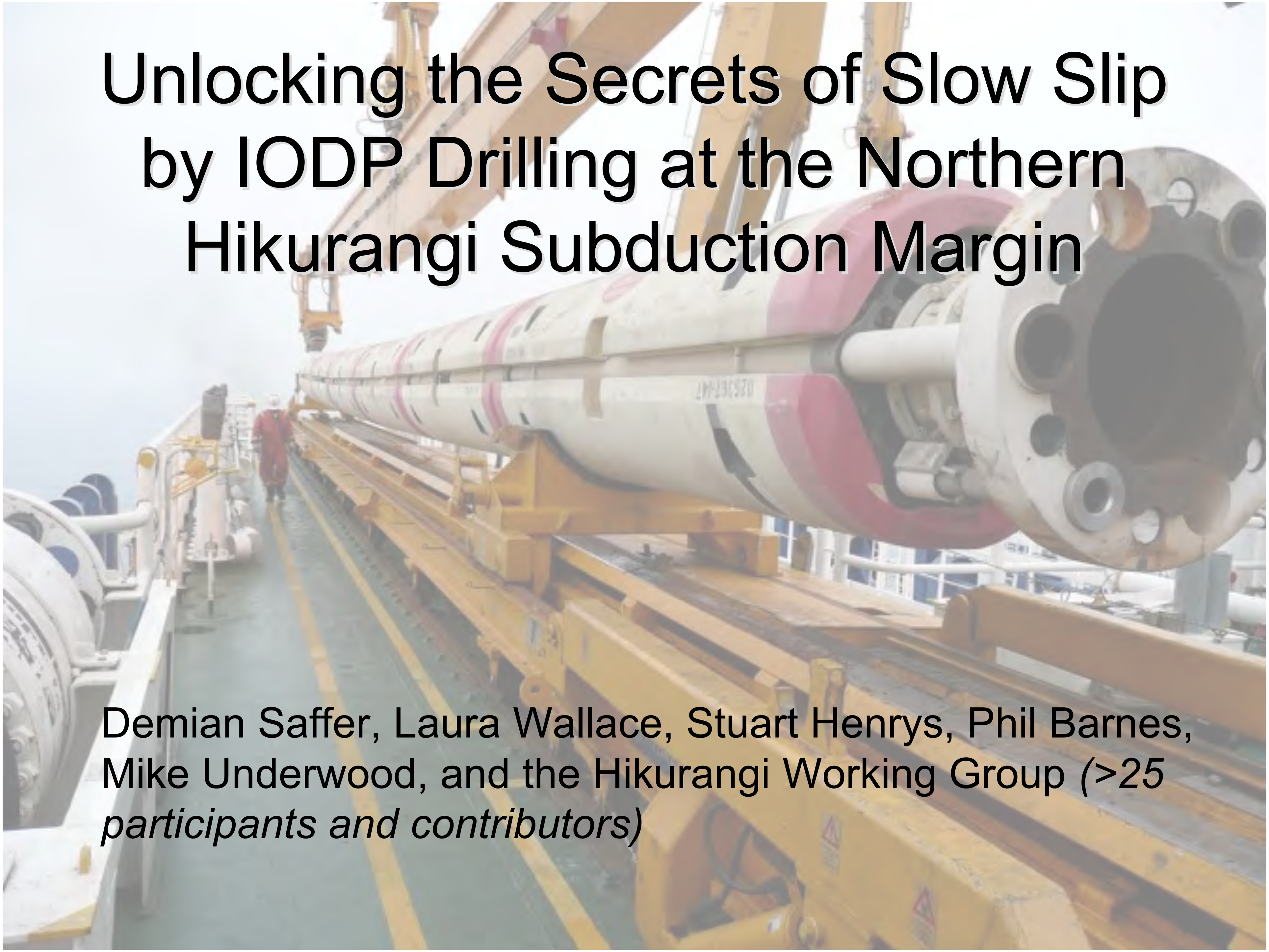


Unlocking the Secrets of Slow Slip by IODP Drilling at the Northern Hikurangi Subduction Margin

Demian Saffer, Laura Wallace, Stuart Henrys, Phil Barnes, Mike Underwood, and the Hikurangi Working Group *(>25 participants and contributors)*

IODP New Science Plan and GeoPRISMS science themes are highly complementary:

