Global Overview of Interactions Among Subduction Margin Sedimentation, Climate, Eustasy, and Forearc Deformation

Michael Underwood
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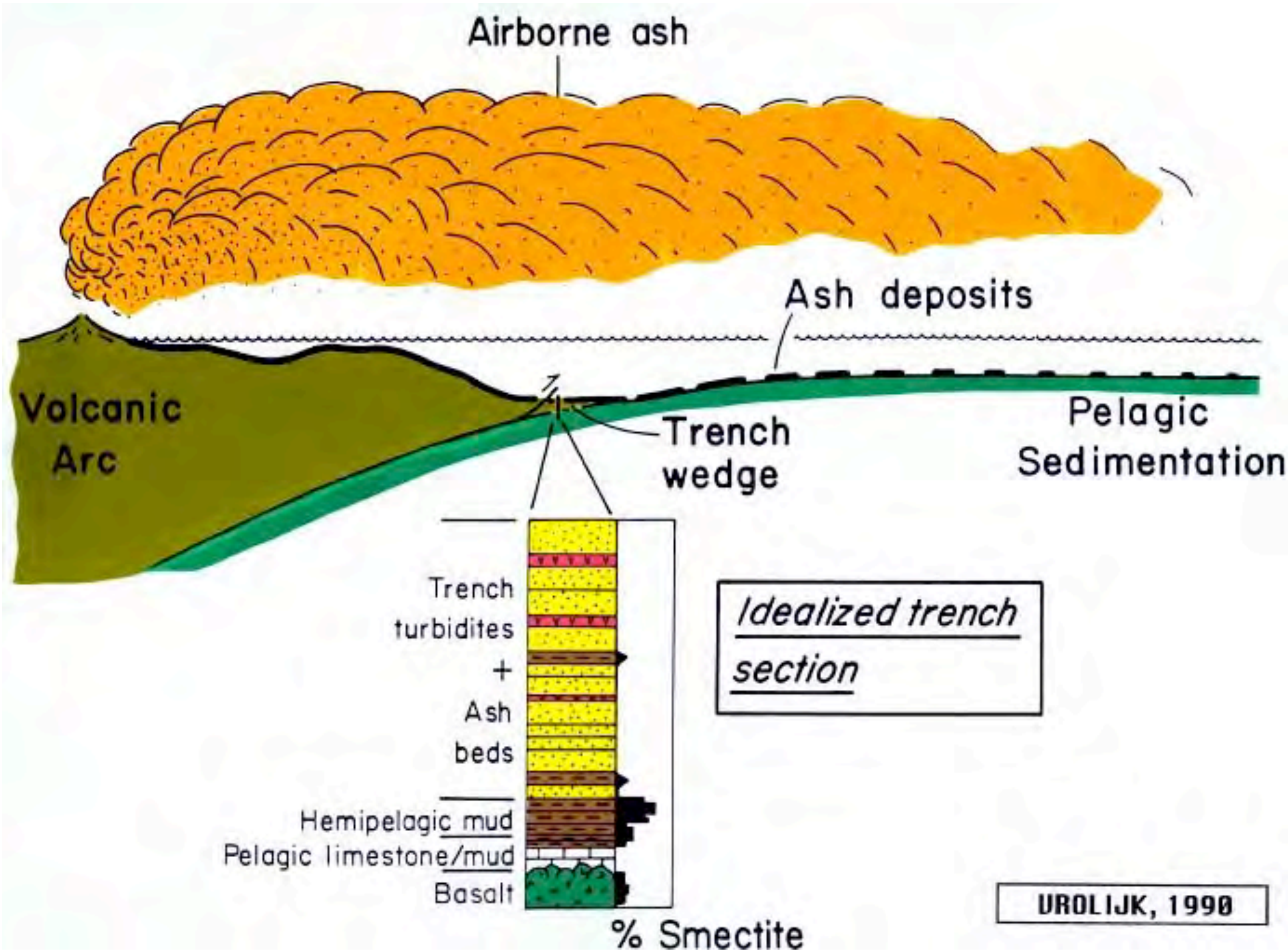
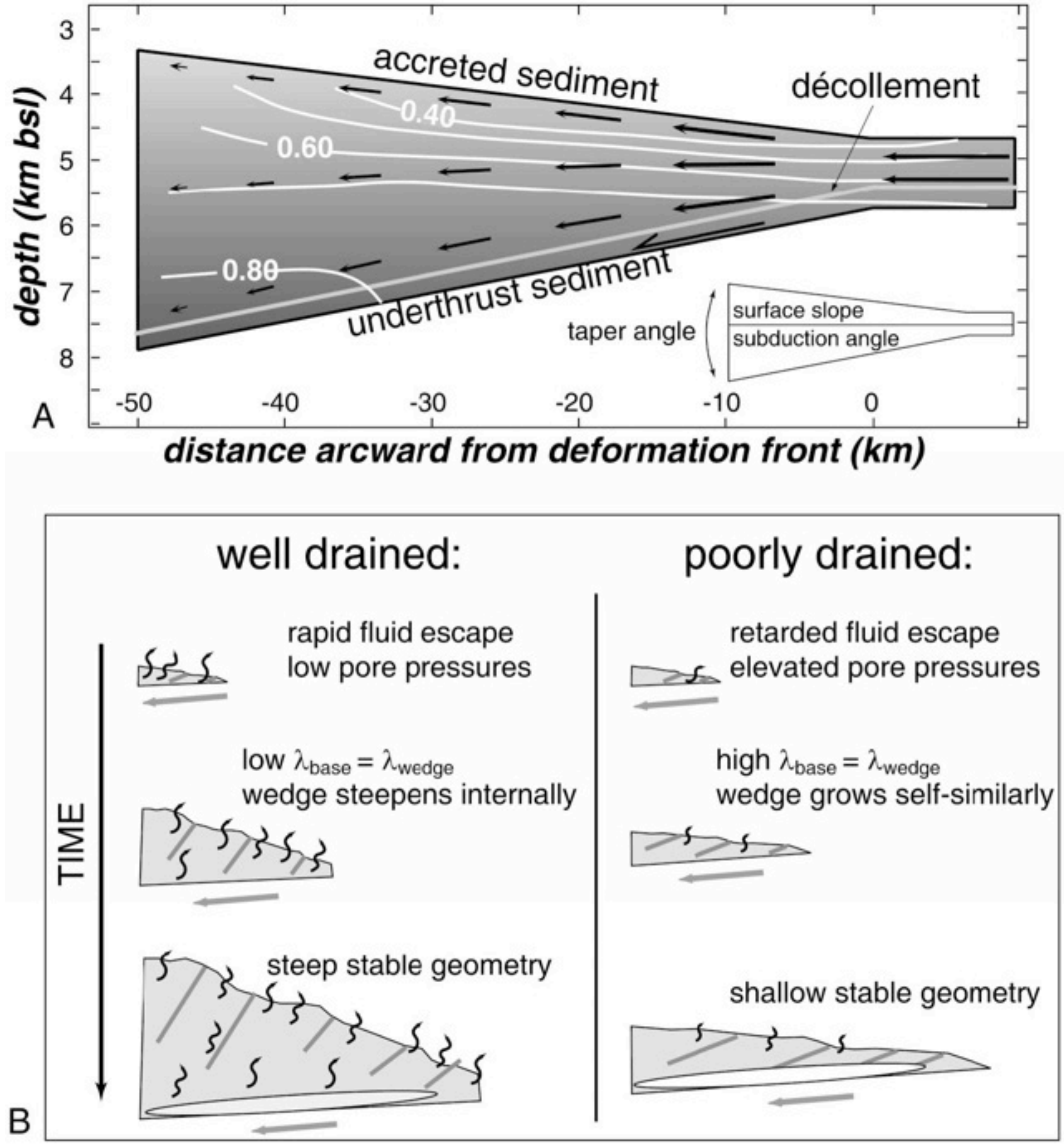
GeoPRISMS - Wellington (04/15/13)



Tectonics affects sedimentation; sedimentation affects tectonics

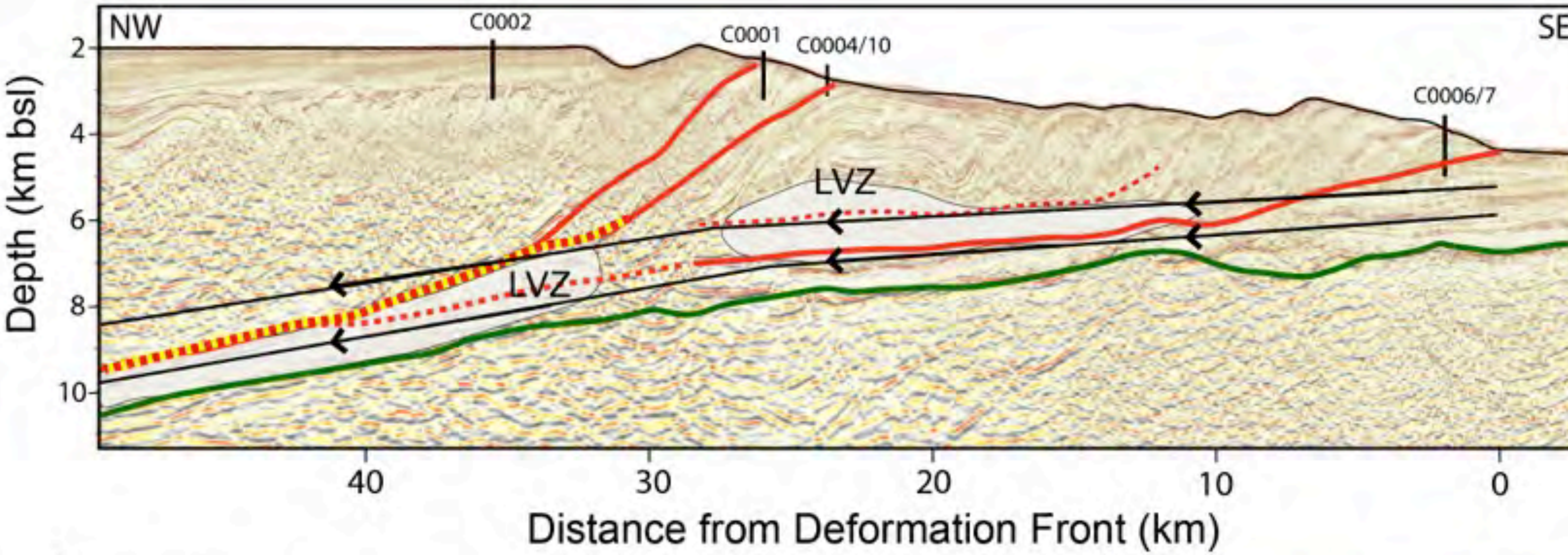
Why do subduction inputs matter?

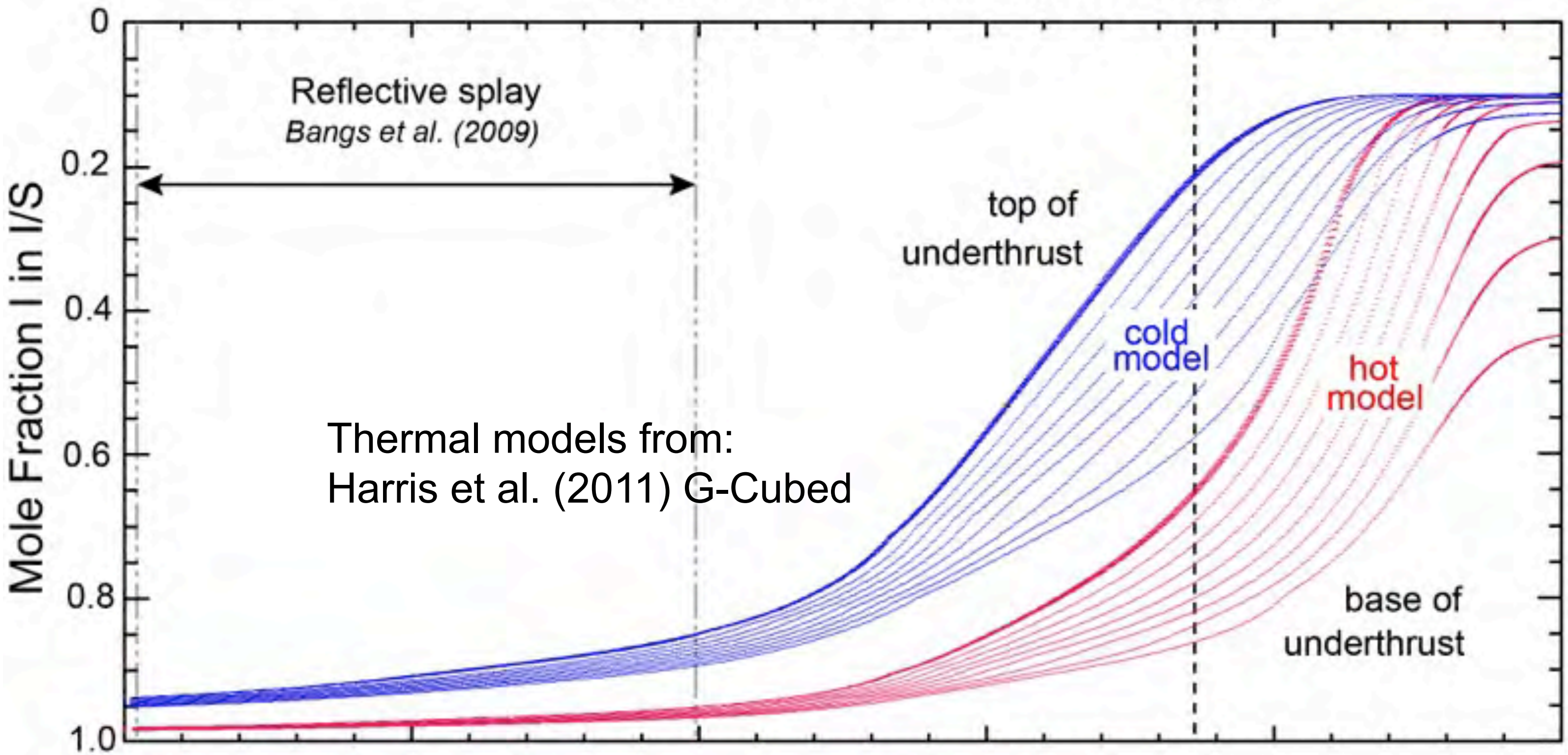
- Stratigraphic partitioning at décollement interval
  - imbricate thrusts/folds, splay faults, thrust vergence
- Sandy turbidite intervals above/below décollement
  - diffuse/focused drainage, pore pressure, critical taper
- Detrital clay mineral assemblages above/below décollement interval
  - friction, fault-slip behavior (SSE)
- Diagenesis and fluid production above/below décollement interval
  - pore pressure, effective stress



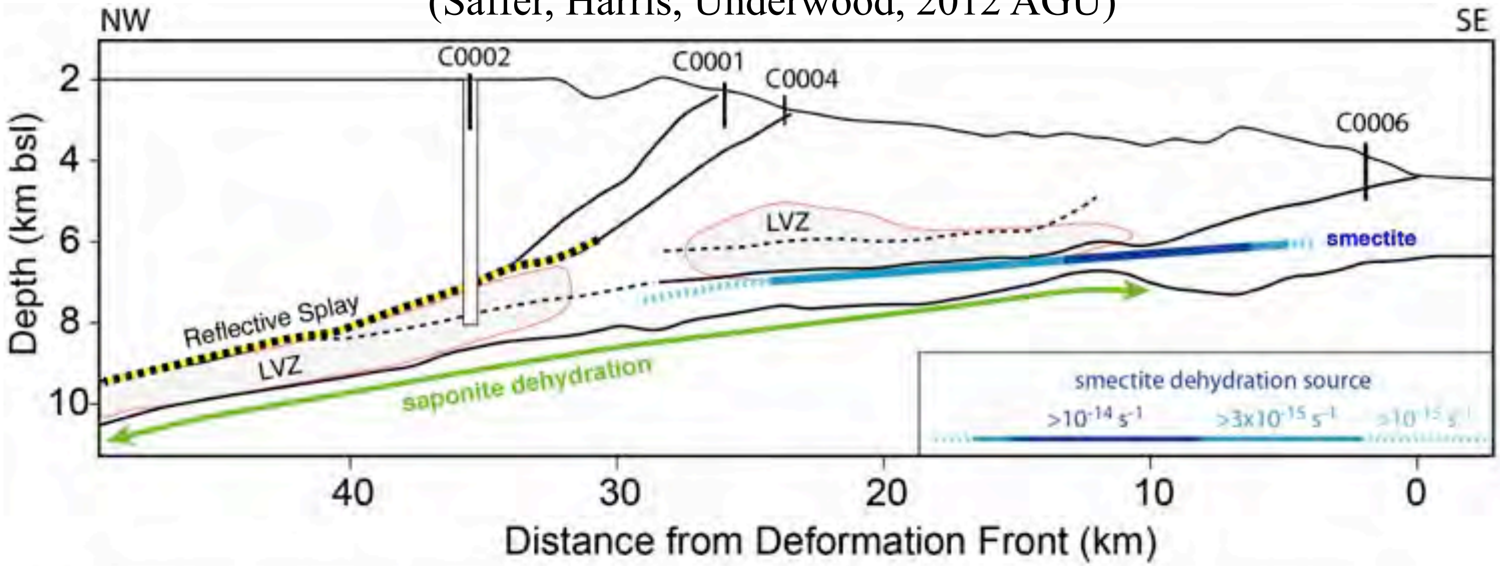
Saffer & Bekins (2002)
Geology

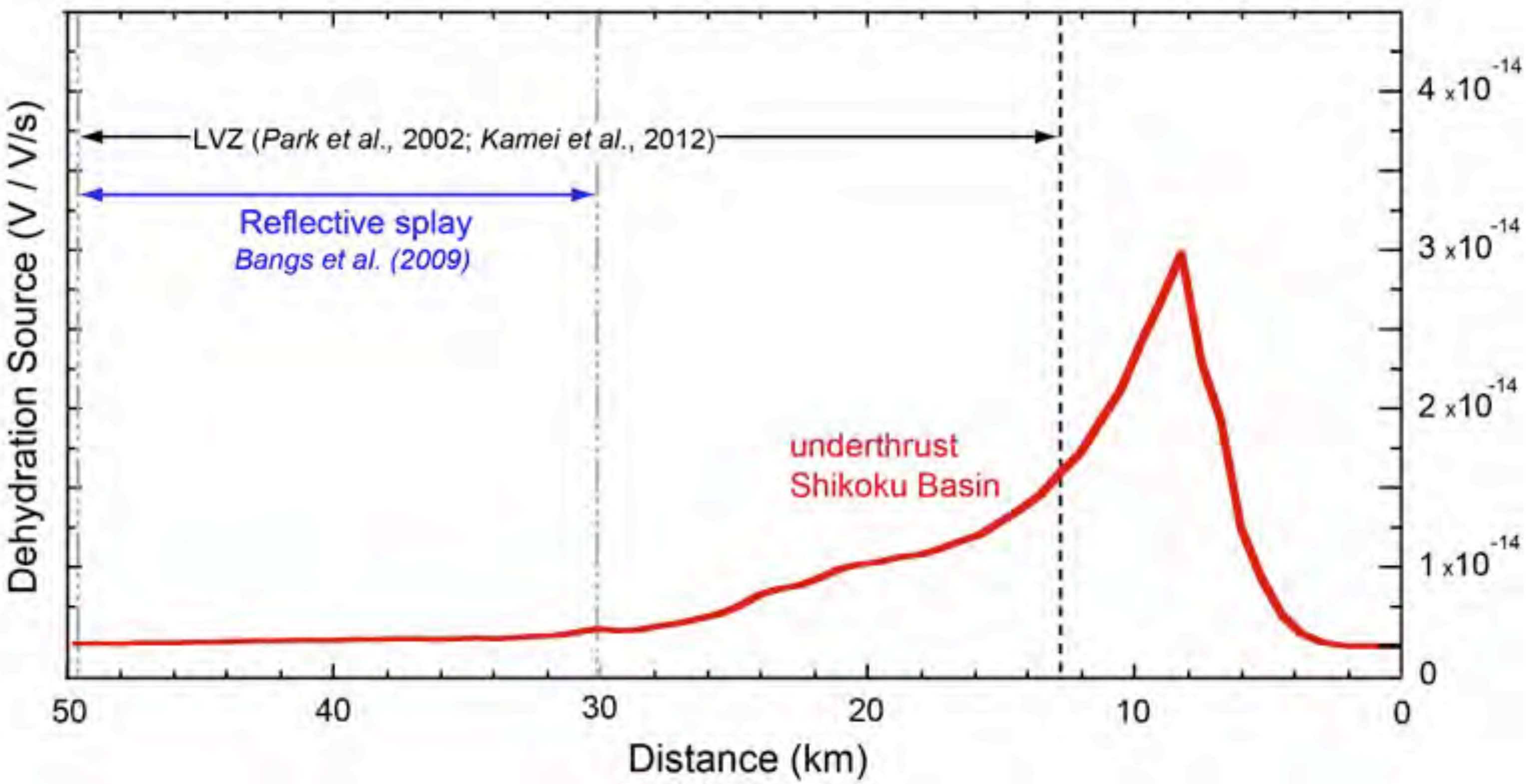
(Saffer, Harris, Underwood, 2012 AGU)

