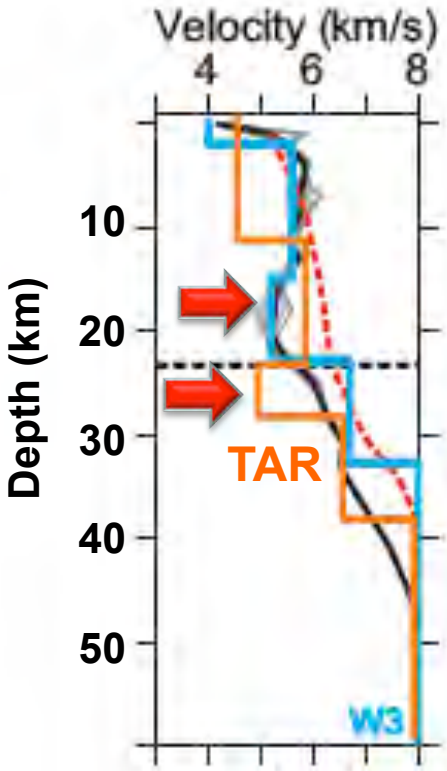
PcP

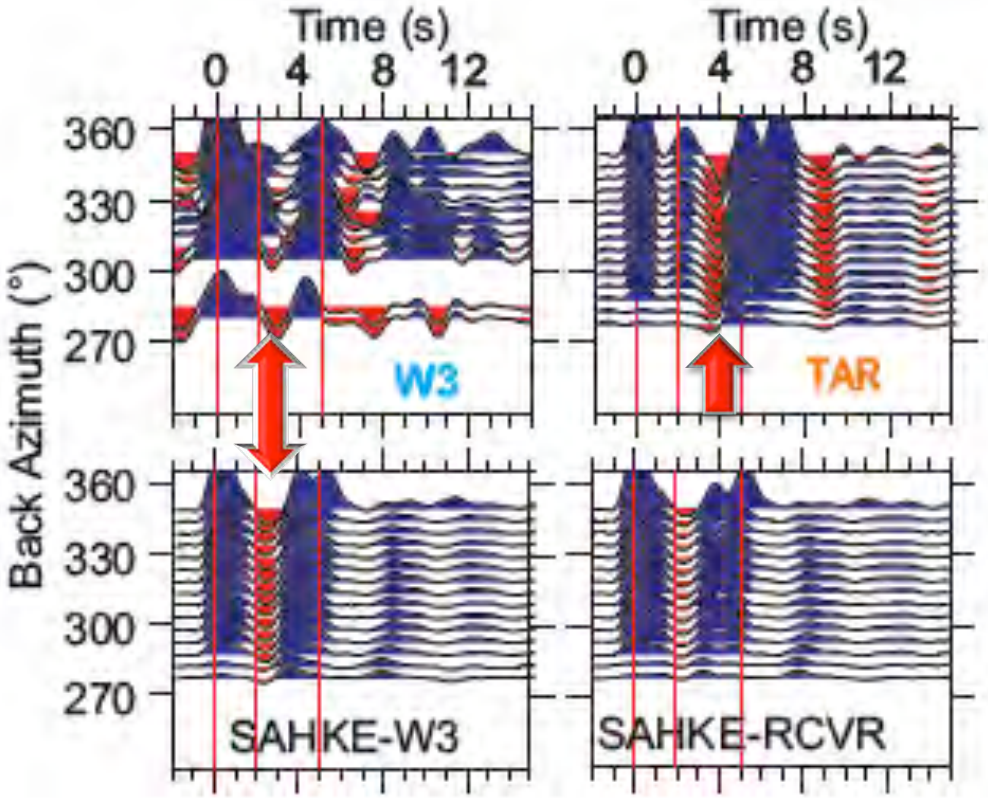

KIW
PcP
PmP
Pg
a
T – X/6 (s)
Distance (km)
PbaseP
SHOT12
PintP
PintP
PcP
PtoppP
Pg
b
Distance (km)
TS038
PbaseP
SHOT11
PintP
PintP
PcP
PtopP
Pg
c
Distance (km)
KIW
SHOT12
TS038/SHOT11
Depth (km)
Velocity (km/s)
2.0
4.0
6.0
8.0
10°
d
Distance (km)
KIW
SHOT12
TS038/SHOT11
Waiarapa F
PcP
Depth (km)
Velocity (km/s)
2.0
4.0
6.0
8.0
10°
e
Distance (km)