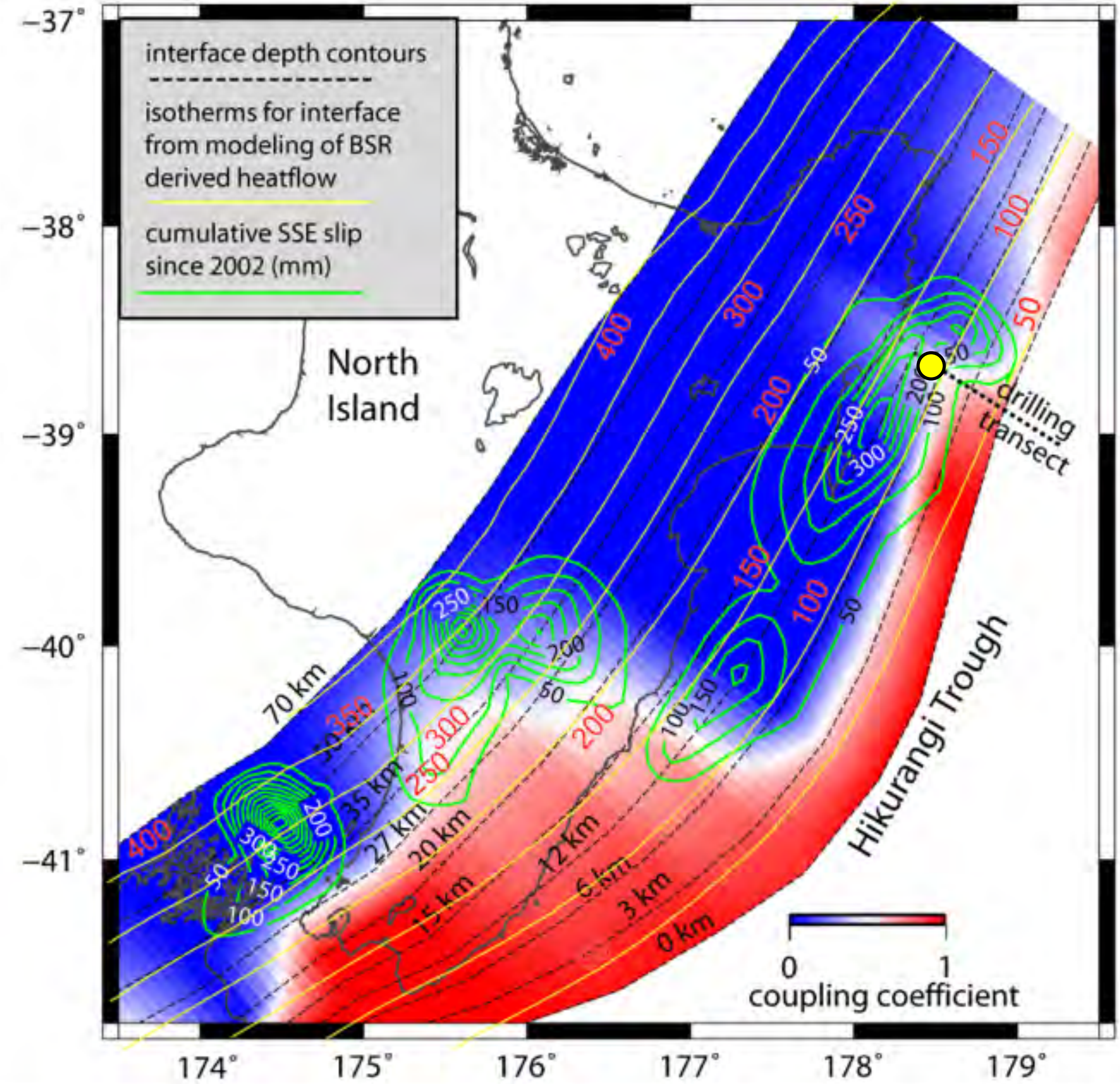
- *"Earth In Motion"* Theme includes: subduction megathrust behavior, volcanic activity, feedbacks between climate, deformation, sedimentation (parallels to Breakouts #2,3,4).

- "*Earth Connections*" Theme includes: subduction initiation, fluxes of mass & volatiles, growth of arcs (Breakouts #1-2)

Unlocking the secrets of slow slip by drilling at the northern Hikurangi subduction margin, N.Z.

- **781-MDP** "Umbrella Prop"; **781A-Full**: Riserless drilling to ***log, sample*** and ***monitor*** the forearc and subducting plate (Saffer, Barnes, Wallace, Henrys, Underwood et al.)
  - Submitted October, 2011
  - Sent for external review
  - Forwarded from PEP with "Excellent Ranking"
  - Eligible for scheduling, possible 2016-2017 timeframe?

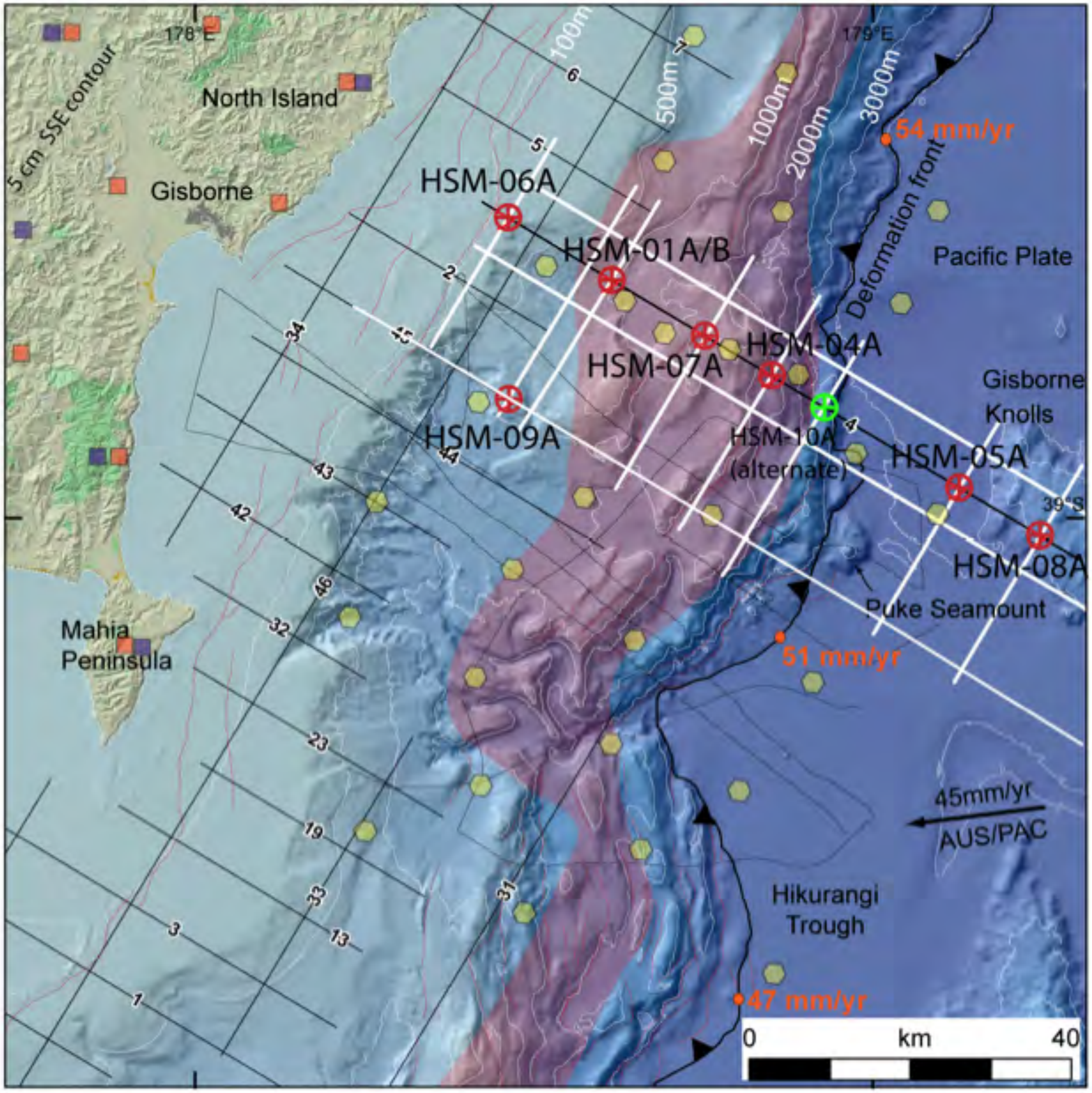
- **781-B-Full**: Riser drilling to intersect the plate interface (Wallace, Henrys, Barnes, Saffer, et al.)
  - Submitted April, 2013

