Mechanics, structure, and evolution of forearcs: the Aleutian margin as seen from a global perspective

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Significant collaborators:

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Japan- E. Kirby, K. Furlong, C. Regalla

Sumatra- J. Austin, D. Mosher, S. Gulick

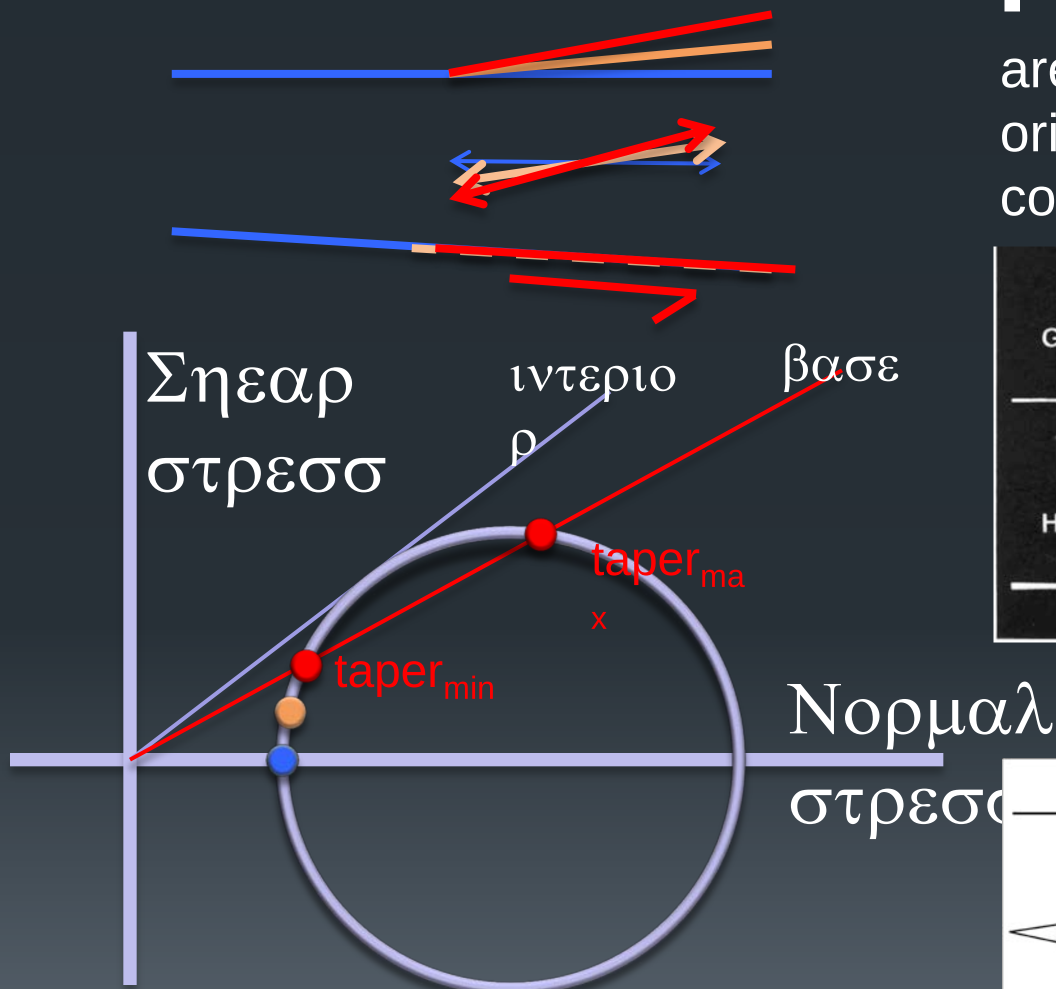
Alaska- S. Brantley, B. Clark, T. Byrne

Taiwan- S. Willett, E.-C Yeh, C. Fuller

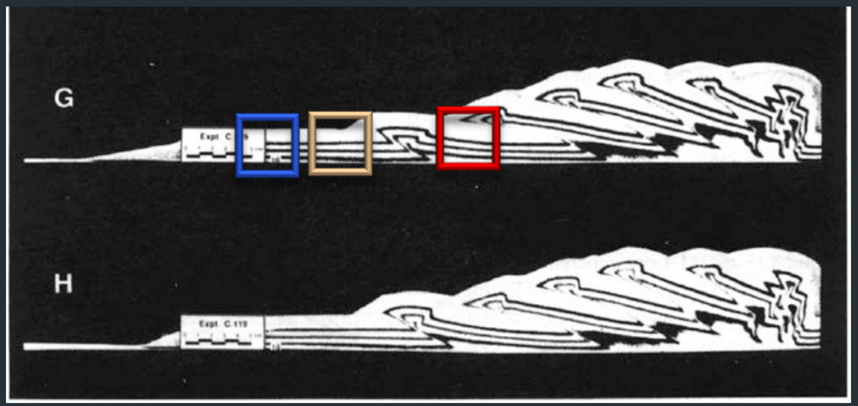
What do other convergent margins tell us about the Aleutians?

- Coulomb wedge mechanics- minimum and maximum taper
- Accretionary vs. non-accretionary (or erosive) margins- wedge taper
- Accretionary examples- Taiwan, N. Sumatra
- Erosional examples- Costa Rica- Northern Japan
- The Aleutian trench- Basal dip, topographic slope- What do Coulomb wedge mechanics tell us?

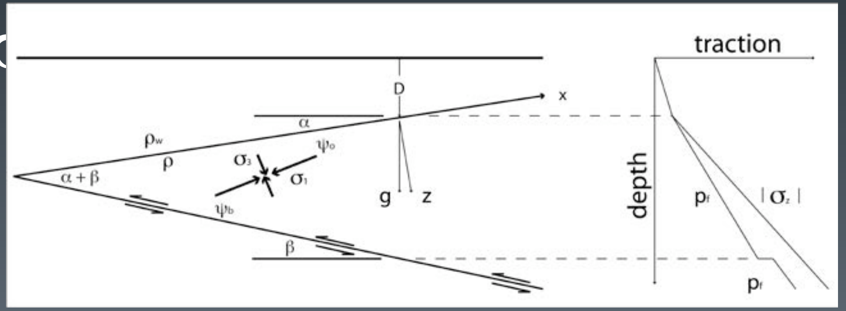
Coulomb Wedge Theory-How does surface slope relate to principal stress orientations and wedge strength?



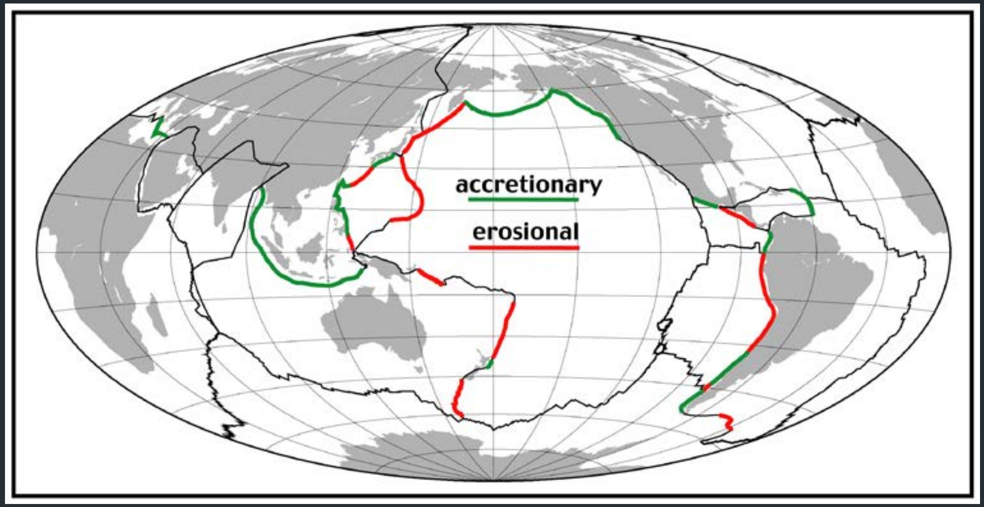
- If material and basal detachment are Coulomb, principal stress orientation and taper angle are constant. (Dahlen, 1984)



Dahlen, 1984



How do long term processes in the forearc relate to or reflect plate boundary coupling?



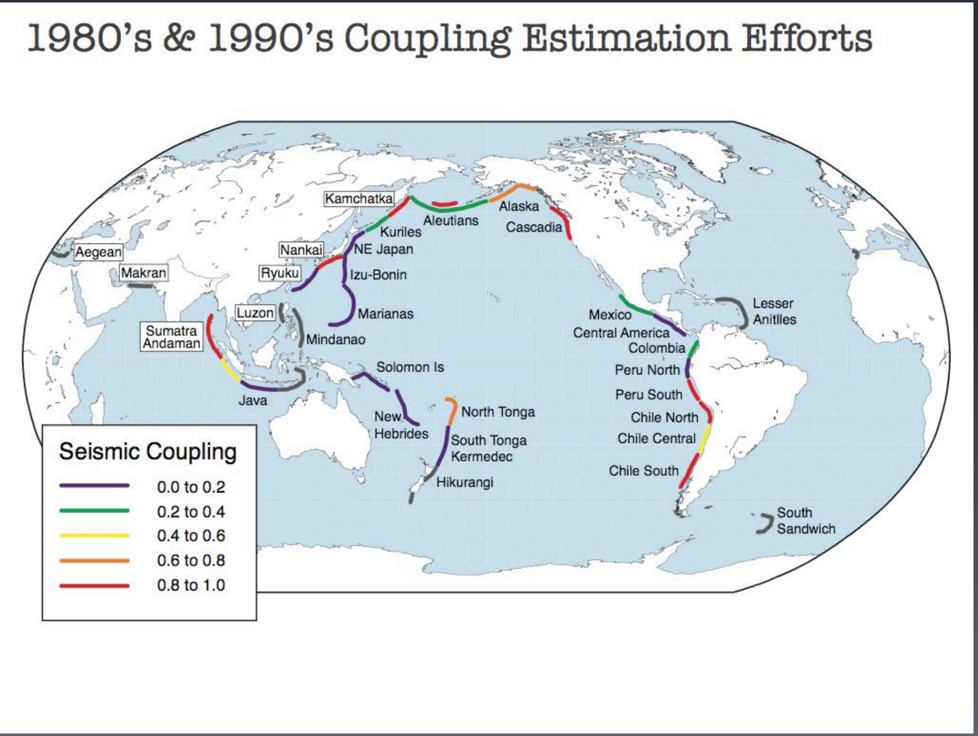
Mass Balance

Ranero, C.

