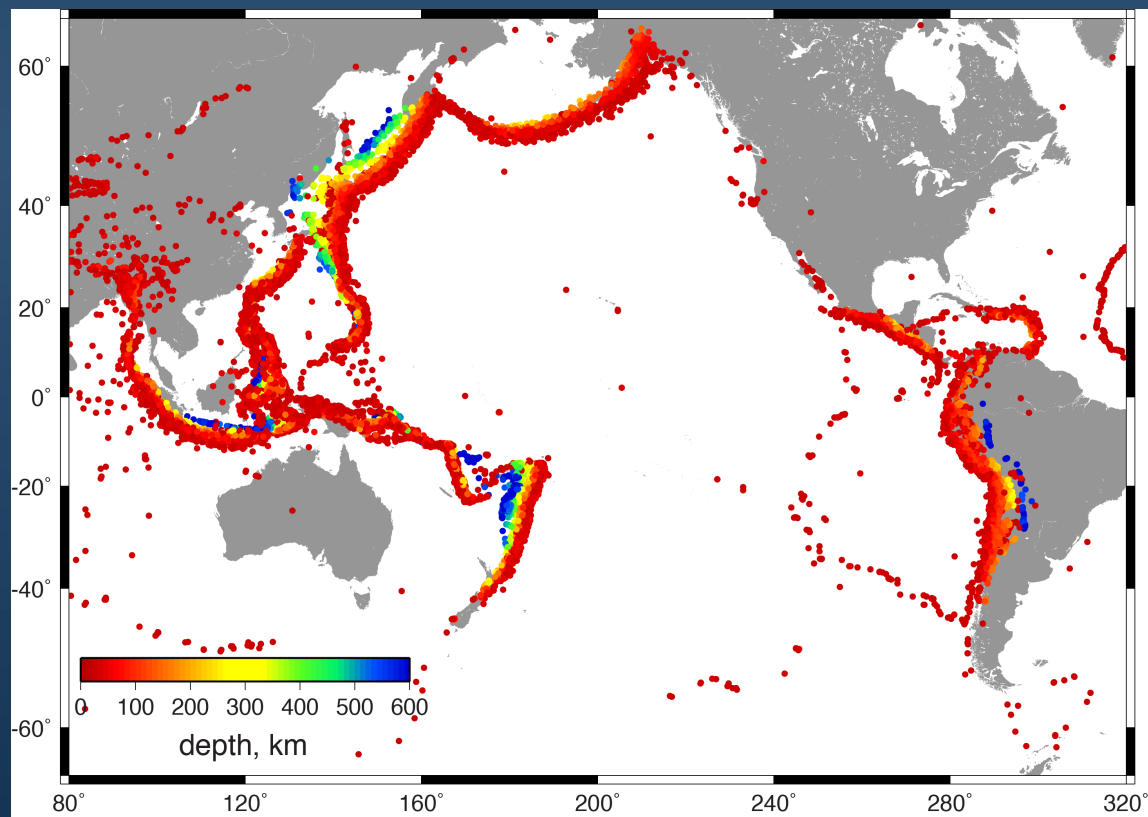


Seismic observations of subduction zones and implications for modelling, hydration, and volcanism

Ellen Syracuse
University of Wisconsin-Madison, USA



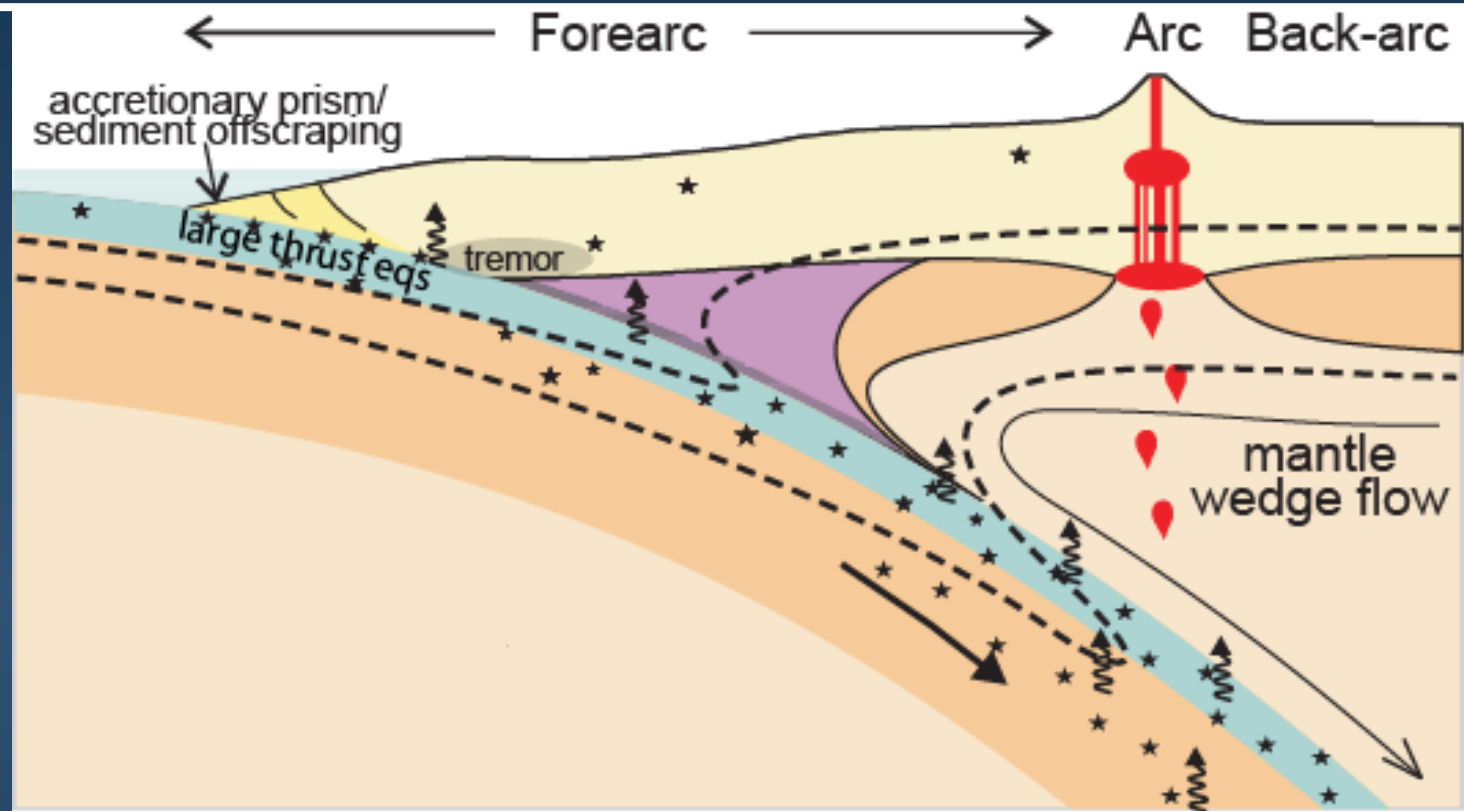
Outline

- Subduction overview
- Methods
 - Slab seismicity distributions
 - Velocity tomography
 - Attenuation tomography
 - Shear-wave splitting
- 2D thermal and mineralogical modeling

Outline

- Subduction overview
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Subduction overview

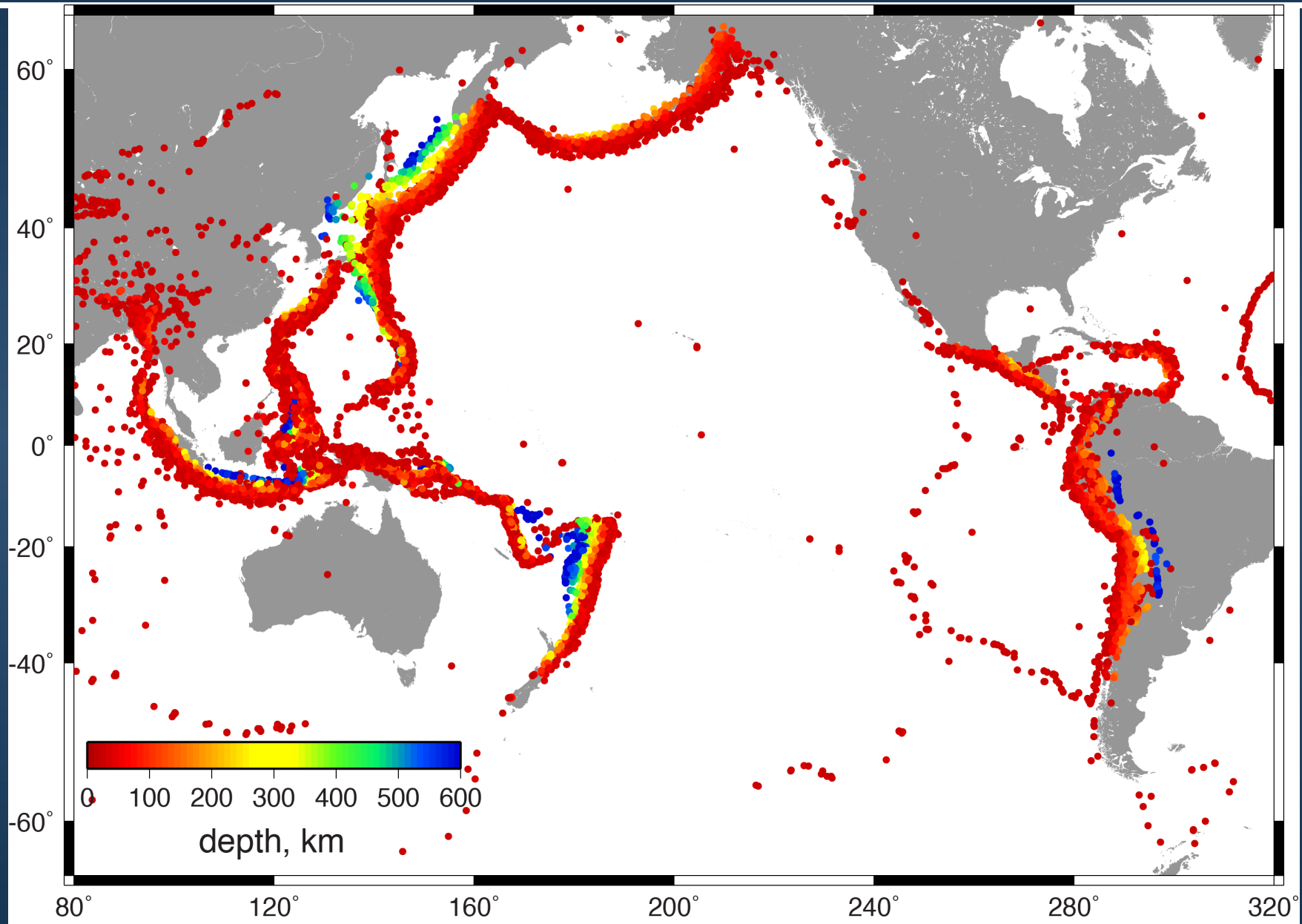


- | | | | |
|---|-----------------------|---|---|
|  | Continental/Arc crust |  | Cold nose/mantle wedge serpentinization |
|  | Oceanic crust |  | Partial melt |
|  | Lithospheric mantle |  | Earthquakes |
|  | Asthenospheric mantle |  | Fluid release |