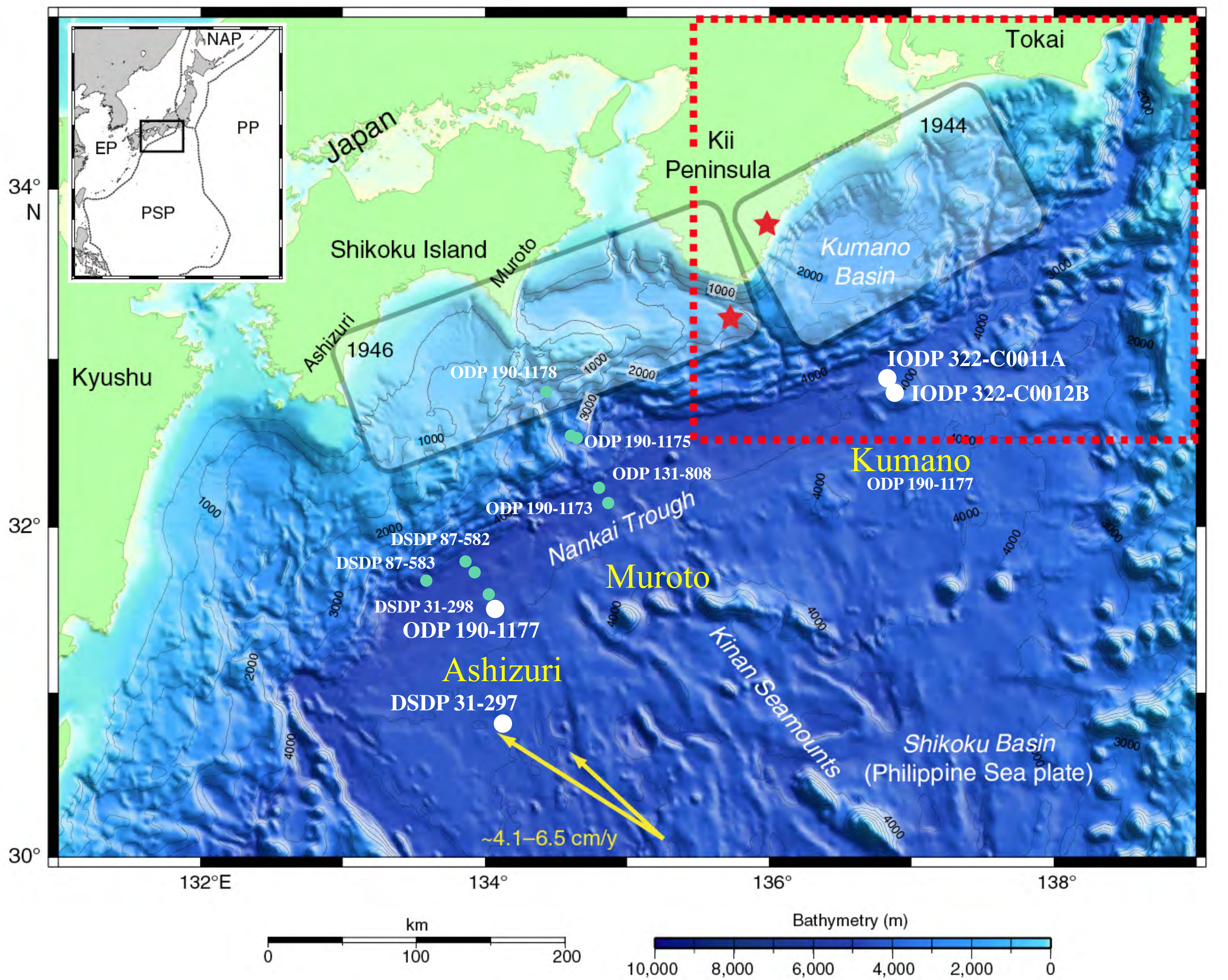




(Saffer, Harris, Underwood, 2012 AGU)

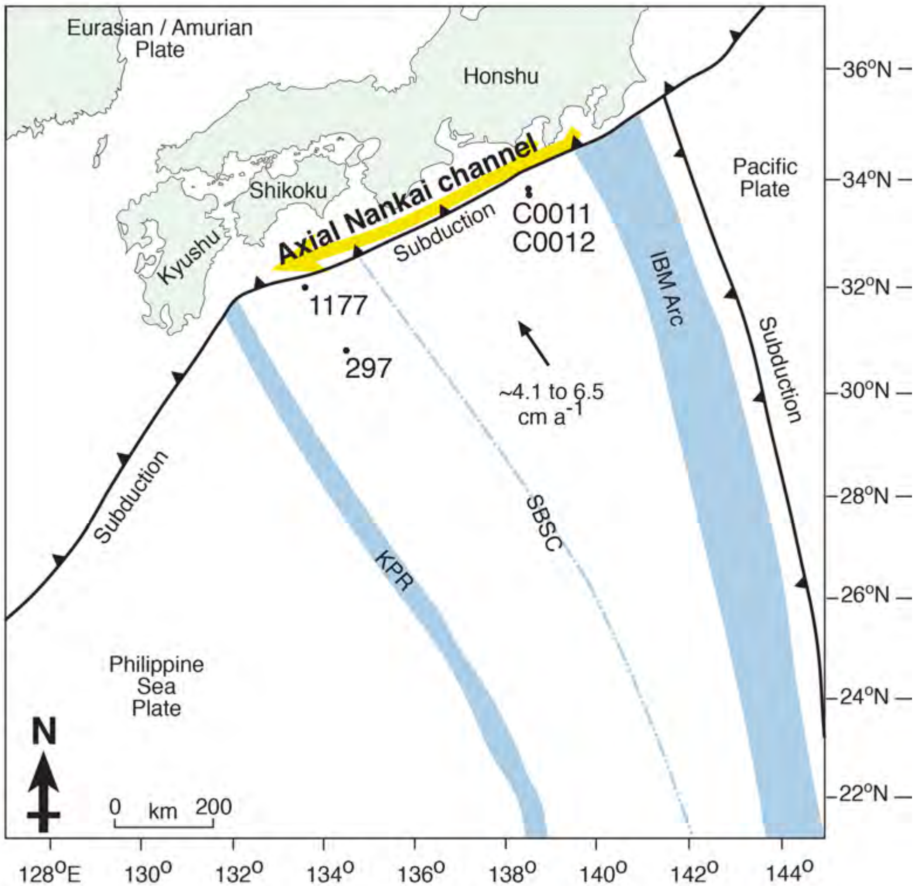


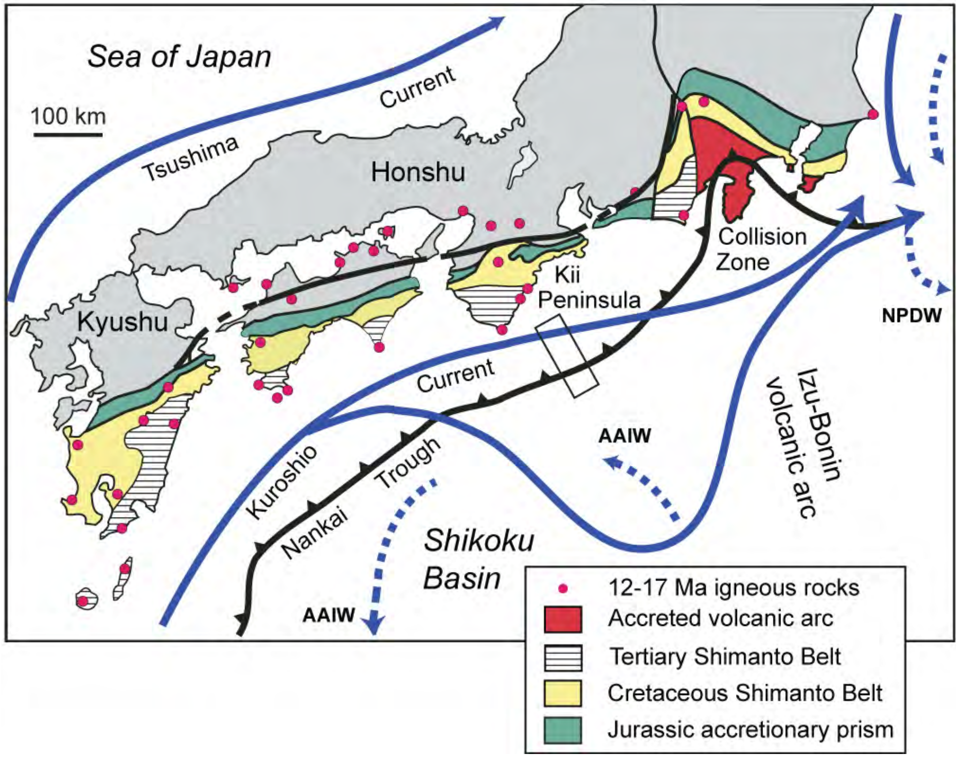




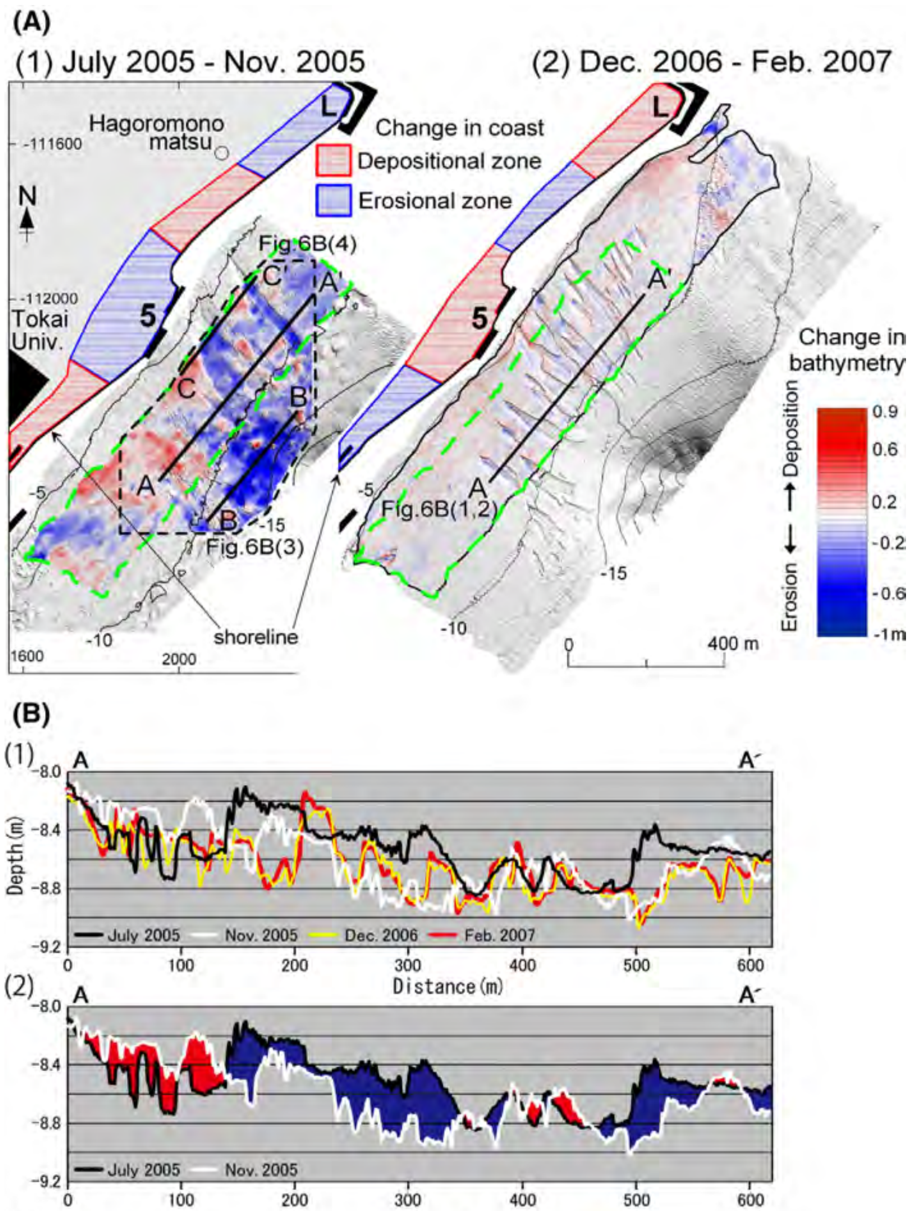
NAP
EP
PP
PSP
Japan
Tokai
1944
Kii
Peninsula
Shikoku Island
Muroto
Ashizuri
1946
Kyushu
Kumano
Basin
IODP 322-C0011A
IODP 322-C0012B
ODP 190-1178
ODP 190-1175
ODP 131-808
ODP 190-1173
Kumano
ODP 190-1177
DSDP 87-582
DSDP 87-583
DSDP 31-298
ODP 190-1177
Nankai Trough
Muroto
Ashizuri
DSDP 31-297
Kinan Seamounts
Shikoku Basin
(Philippine Sea plate)
~4.1–6.5 cm/y
34°
N
32°
30°
132°E
134°
136°
138°
km
0
100
200
Bathymetry (m)
10,000
8,000
6,000
4,000
2,000
0

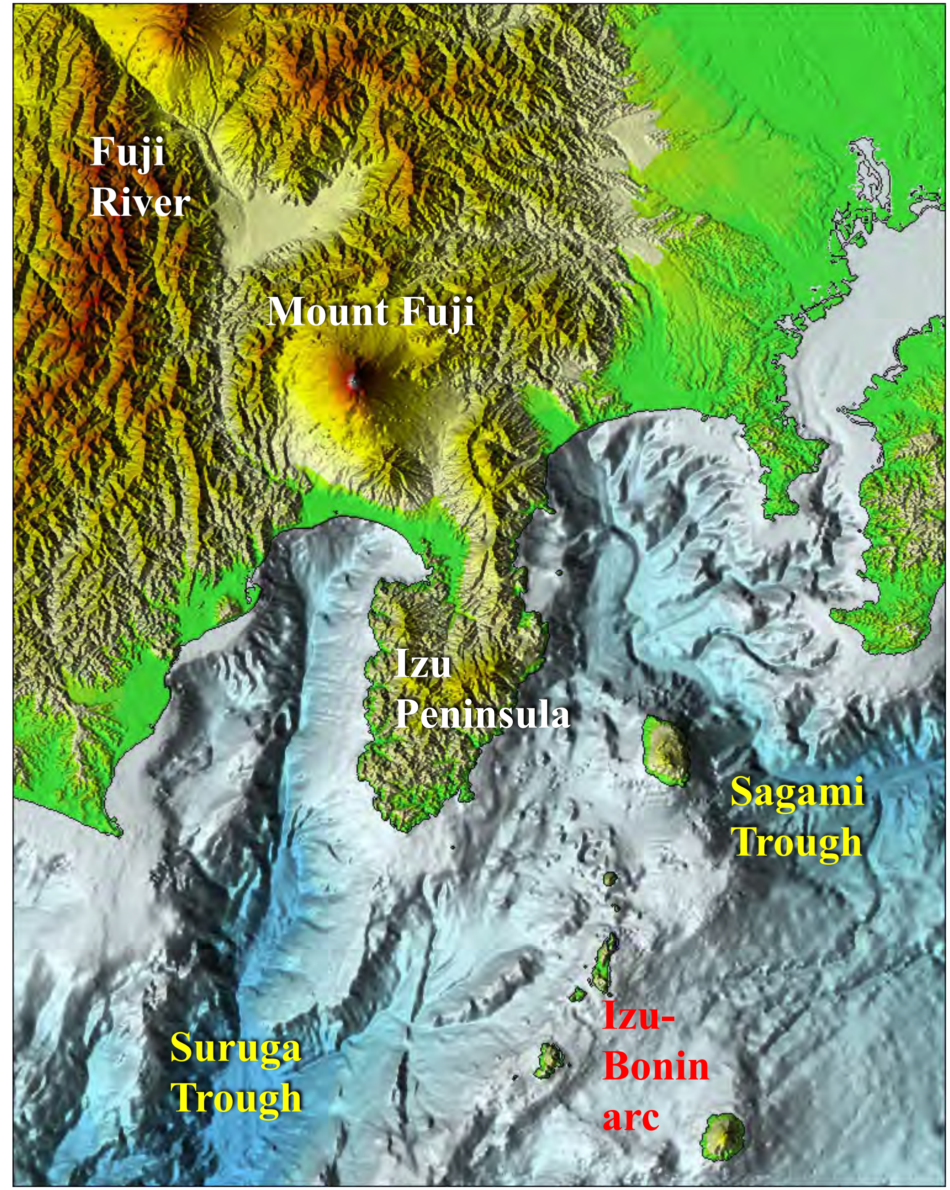
Present



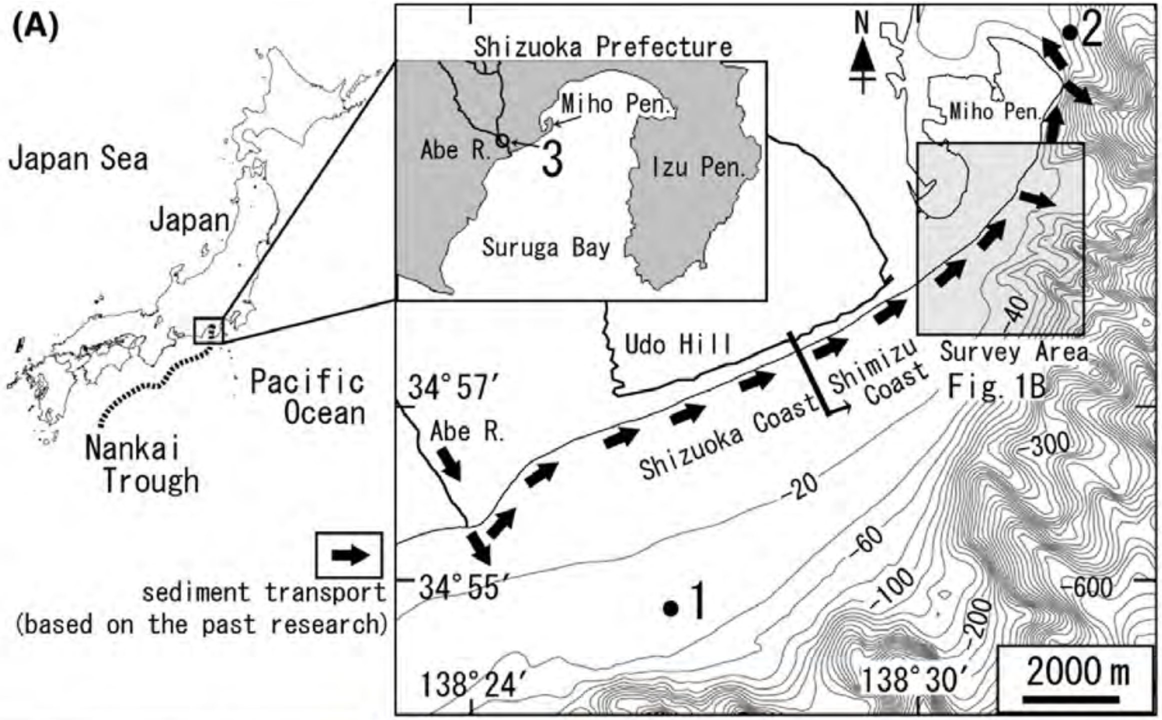


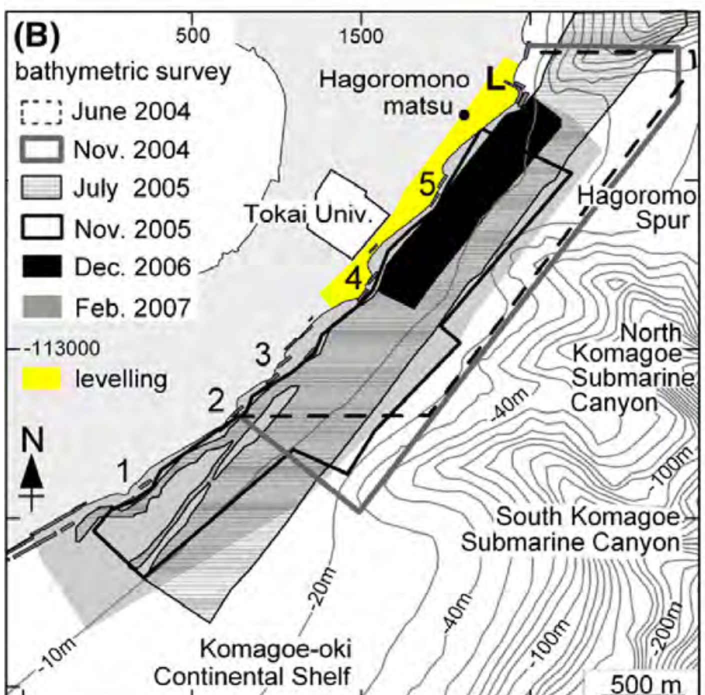
Note that Kuroshio Current intensified ~3 Ma
Isthmus of Panama closed
Stronger subtropical gyre