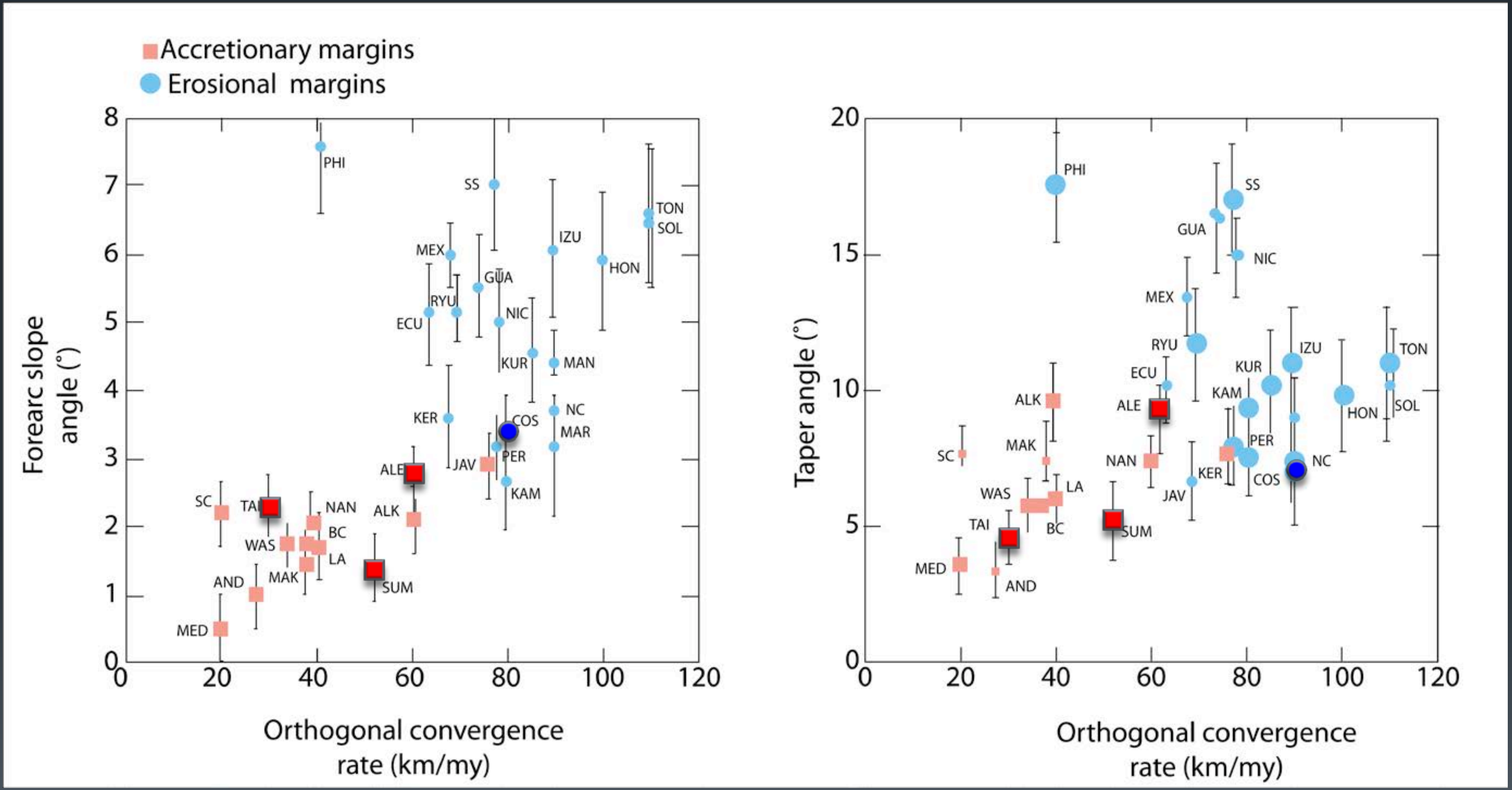
Seismic Coupling

Peterson and Seno, 1984

Pacheco, Sykes, and Scholz, 1993

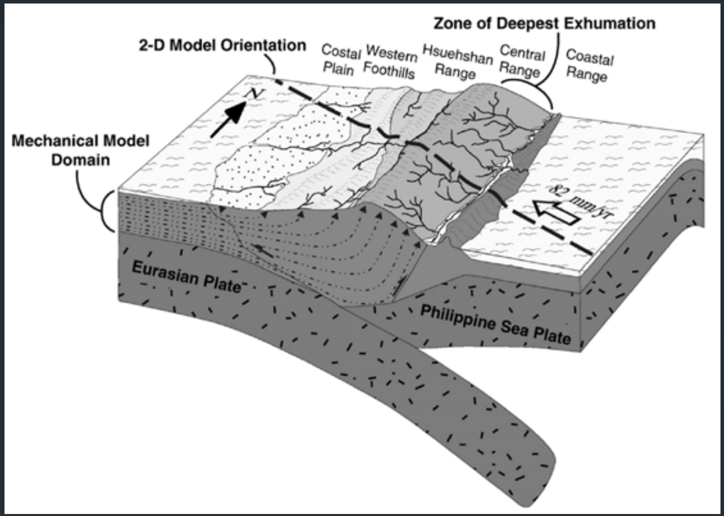


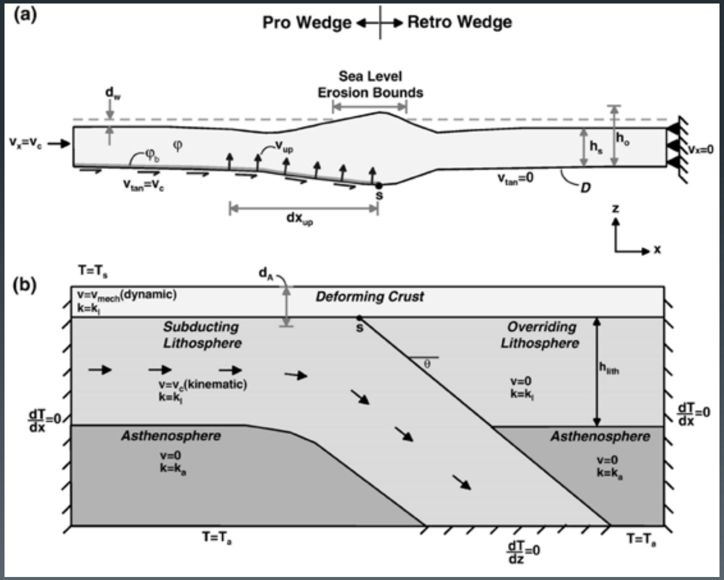
Forearc Slope and Wedge Taper for accretionary and erosional margins