Outline

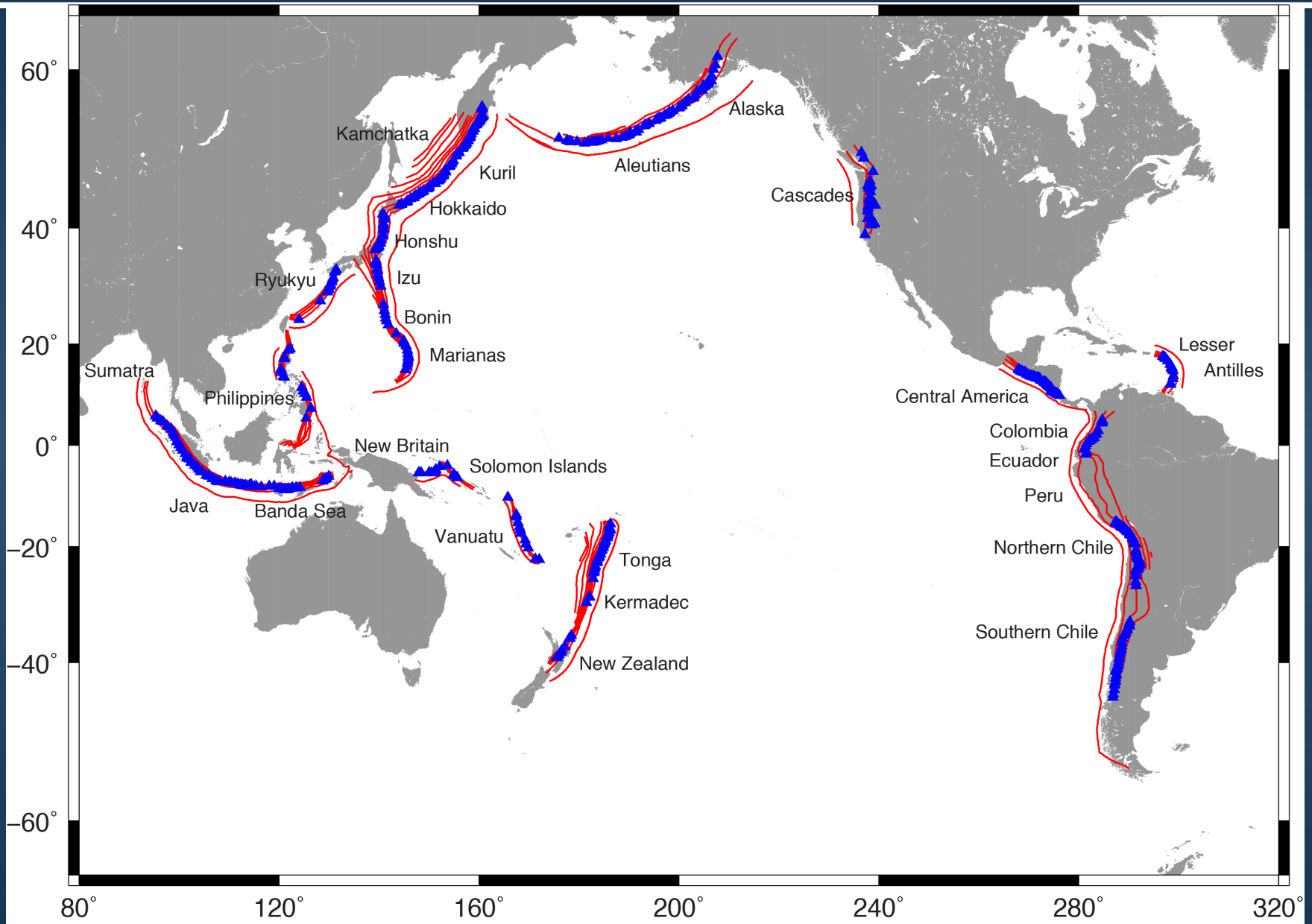
- Subduction overview
- **Methods**
 - **Slab seismicity distributions**
 - Velocity tomography
 - Attenuation tomography
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Slab seismicity

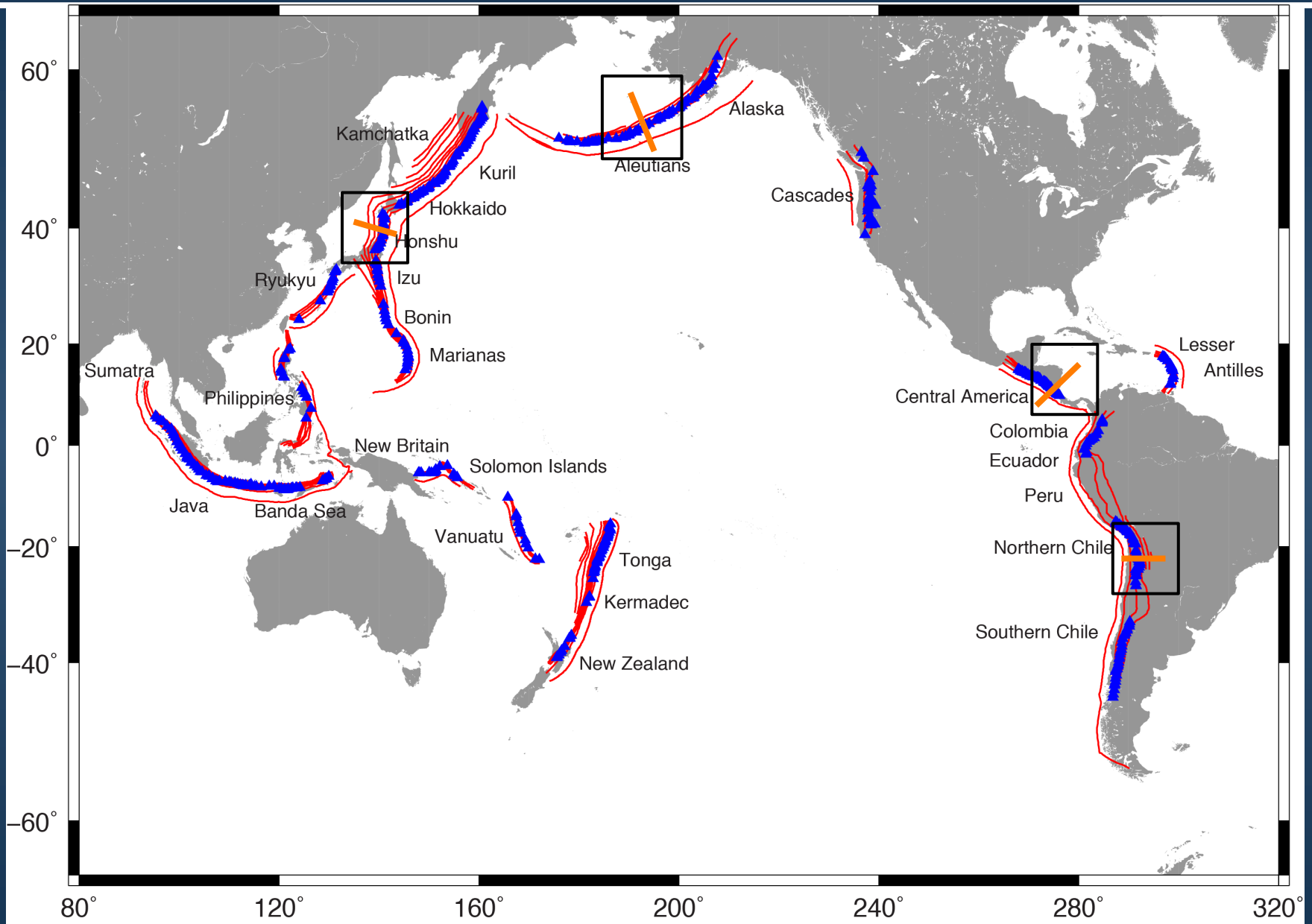


seismicity from Engdahl et al., 1998

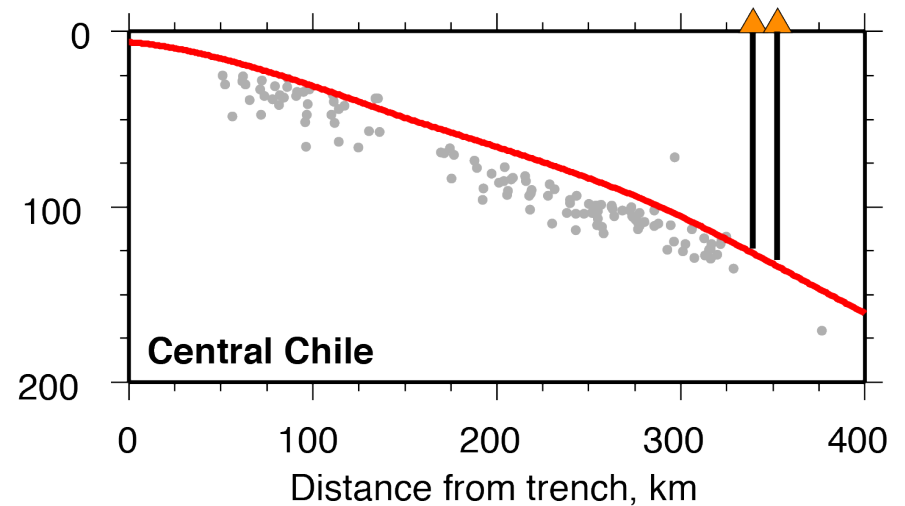
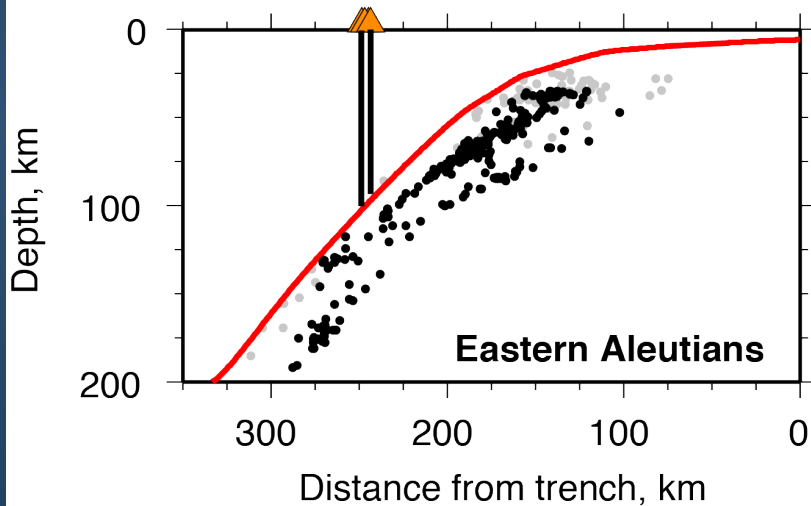
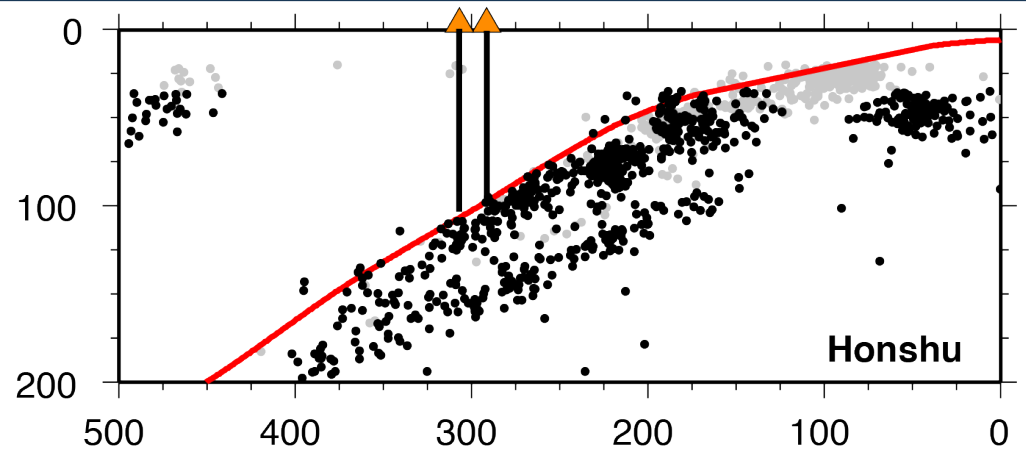
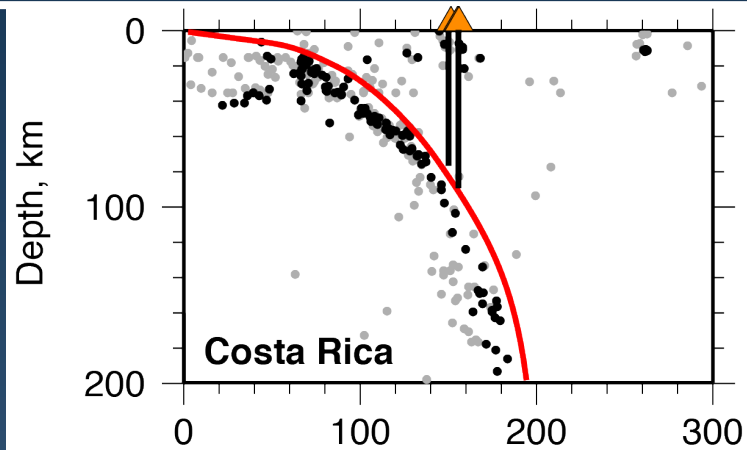
Slab seismicity