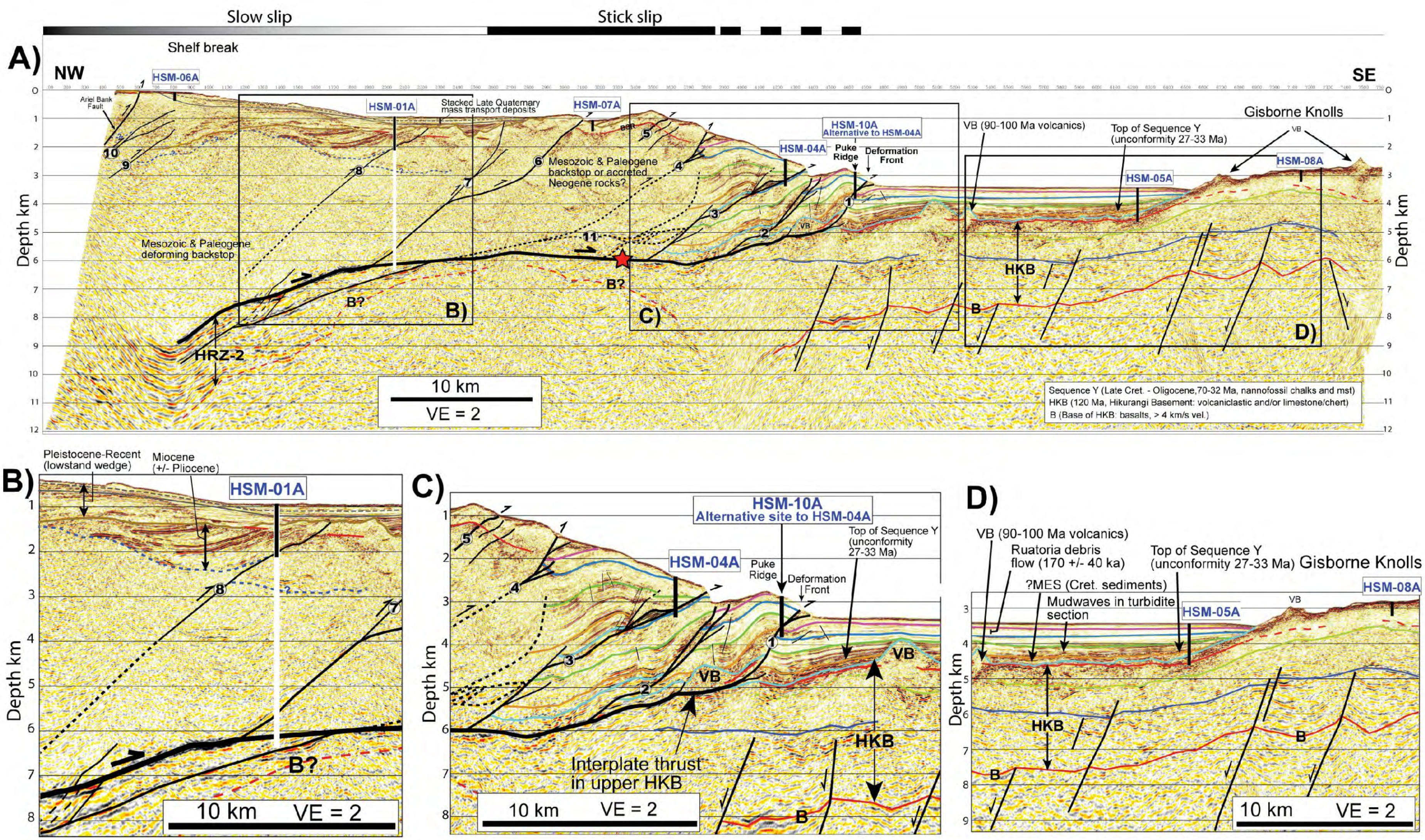


interface depth contours
isotherms for interface from modeling of BSR derived heatflow
cumulative SSE slip since 2002 (mm)
North Island
Hikurangi Trough
drilling transect
70 km
35 km
27 km
20 km
15 km
12 km
6 km
3 km
0 km
400
300
250
200
150
100
50
0
1
coupling coefficient
−37°
−38°
−39°
−40°
−41°
174°
175°
176°
177°
178°
179°