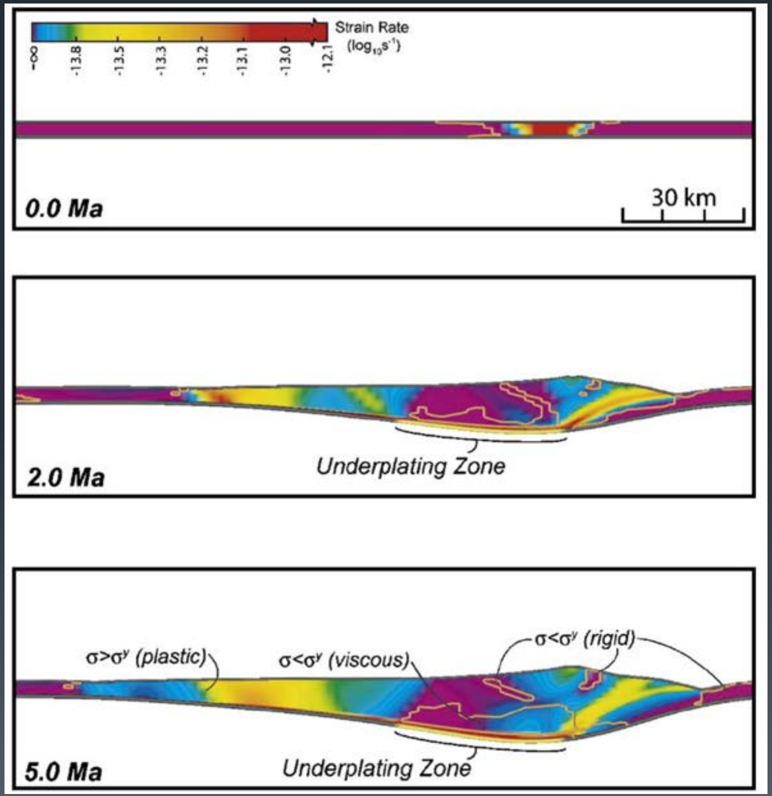
Clift and Vannucchi, 2004

Taiwan-an accretionary wedge backed by a non-accretionary wedge





Double-sided wedge with underplating



Fuller, Willett, Fisher, and Lu, 2006

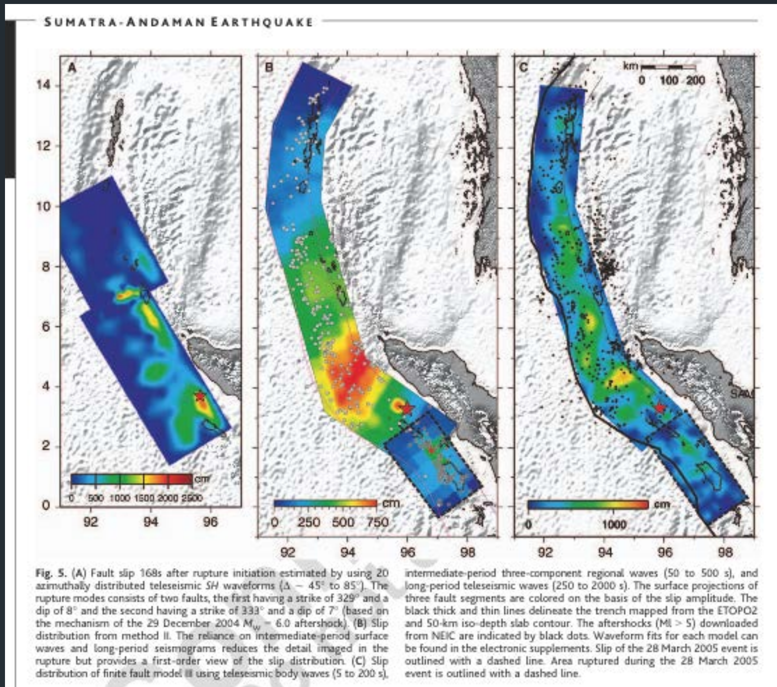
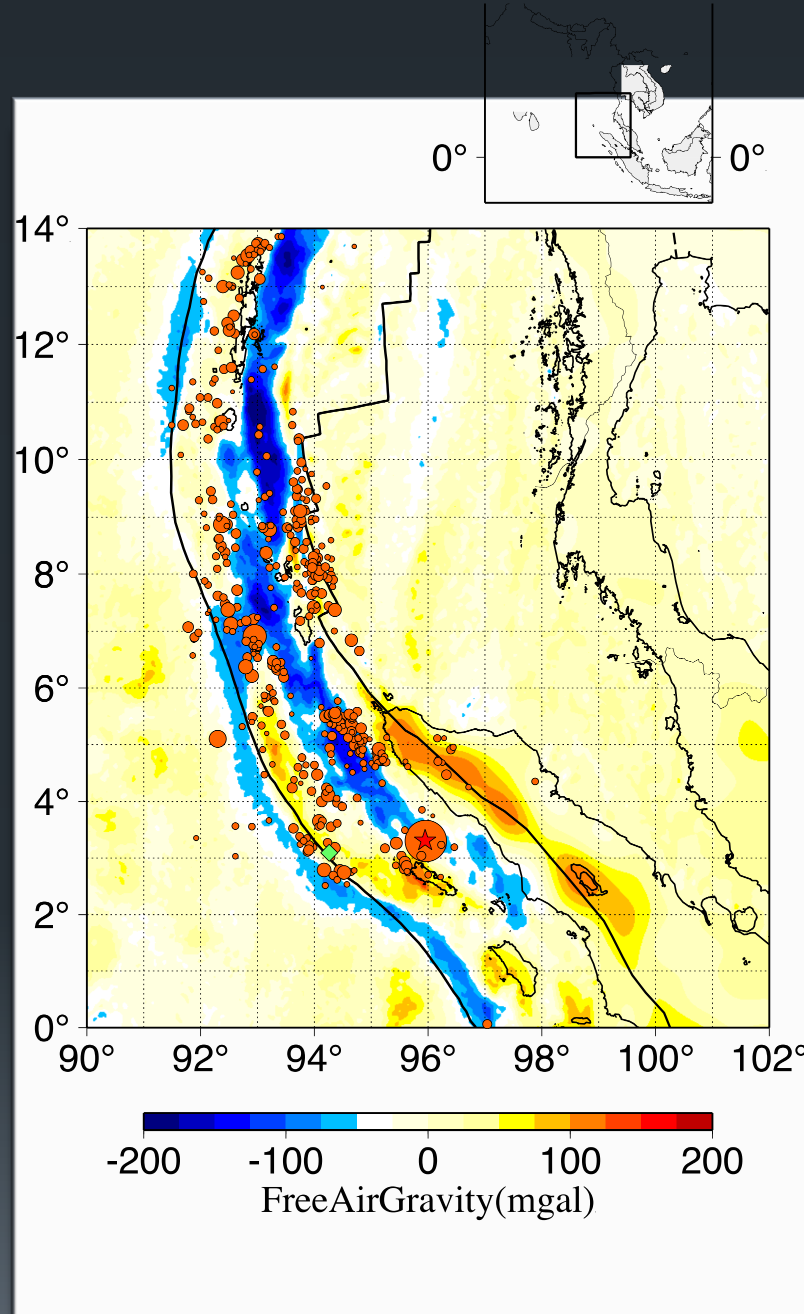

SUMATRA-ANDAMAN EARTHQUAKE

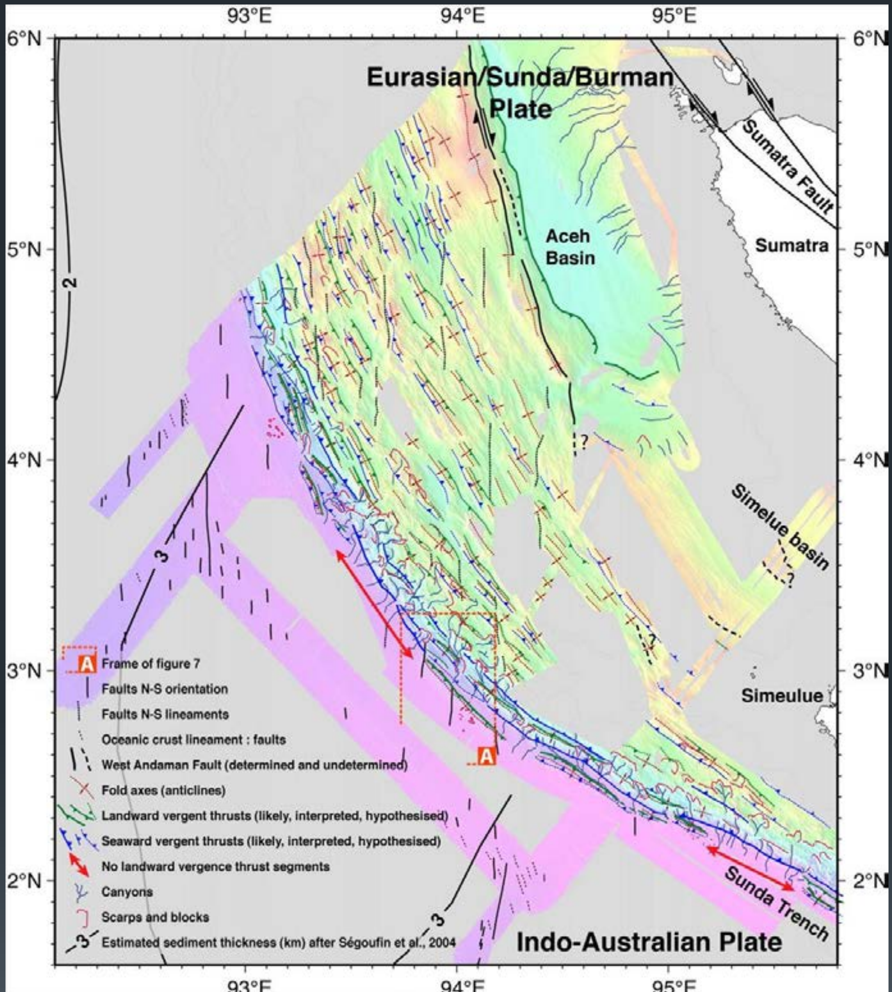
Fig. 5. (A) Fault slip 168s after rupture initiation estimated by using 20 azimuthally distributed teleseismic *SH* waveforms (Δ = 45° to 85°). The rupture modes consists of two faults, the first having a strike of 329° and a dip of 8° and the second having a strike of 333° and a dip of 7° (based on the mechanism of the 29 December 2004 M_w = 6.0 aftershock). (B) Slip distribution from method II. The reliance on intermediate-period surface waves and long-period seismograms reduces the detail imaged in the rupture but provides a first-order view of the slip distribution. (C) Slip distribution of finite fault model III using teleseismic body waves (5 to 200 s), intermediate-period three-component regional waves (50 to 500 s), and long-period teleseismic waves (250 to 2000 s). The surface projections of three fault segments are colored on the basis of the slip amplitude. The black thick and thin lines delineate the trench mapped from the ETOPO2 and 50-km iso-depth slab contour. The aftershocks (Ml > 5) downloaded from NEIC are indicated by black dots. Waveform fits for each model can be found in the electronic supplements. Slip of the 28 March 2005 event is outlined with a dashed line. Area ruptured during the 28 March 2005 event is outlined with a dashed line.

Ammon et al., 2005, Science

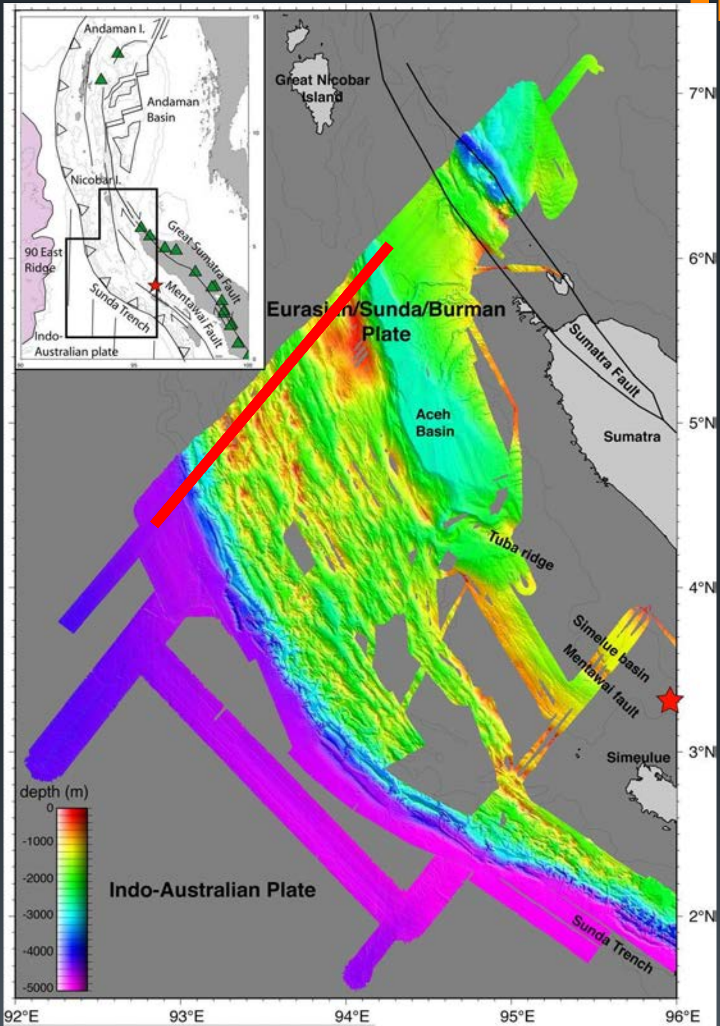


Sumatra

Sumatran Forearc Plateau- coincidence of an asperity with a positive TPTA



Graindorge, D., Klingelhoefer, F., Sibuet, J. C., McNeill, L., Henstock, T. J., Dean, S., et al. (2008). Impact of lower plate structure on upper plate deformation at the NW Sumatran convergent margin from seafloor morphology [Figure 3]. Earth and Planetary Science Letters, 275, 201-210.
Publisher: Elsevier Science