Slab seismicity



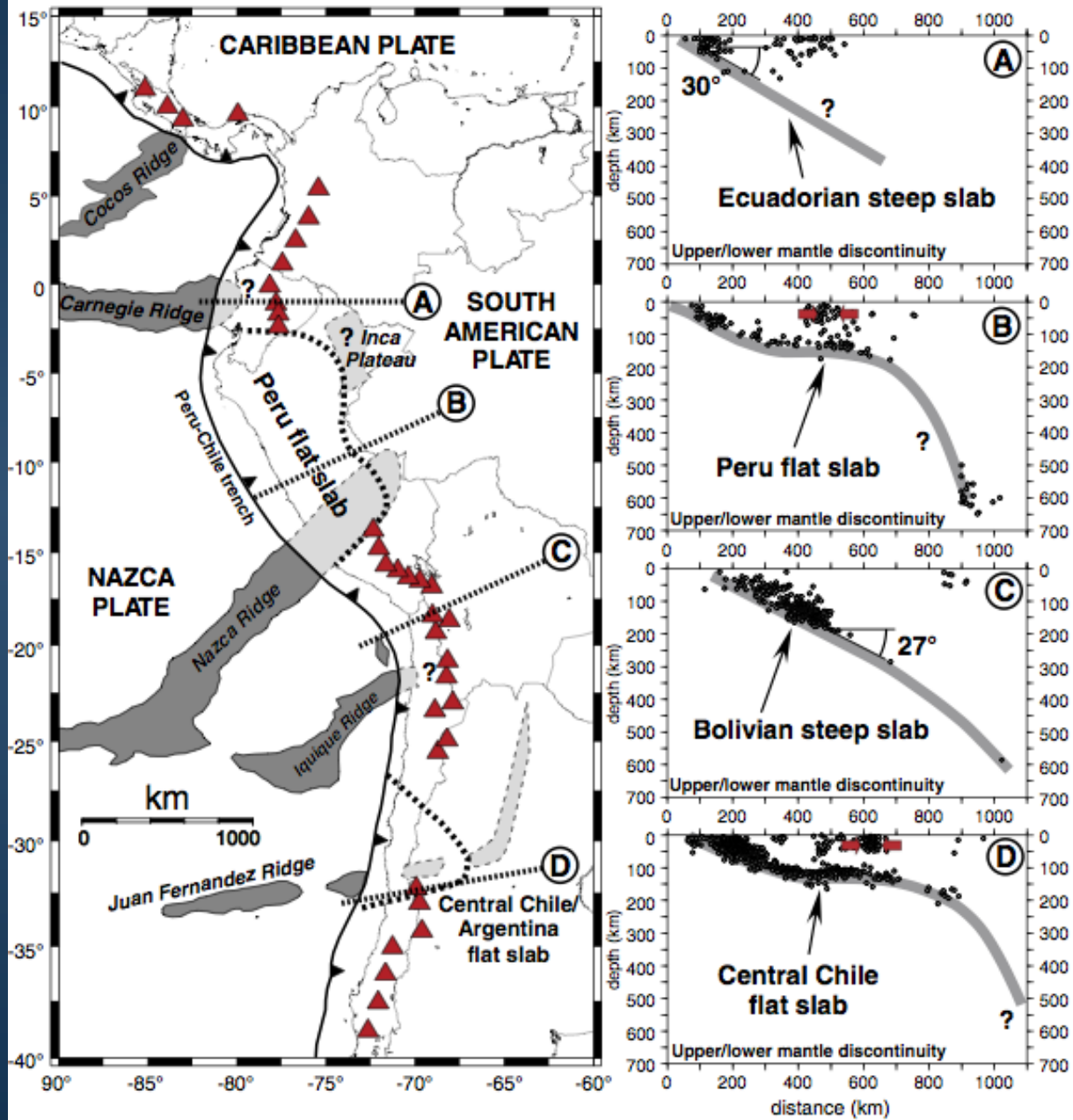
Slab seismicity



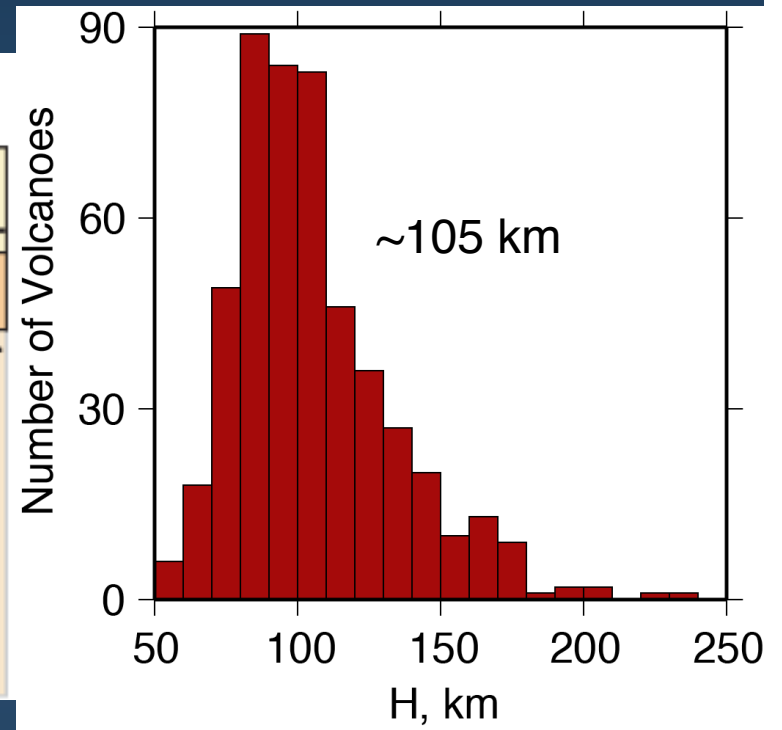
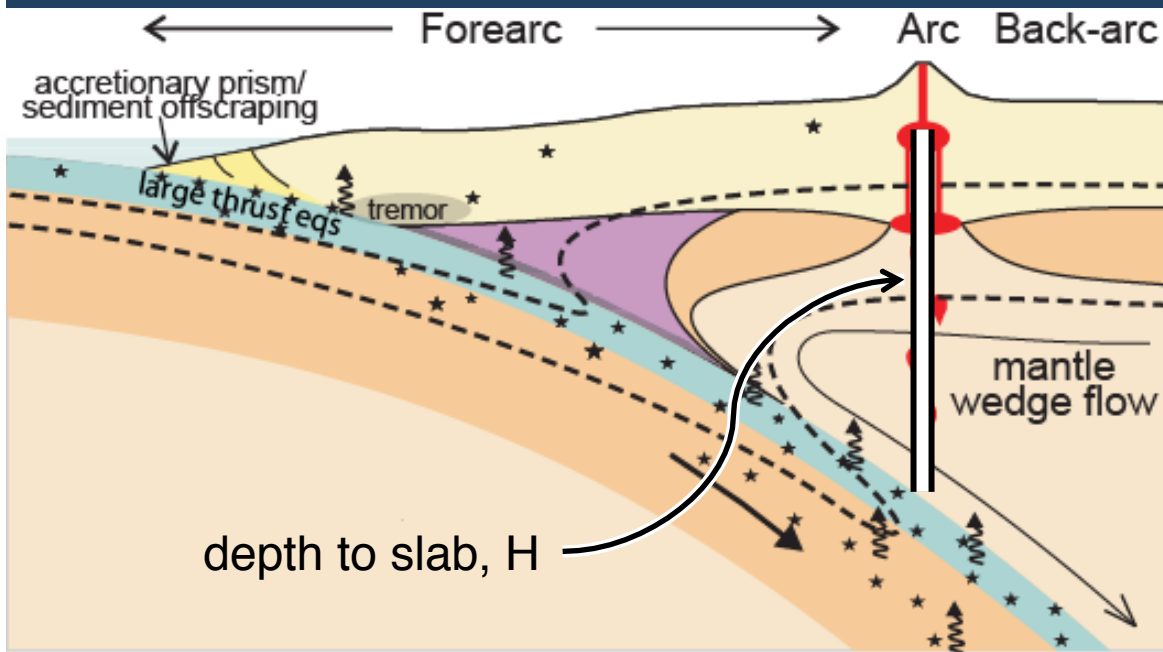
• teleseismic relocation