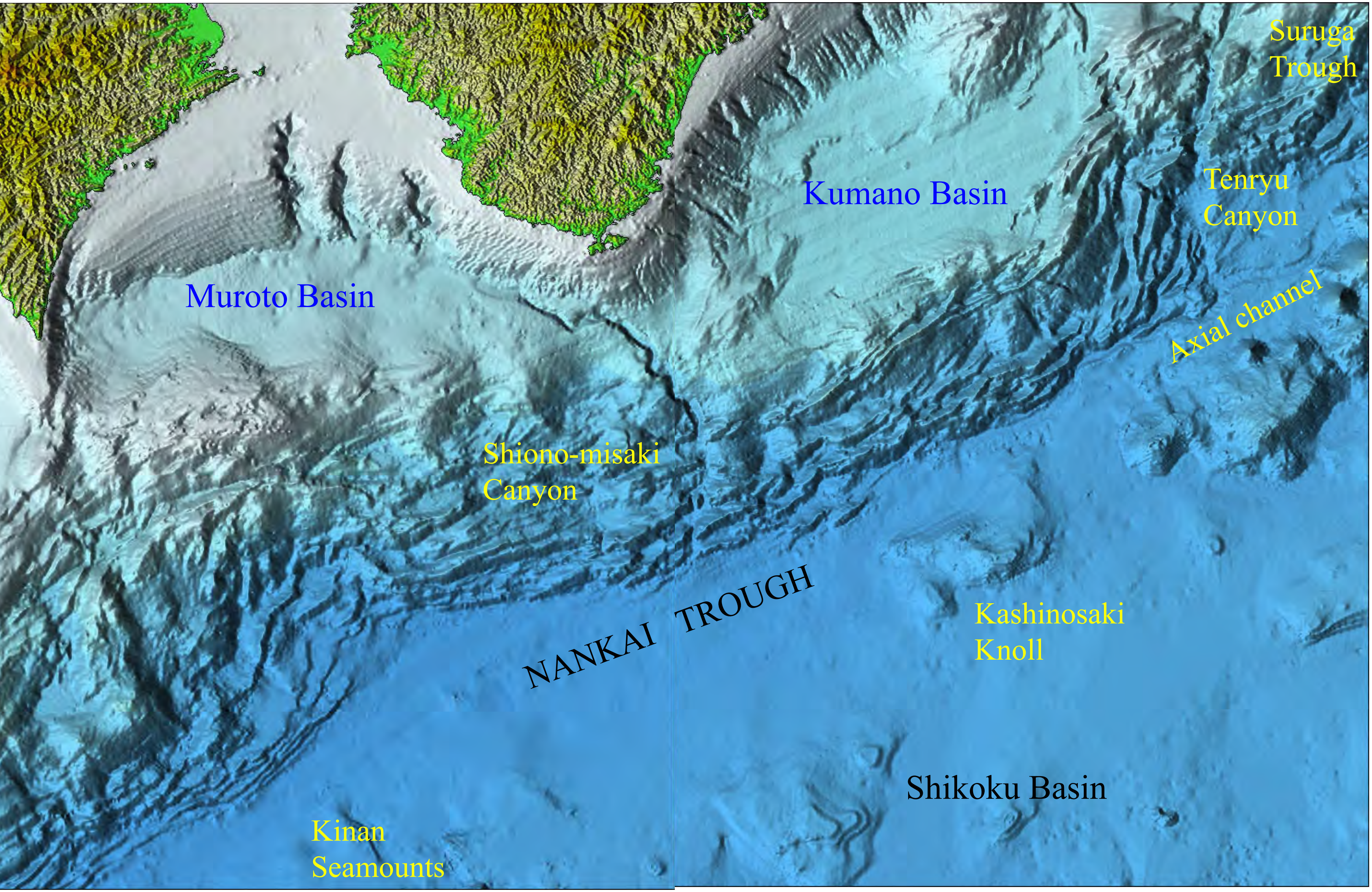


Yoshikawa & Nemoto (2010) *Marine Geology*

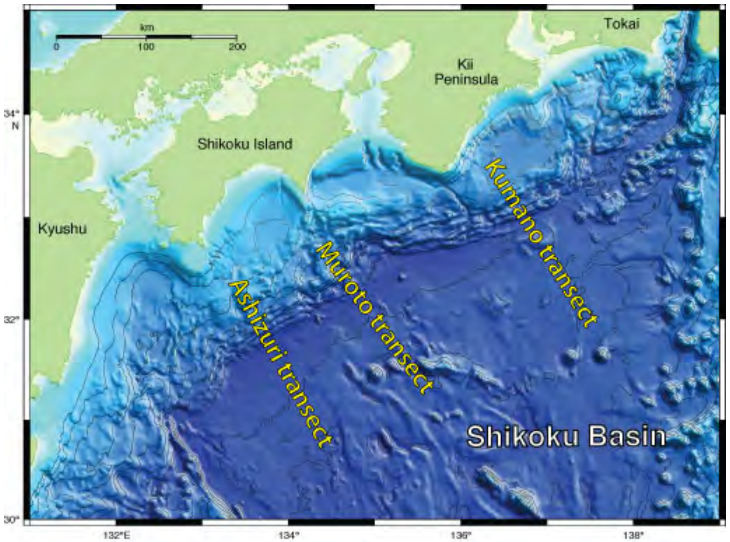


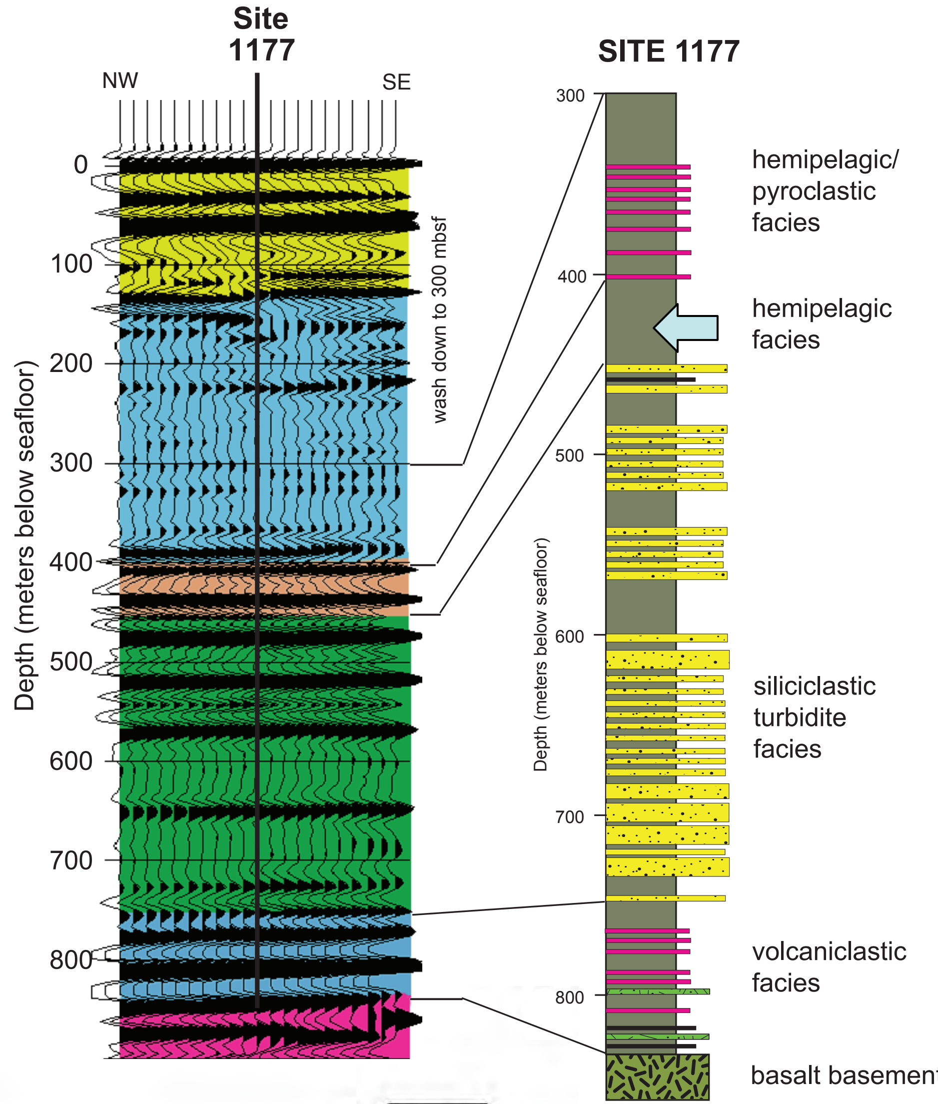


Yoshikawa & Nemoto (2010) *Marine Geology*

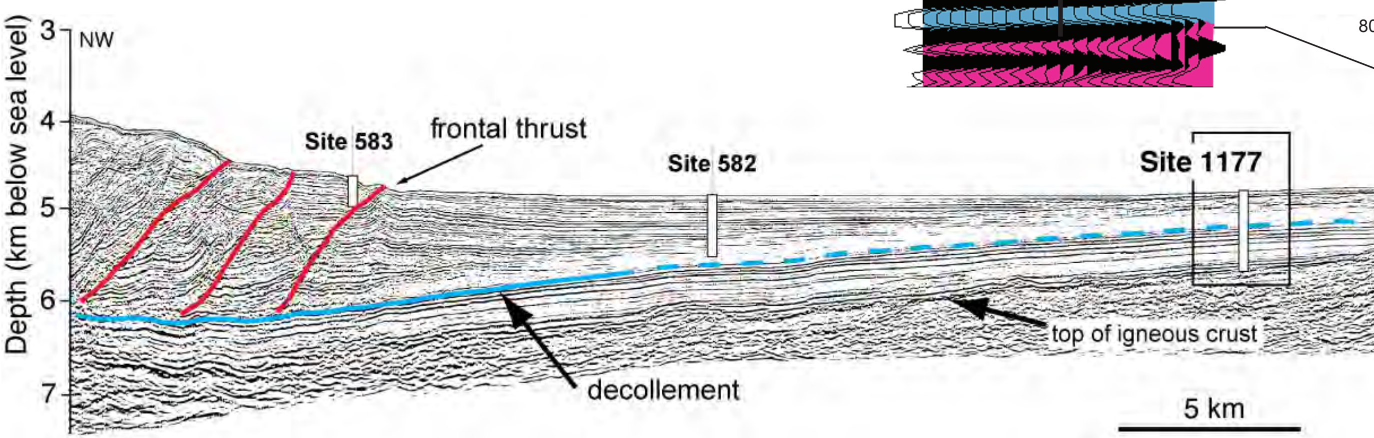

Suruga Trough
Kumano Basin
Tenryu Canyon
Muroto Basin
Axial channel
Shiono-misaki Canyon
NANKAI TROUGH
Kashinosaki Knoll
Shikoku Basin
Kinan Seamounts