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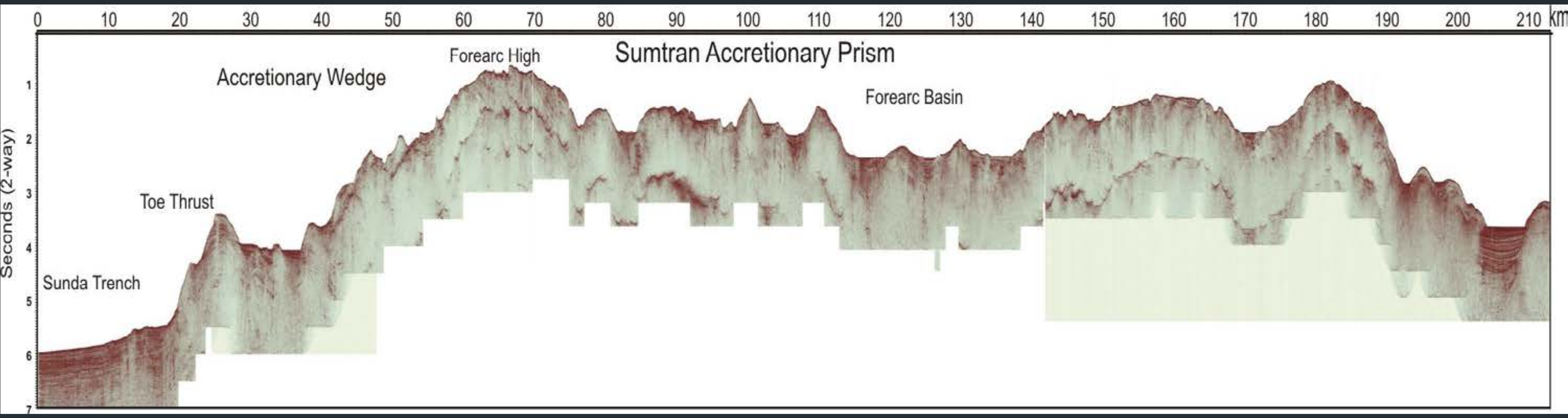
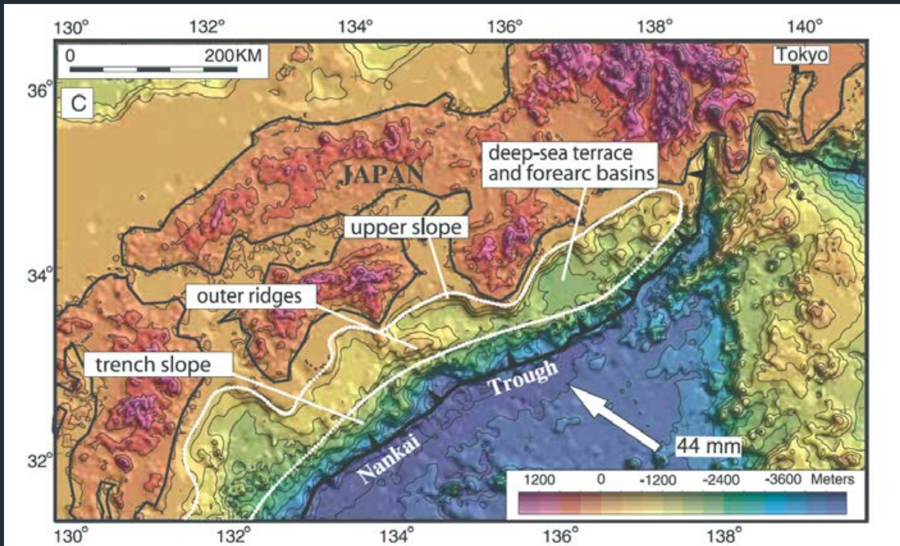
Graindorge et al., 2008



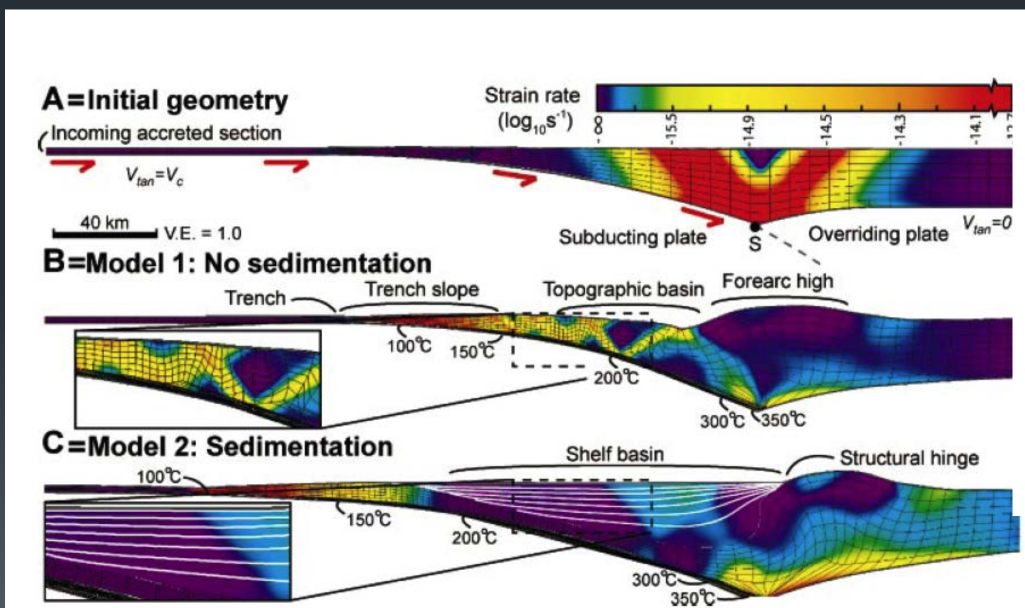
Deformation at long wavelengths-two forearc highs- regularly spaced (~13 km) ridges

Fisher, Mosher, Austin, Gulick, Masterlark, Moran, 2009

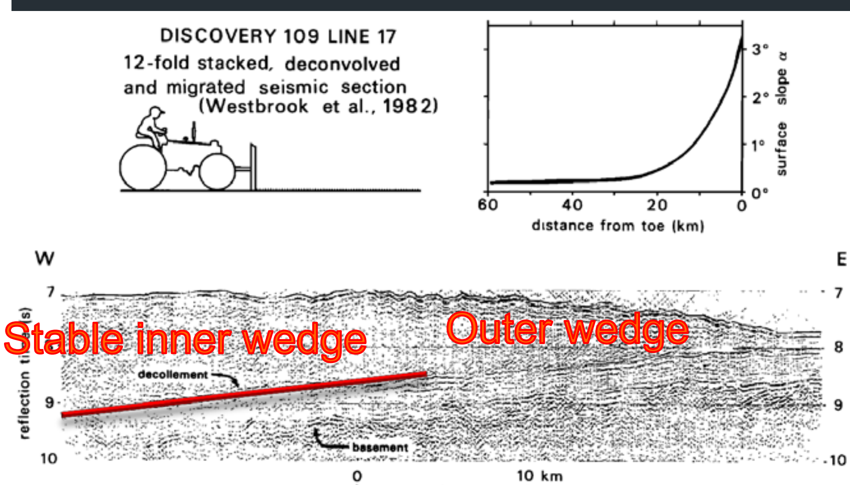
Convex-up profiles and horizontal wedge tops



Wells, Blakely, Sugiyama, Scholl Dinterman, 2003



Fuller, Willett, Brandon, 2006

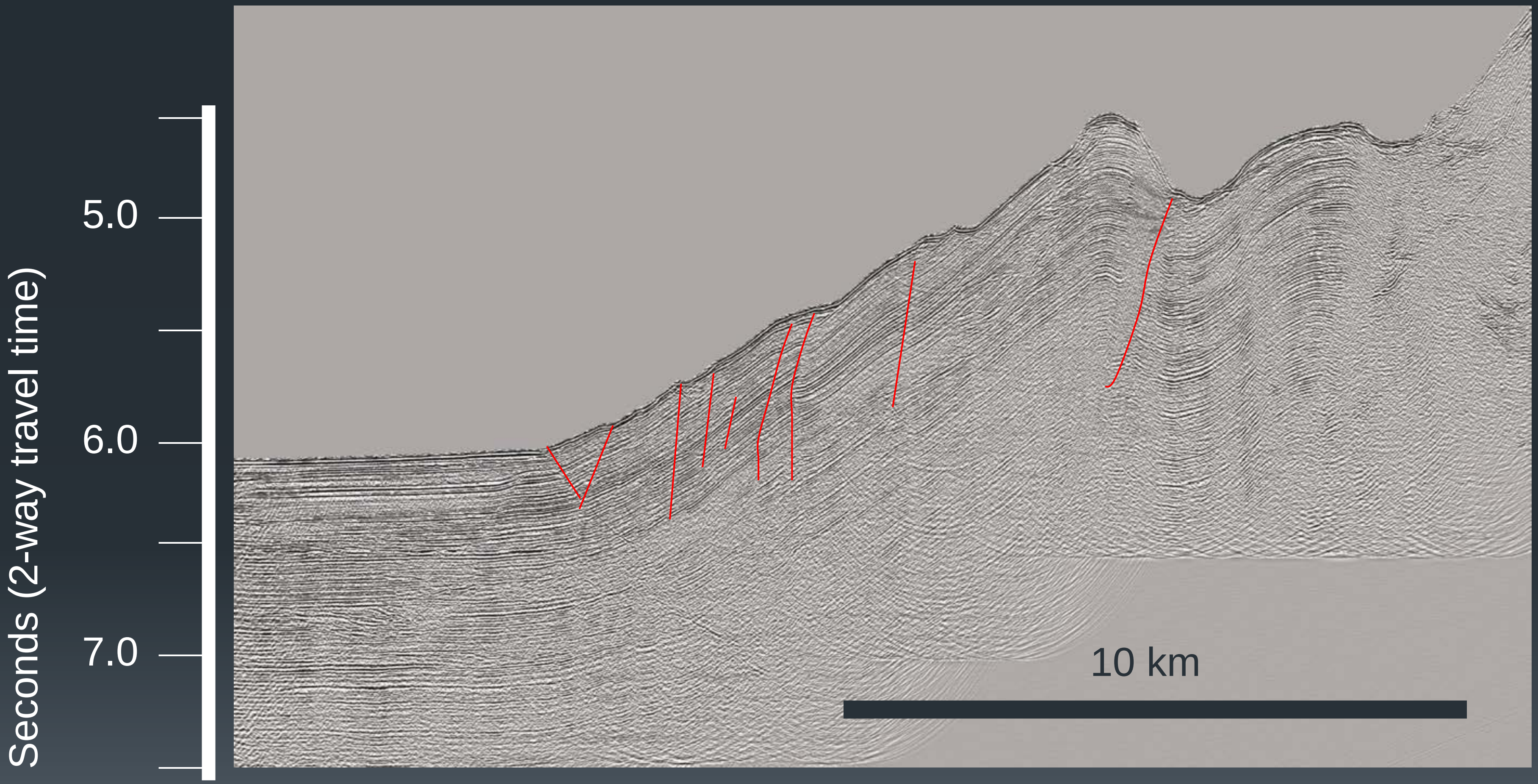


Zhao Davis, Dahlen, Suppe, 1986

Wang and Hu, 2006

Mosher, Austin, Fisher, Gulick, 2008

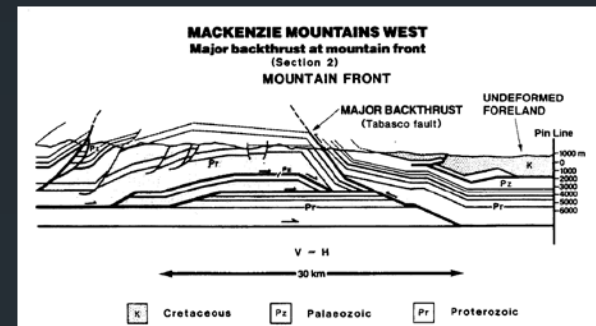
The Toe



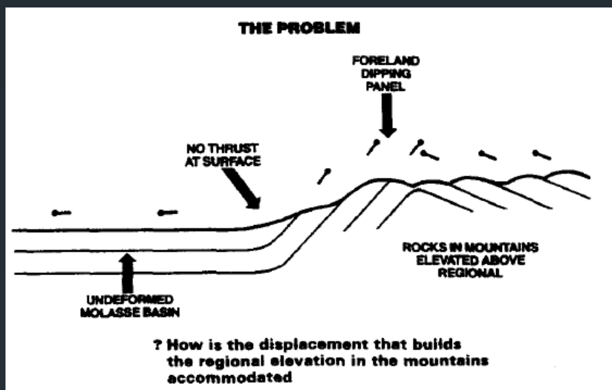
Backthrusting and arcward vergent folding