• local relocation

Slab seismicity



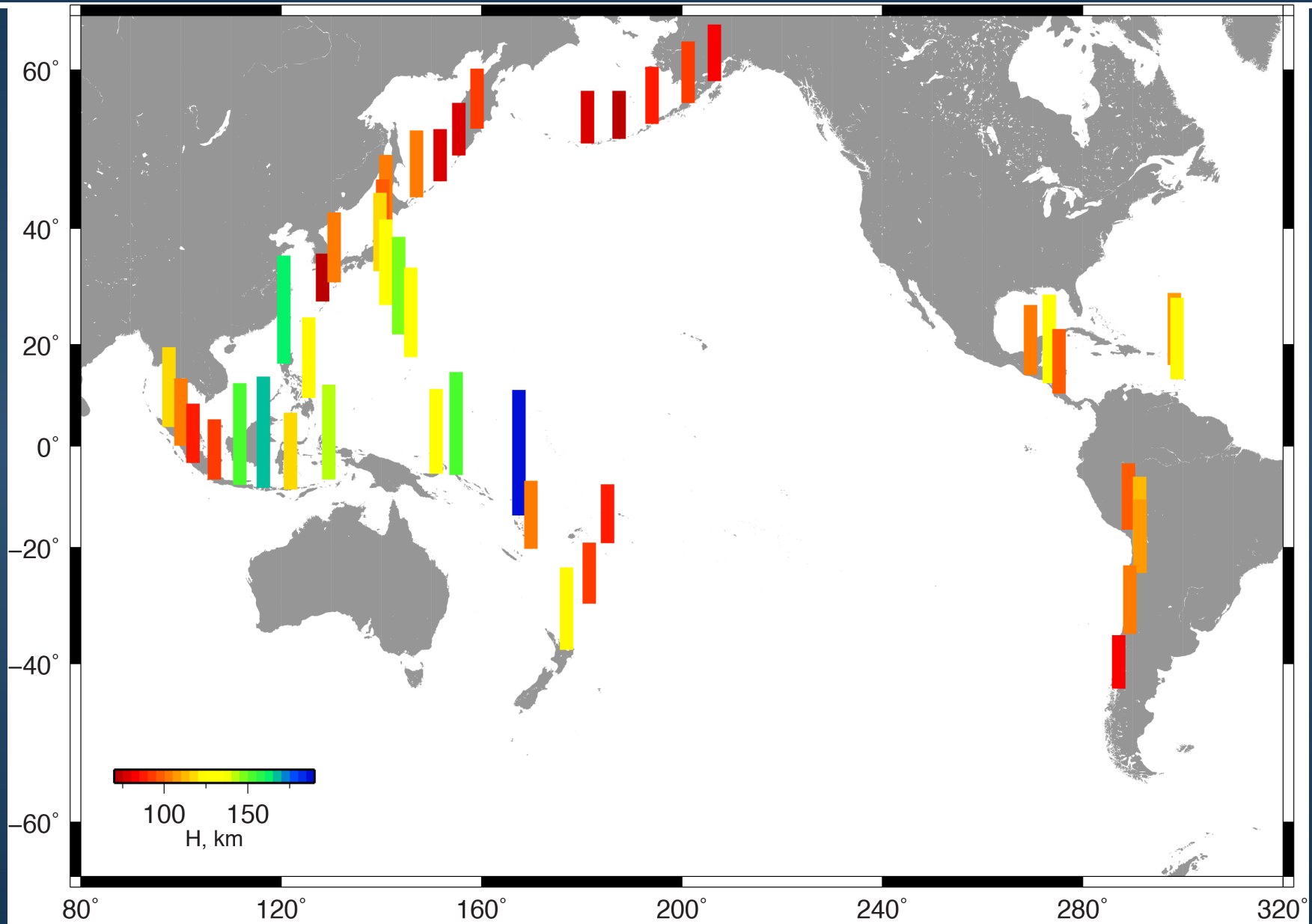
Slab seismicity - subarc region



modified from Wada & Wang, 2009

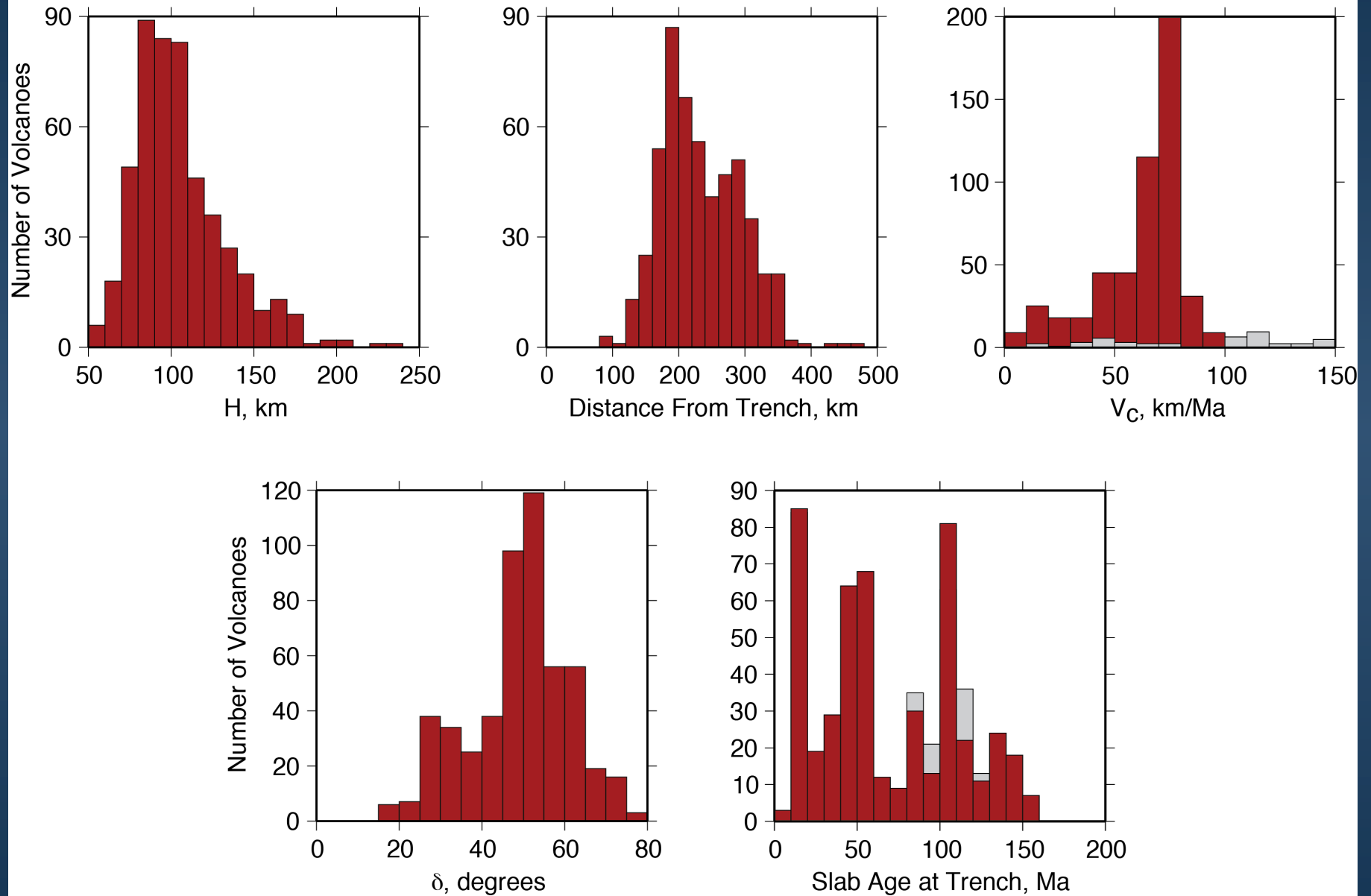
Syracuse & Abers, 2006

Slab seismicity - subarc region

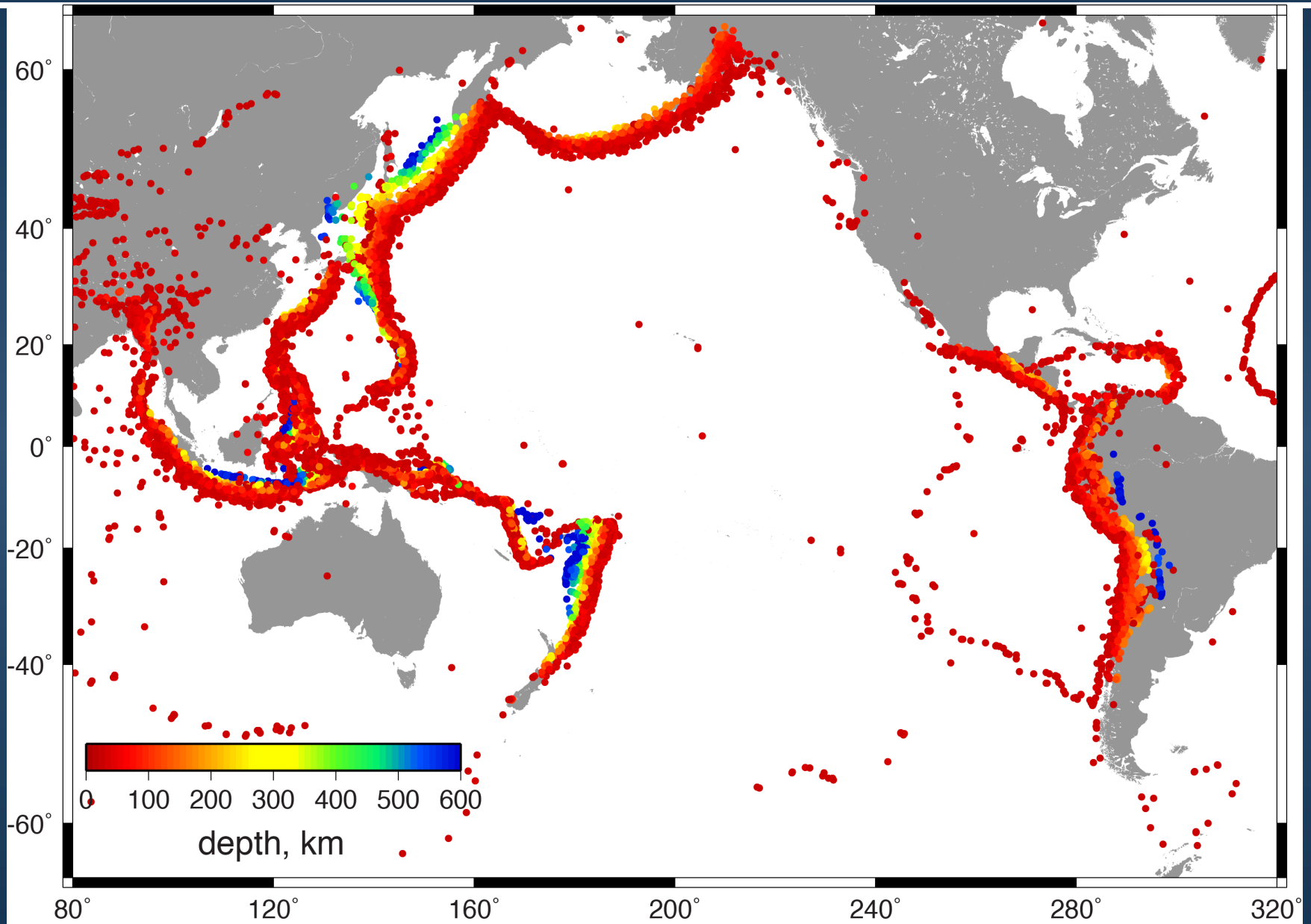


data from Syracuse & Abers, 2006

Slab seismicity - subarc region

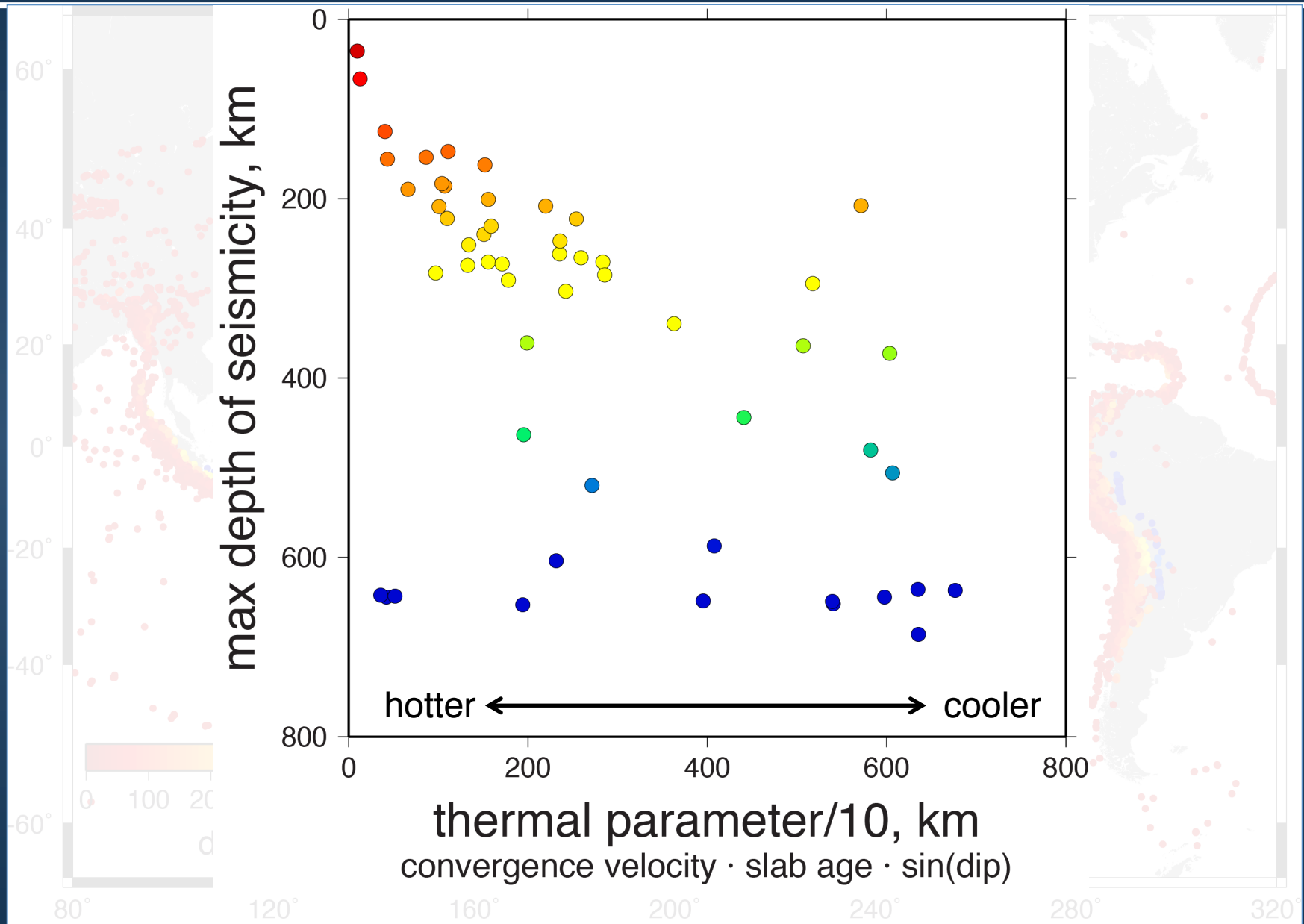


Slab seismicity - post arc



seismicity from Engdahl et al., 1998

Slab seismicity - post arc

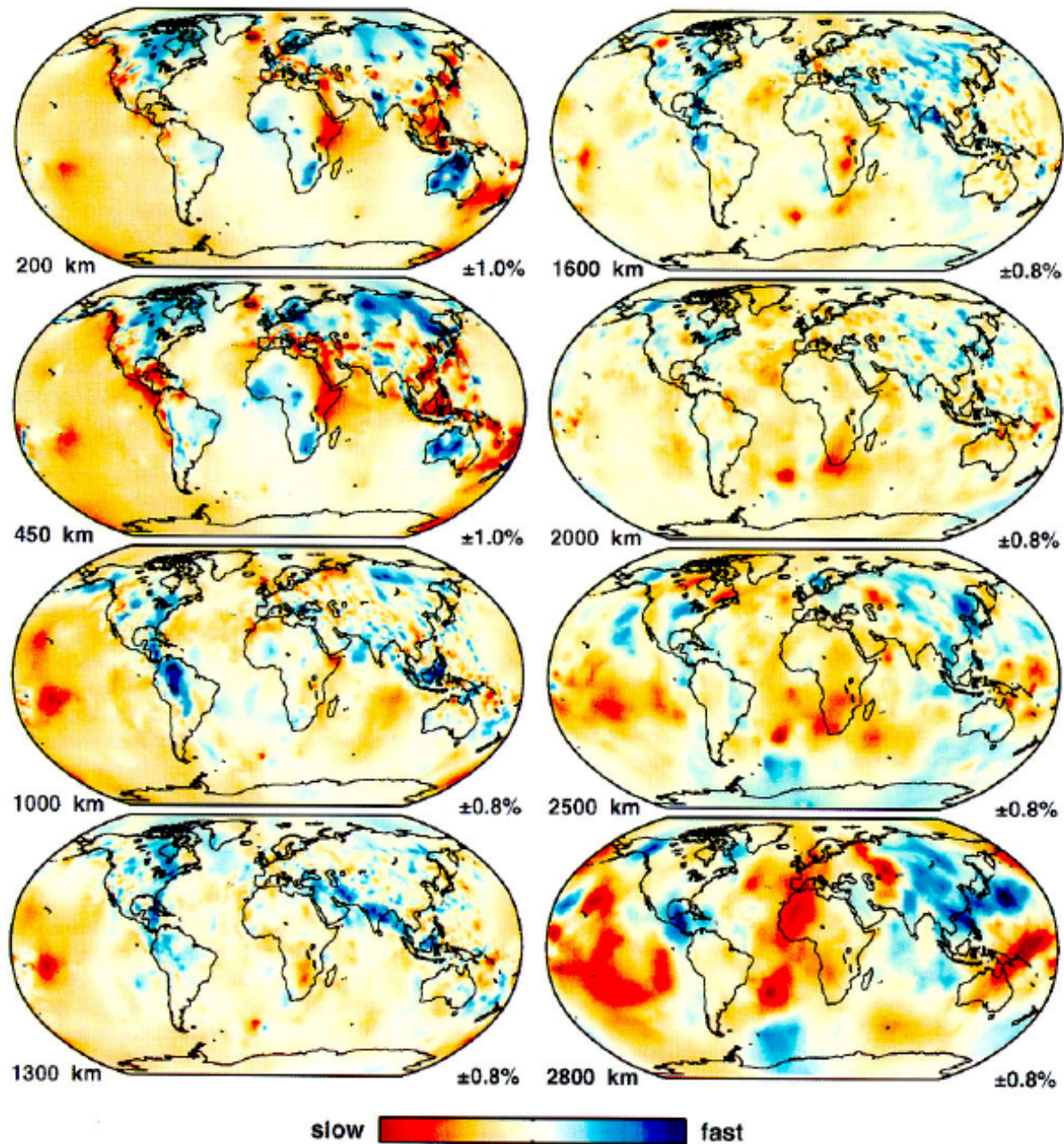


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- Subduction overview
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 - Attenuation tomography
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Velocity tomography - global