NW
Kapiti I.
Tararua R.
East Coast
SE
PcP
PintP
PtopP
PmP
PintP
PbaseP
10°
Velocity (km/s)
2.0
4.0
6.0
8.0
Depth (km)
0
10
20
30
40
50
60
50
100
150
200
250
300
350
Distance (km)

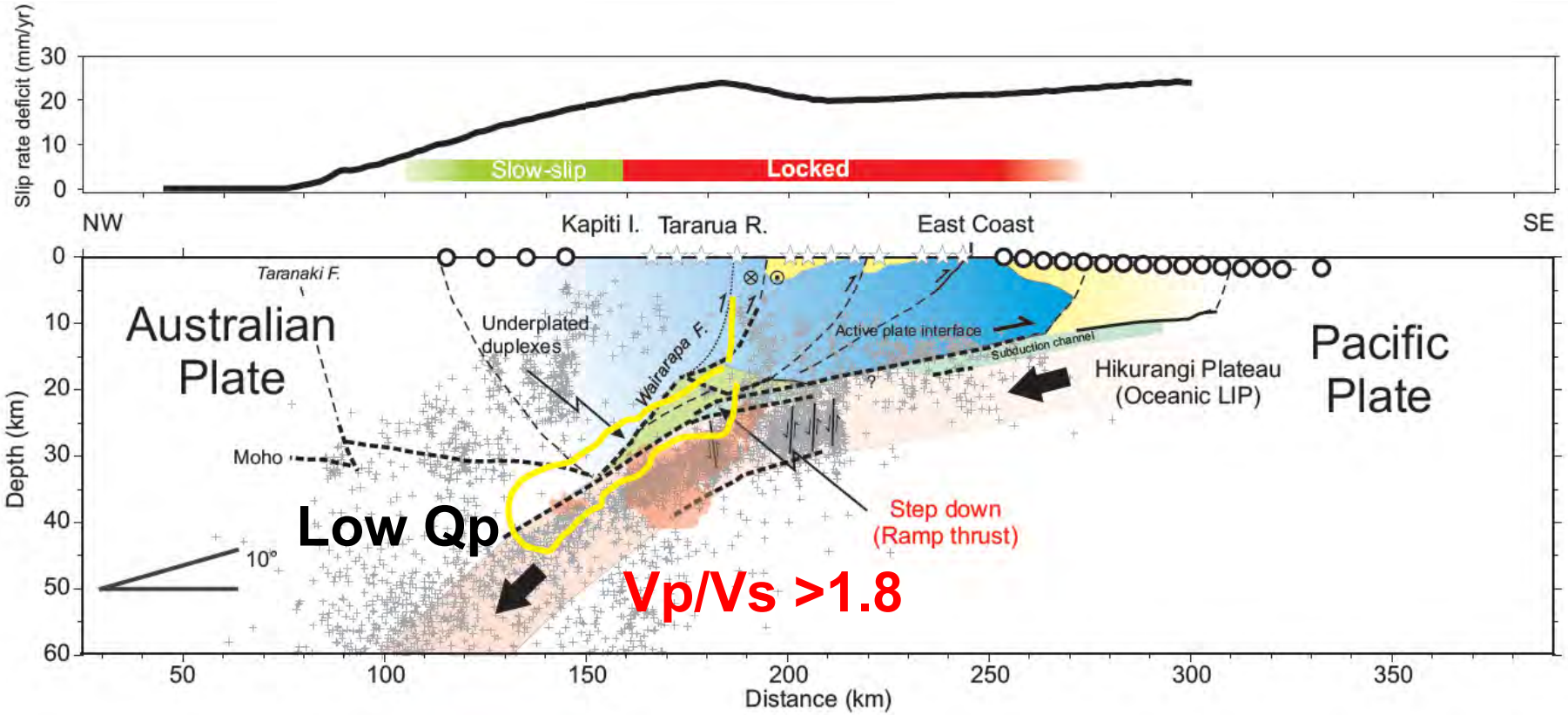

NW
Kapiti I.
Tararua R.
East Coast
SE
Depth (km)
Distance (km)
PcP
PintP
PtopP
PmP
PintP
PbaseP
10°
Velocity (km/s)
2.0
4.0
6.0
8.0
Depth (km)
Distance (km)