Mountain Fronts

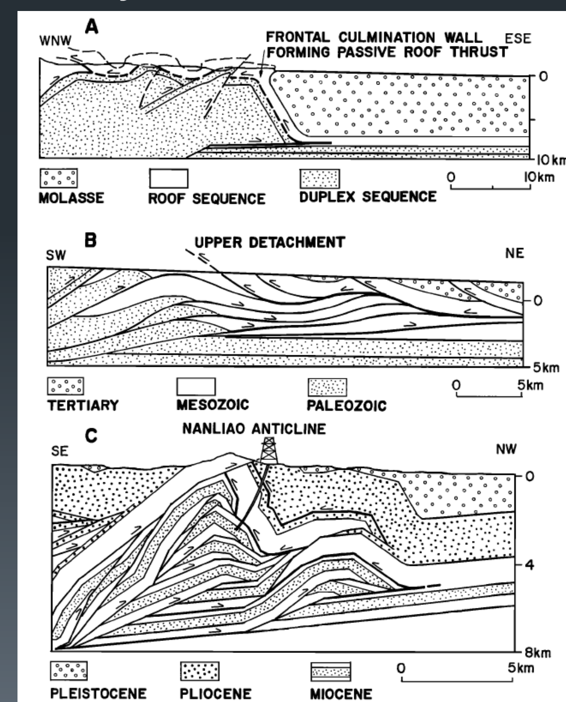
Mackenzie Mts.: Vann et al., 1986



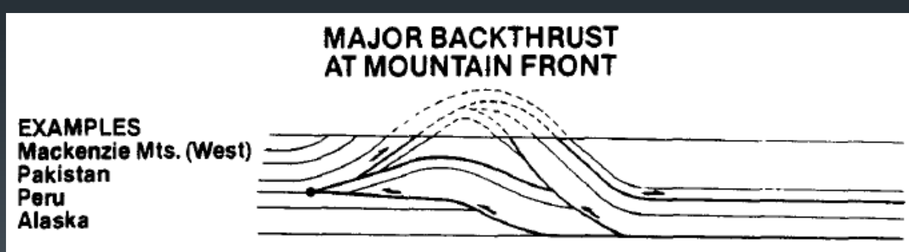
The problem: Vann, Graham, Hayward, 1986



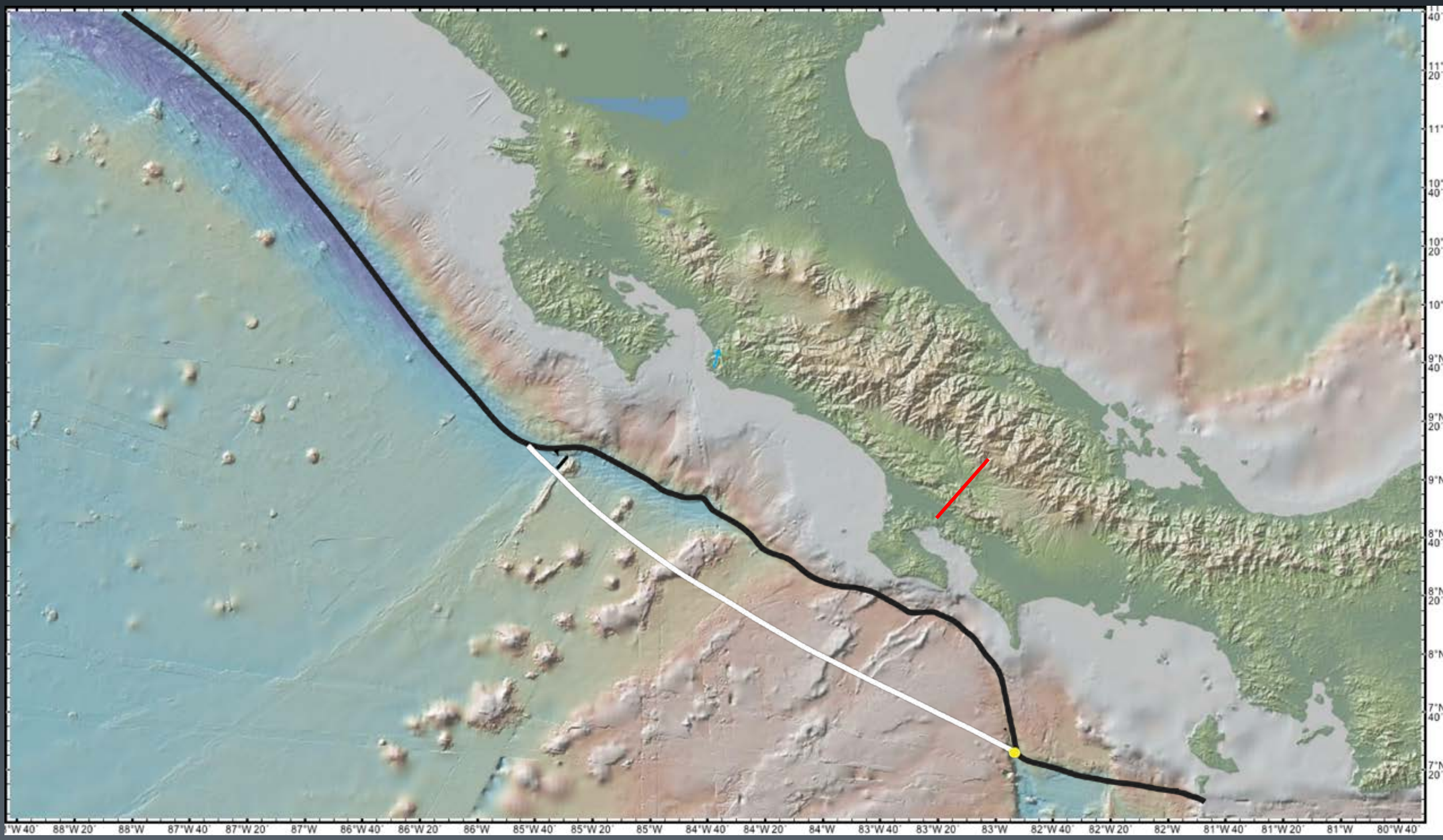
Pakistan, Alberta, Taiwan: Humayon Lillie, Lawrence, 1991