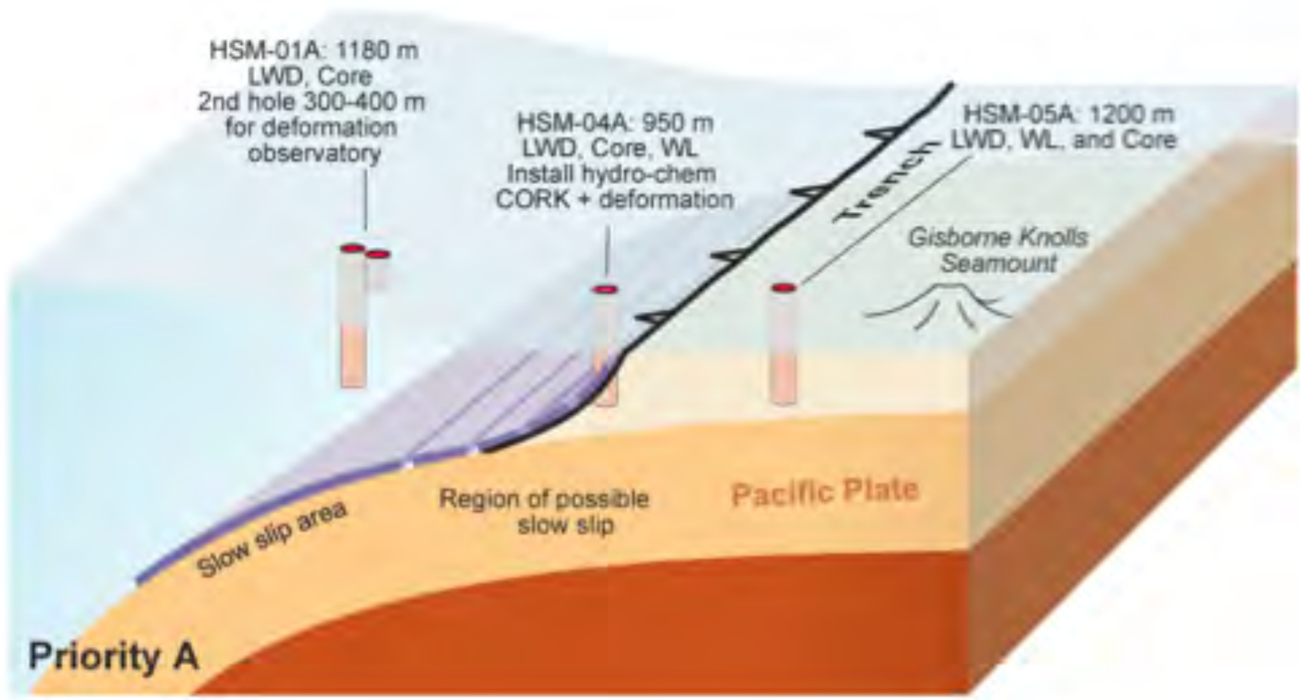
Overarching Questions Addressed by Drilling

- *Hypothesis #1: Slow slip events occur within a conditionally stable frictional regime.*
- *Hypothesis #2: Slow slip events occur in regions of near-lithostatic fluid pressures, driven by mineral dehydration reactions.*
- *Hypothesis #3: The environments that host episodic slow slip are not restricted to a specific pressure or temperature range.*
- *Hypothesis #4: There is a continuum of duration and magnitude characteristics of SSEs and slow seismic behavior.*
- *Hypothesis #5: Subduction interfaces dominated by aseismic slip are structurally distinct from those that fail in large magnitude EQ, and are characterized by a thick zone of distributed shearing.*


178°E
179°E
39°S
North Island
Gisborne
Mahia Peninsula
5 cm SSE contour
100m
500m
1000m
2000m
3000m
54 mm/yr
51 mm/yr
47 mm/yr
Deformation front
Pacific Plate
Gisborne Knolls
Puke Seamount
Hikurangi Trough
HSM-06A
HSM-01A/B
HSM-07A
HSM-04A
HSM-09A
HSM-10A (alternate)
HSM-05A
HSM-08A
45mm/yr
AUS/PAC
0
km
40