V_p

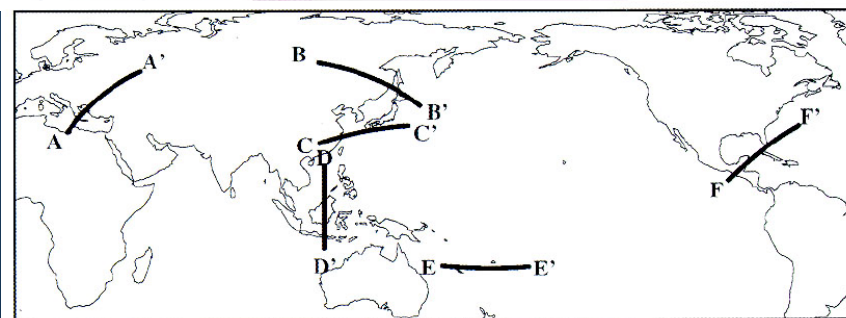
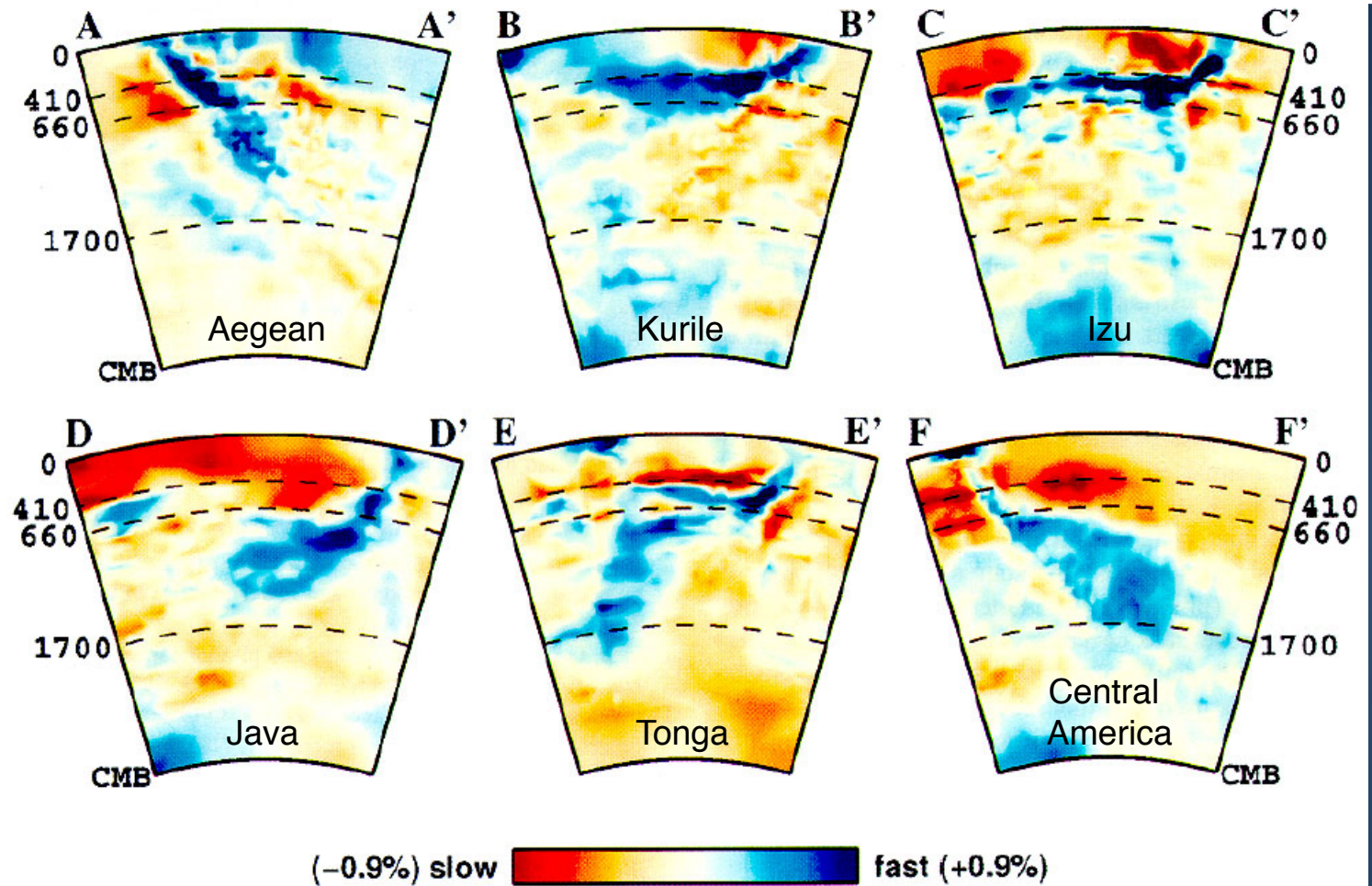


Kárason and
van der Hilst, 2000

Velocity tomography - global

V_p

- high-velocity cold slab
- low-velocity hot mantle wedge
- variety of ways in which slabs interact with the transition zone



Velocity tomography

Velocity affected by:

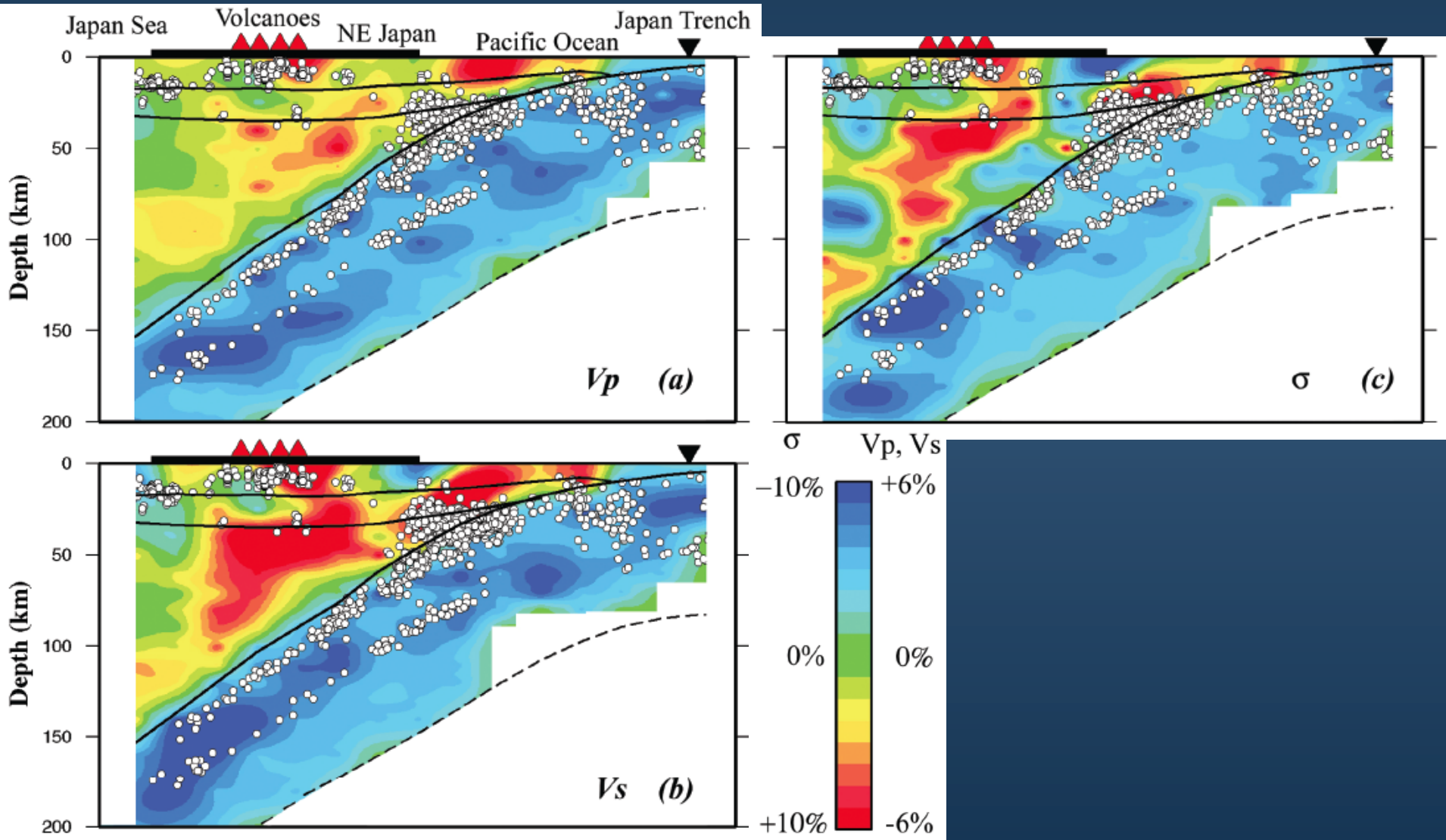
- temperature: $T \uparrow$, $V_p \downarrow$, $V_s \downarrow$, $V_p/V_s \uparrow$
- composition: mafic \uparrow , $V_p \uparrow$, $V_s \uparrow$
- melt: melt \uparrow , $V_p \downarrow$, $V_s \downarrow$, $V_p/V_s \uparrow$
- water: water \uparrow , $V_p \downarrow$, $V_s \downarrow$