Vp/Vs = 1.78 **Vp/Vs = 1.7**

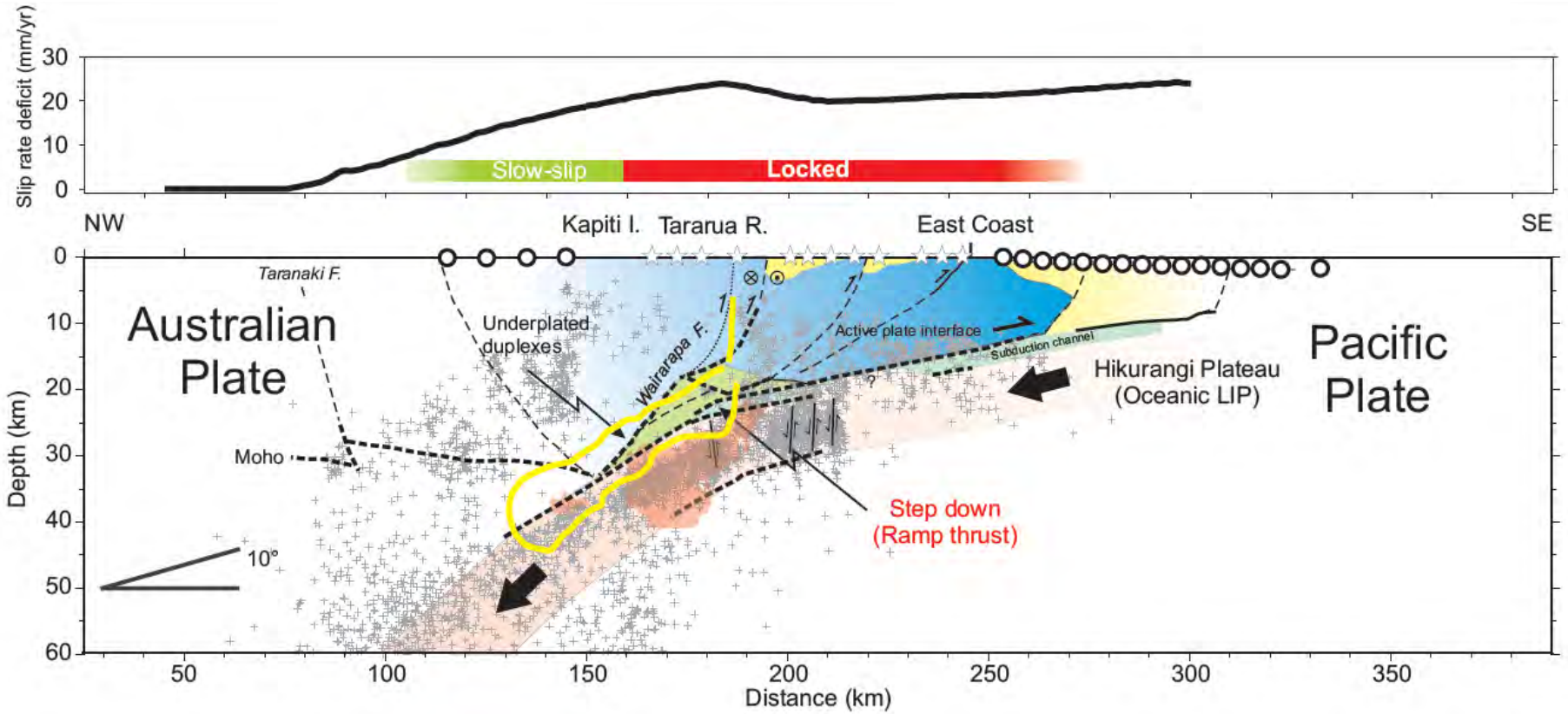


Eberhart-Phillips et al., 2005

[Eberhart-Phillips and Reyners, 2012

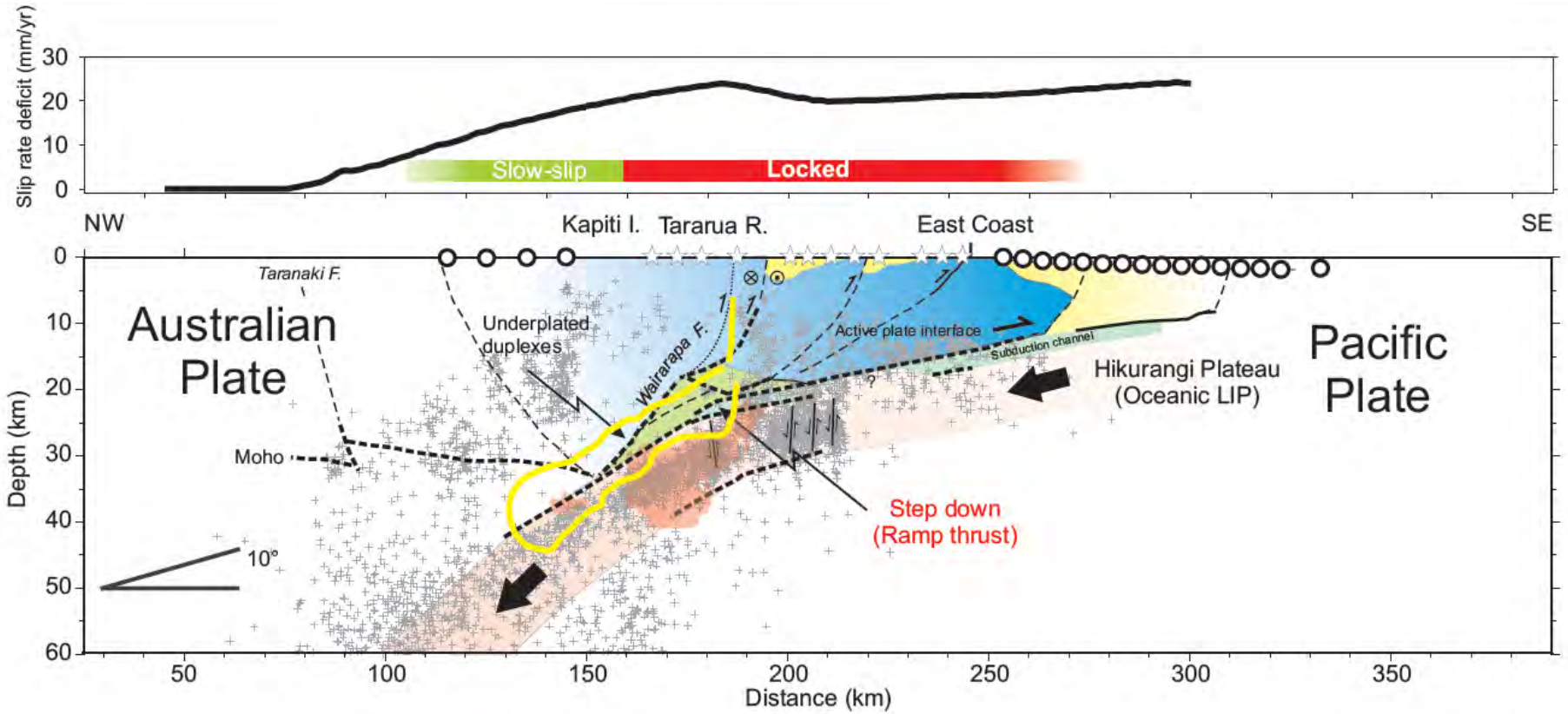
Subducting Sediment Channel and Underplating

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