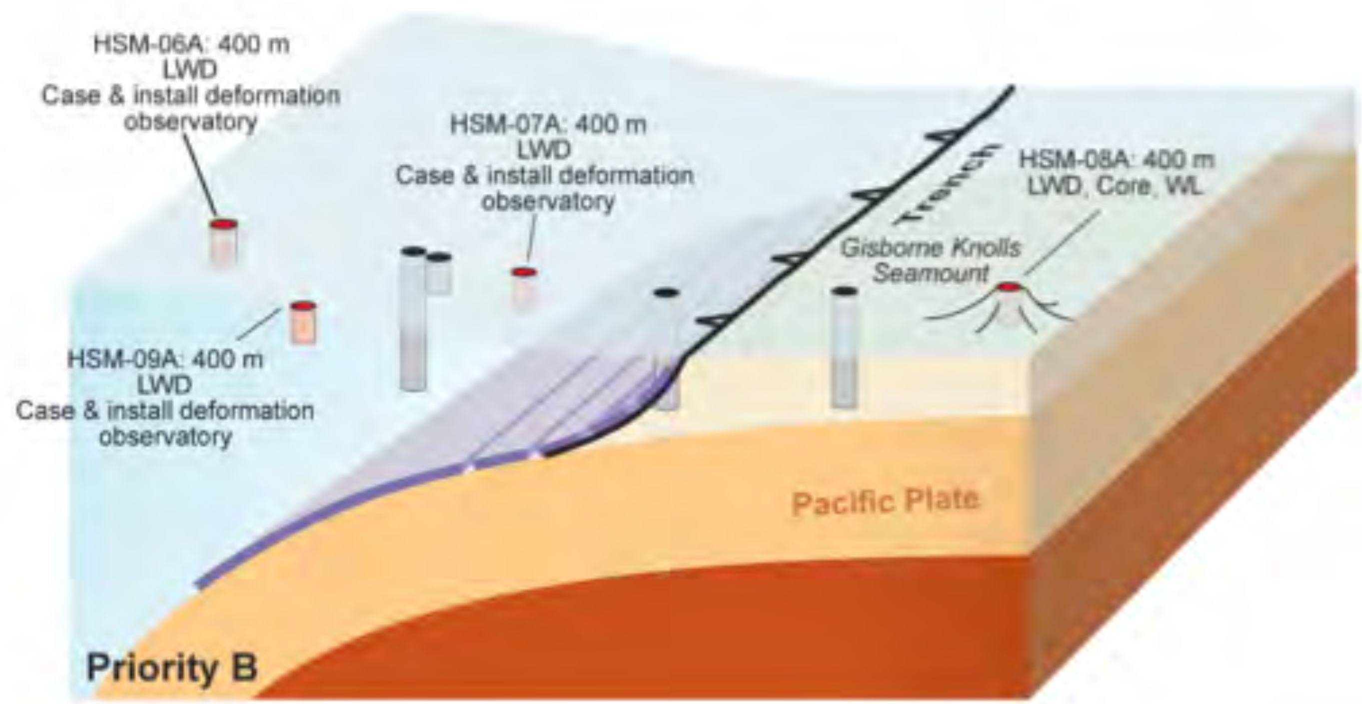
Slow slip
Stick slip
A)
Shelf break
NW
SE
HSM-06A
Ariel Bank Fault
HSM-01A
Stacked Late Quaternary mass transport deposits
HSM-07A
HSM-10A
Alternative to HSM-04A
HSM-04A
Puke Ridge
Deformation Front
VB (90-100 Ma volcanics)
Top of Sequence Y (unconformity 27-33 Ma)
Gisborne Knolls
HSM-05A
HSM-08A
Mesozoic & Paleogene backstop or accreted Neogene rocks?
Mesozoic & Paleogene deforming backstop
HKB
HRZ-2
B?
B)
C)
D)
10 km
VE = 2
Depth km
Sequence Y (Late Cret. - Oligocene,70-32 Ma, nannofossil chalks and mst)
HKB (120 Ma, Hikurangi Basement: volcaniclastic and/or limestone/chert)
B (Base of HKB: basalts, > 4 km/s vel.)
B)
Pleistocene-Recent (lowstand wedge)
Miocene (+/- Pliocene)
HSM-01A
C)
HSM-10A
Alternative site to HSM-04A
Top of Sequence Y (unconformity 27-33 Ma)
Interplate thrust in upper HKB
D)
VB (90-100 Ma volcanics)
Ruatoria debris flow (170 +/- 40 ka)
?MES (Cret. sediments)
Mudwaves in turbidite section
Top of Sequence Y (unconformity 27-33 Ma)
Gisborne Knolls



- Inputs sites: Log & Core to characterize composition, thickness, state, phys. props of incoming sed & basement
- Shallow fault (750 m): Log & core to characterize plate boundary in updip region of SSE zone. Install observatory to monitor pore pressure & fluid geochemistry.
- Shallow observatories on lower slope: Drill to ~300-400 m, case, install simple “geodetic” observatories.
- Pilot hole for riser drilling to SSE source region.

Secondary Sites:

- Additional shallow observatories - increased aperture
- Include along-strike component of monitoring



Logging and Coring:

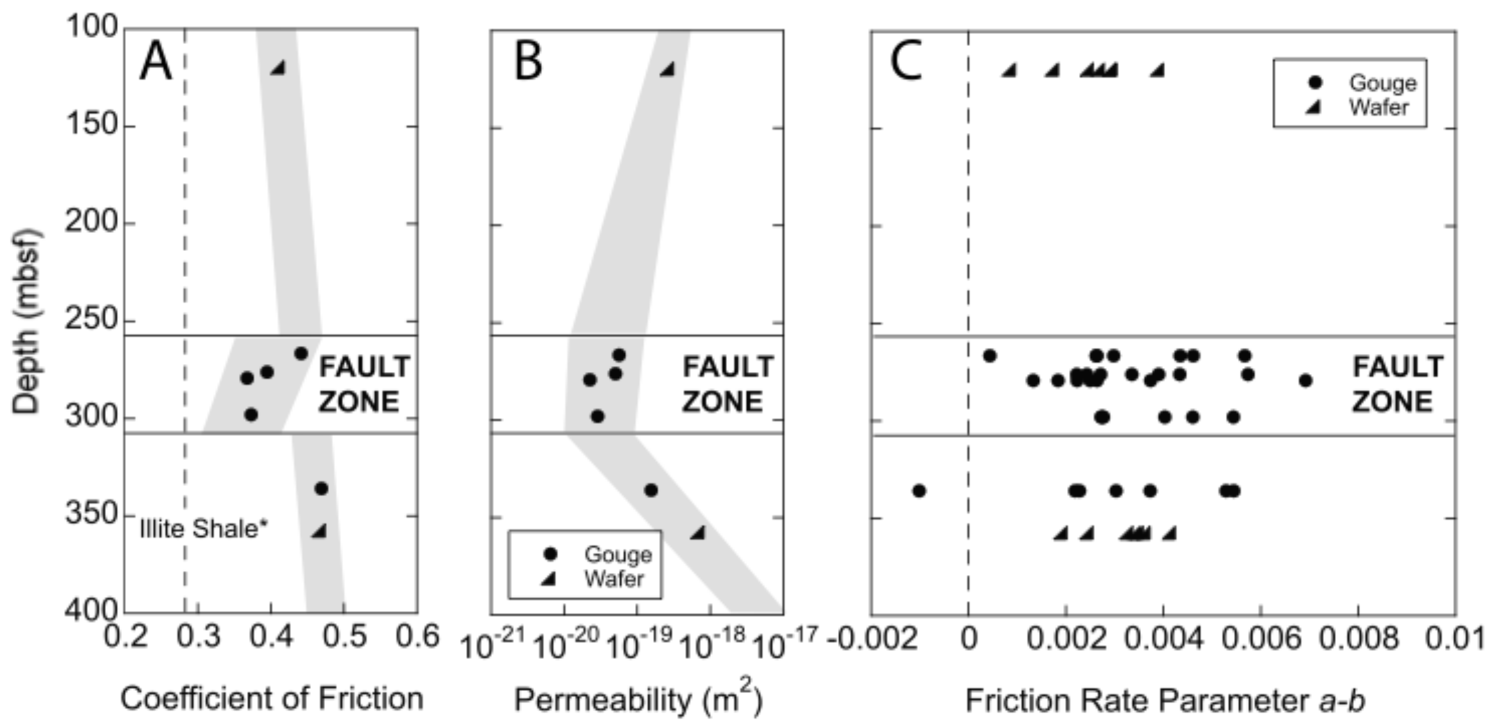
→ Lithologies and composition

→ Frictional properties of fault rock

→ Fault zone architecture

→ Physical properties (porosity, permeability, Vp, etc…)

→ In situ pore pressure and stress estimates (indirect)



Ikari et al., 2009

Logging and Coring:

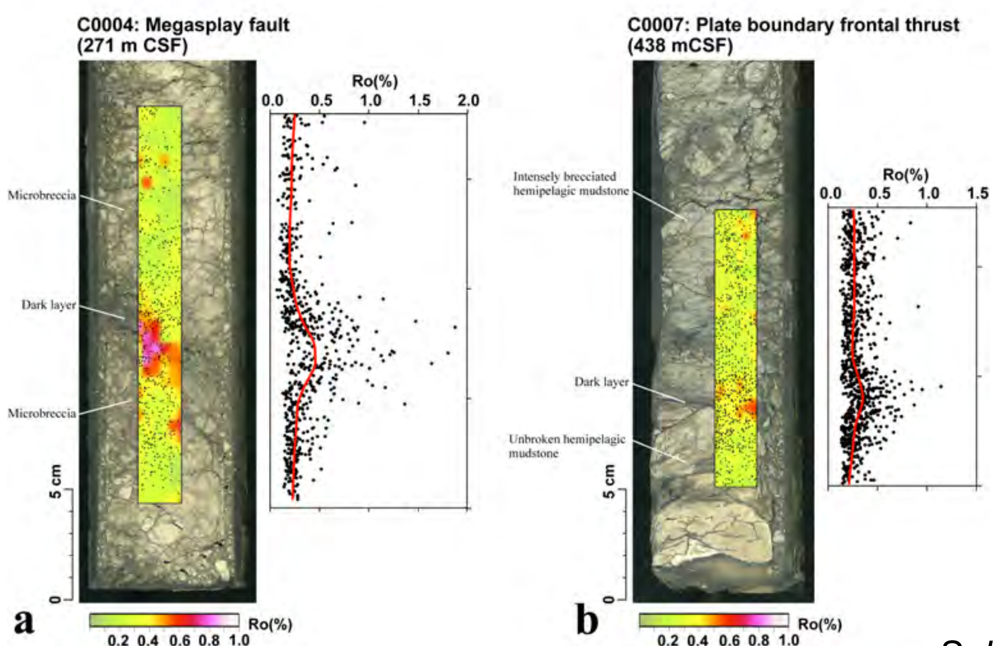
→ Lithologies and composition; shallow thermal gradient

→ Frictional properties of fault rock

→ Fault zone architecture

→ Physical properties (porosity, permeability, Vp, etc…)

→ In situ pore pressure and stress estimates (indirect)



Sakagucji et al., 2010

Logging and Coring:

- → Lithologies and composition
- → Frictional properties of fault rock
- → Fault zone architecture
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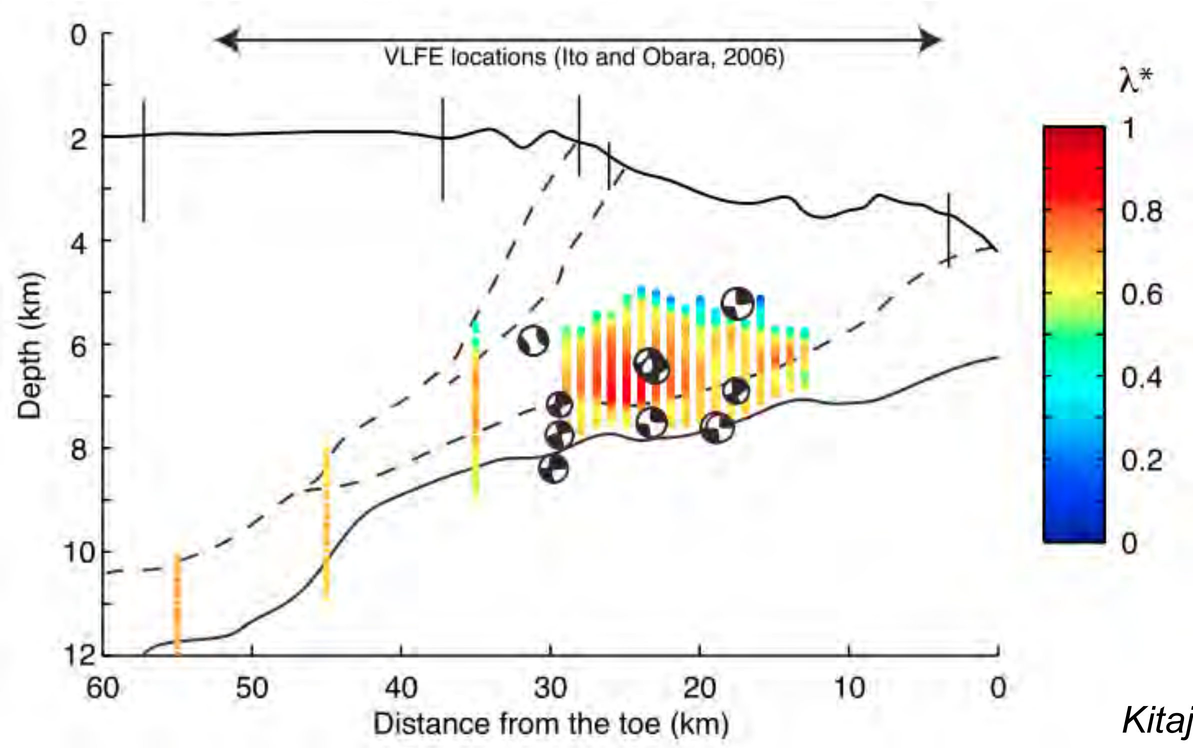
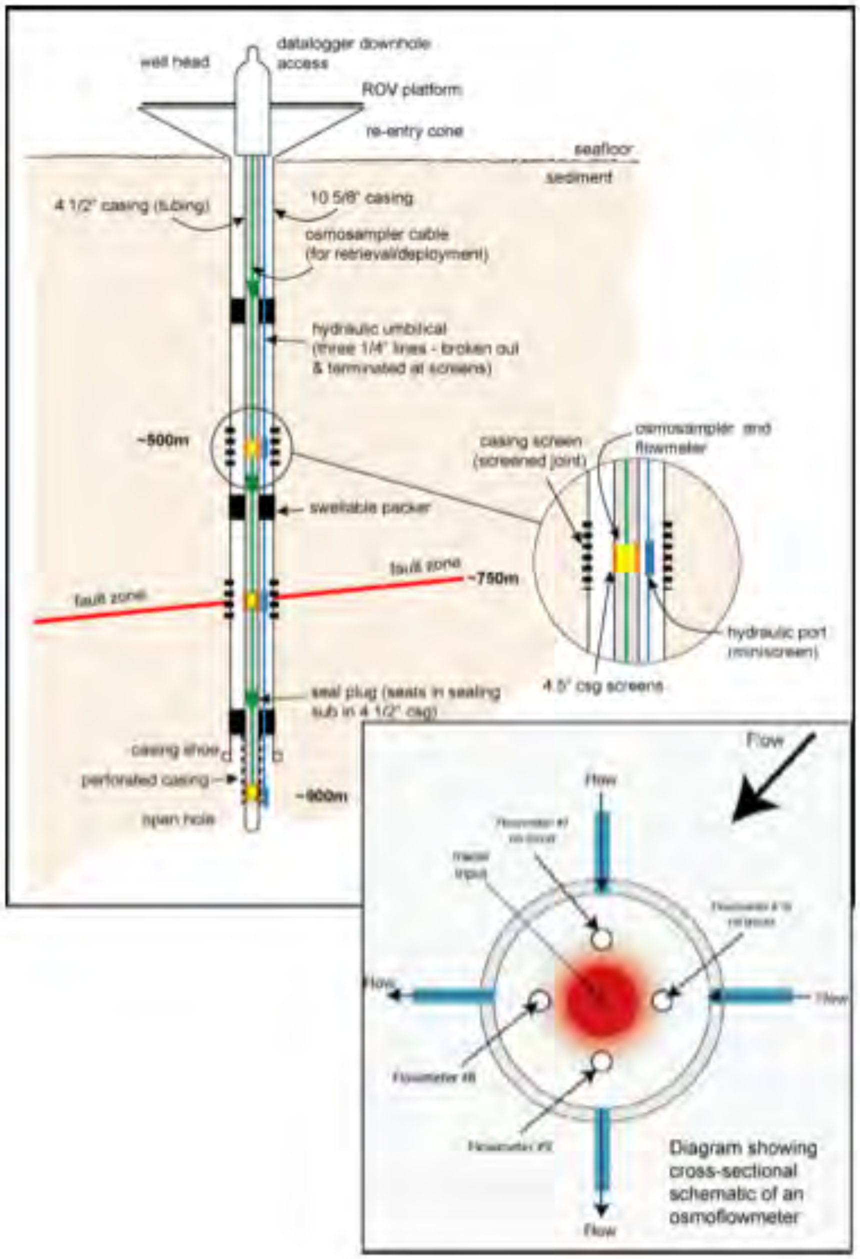