Inputs to Ashizuri transect



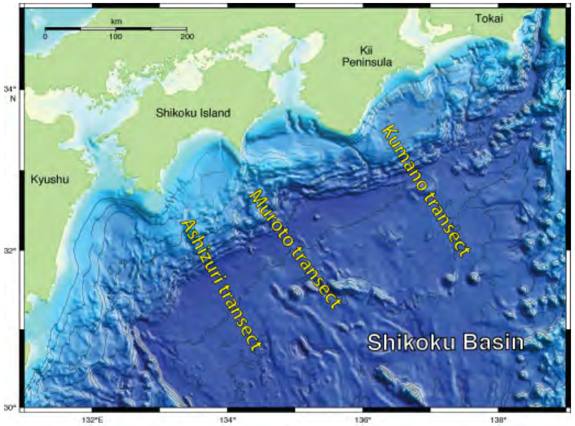


Décollement propagates just above turbidite facies

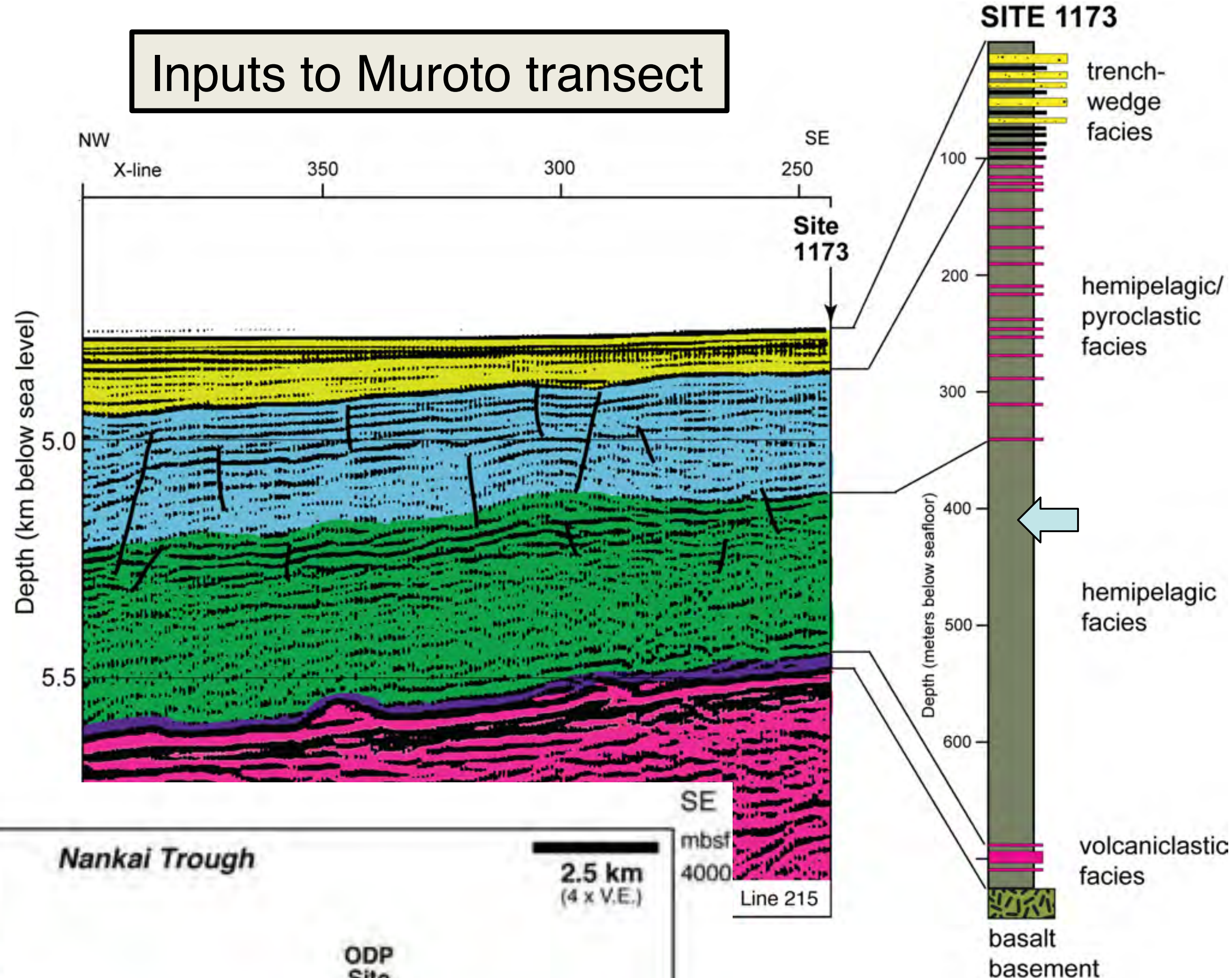


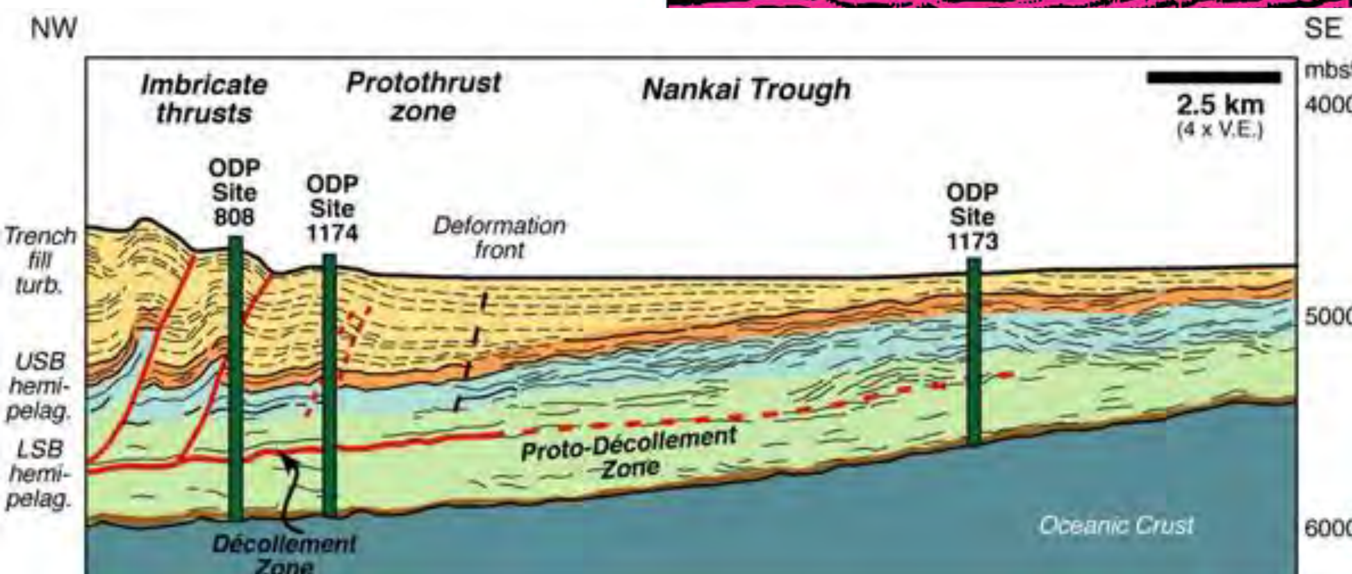
Smooth basement;
turbidites subducted

Inputs to Muroto transect



Décollement propagates within hemipelagic facies



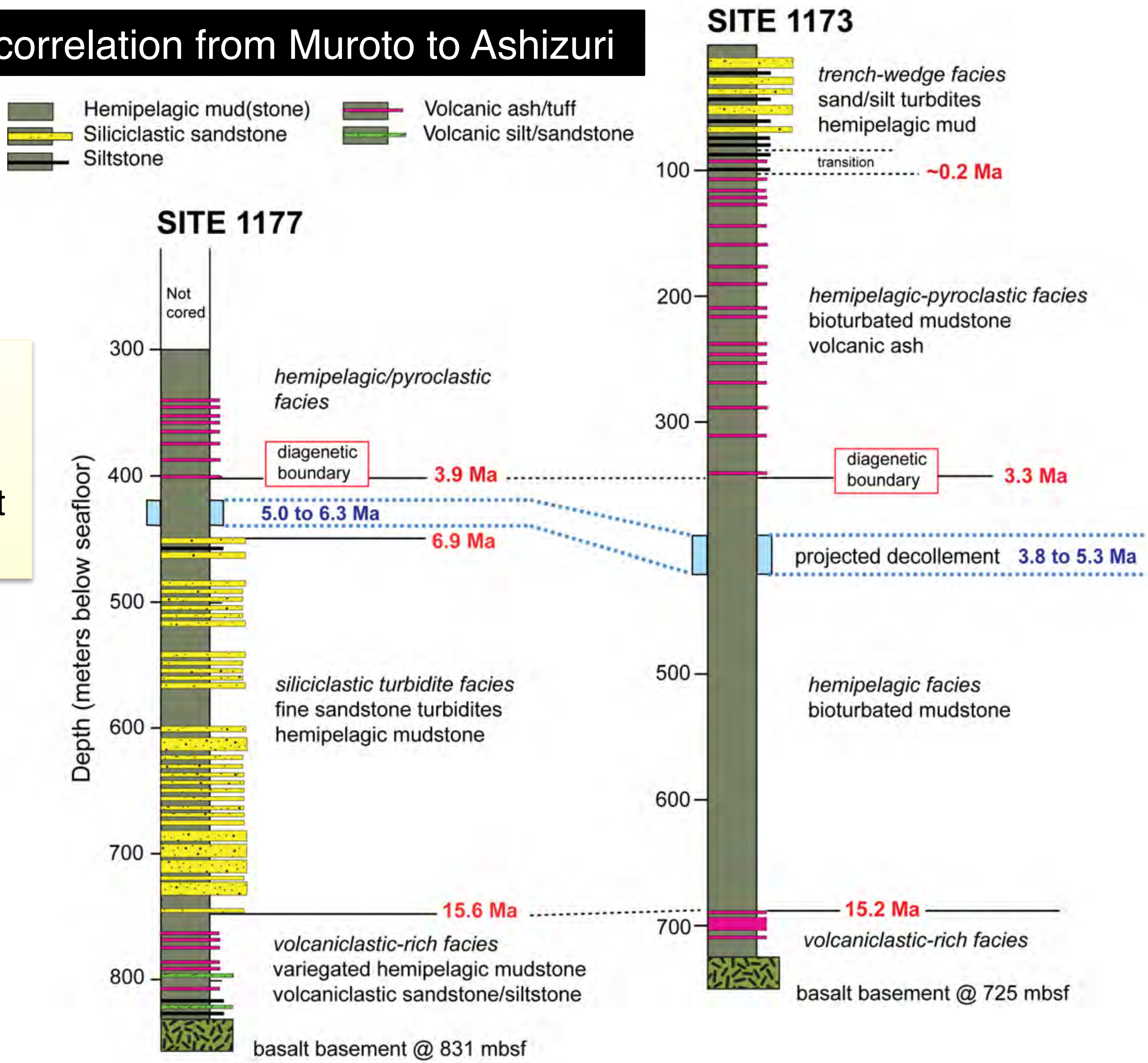


Basement high along Kinan seamount chain; *no turbidites subducted*

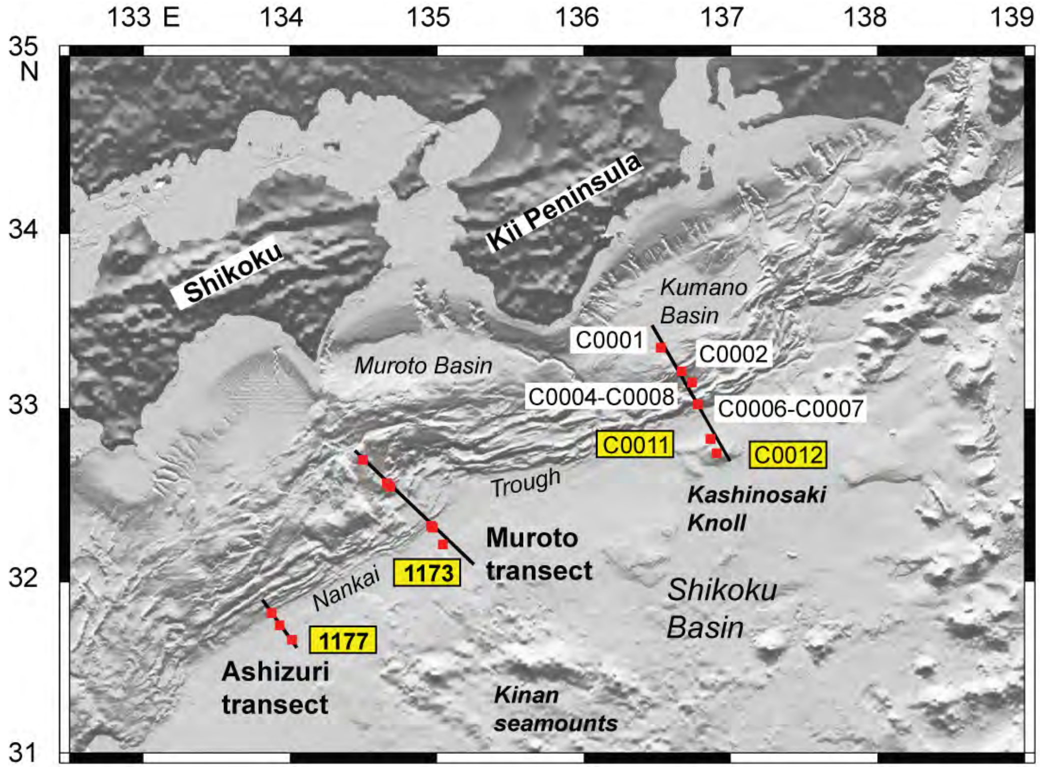
Stratigraphic correlation from Muroto to Ashizuri

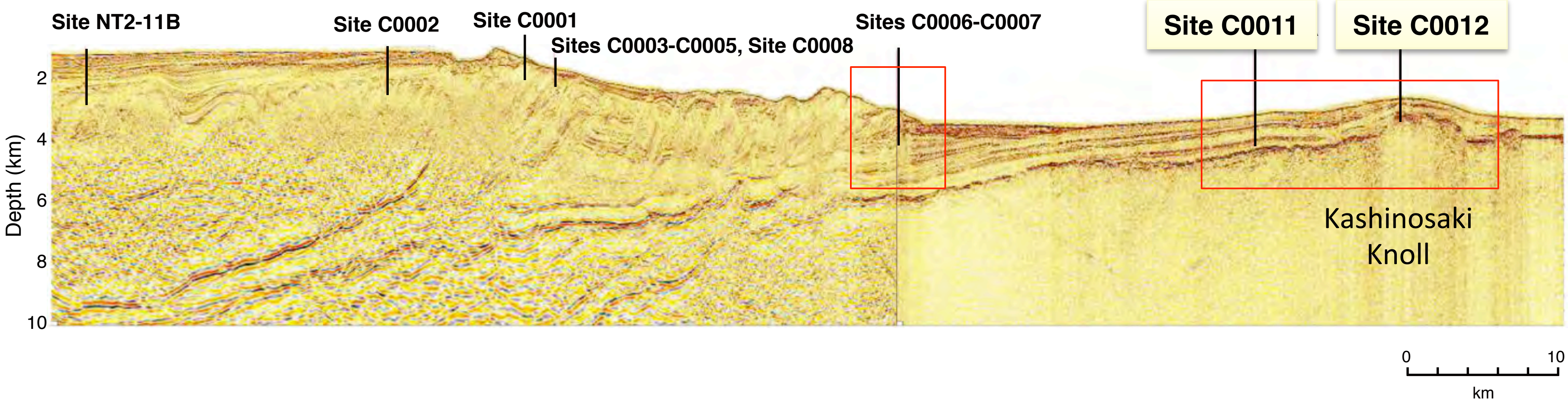
Base of hemipelagic/ pyroclastic facies (USB) at 3.3 to 3.9 Ma

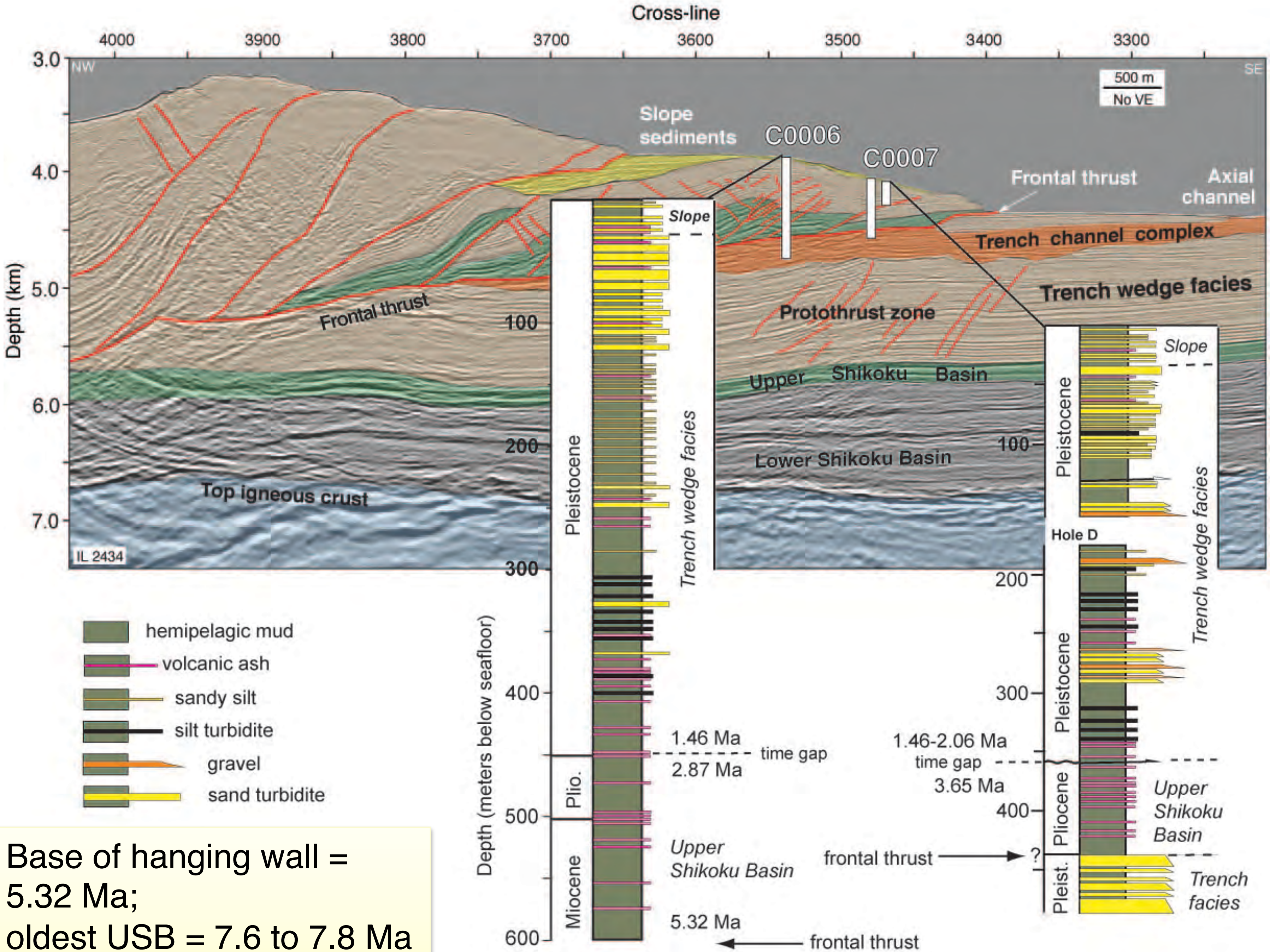
Age of décollement zone = 3.8-5.3 Ma 5.0-6.3 Ma



Seismogenic Zone Experiment: Which units subduct to up-dip limit?



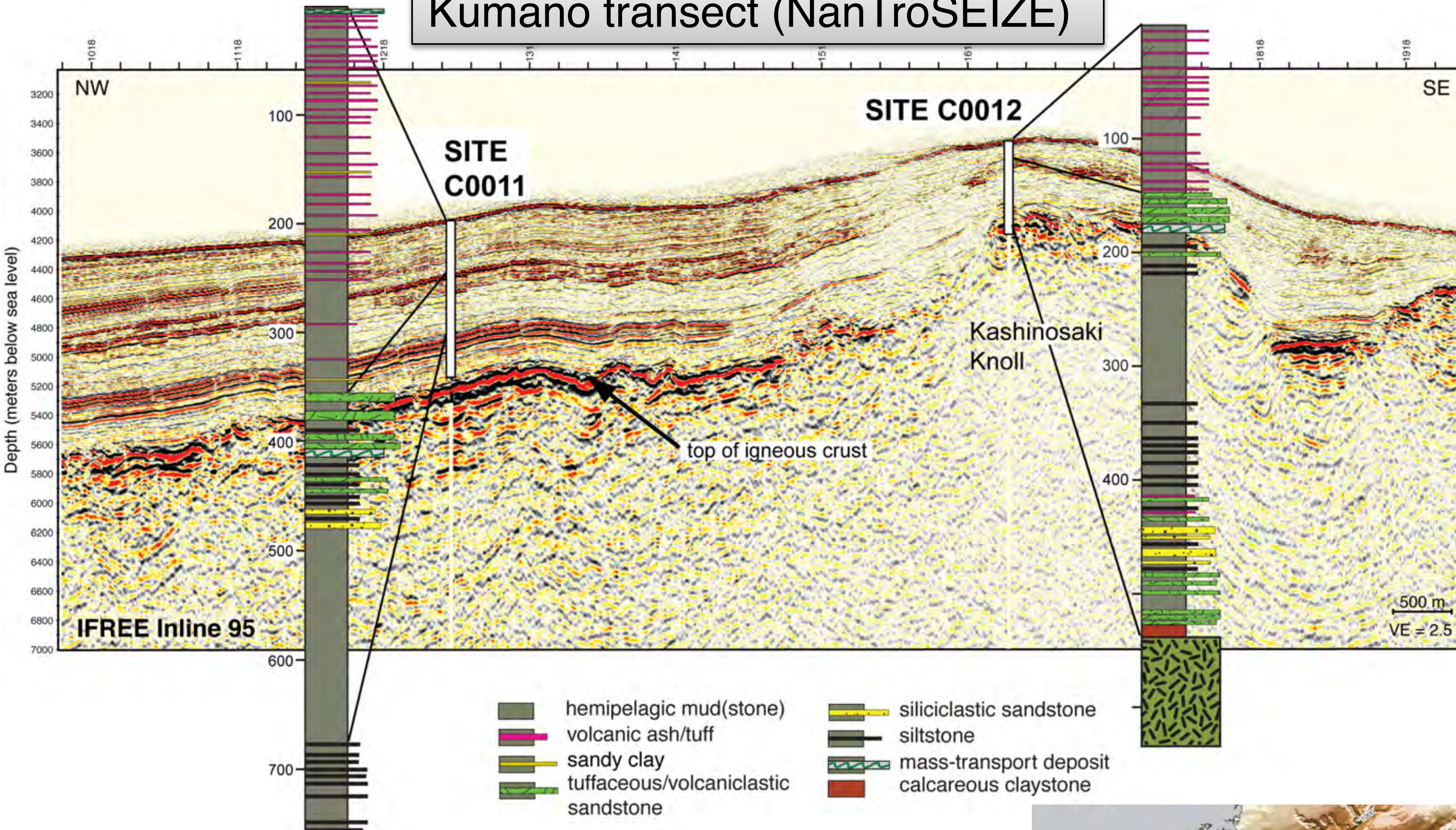




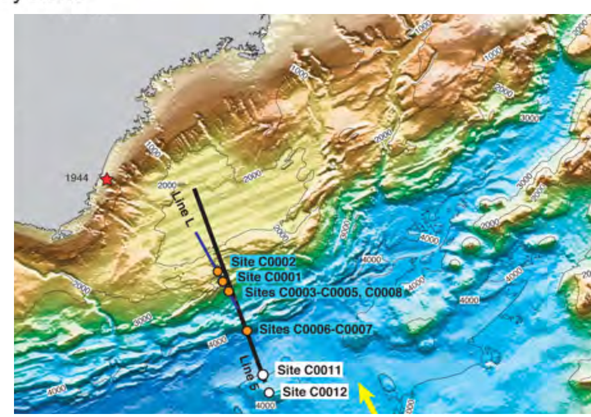
Base of hanging wall = 5.32 Ma;
oldest USB = 7.6 to 7.8 Ma

Underwood & Moore (2012)

Kumano transect (NanTroSEIZE)

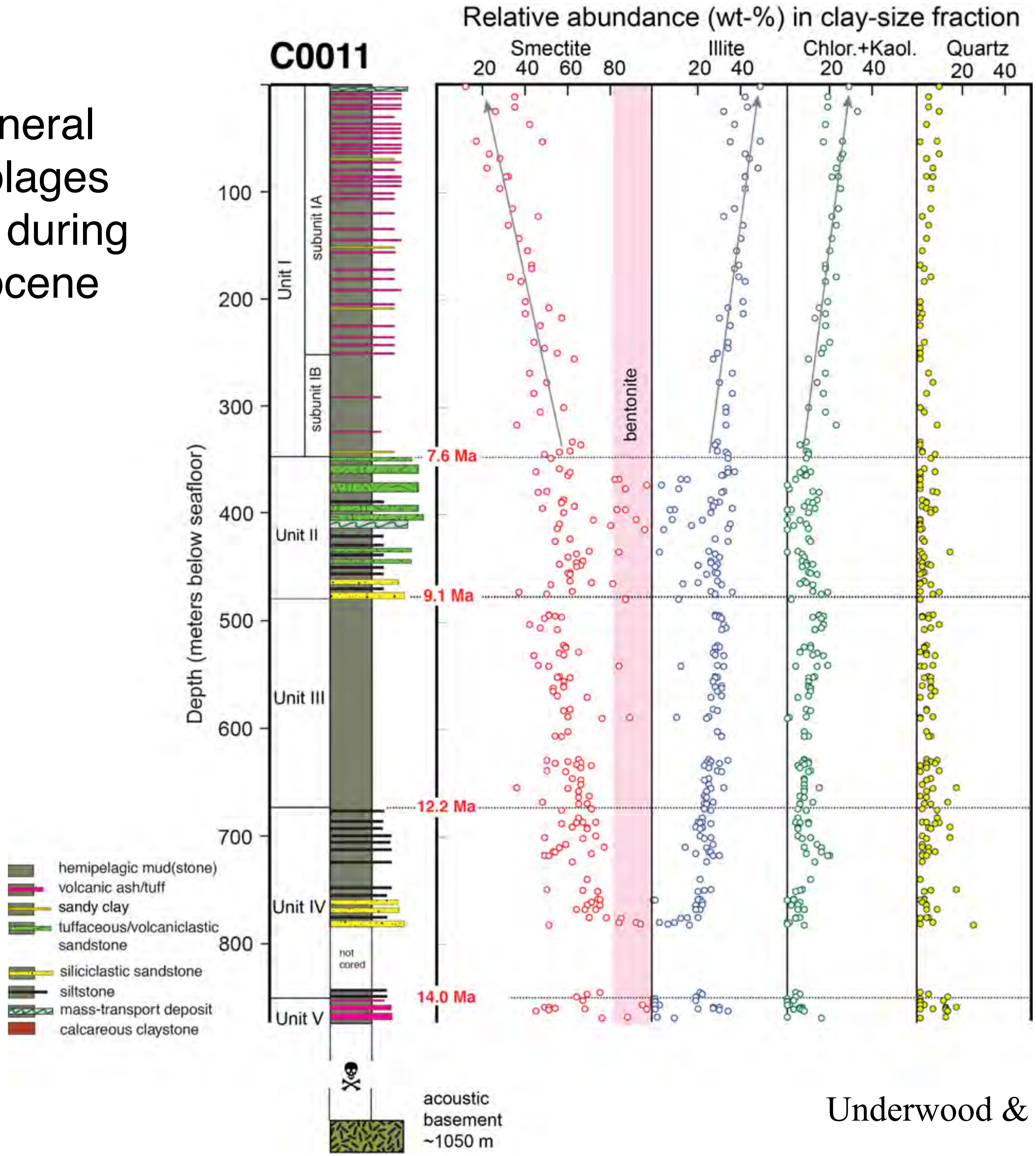


Miocene turbidites in lower Shikoku Basin are subducted



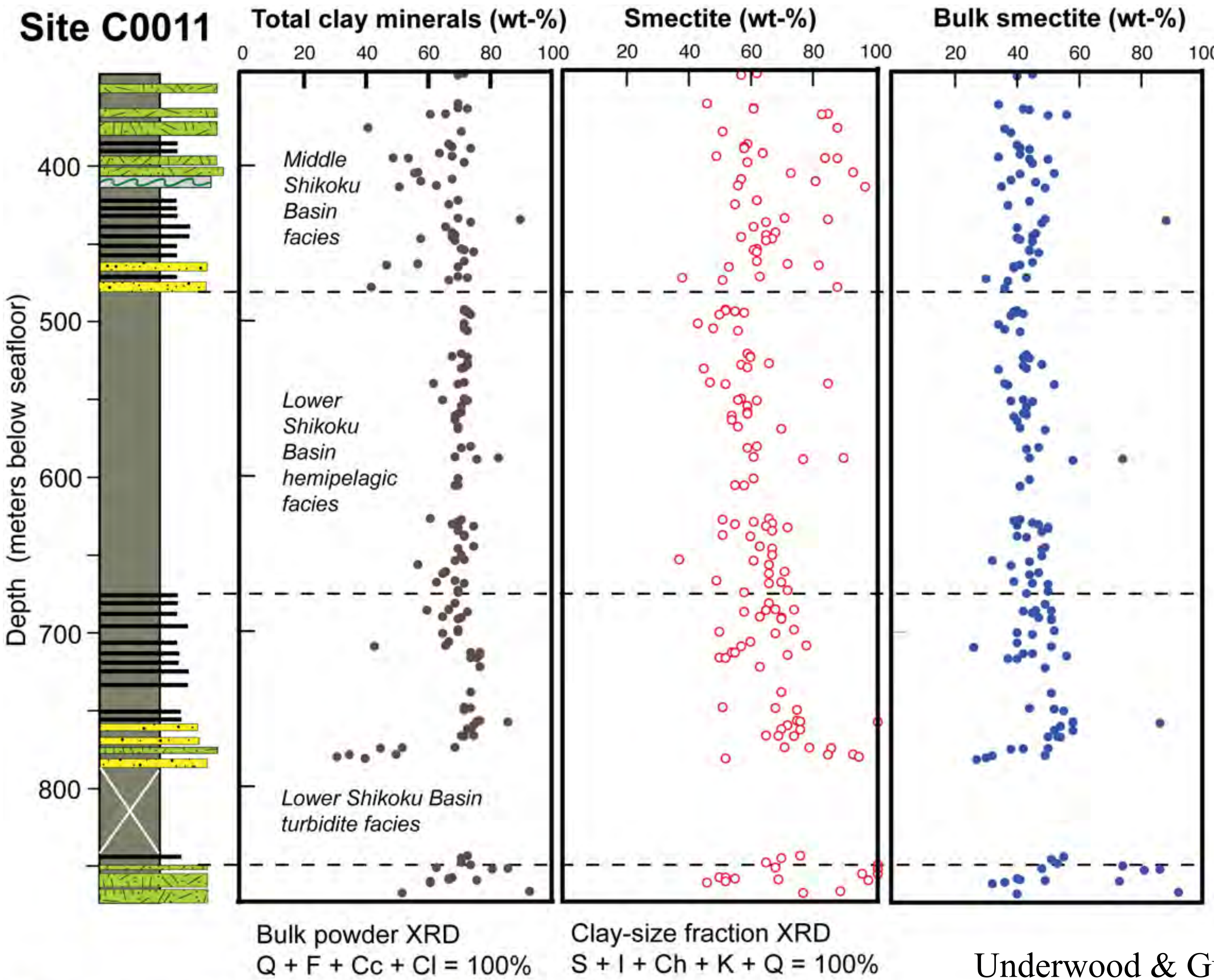
IODP Expeditions 322, 333 & 338

Clay mineral assemblages change during late Miocene



Underwood & Guo (in press)