$$V_p = \left(\frac{\kappa + 4/3\mu}{\rho} \right)^{1/2}$$

$$V_s = \left(\frac{\mu}{\rho} \right)^{1/2}$$

Velocity tomography - local

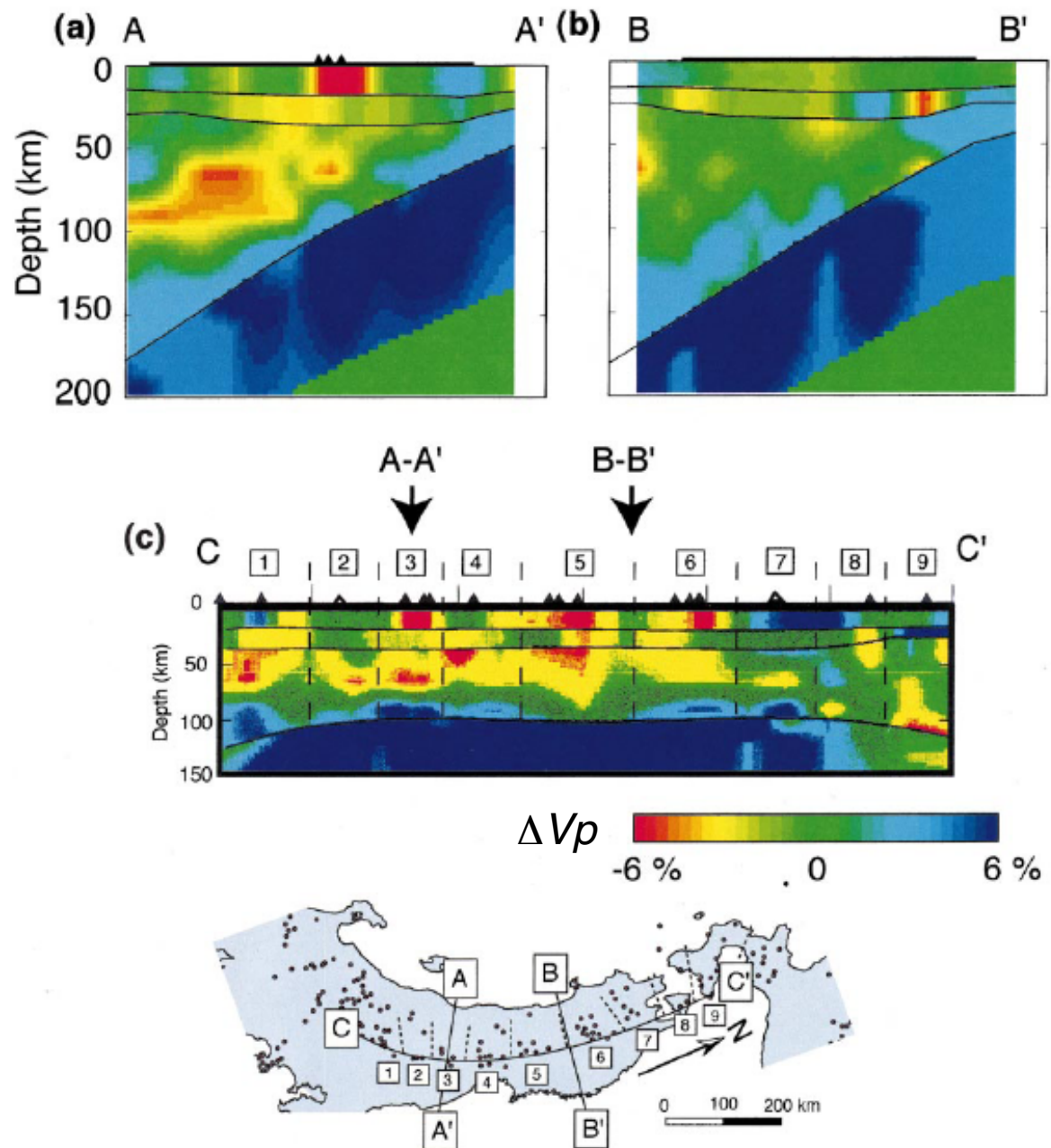
Honshu



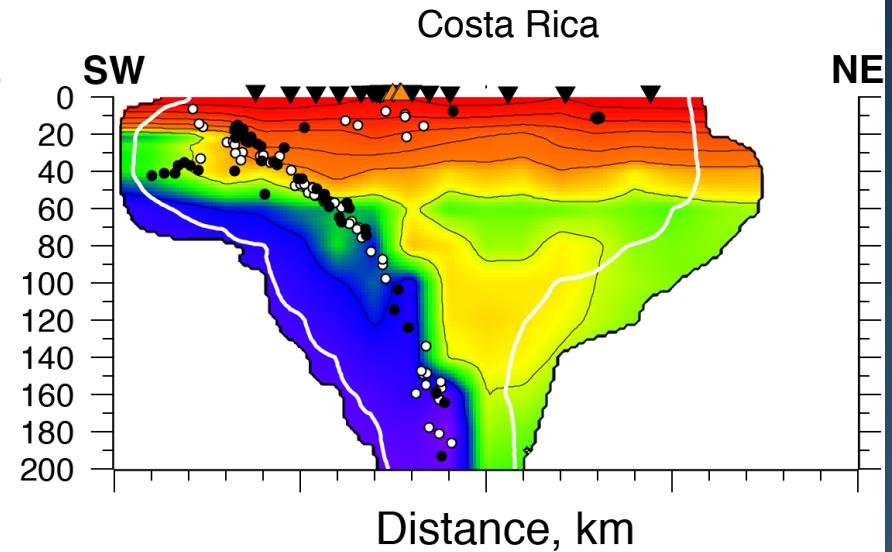
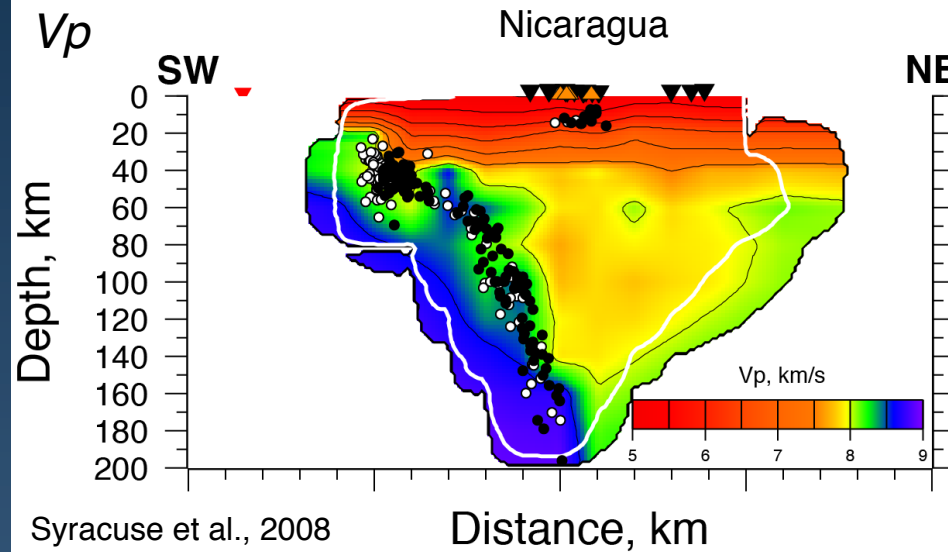
Velocity tomography - local

Honshu

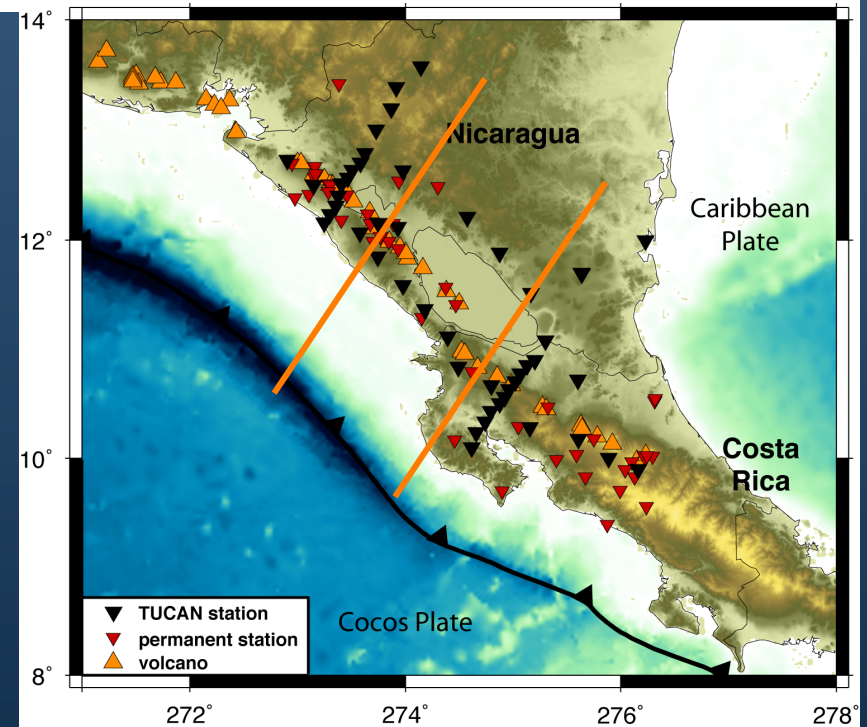
- low-velocity 'hot fingers' beneath volcanic clusters
- indicate ~50-km-scale T oscillations and highly 3D structure



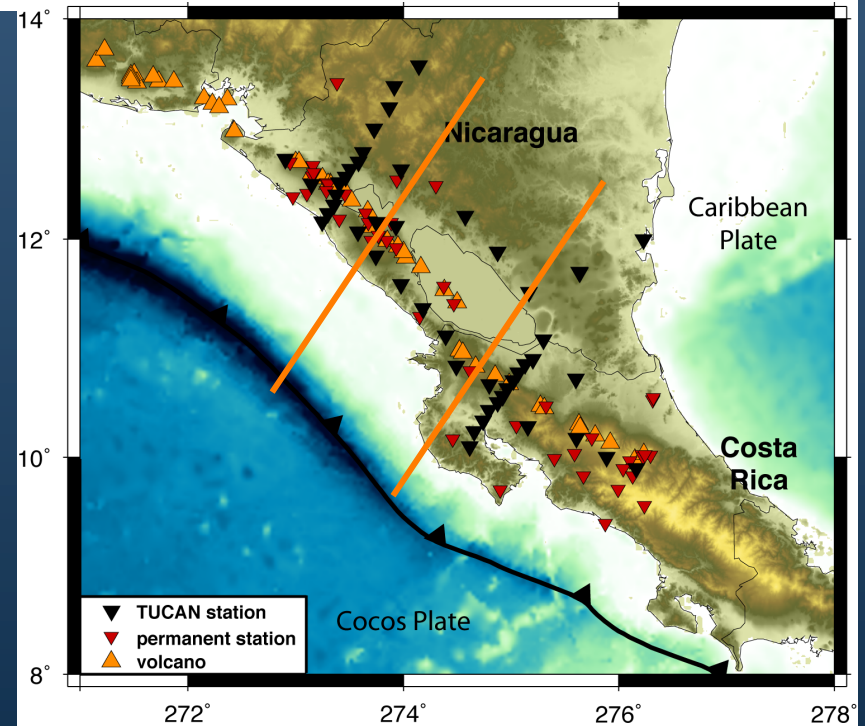
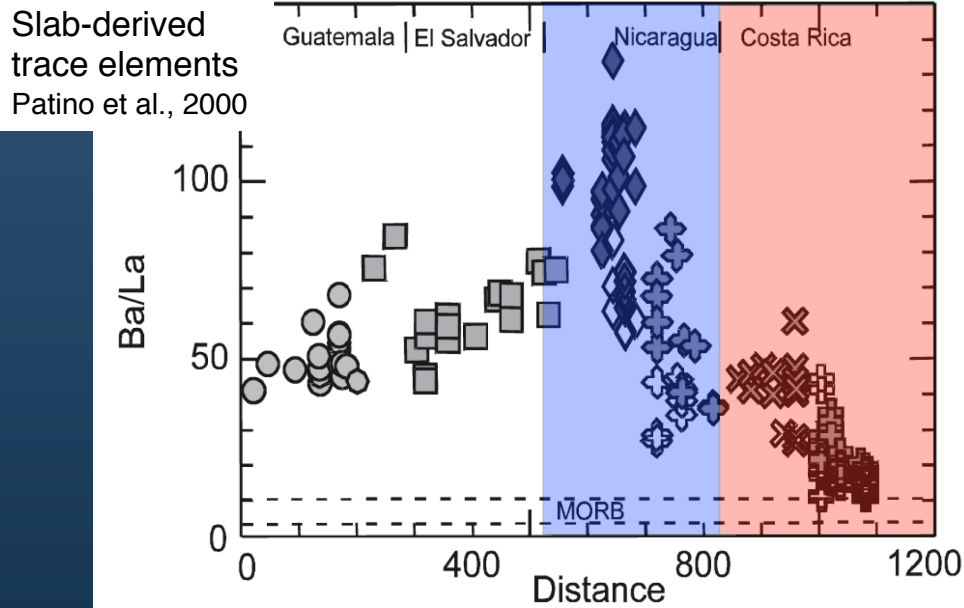
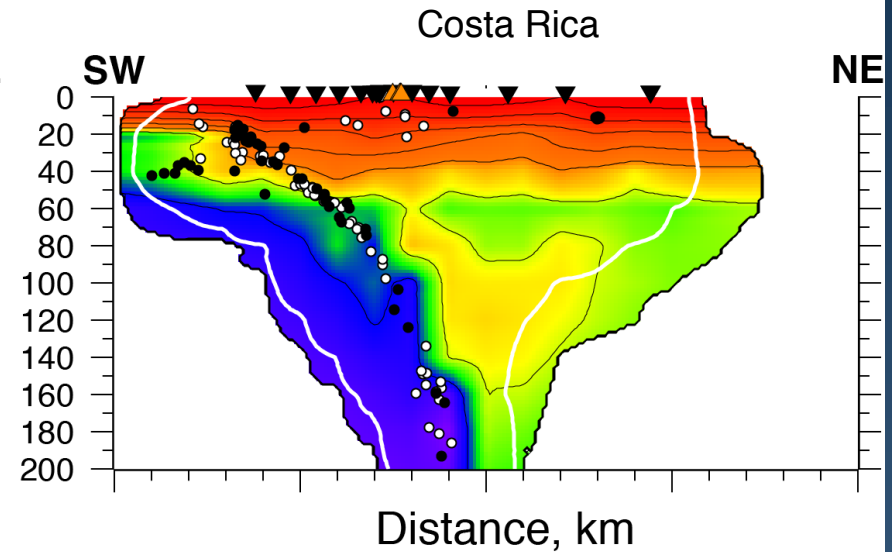
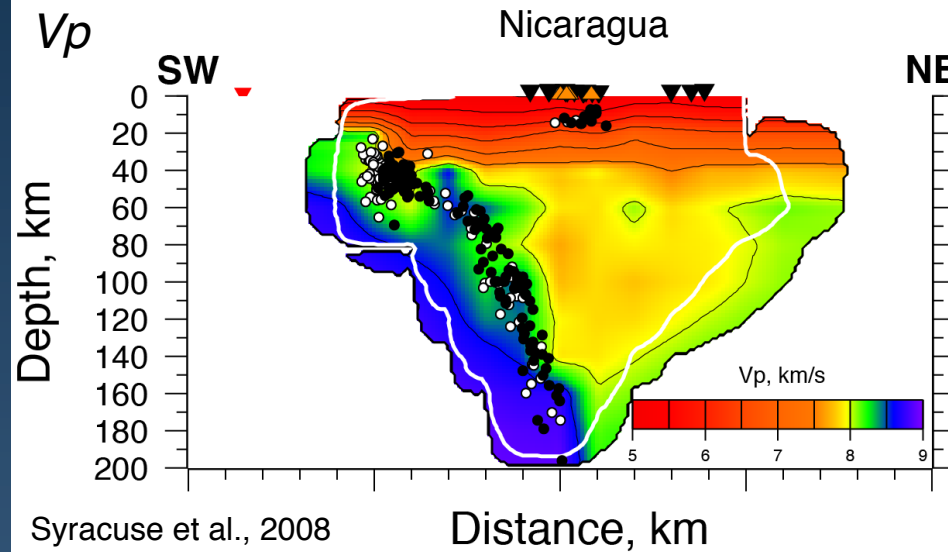
Velocity tomography - local