The solution: Vann, Graham, and Hayward, 1986

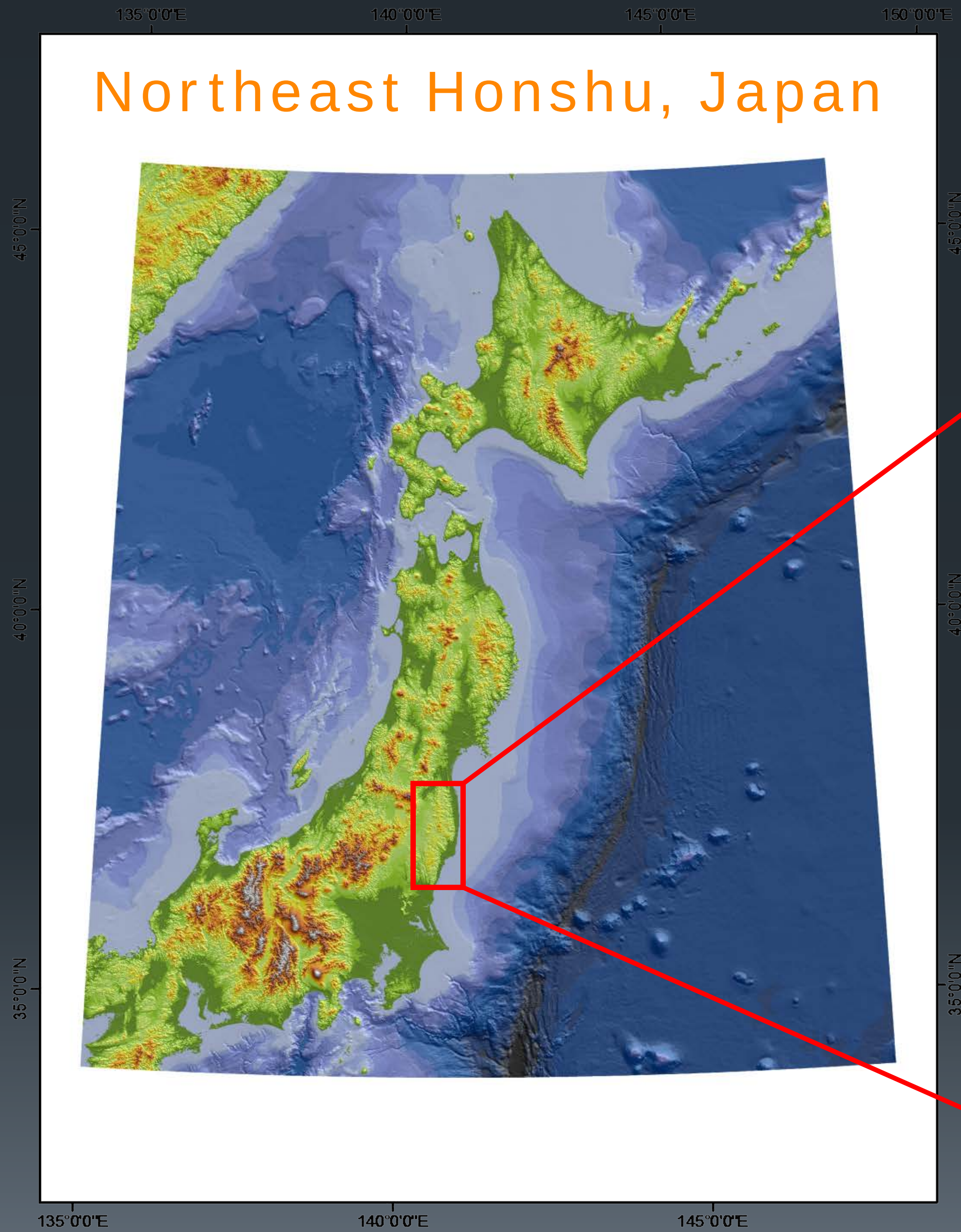


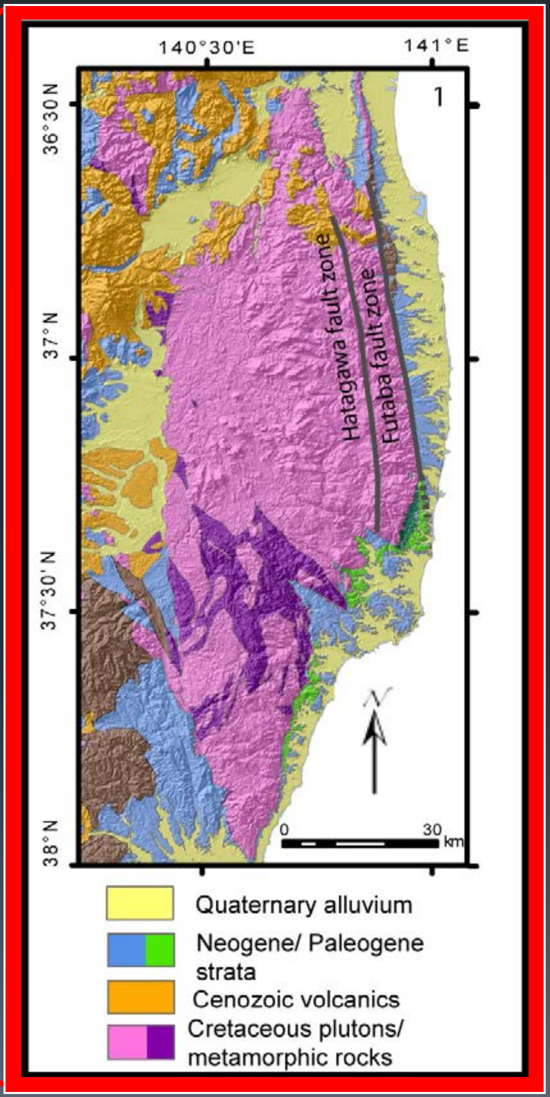
Costa Rica-outer forearc subsidence (erosion) coupled to uplift of the inner forearc and arc

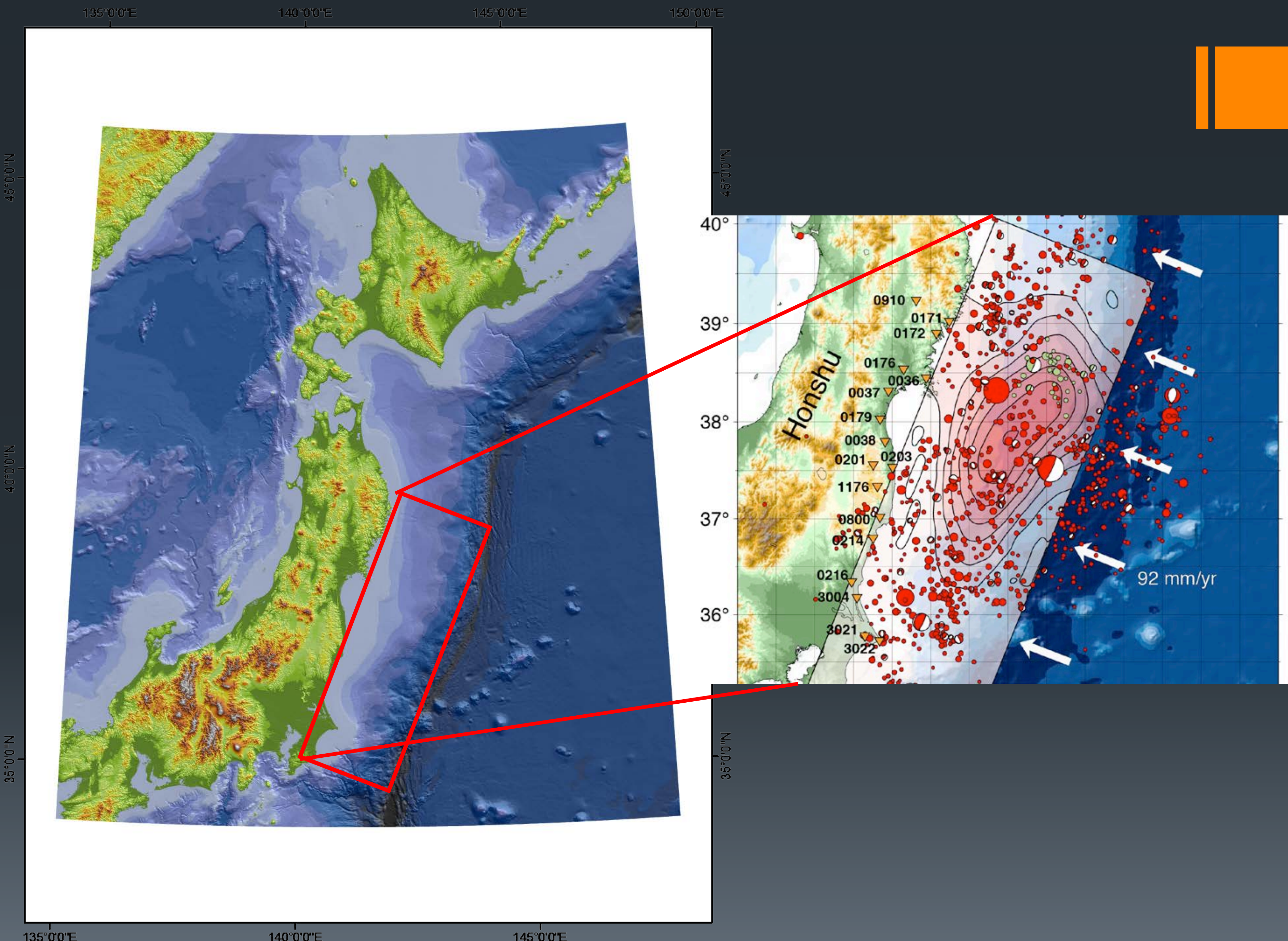


Regalla, Fisher, and Kirby, 2010

Northeast Honshu, Japan







135°0'0"E
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40°0'0"N
35°0'0"N
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39°
38°
37°
36°
Honshu
0910
0171
0172
0176
0036
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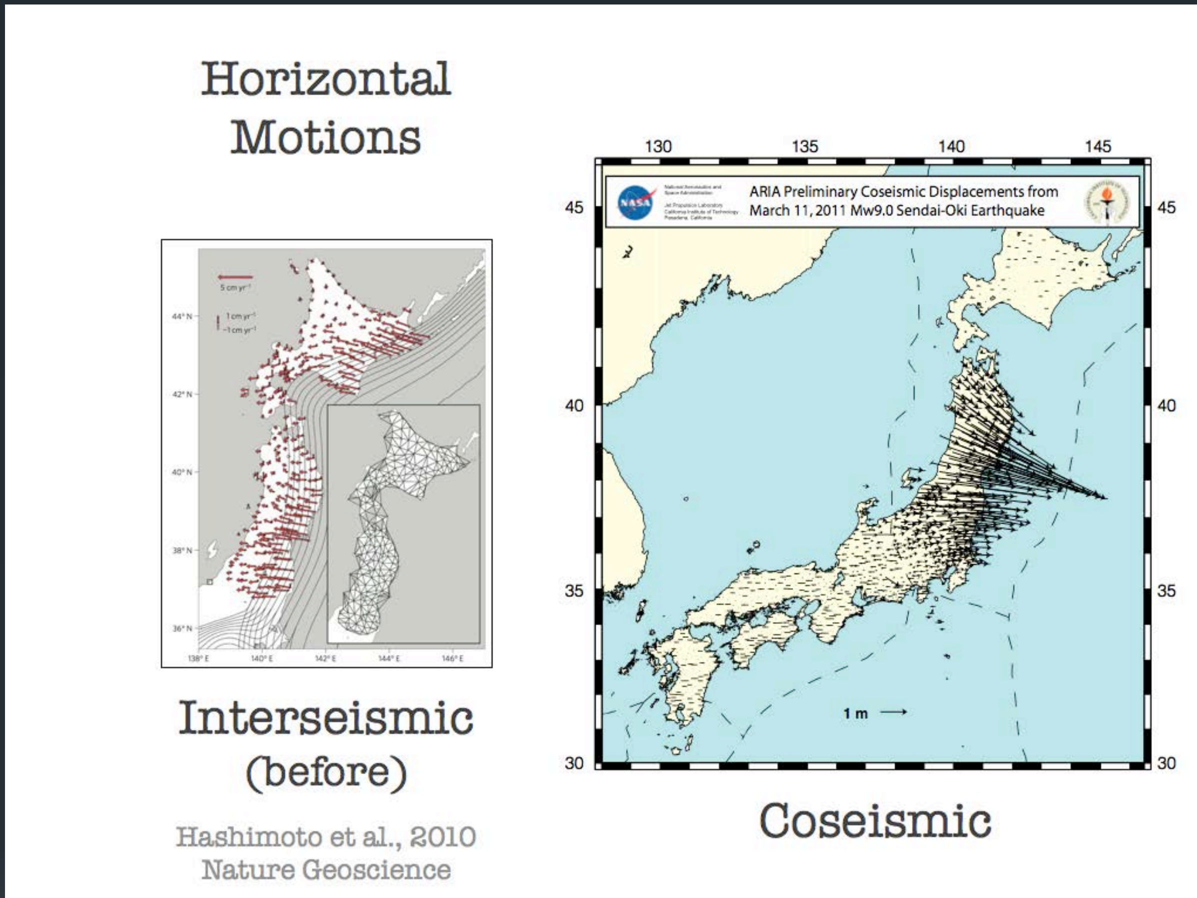
0214
0216
3004
3021
3022
92 mm/yr