Unusually high content of smectite – important for fluid production and pore pressure as strata move toward up-dip limit of seismogenic zone

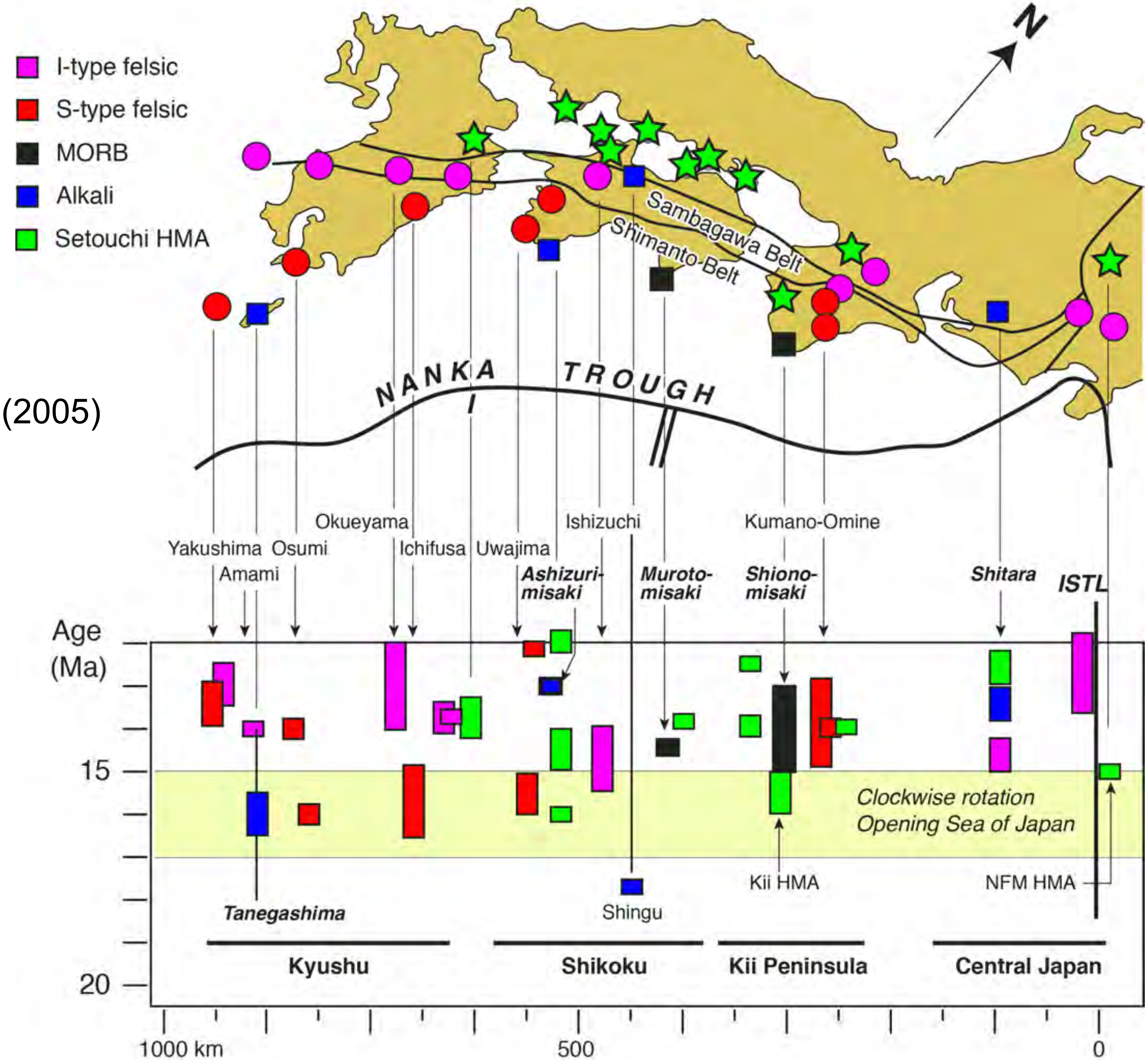


Underwood & Guo (in press)

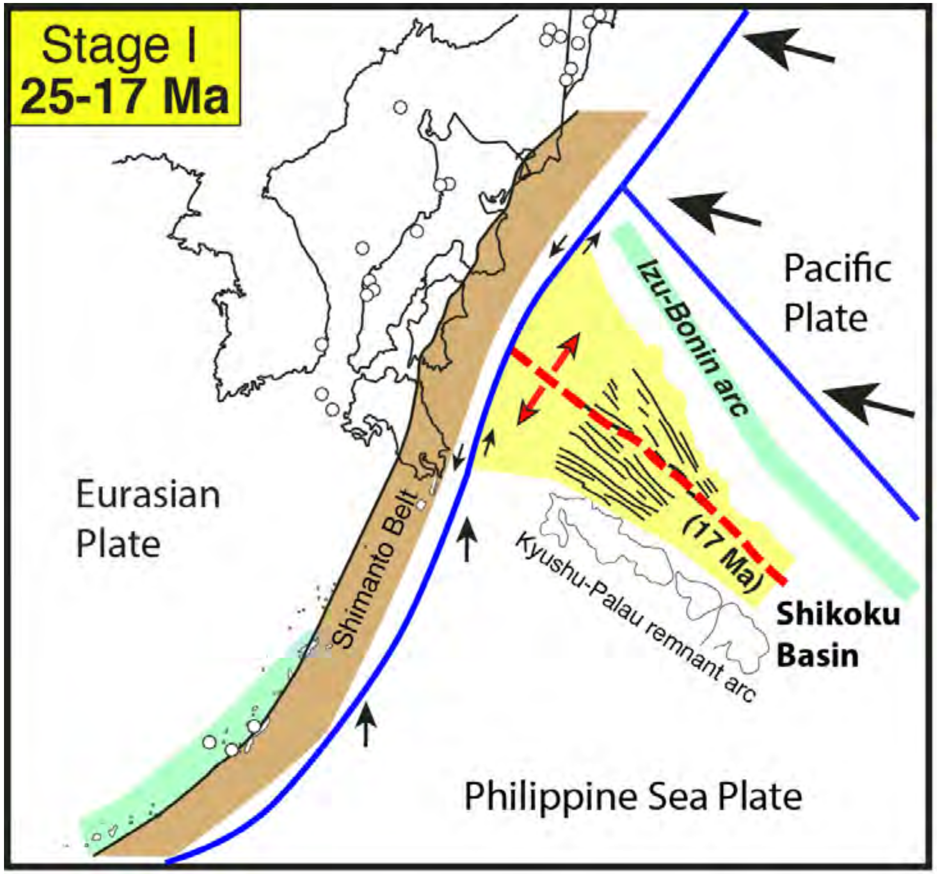
Modulation of clay minerals

- Parent rocks in source areas
- Climate and topography
- Volcanism
- Prevailing wind direction
- Surface/bottom currents
- Bathymetry => gravity flows
- Early diagenesis (volc. glass => smectite)

Kimura et al. (2005)
GSA Bulletin

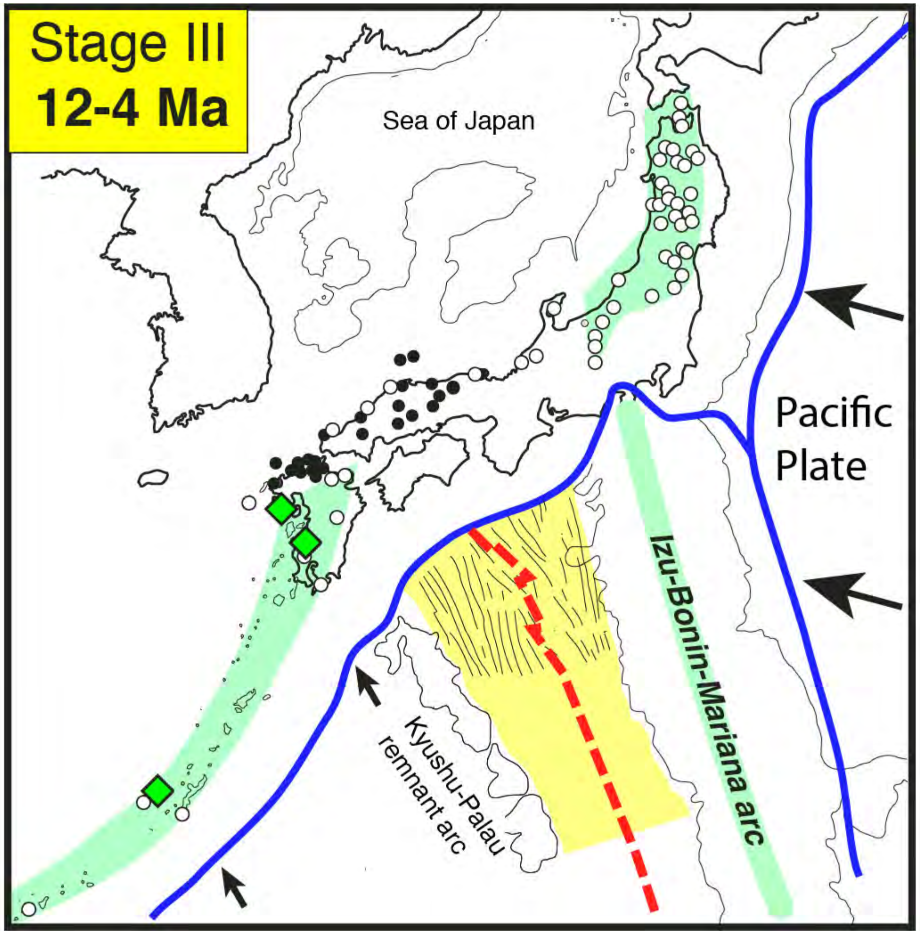


After: Kimura et al. (2005) – *GSA Bulletin*



Formation of basement high (Kashinosaki Knoll) near back-arc ridge axis (Kinan seamounts)

After: Kimura et al. (2005) – *GSA Bulletin*



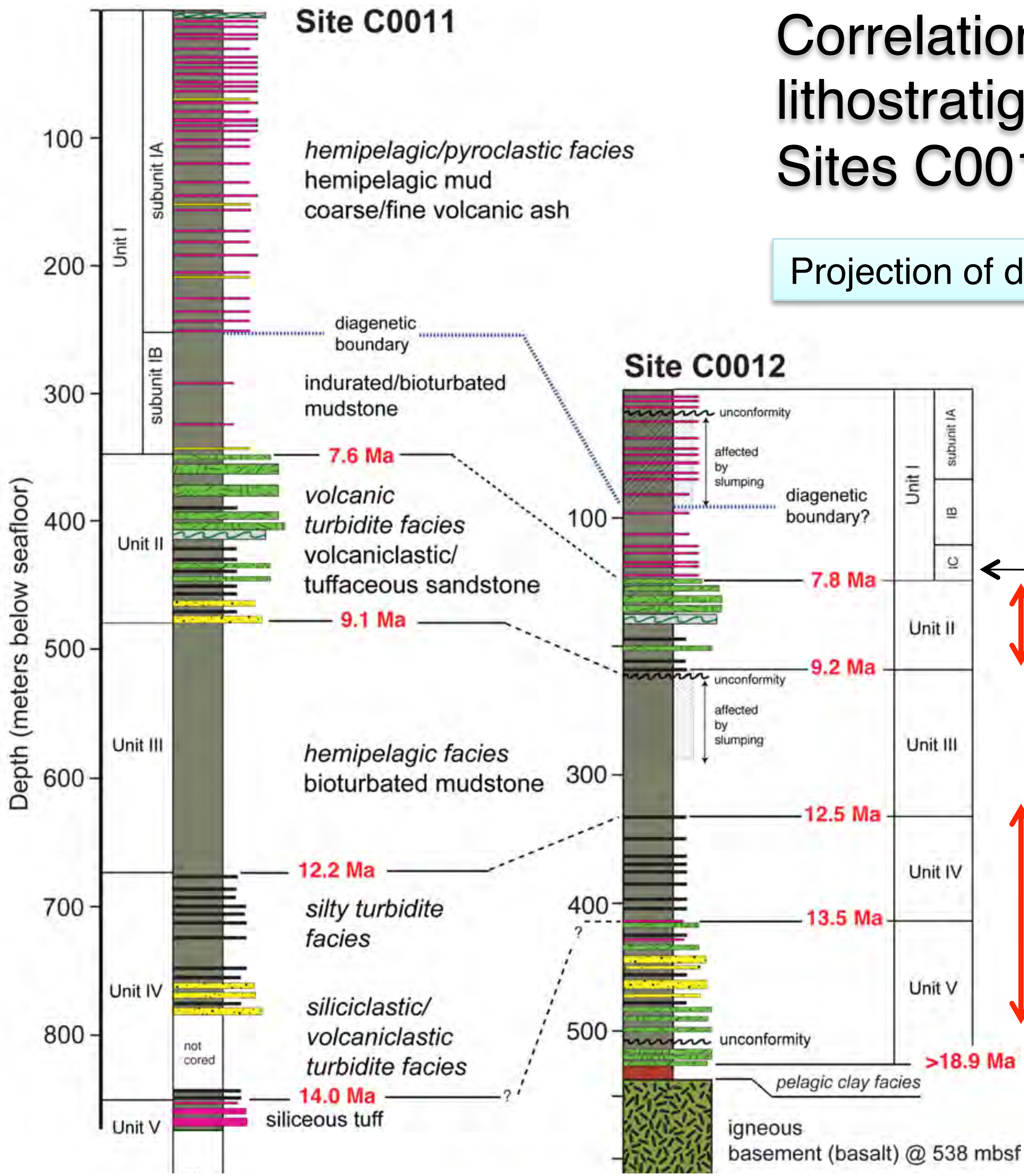
Cessation of near-trench volcanism
Progressive erosion of plutons and
accretionary prism

Influences on sand bodies

- Parent rocks in source areas
- Climate and topography
- Volcanism
- Bathymetry => gravity flows
- Incision of submarine canyons
- Sea level
- Basement relief (seamounts)
- Prism architecture (upslope trapping)

Correlation of lithostratigraphy between Sites C0011 and C0012

Projection of décollement zone ~5.3 Ma)