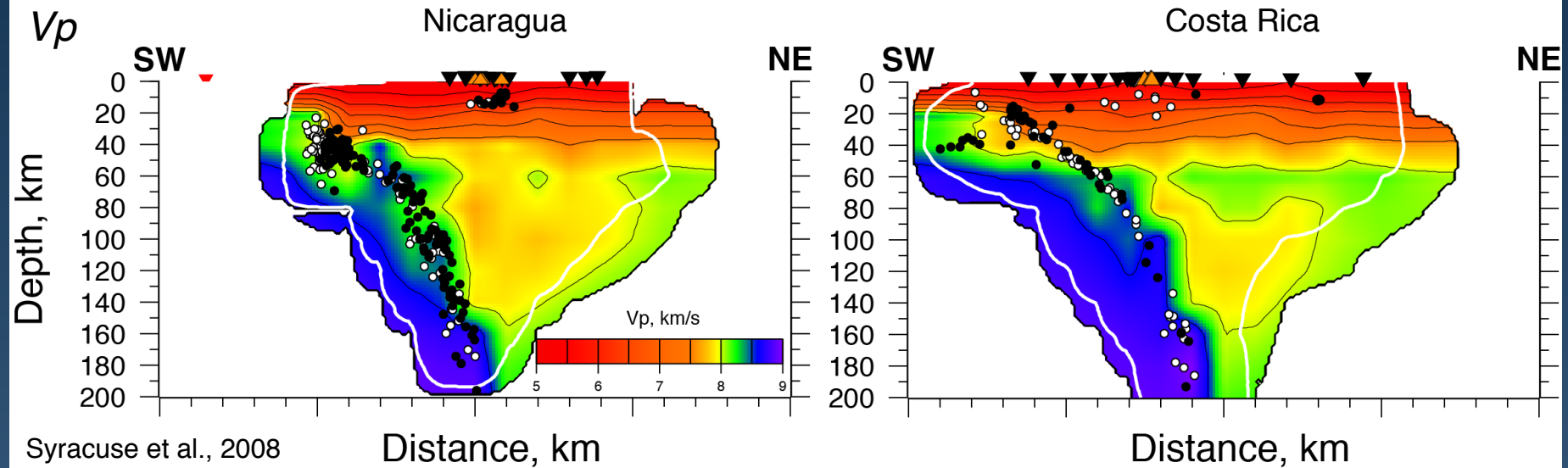
- up to 20% serpentinization or 3 wt% H₂O in Nicaraguan slab



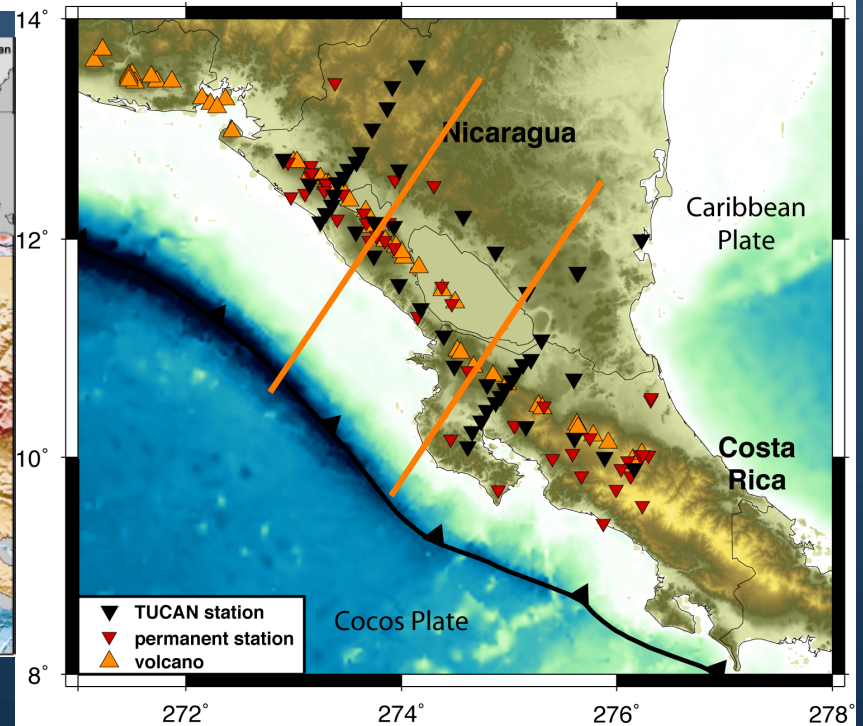
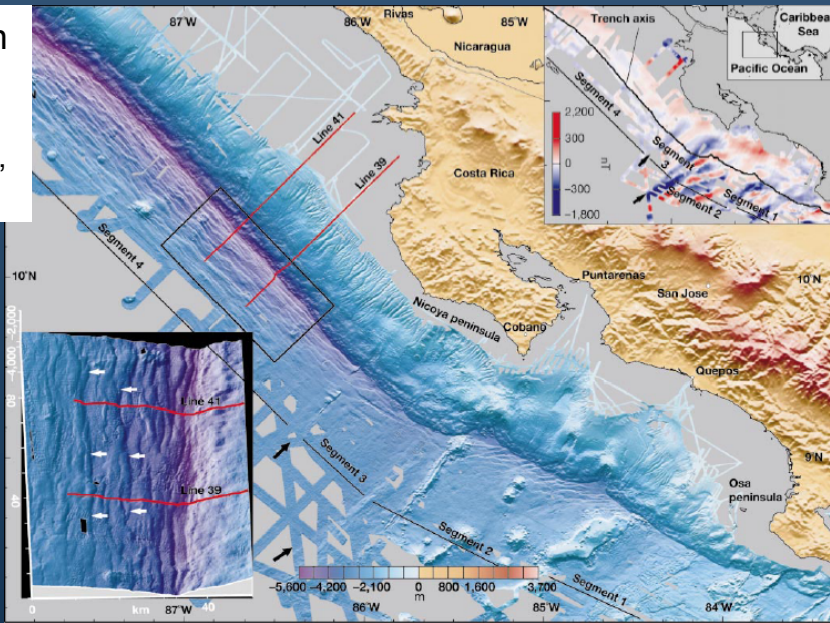
Velocity tomography - local



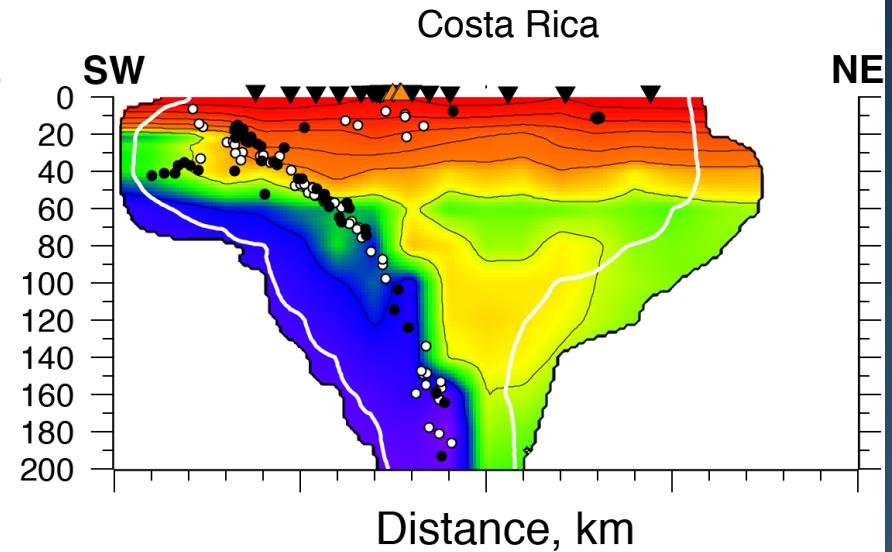
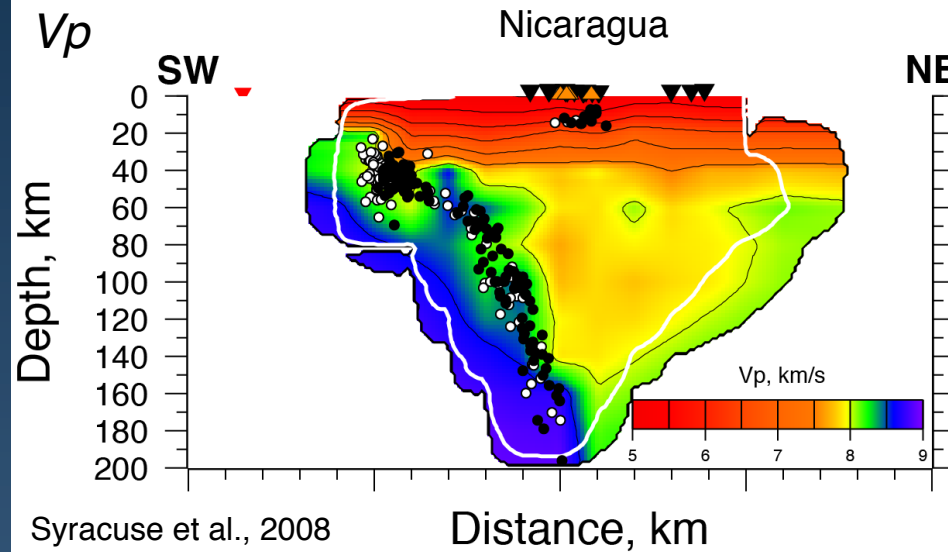
Velocity tomography - local



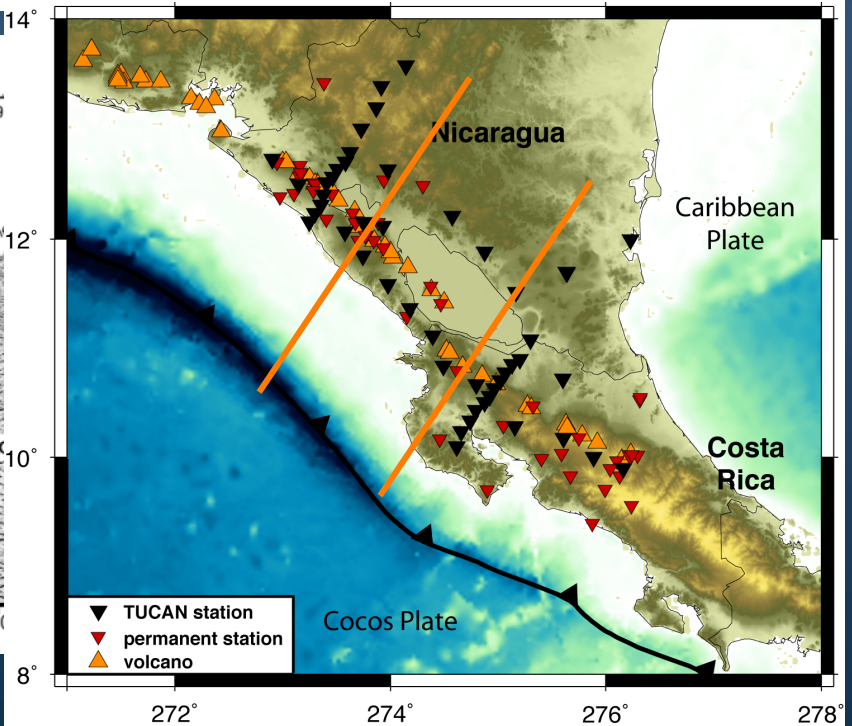
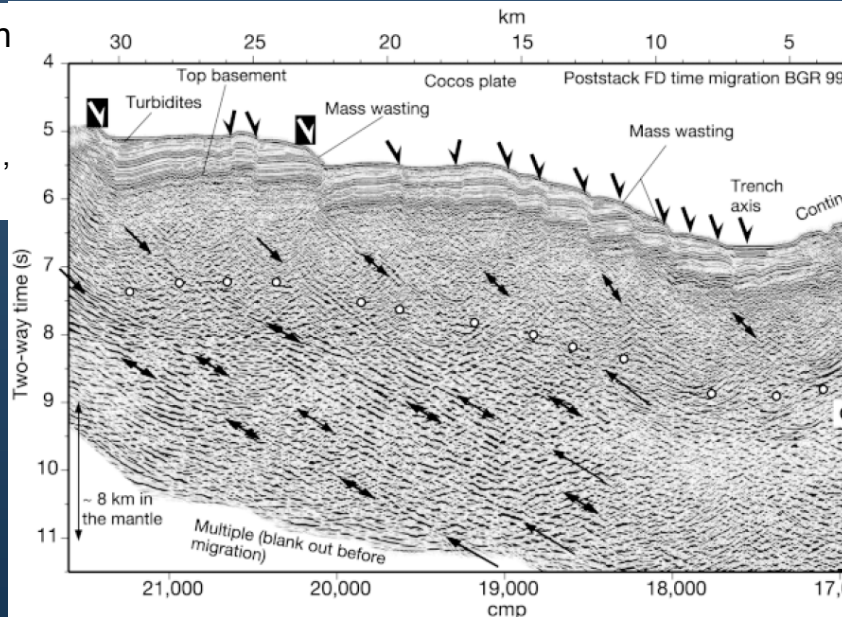
Nicaraguan
outer-rise
faulting
Ranero et al.,
2003