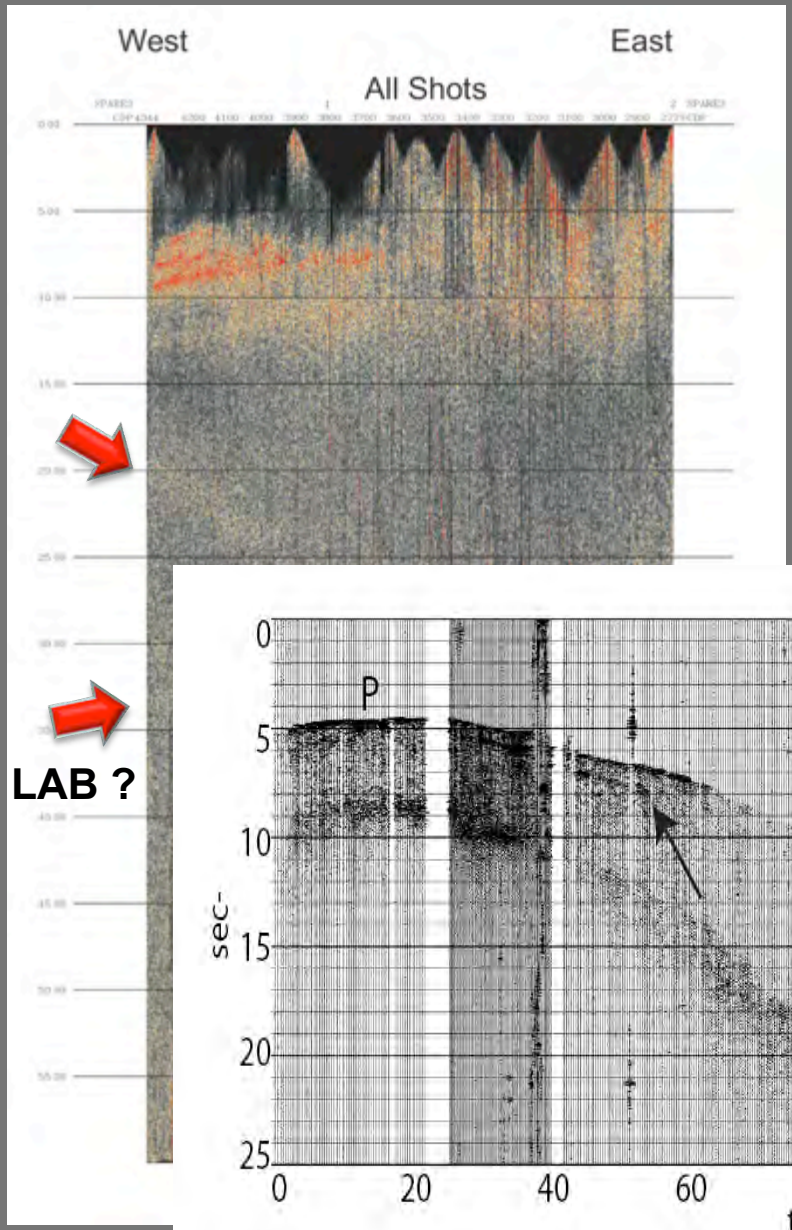
1. We have developed a 2D P-wave velocity model across a 350 km long transect of the Hikurangi margin subduction zone with the aim of determining properties of the locked subduction thrust.