Base of hemipelagic/pyroclastic facies (USB) at 7.6-7.8 Ma

Zenisu fan

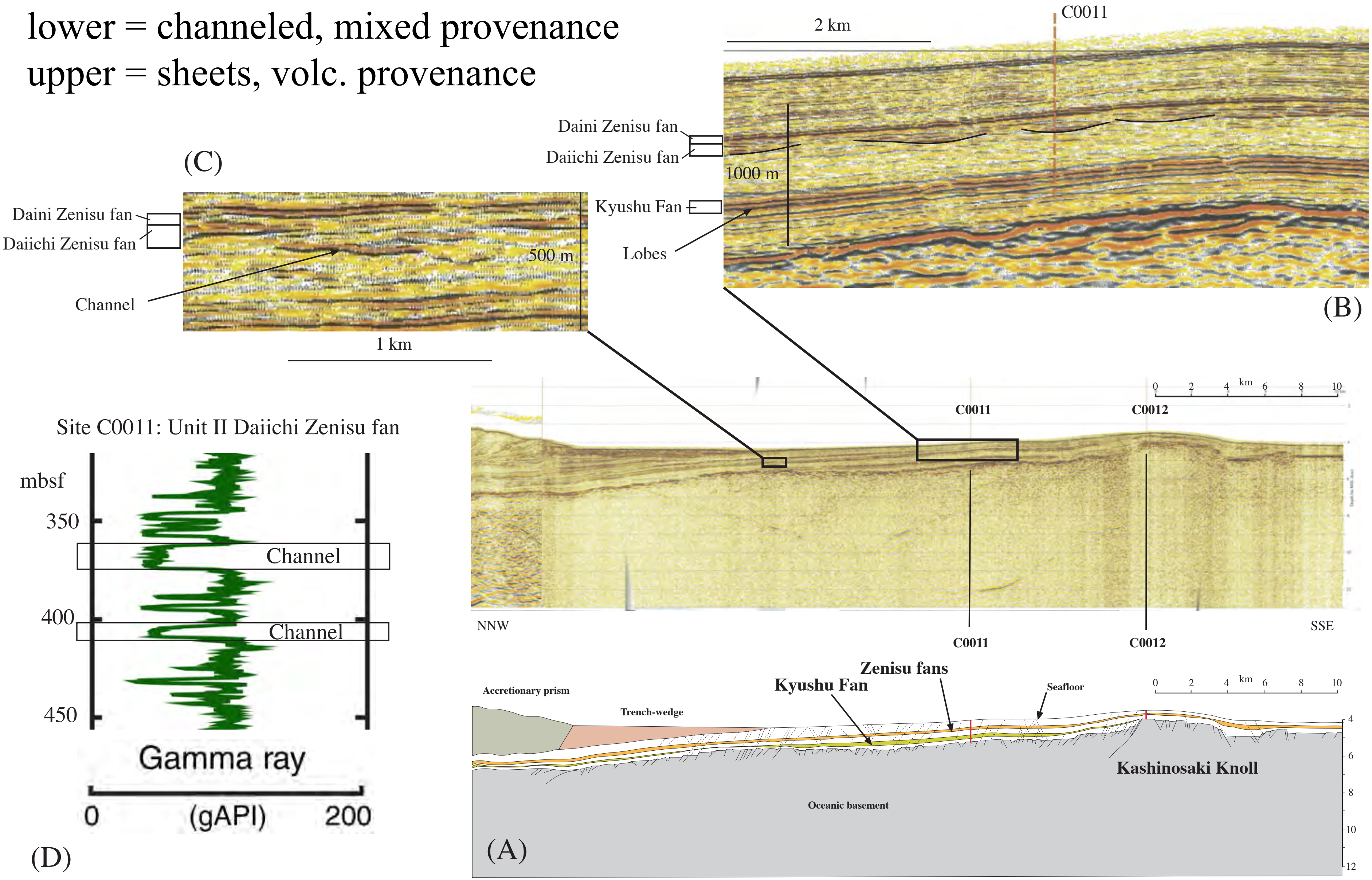
Kyushu fan

Note that sand bodies extend to crest of Kashinosaki Knoll

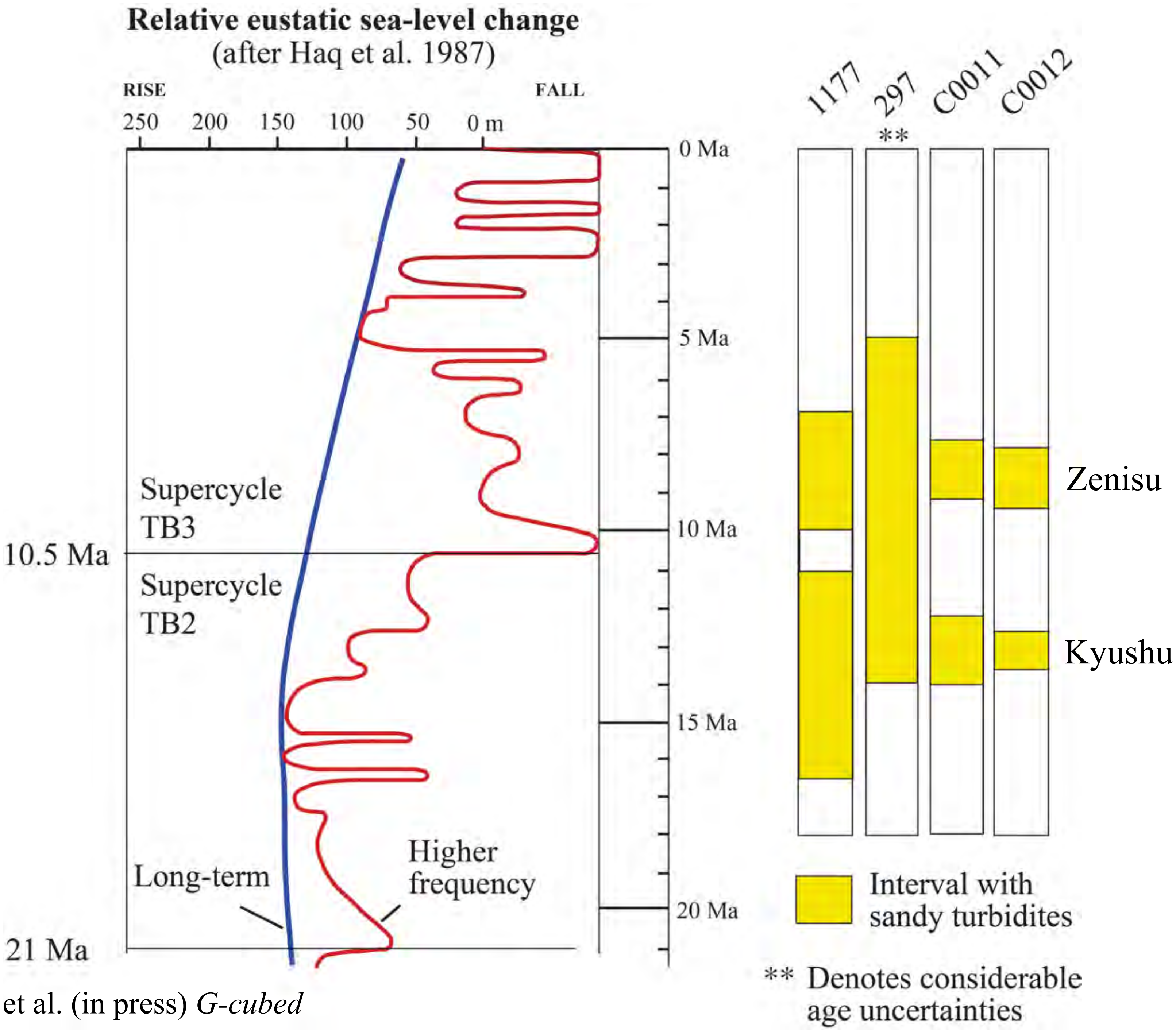
Zenisu fan

lower = channeled, mixed provenance

upper = sheets, volc. provenance

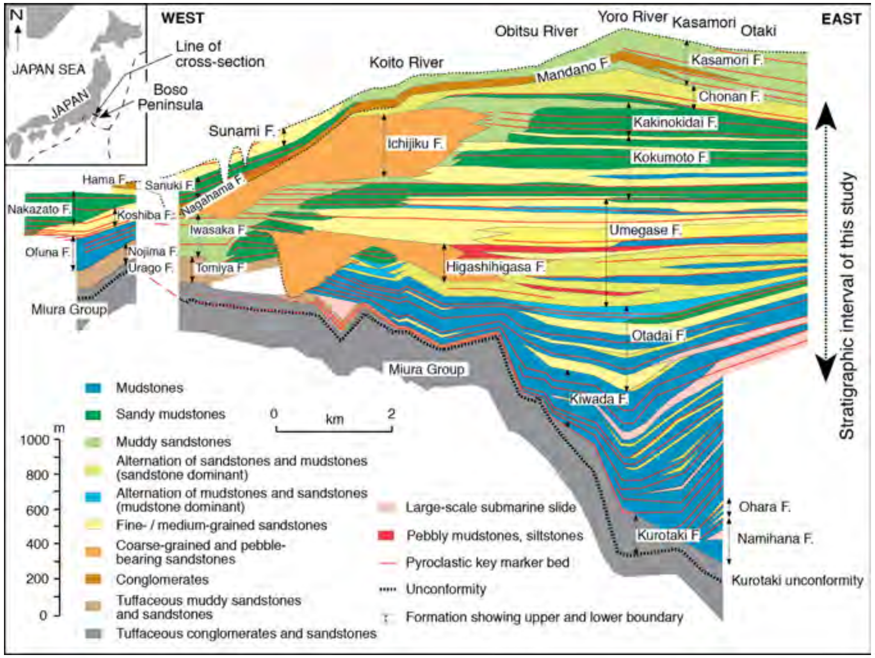


Pickering et al. (in press) *G-cubed*

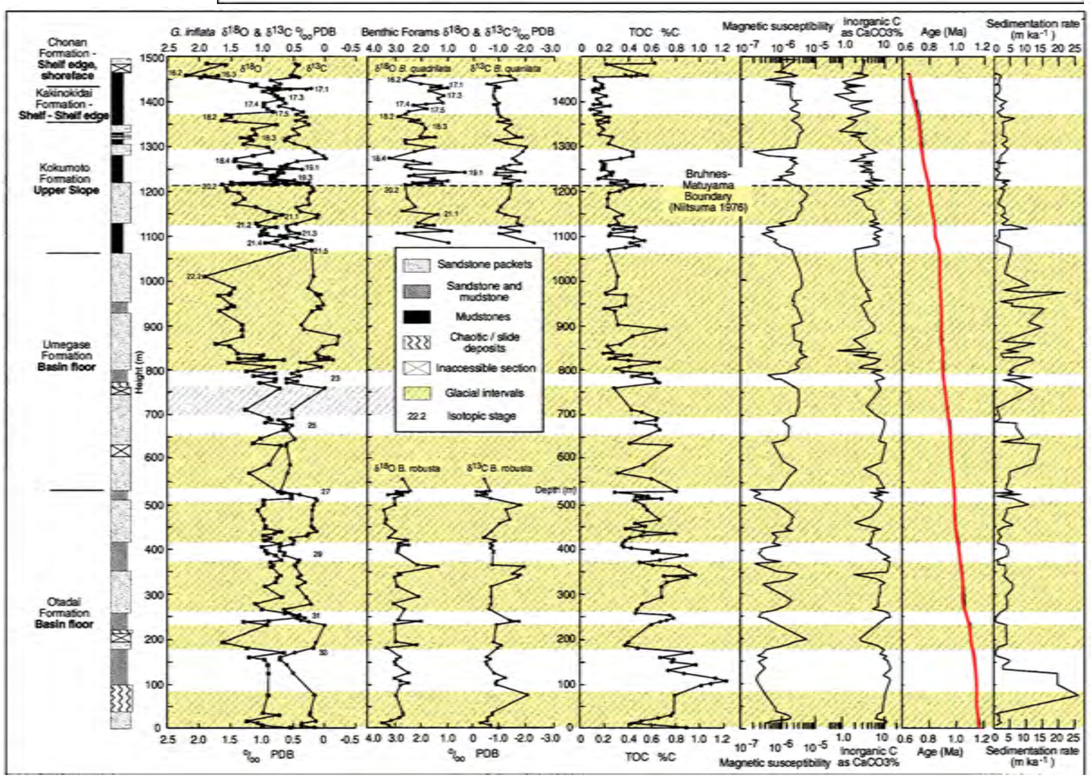


Pickering et al. (in press) *G-cubed*

Plio-Pleistocene Kazusa Group Boso Peninsula (forearc basin)