Kitajima & Saffer, 2012

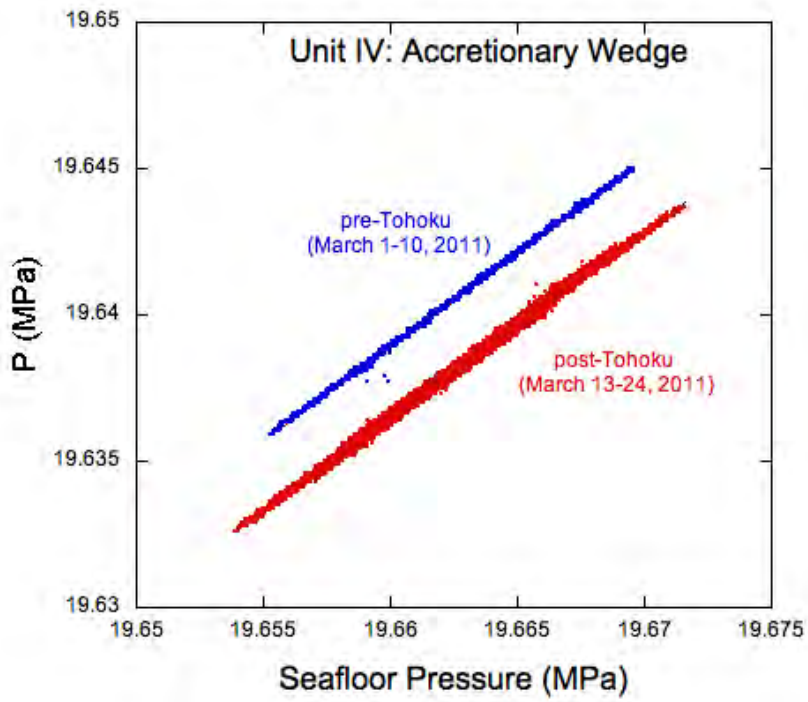


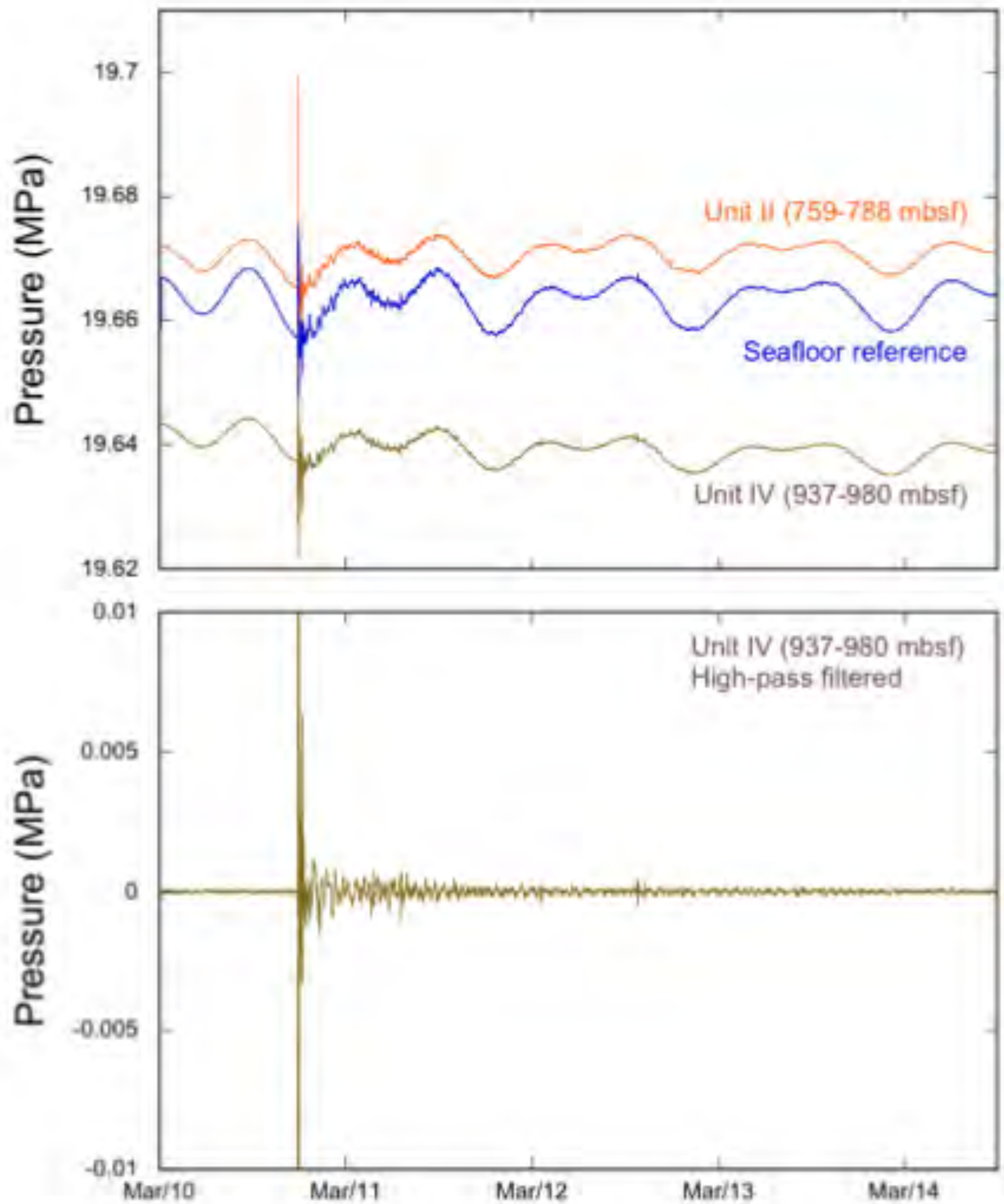
Observatories:

- → Seismicity in near field, low(er) attenuation, quiet environment
- → Strain accumulation & release (pore pressure, strainmeters, tilt)
- → Pore fluid pressure, flow rates, and chemistry
- → In situ temperature
- → Triggering & precursory phenomena?

Example from the Nankai Trough: Response to the March 2011 Tohoku EQ:

- *dynamic response*
- *static P change (strain)*
- *permeability change?*





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Now that is ant-icipation! German insects able to sense an earthquake before it hits

- **Ants in Germany prefer to build their colonies along active faults**
- **Researchers discover their behaviour significantly alters before earthquake**
- **Behaviour only returns to normal a day after the earthquake**
- **Ants may pick up changing gas emissions or shifts in Earth's magnetic field**

Alas, there are no ants offshore.