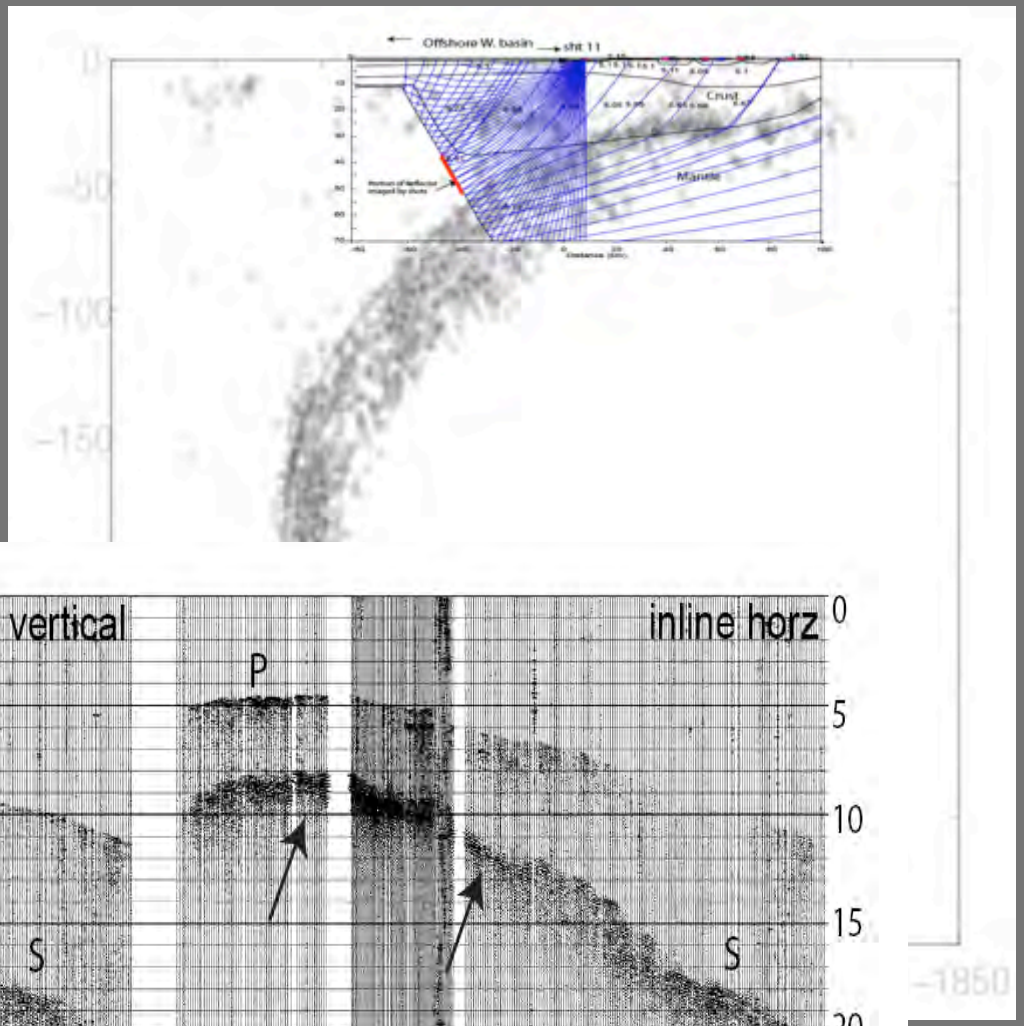
2. Imaged stacked imbricated sheets of sedimentary material from the top of the Hikurangi Plateau, into the footwall of the Wairarapa fault, driving uplift of the Tararua Range, and may be acting as a seal trapping fluid in the oceanic crust.