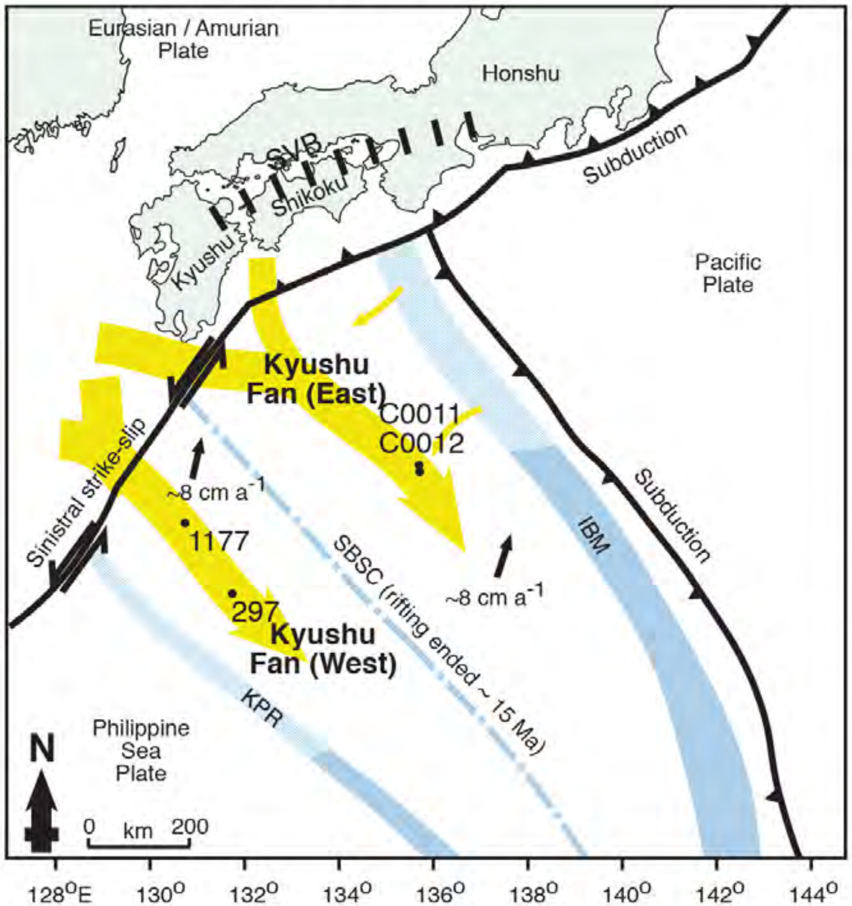


Pickering et al. (1999)
J. Geol. Soc. London



Model for comparison to Kumano forearc basin

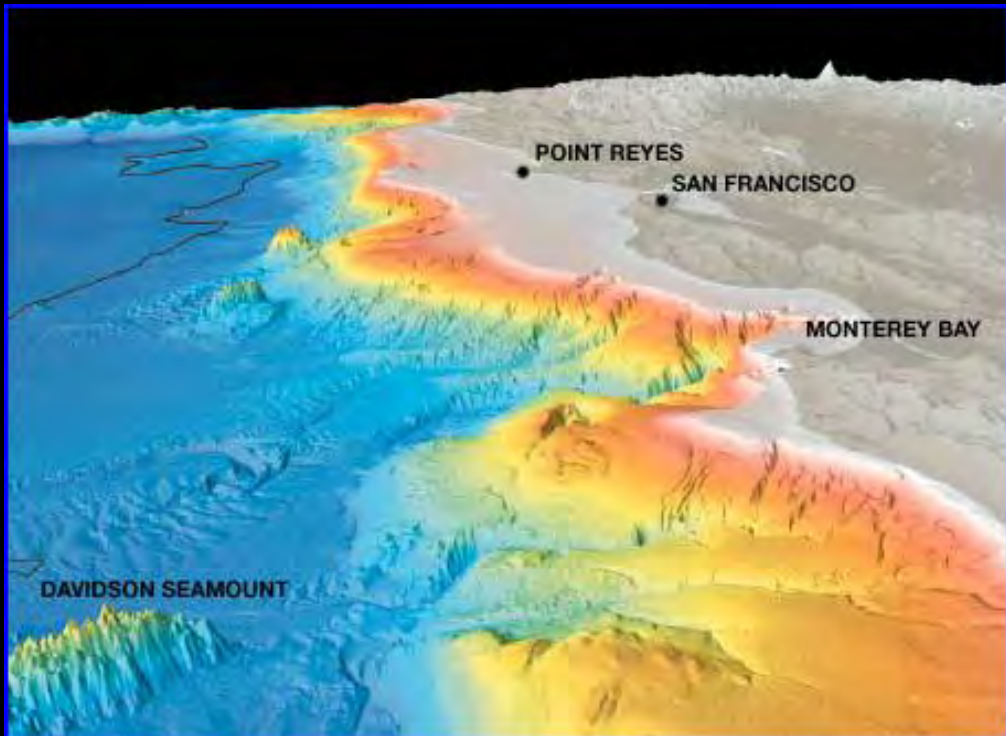
~13 Ma

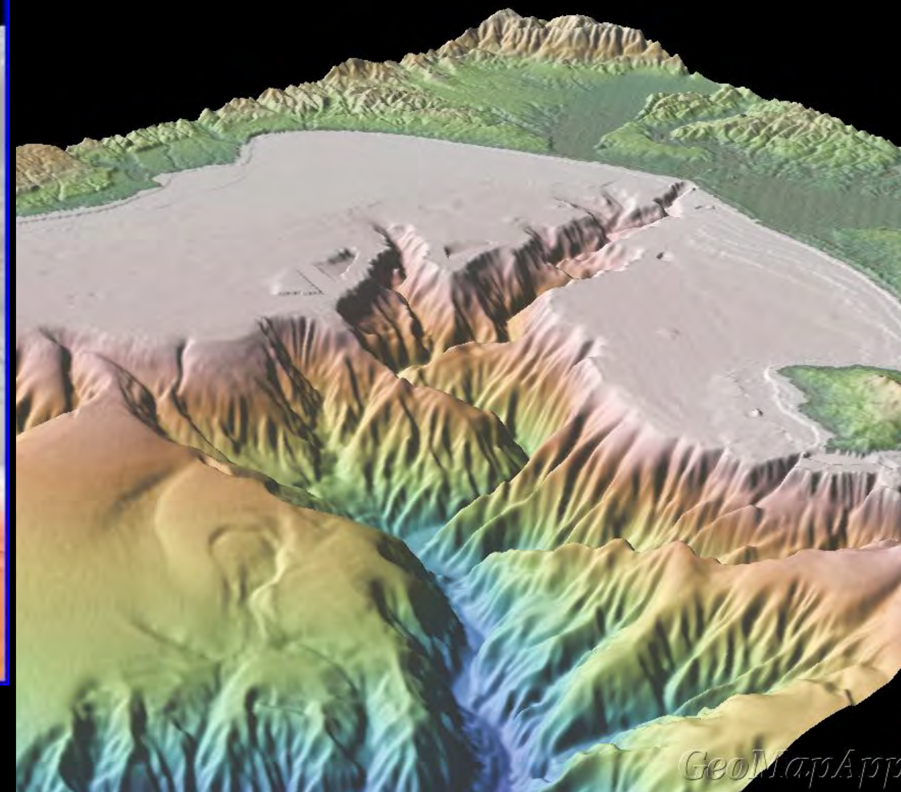


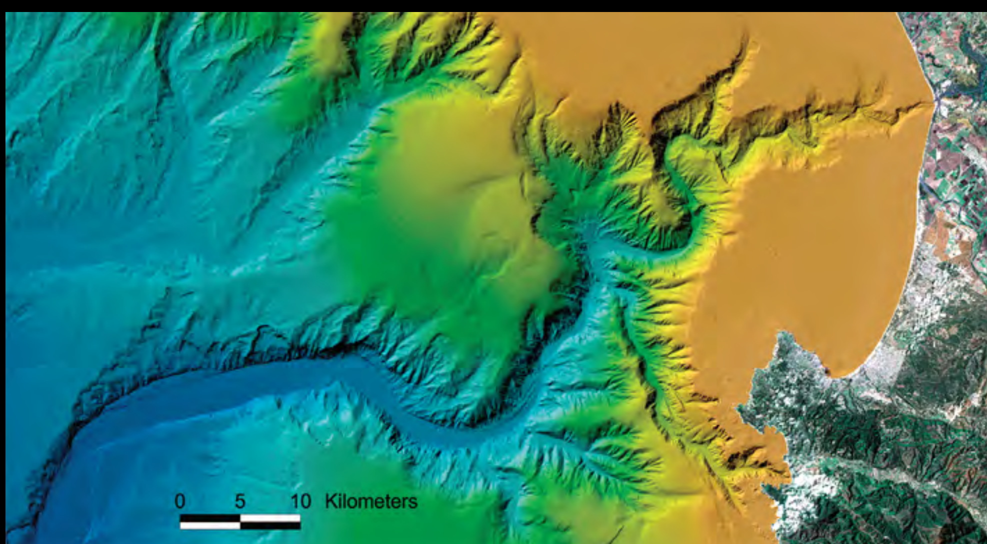
Kyushu Fan ~14.3 to 12.2 Ma

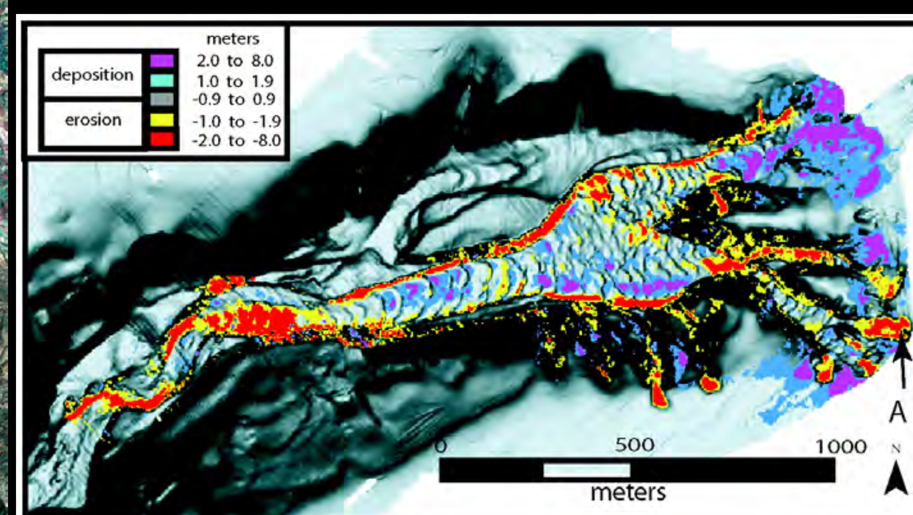
Pickering et al. (in press) *G-cubed*

Monterey canyon/fan



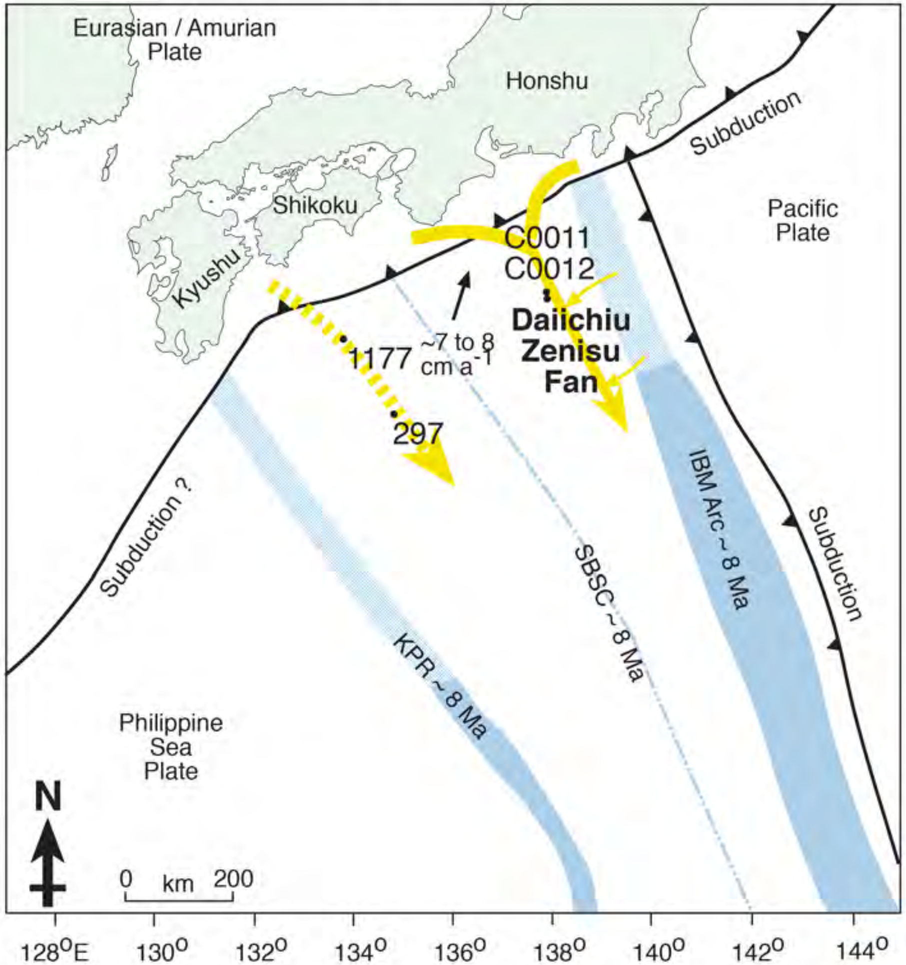






~ 8 Ma

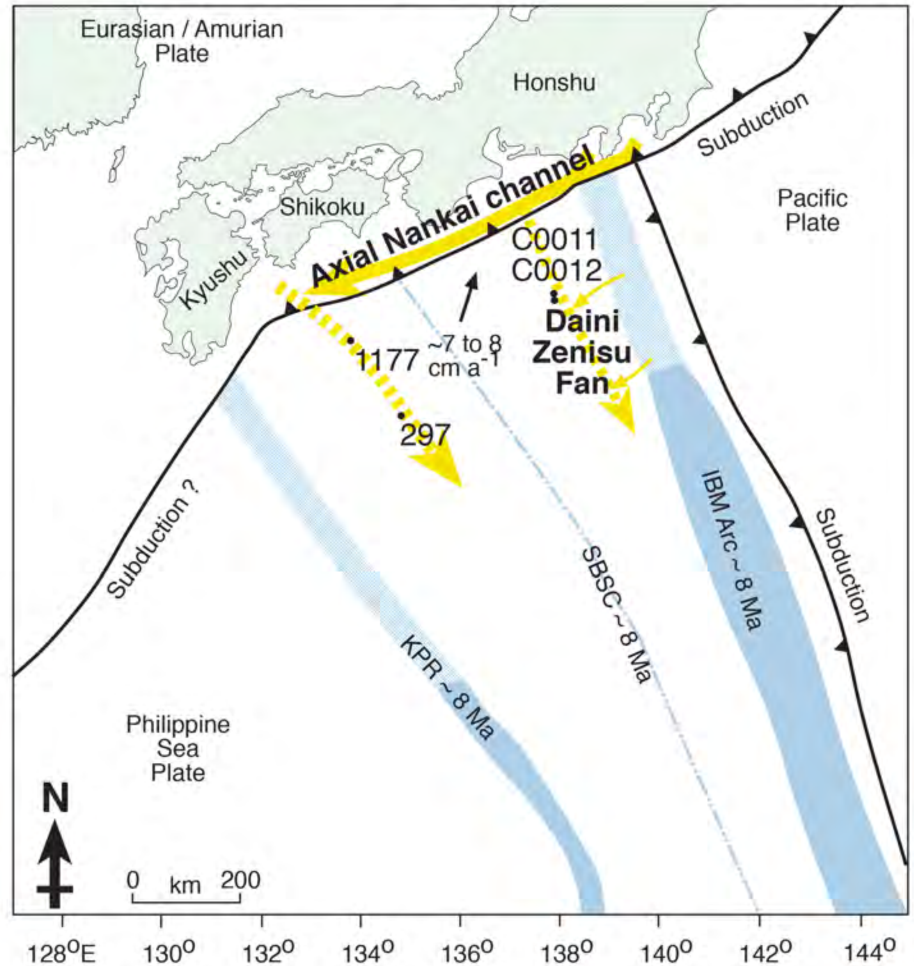
Pickering et al. (in press) *G-cubed*



Daiichi Zenisu Fan ~8 to 7.6 Ma

(Pre re-initiation of northward subduction of Shikoku basin)

~ 8 Ma



Daini Zenisu Fan ~8 to 7.6 Ma

(Post re-initiation of northward subduction of Shikoku basin)

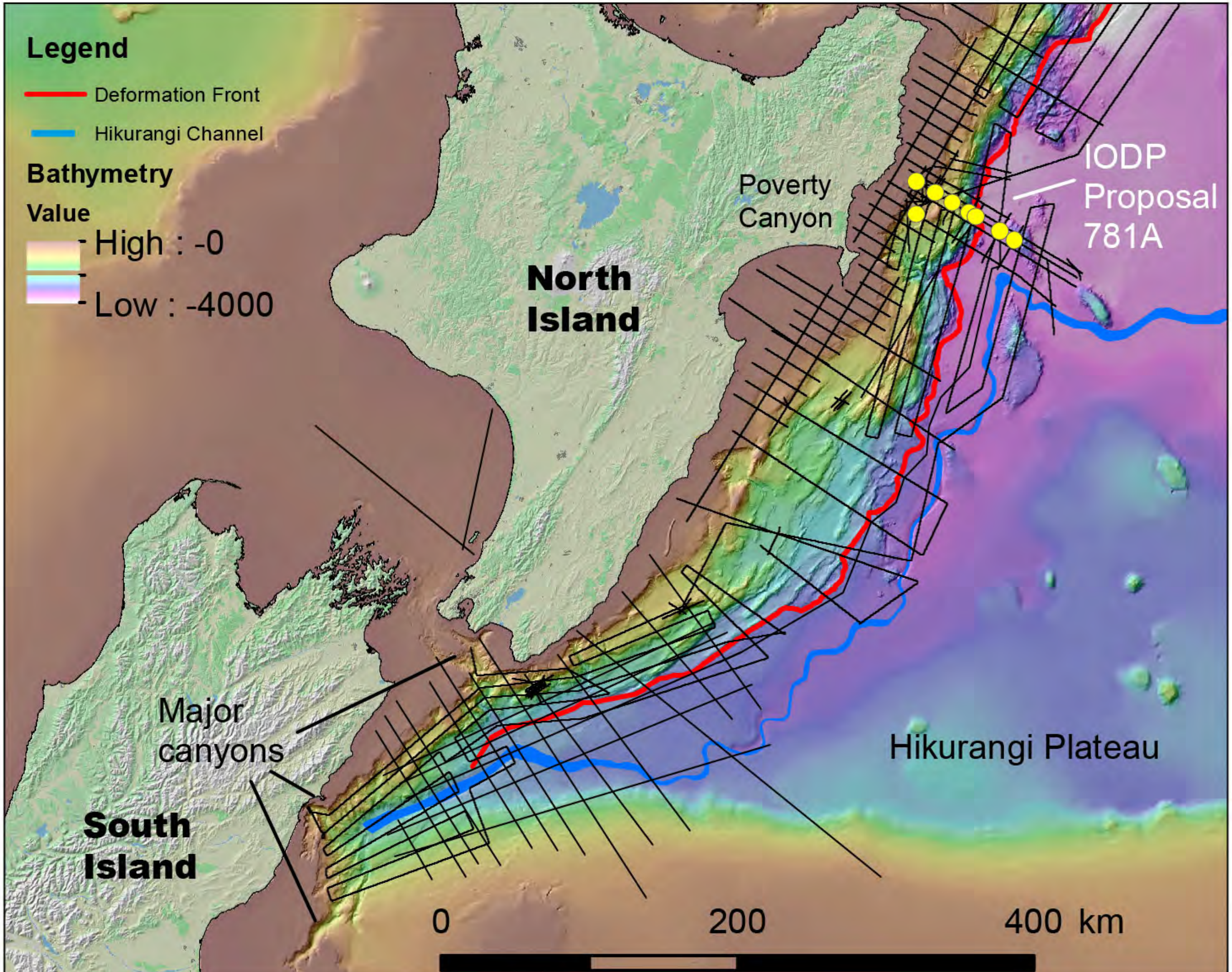
Lessons learned from Nankai:

- Three drilling transects, five decades
- Ashizuri
  - DSDP Legs 31, 87
  - ODP Leg 190
- Muroto
  - ODP Legs 131, 190, 196
- Kumano
  - IODP Expeditions 314, 315, 316, 319, 338 (prism, forearc)
  - IODP Expeditions 322, 333, 338 (inputs)
  - IODP Expedition 348 (scheduled => deep prism)
  - IODP Expedition 3xx (planned => megasplay)

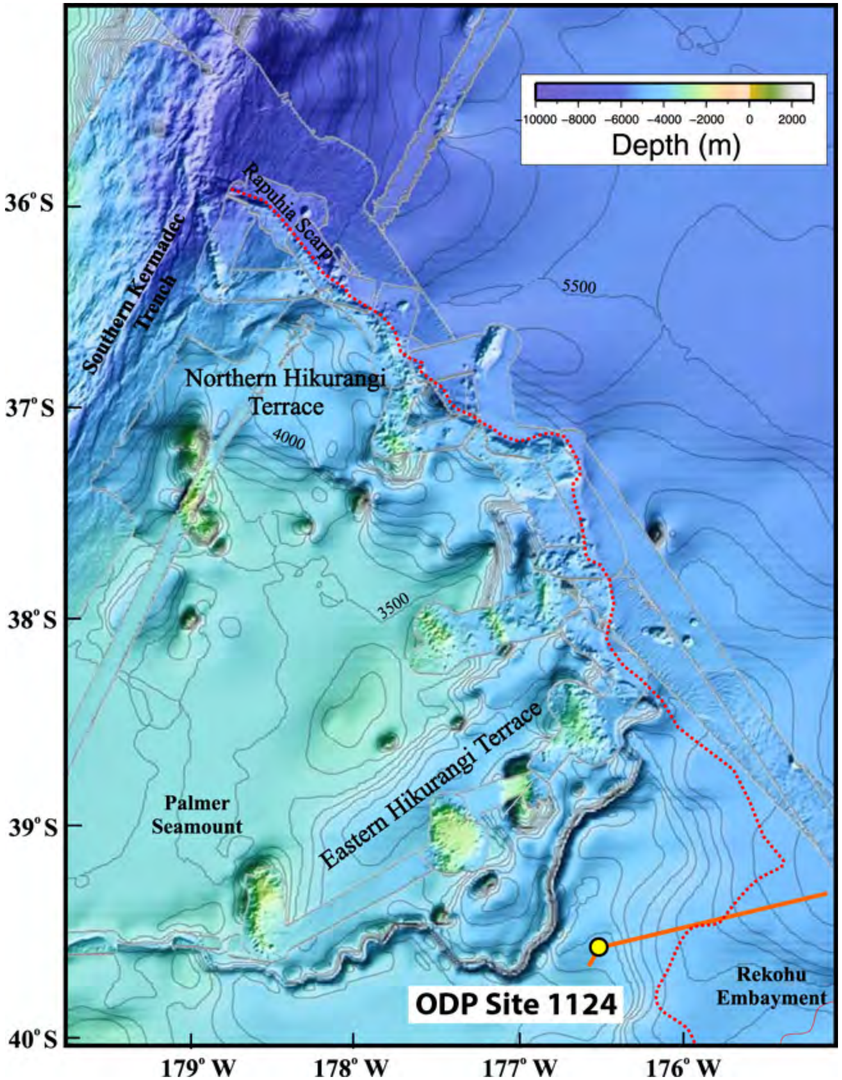
Lessons learned from Nankai:

- Facies boundaries are time-transgressive
- Facies units are not continuous along strike
- Turbidites are subducted at frontal decollement
- Sand influx/deposition were influenced by:
  - Basement topography in Shikoku Basin
  - Reorganizations of plate boundary, arc collision
  - Incision of submarine canyons
  - Eustatic lowstands
- Clay mineral assemblages were influence by:
  - Anomalous near-trench volcanism
  - Progressive unroofing of plutons, accreted sediments
  - Temporal changes in ocean water circulation

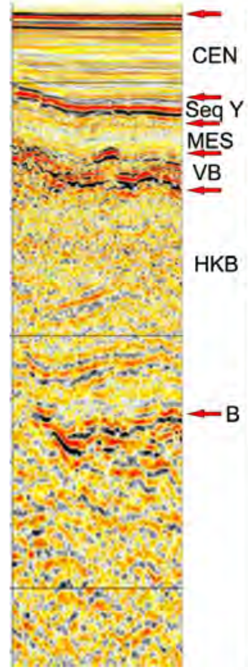
So, what does this mean for planning Hikurangi science?



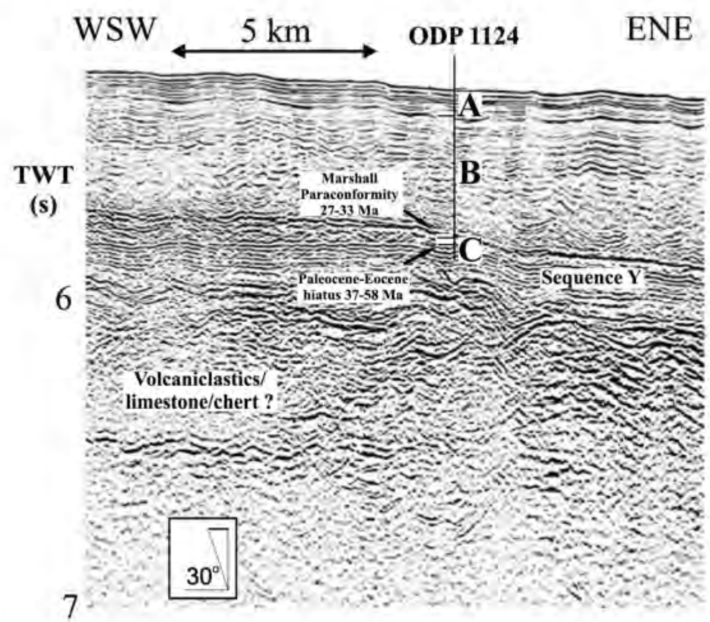
Hikurangi Plateau



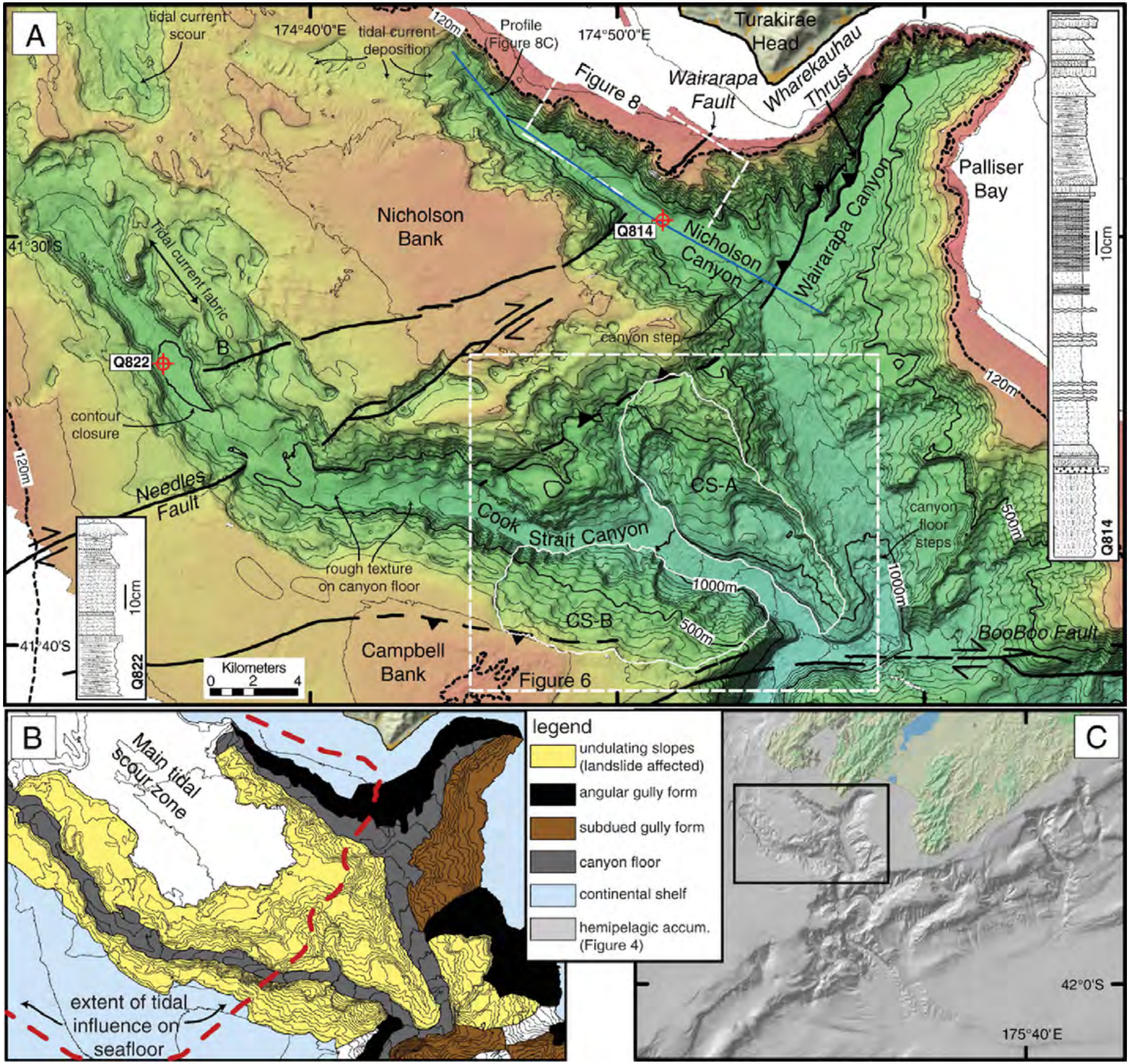
Davy et al. (2008) *G-Cubed*



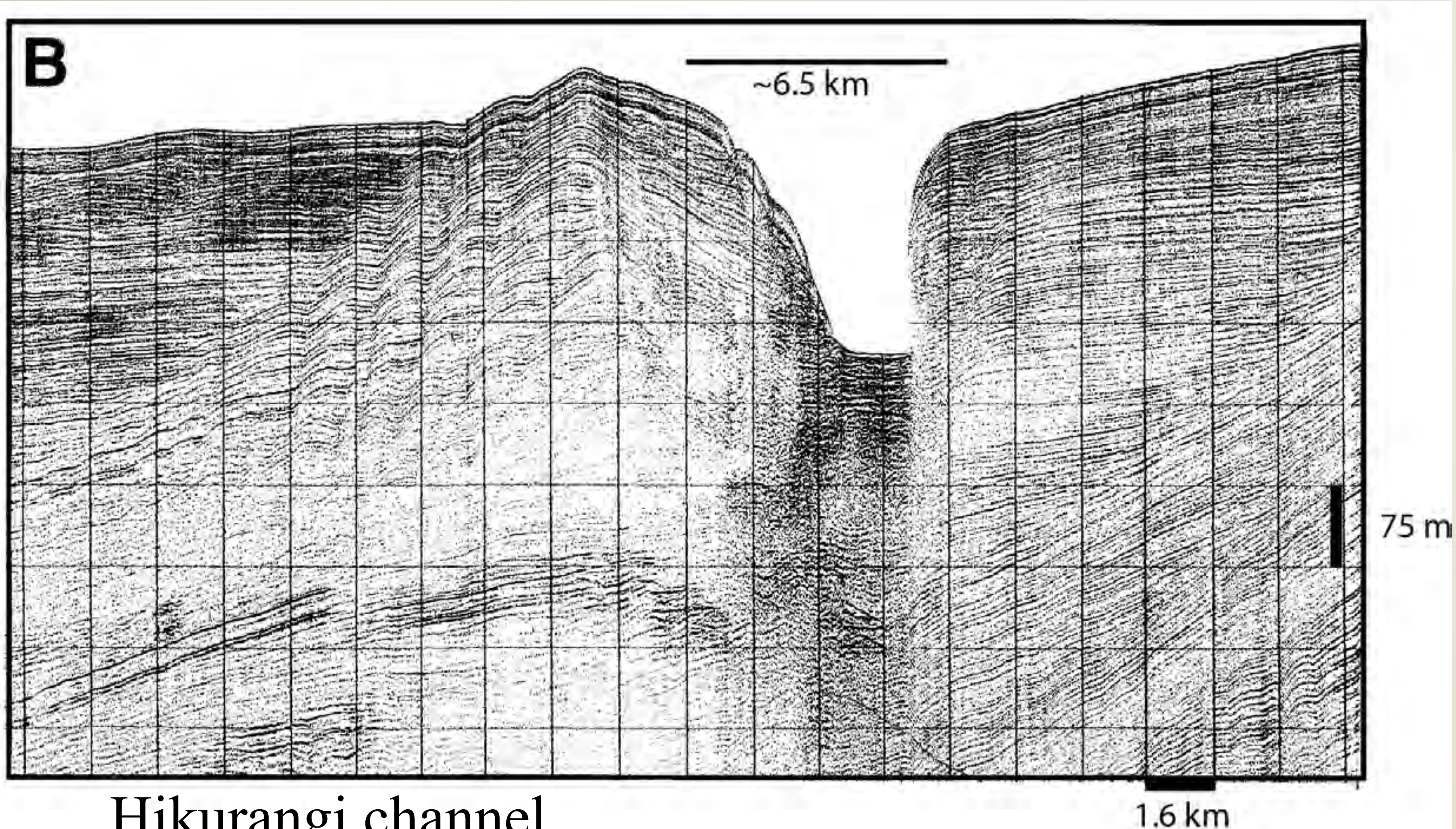
Unit description	Interval velocity	Age range
Cenozoic sediment - nanofossil chalks with interbeds of tephras and clay	1500-1600 m/s	32-0 Ma
E. Oligocene-L.Cretaceous chalks/mudstone	2300-3300 m/s	70-32 Ma