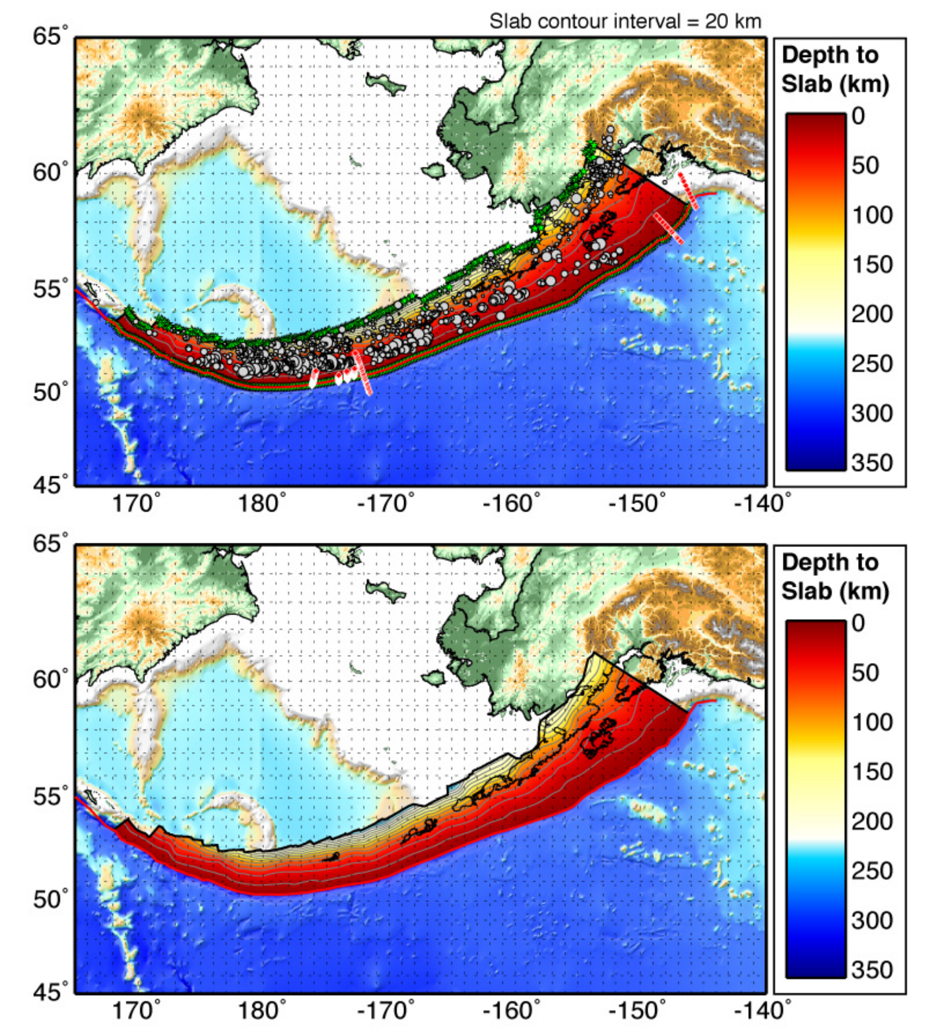


Interseismic onland shortening

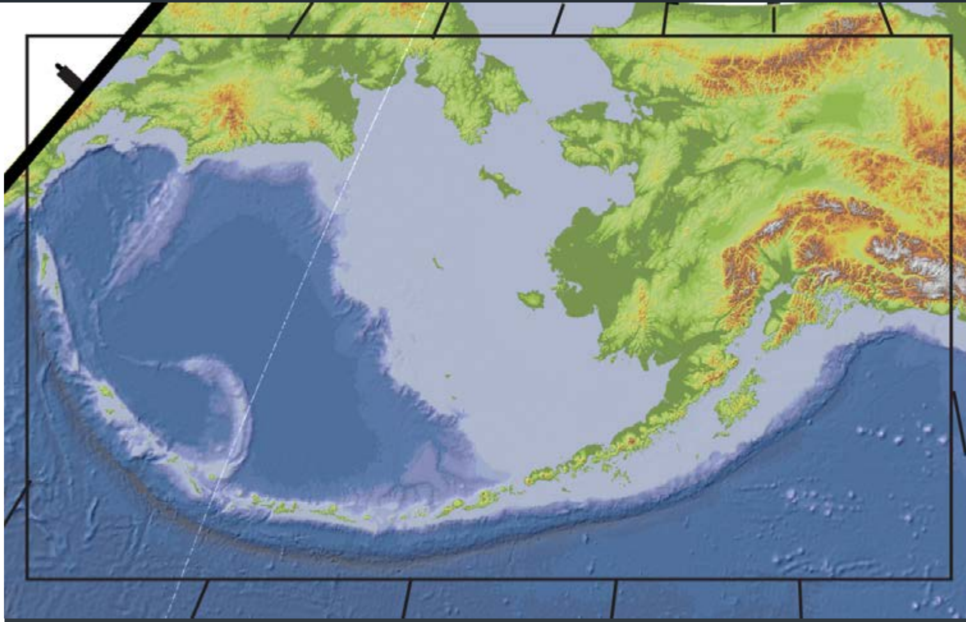
Coseismic onland subsidence and extension

Long Term active shortening across the arc and back arc
Permanent uplift of the coast