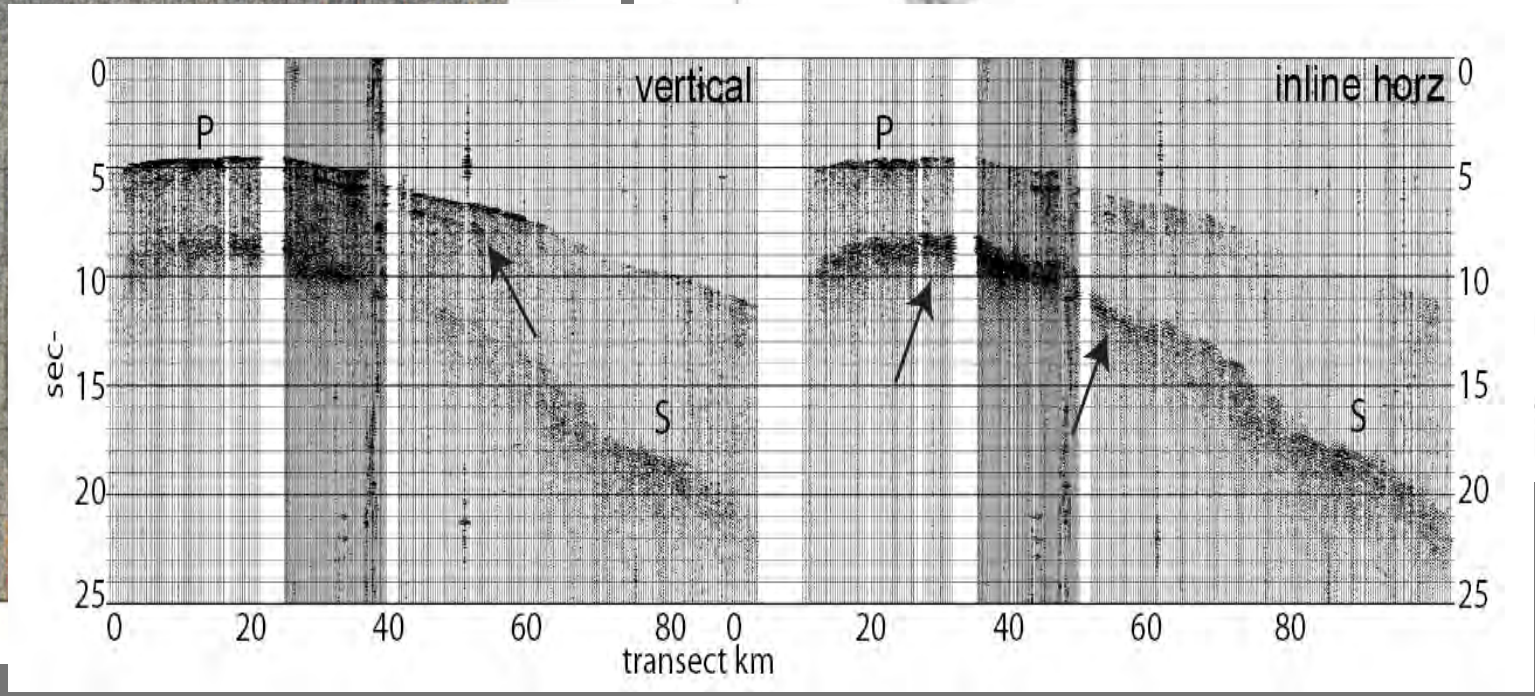
Conclusions

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.