Cook Strait

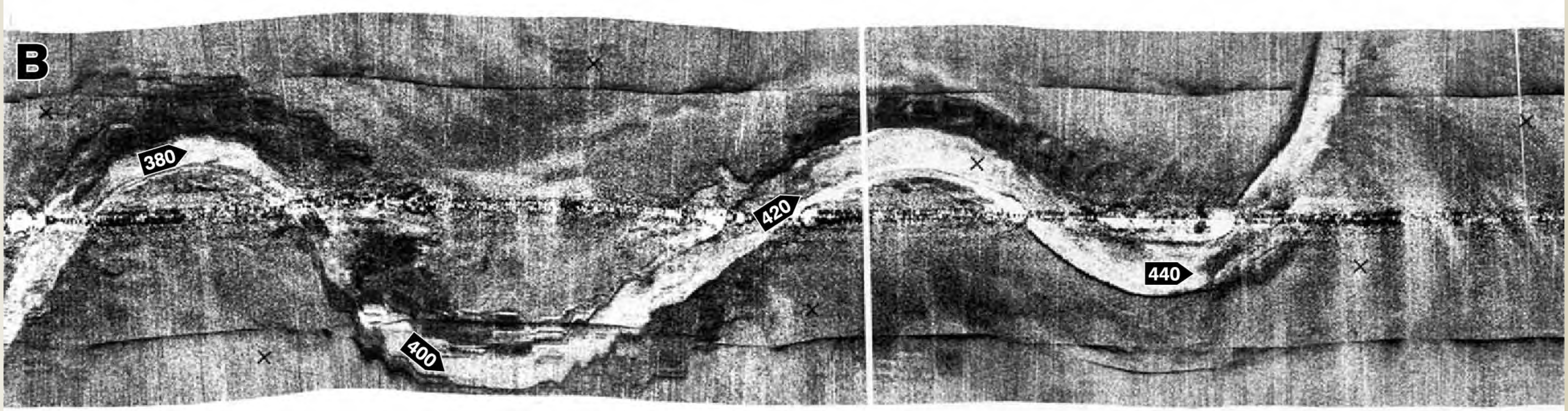


Mountjoy et al. (2009) *Mar. Geol.*

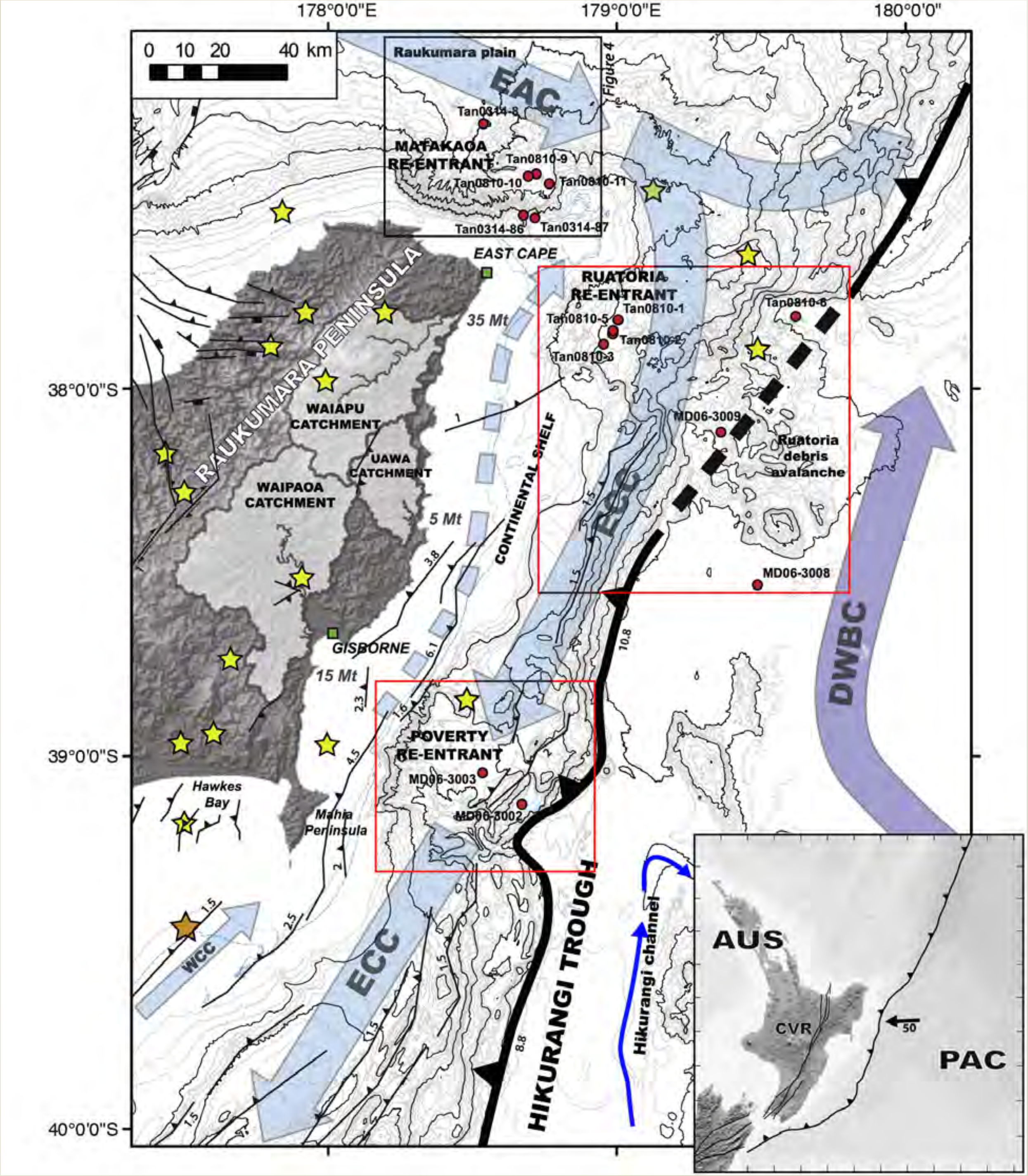


Lewis et al. (1998) *Basin Research*

Hikurangi channel

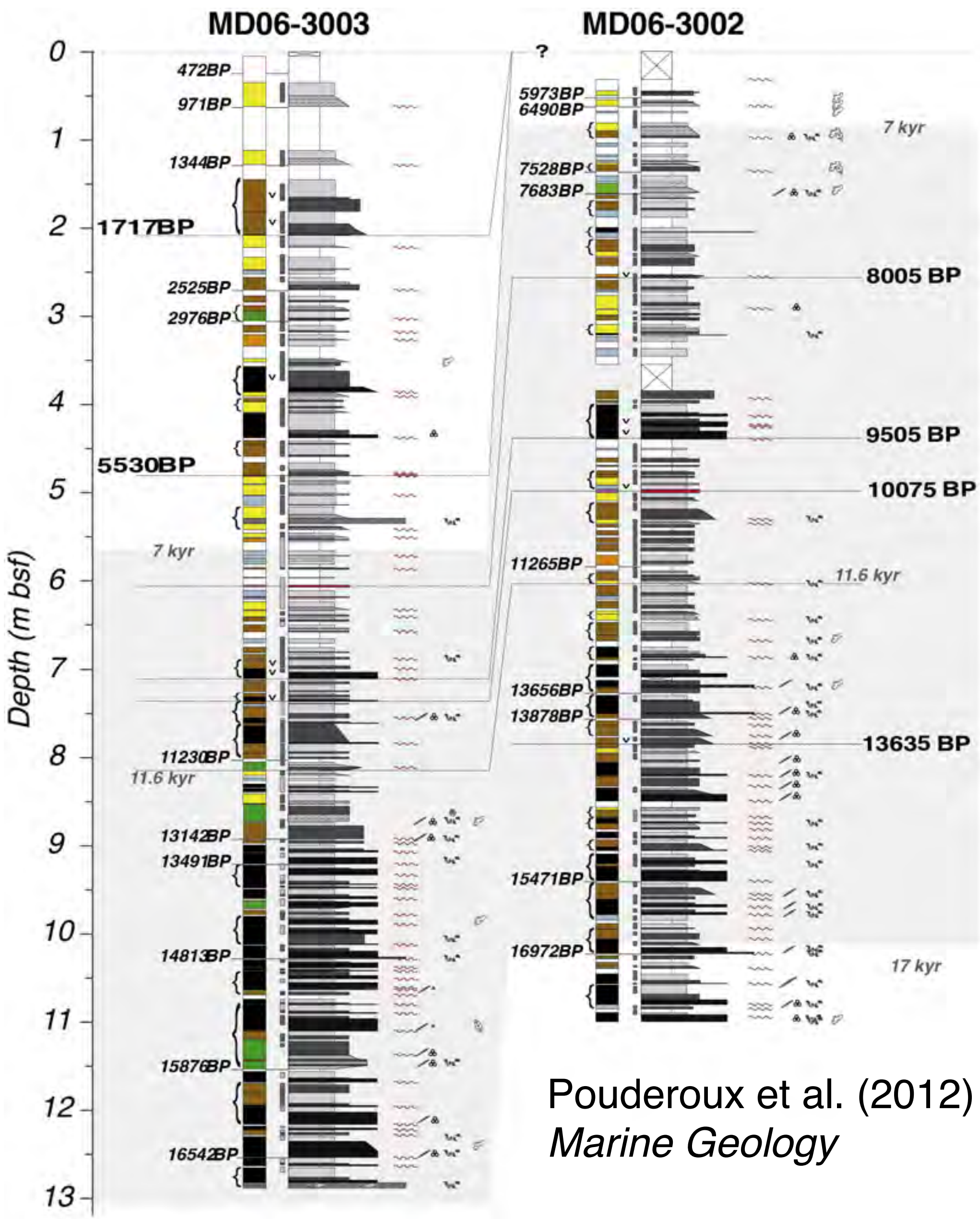


Lewis & Pantin (2002) *Marine Geol.*

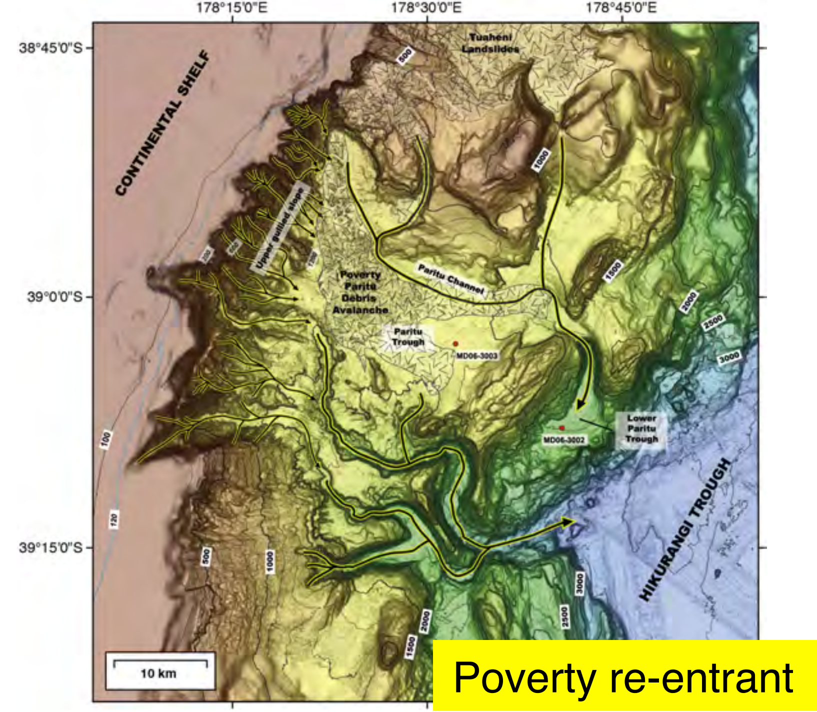


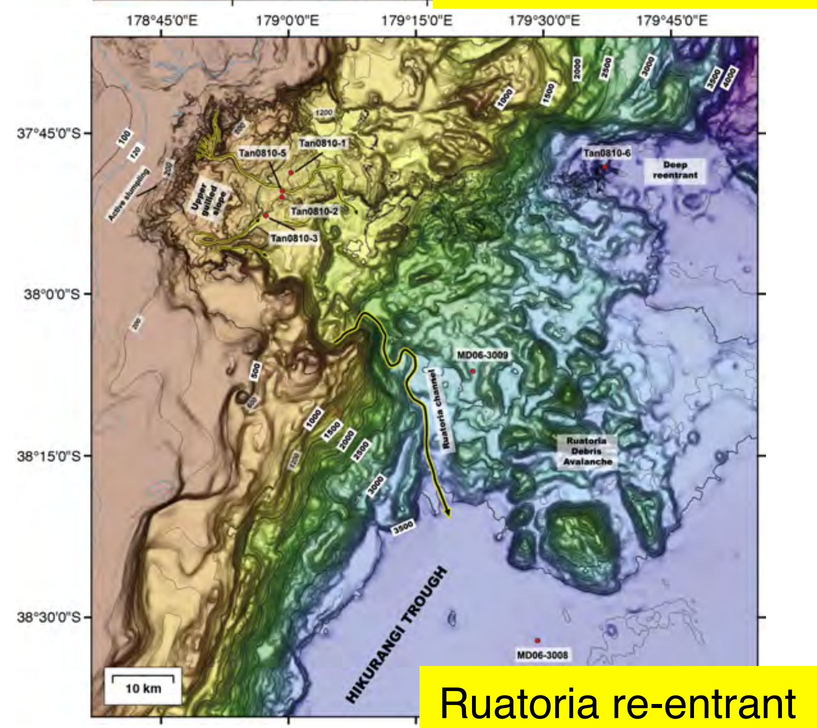
Pouderoux et al. (2012)
Marine Geology

Transverse inputs:
Fewer turbidity currents with rising S.L.

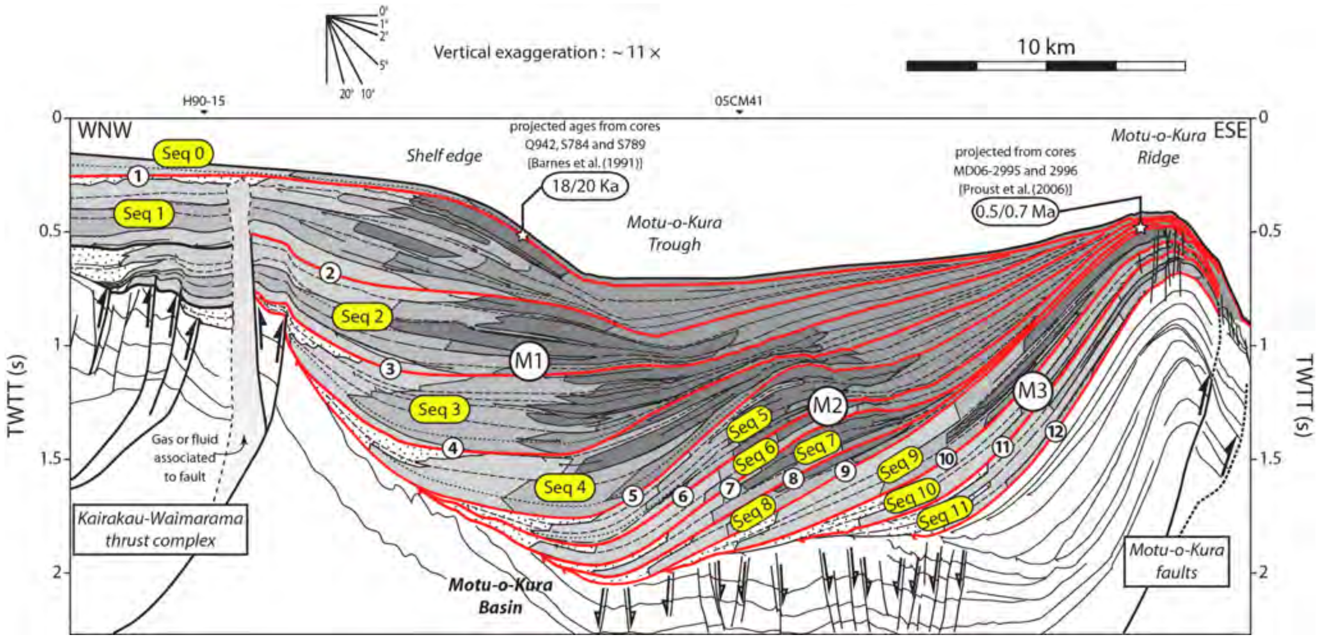


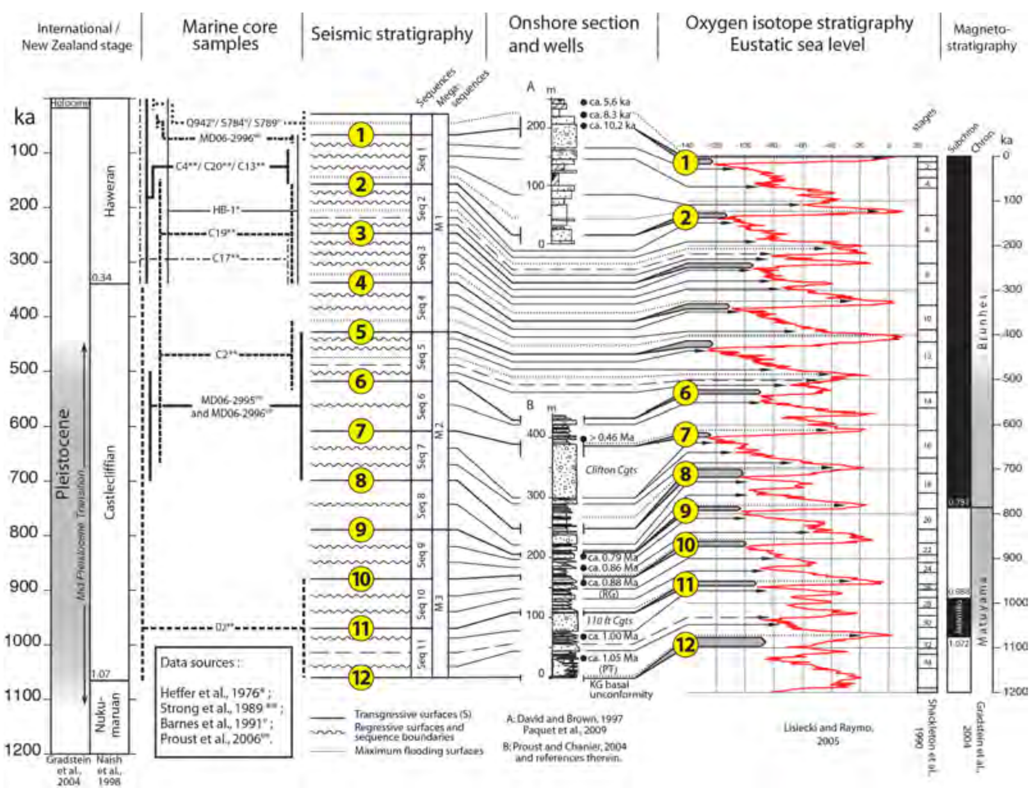
Pouderoux et al. (2012)
Marine Geology





Hawke Bay forearc basin





Paquet et al. (2011) *GSA Bull.*

Detailed stratigraphic architecture
History of last 1.1 Myr
11 depositional sequences
Strat. ties to onshore + wells
Retrogradational trend
Arcward migration of depocenter
Out-of-sequence thrust
Eustatic S.L., O-isotopes

What next? A strawman:

- Holistic 3-D assessment of entire regional system
  - Source (shelf, canyons) to sink (Hikurangi Trough)
  - Provenance, dispersal paths
  - Facies, sand body geometry, submarine slides
- Discriminate between transverse/axial delivery
- Quantify sediment composition (clay + sand)
- Document cycles/timing of climate/eustasy
- Verify timing of major shifts in sedimentation rate
  - Canyon incision, onset of Pleistocene glaciation?
- Drill/core to basement of Hikurangi Plateau
  - Host rocks for SSE