Basal dip and Surface slope

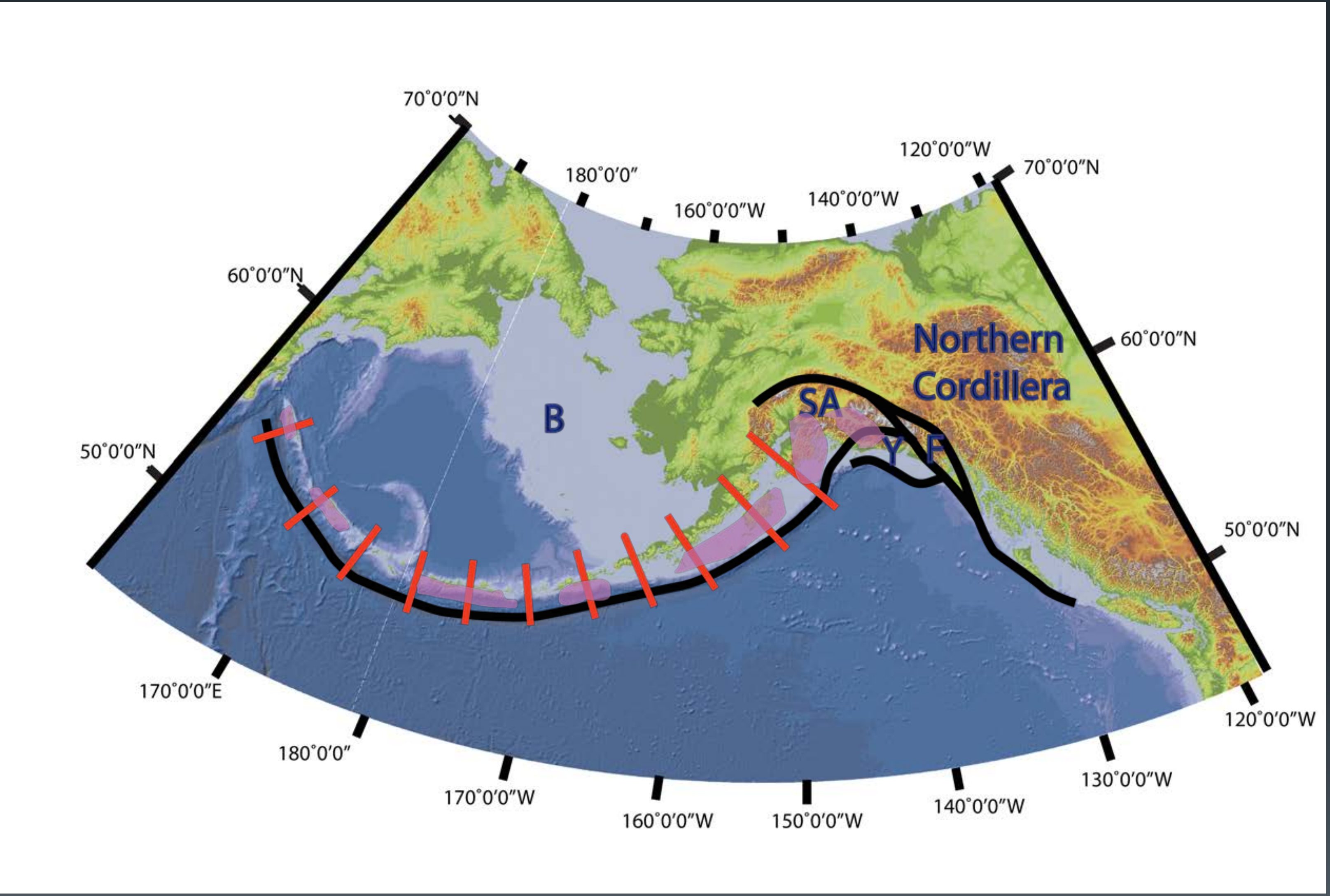


Hayes and Wald, 2009



ETOPO1- NOAA

Aleutian trench

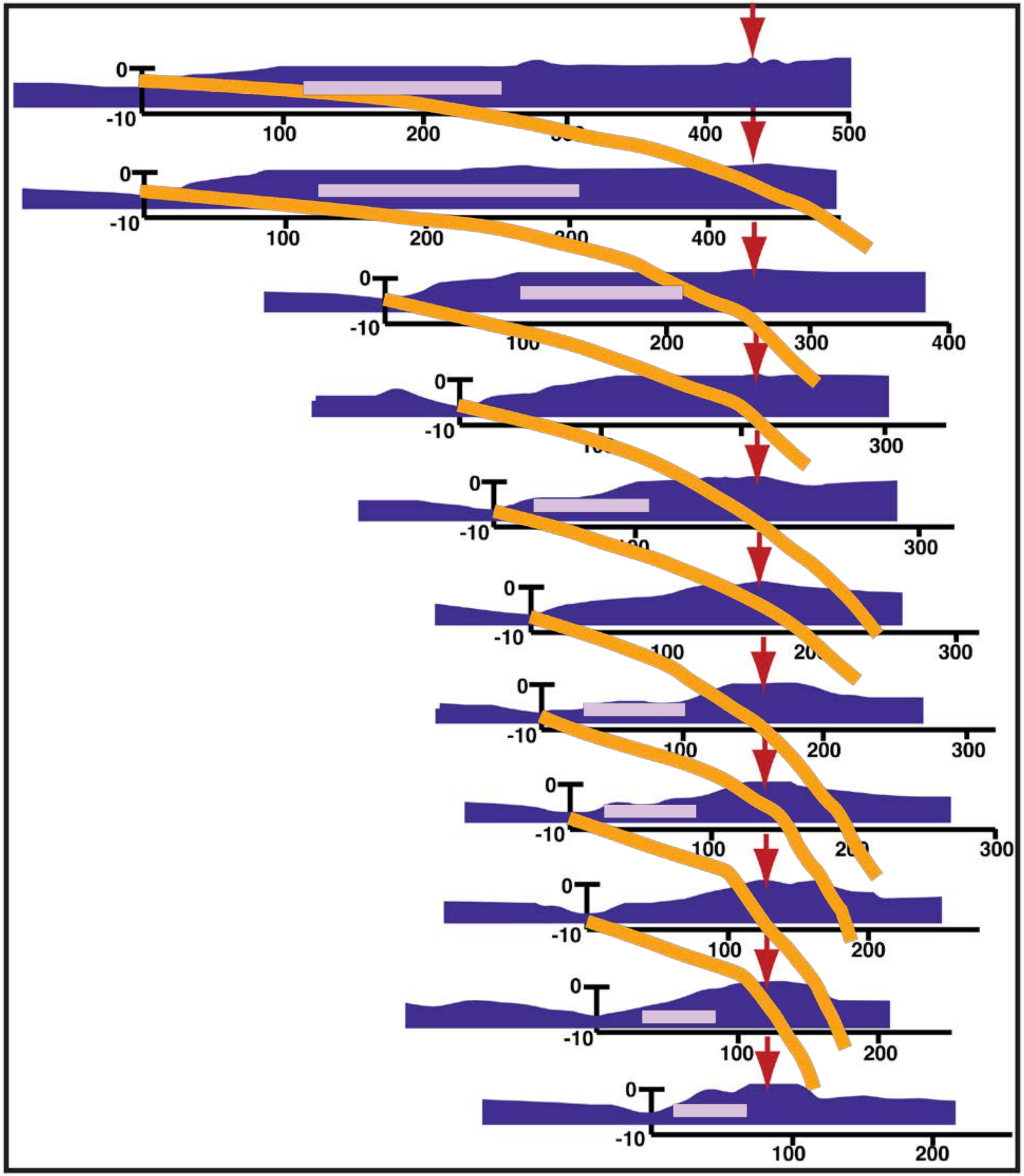


Freymuller et al.,
2008

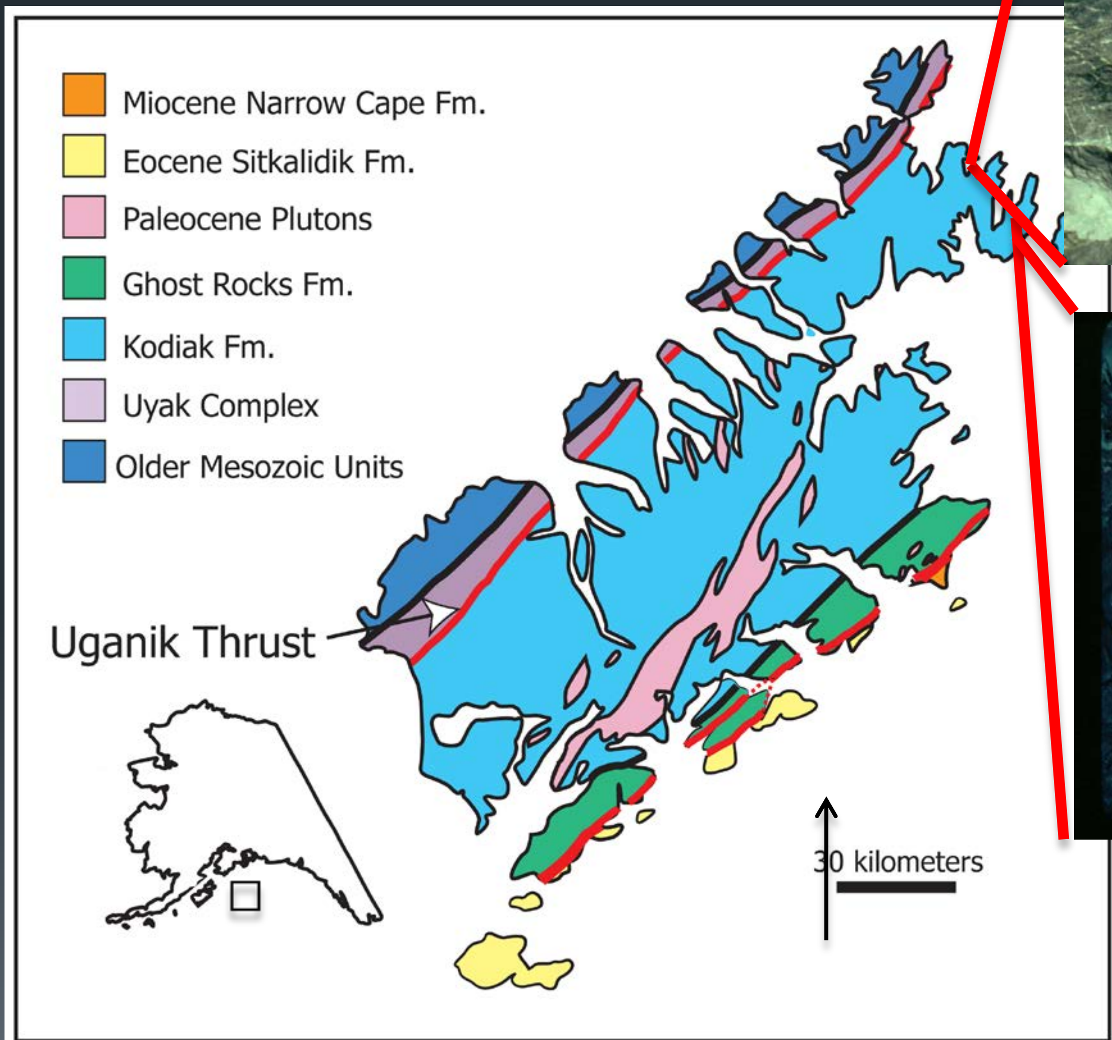
ETOPO1- NOAA

Freymuller et al., 2008

Hayes and Wald, 2009

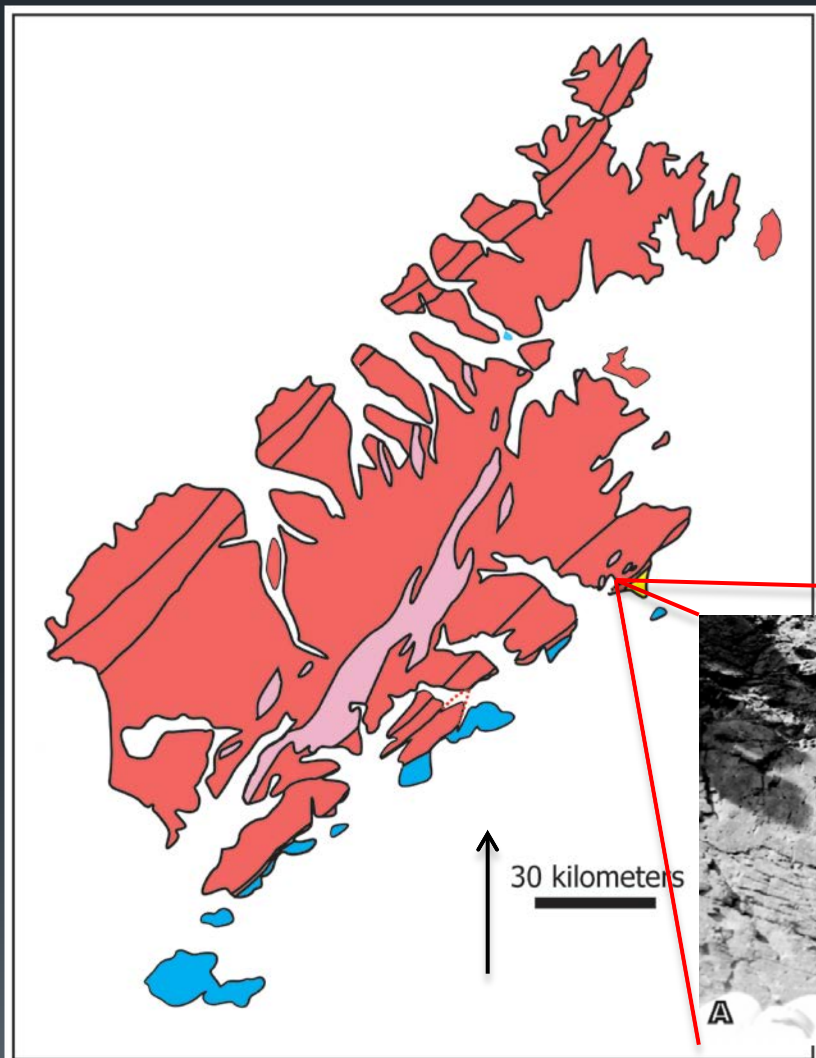


Kodiak Archipelago

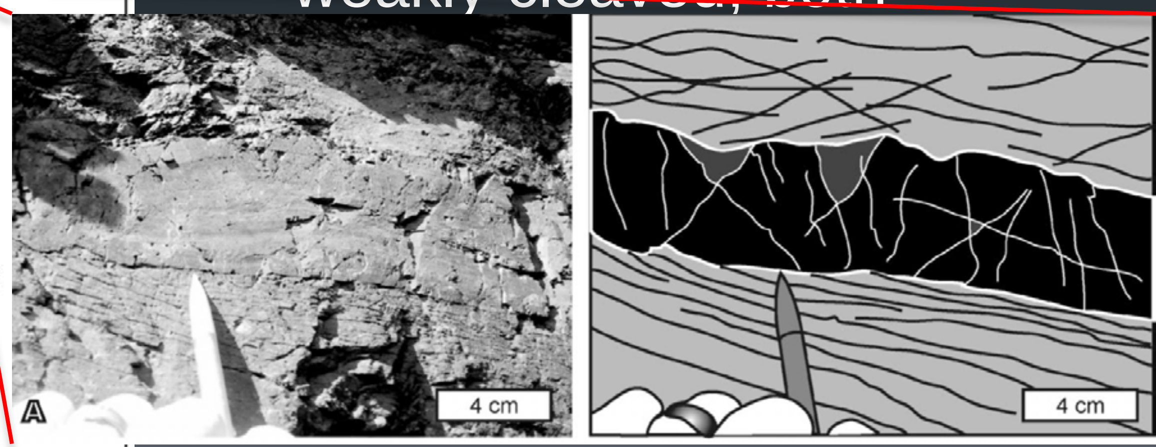


- Penetrative ductile

Kodiak Archipelago



- Underplated rocks (red)- lower greenschist facies, slaty cleavage, southeast vergence
- Offscraped rocks (blue)- unmetamorphosed, weakly cleaved, both



Rowe, Moore, Meneghini, and McKeirnan, 2009

Conclusions

- Strength of the forearc wedge can be linked to topography through Coulomb wedge mechanics
- Most non-accretionary margins evolve beyond the minimum taper (Hmm, the western Aleutians?)
- Regions of high coupling can be associated with flat areas of the forearc- both positive and negative TPTAs
- Portions of the forearc composed of underplated rocks are deformed early but subsequently provide a buttress as they are exhumed during continued underplating and outboard accretion (experienceing elastic strain related to the seismic cycle a la Wang and Hu, 2007).