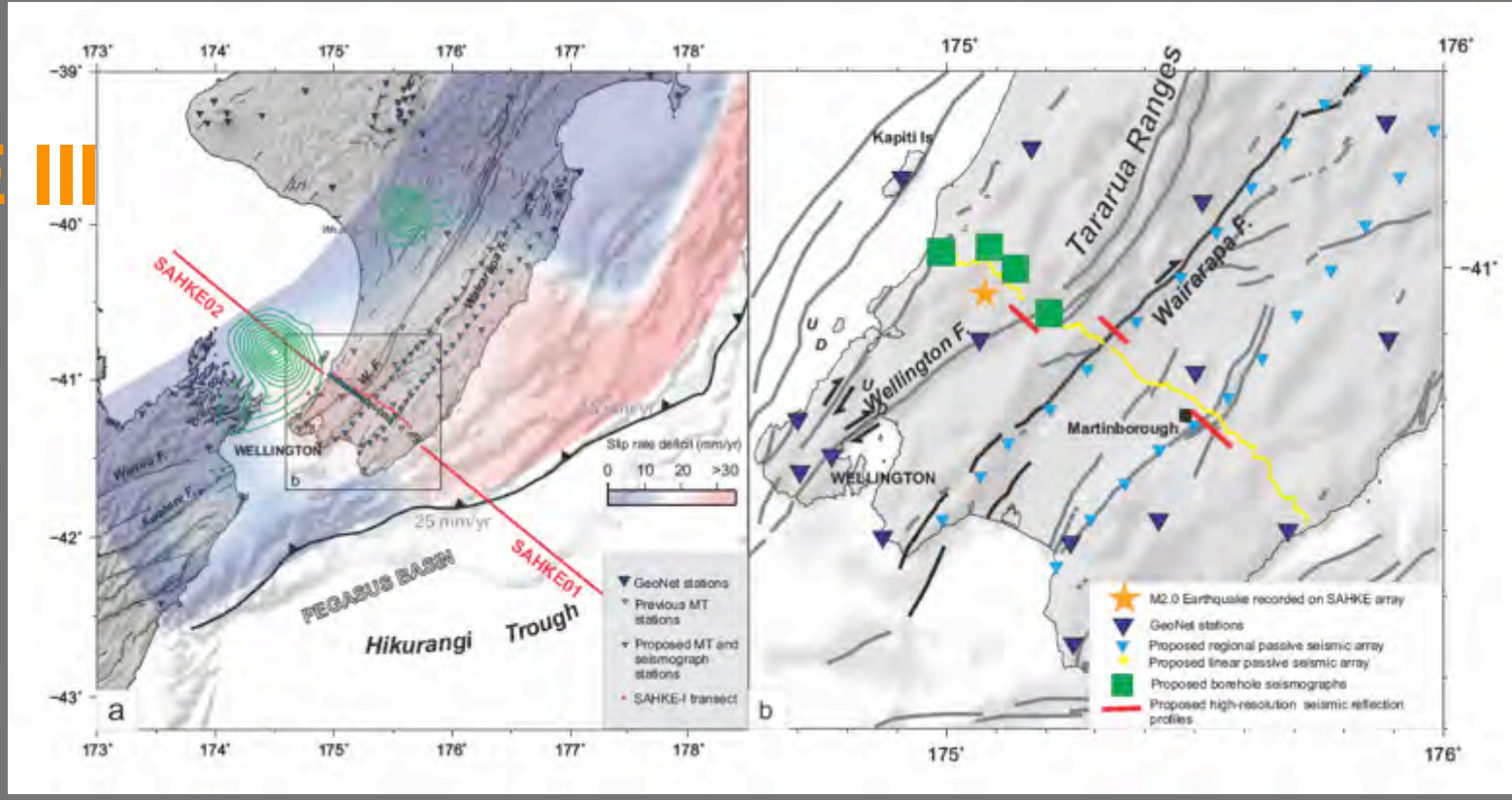
4. Abrupt slab-dip changes are inferred to have implications for seismicity where bending points may act as barriers to rupture propagation.


West
East
All Shots
LAB ?


Offshore W. basin
shit 11
Crust
Mantle


vertical
inline horz
P
P
S
S
sec-
0
5
10
15
20
25
0
20
40
60
80
0
20
40
60
80
transect km

SAHKE III



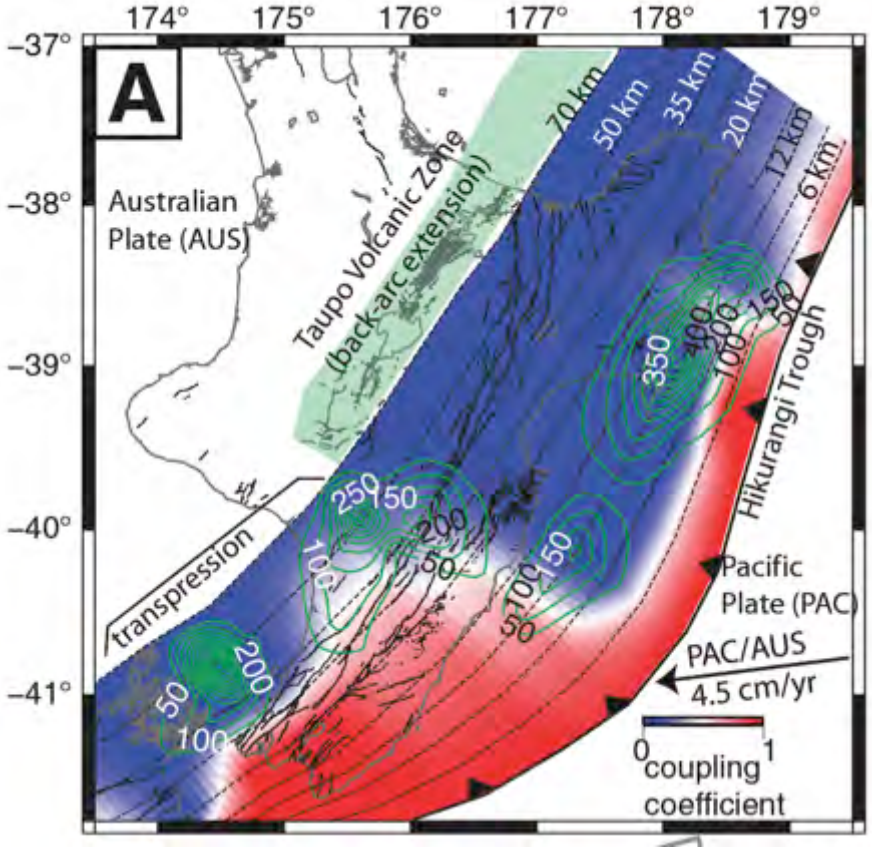
Complimentary seismic and MT observations

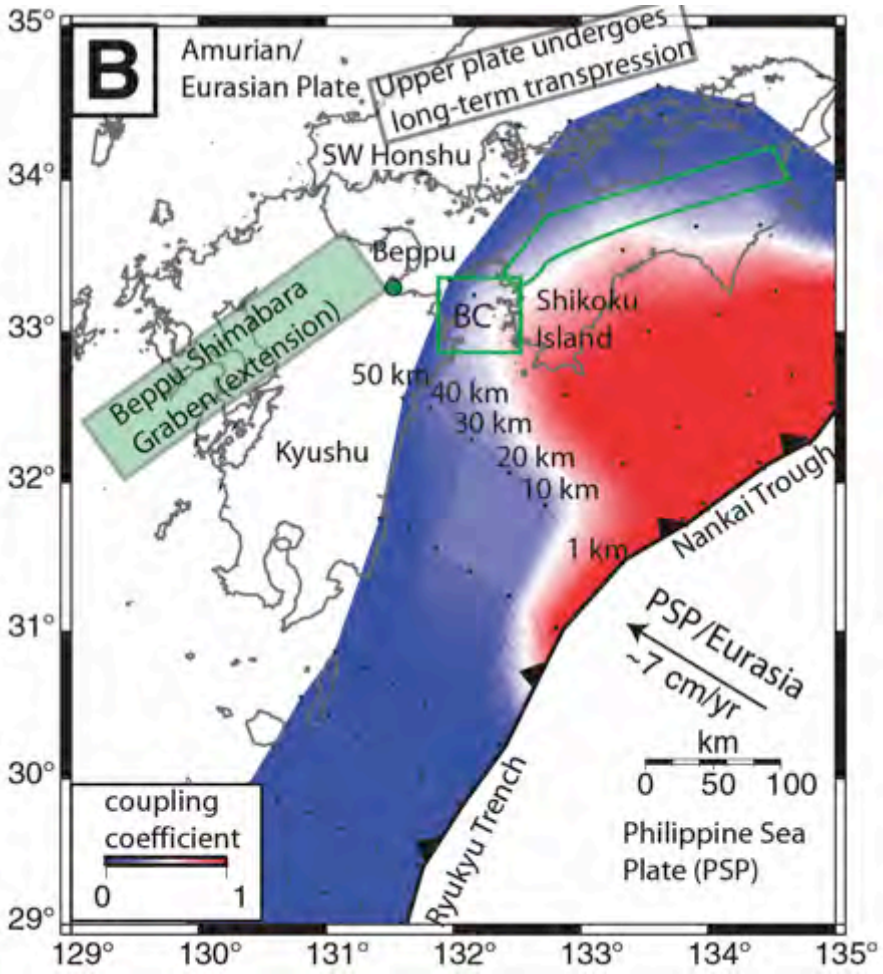
- Reoccupying the temporary SAHKE transect stations
- Augmenting this 2D array with small 3D (100 m spacing) and large regional (10 km spacing) arrays;
- Instrument some SAHKE shot holes with borehole seismographs;
- Collect lines perpendicular to the subduction margin
- Acquire high-resolution seismic 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