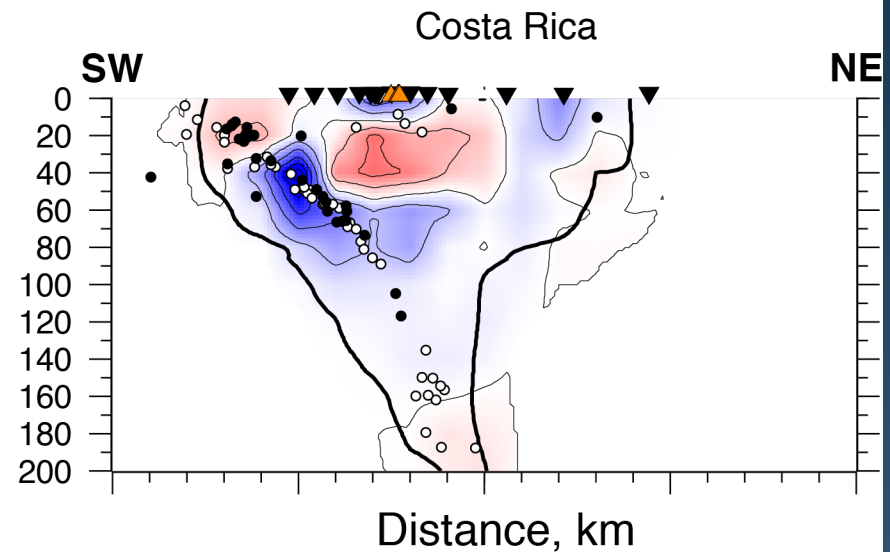
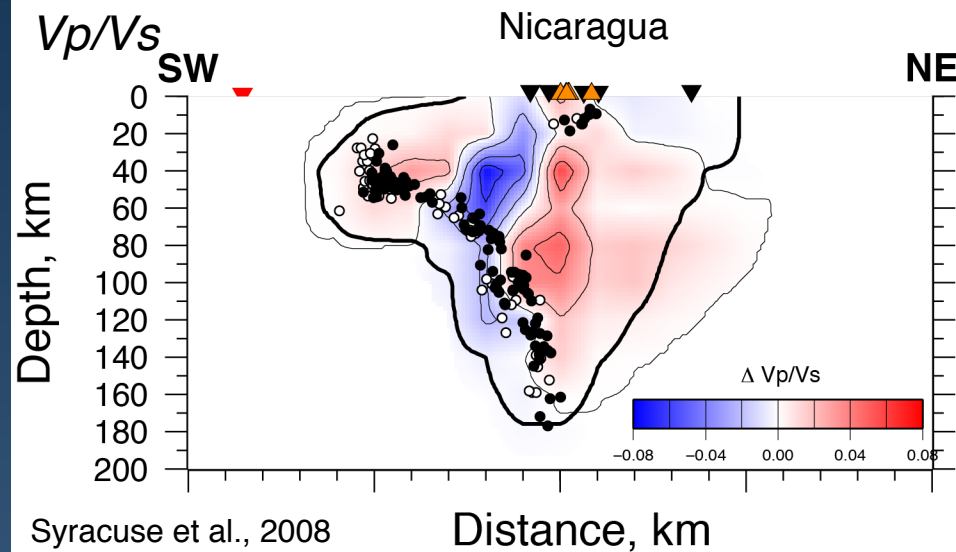
Velocity tomography - local



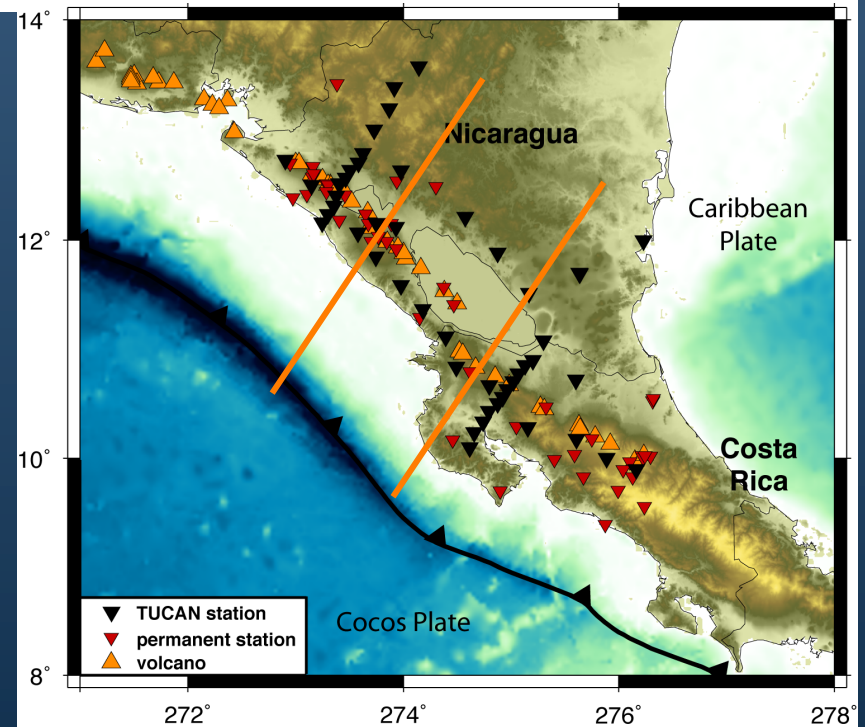
Nicaraguan
outer-rise
faulting
Ranero et al.,
2003



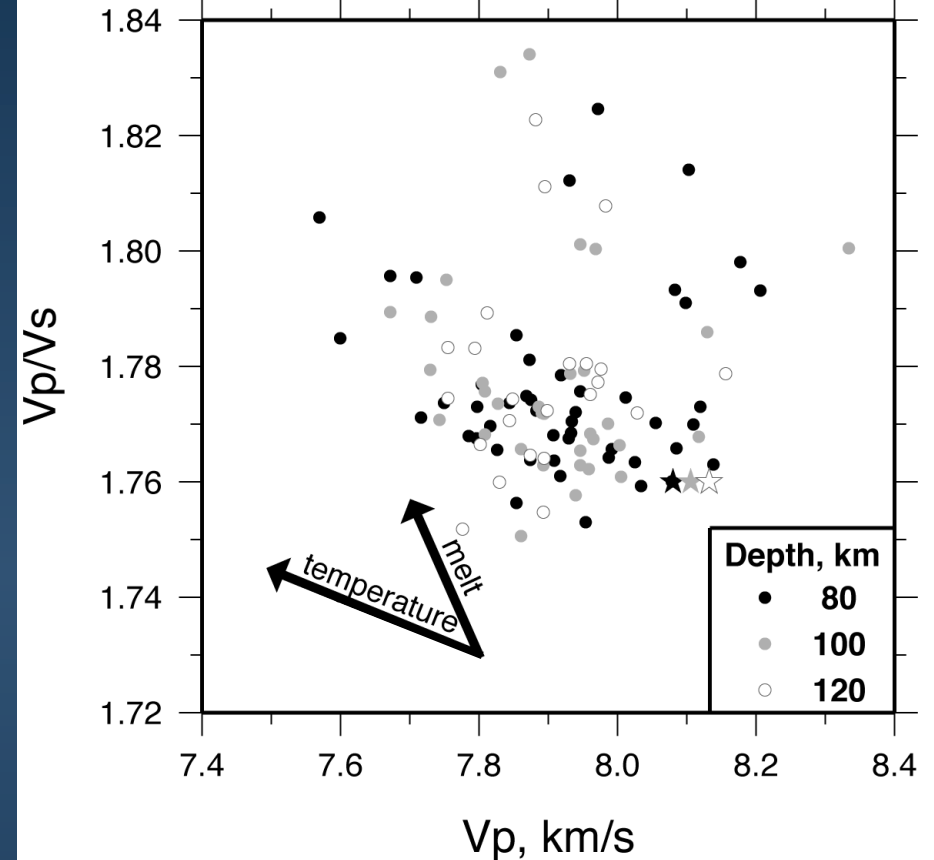
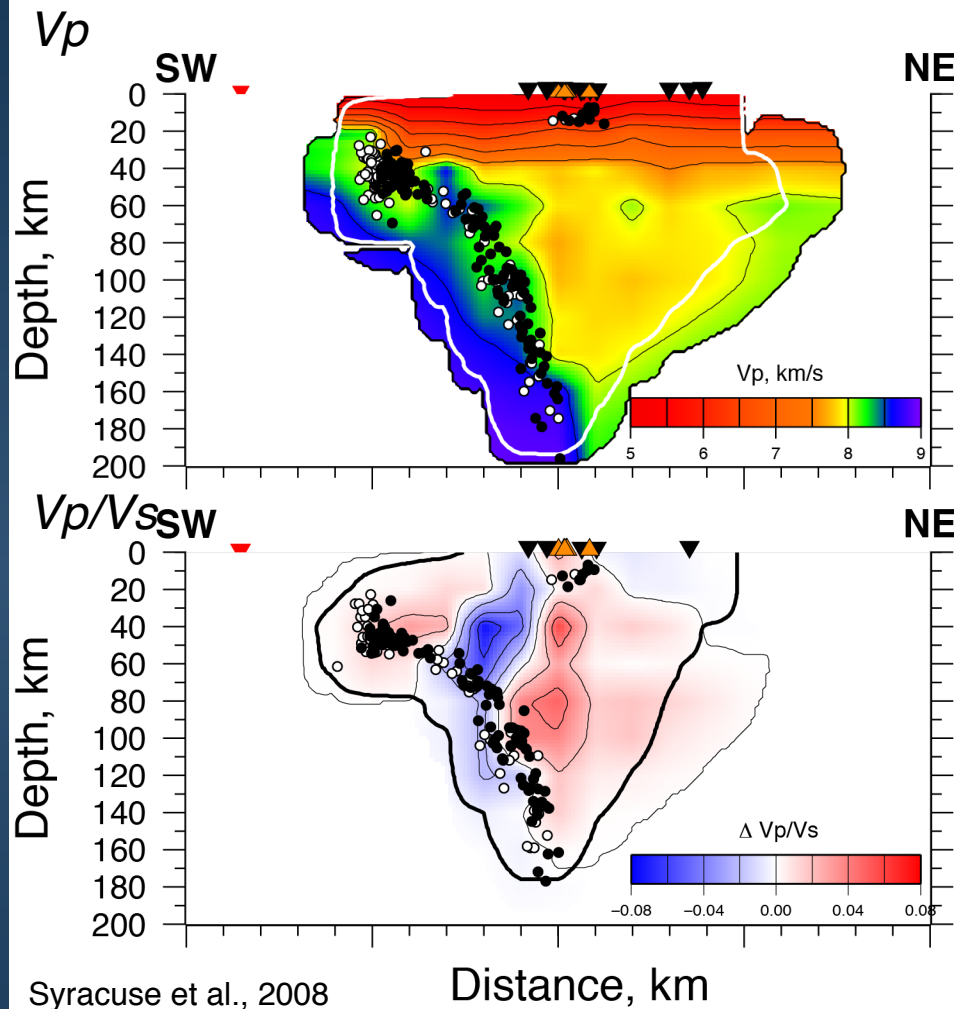
Velocity tomography



- high Vp/Vs sheet below Nicaraguan arc
- decreases into NW Costa Rica



Velocity tomography



- high V_p/V_s sheet follows trend caused by a decrease of shear modulus, such as melt
- Rest of mantle follows trend predicted for a decrease in shear and bulk moduli, such as increased temperature

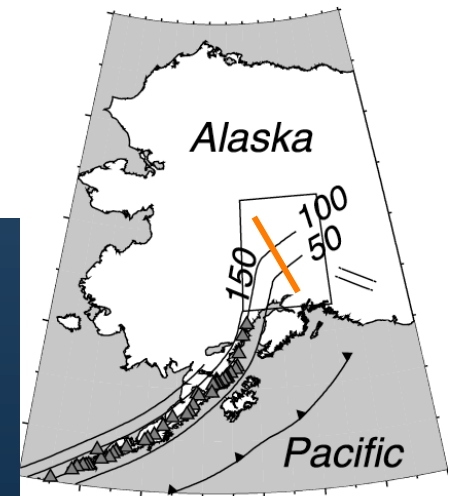
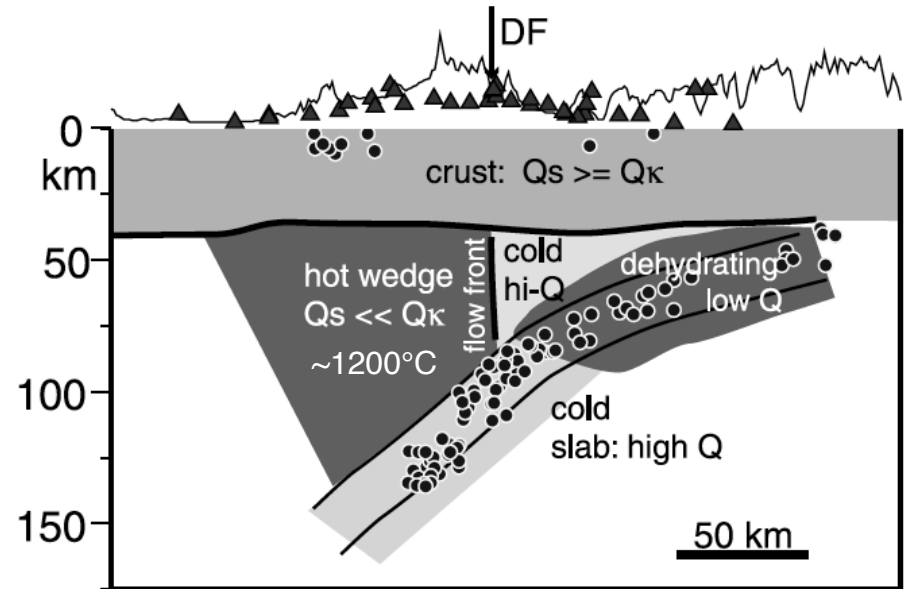
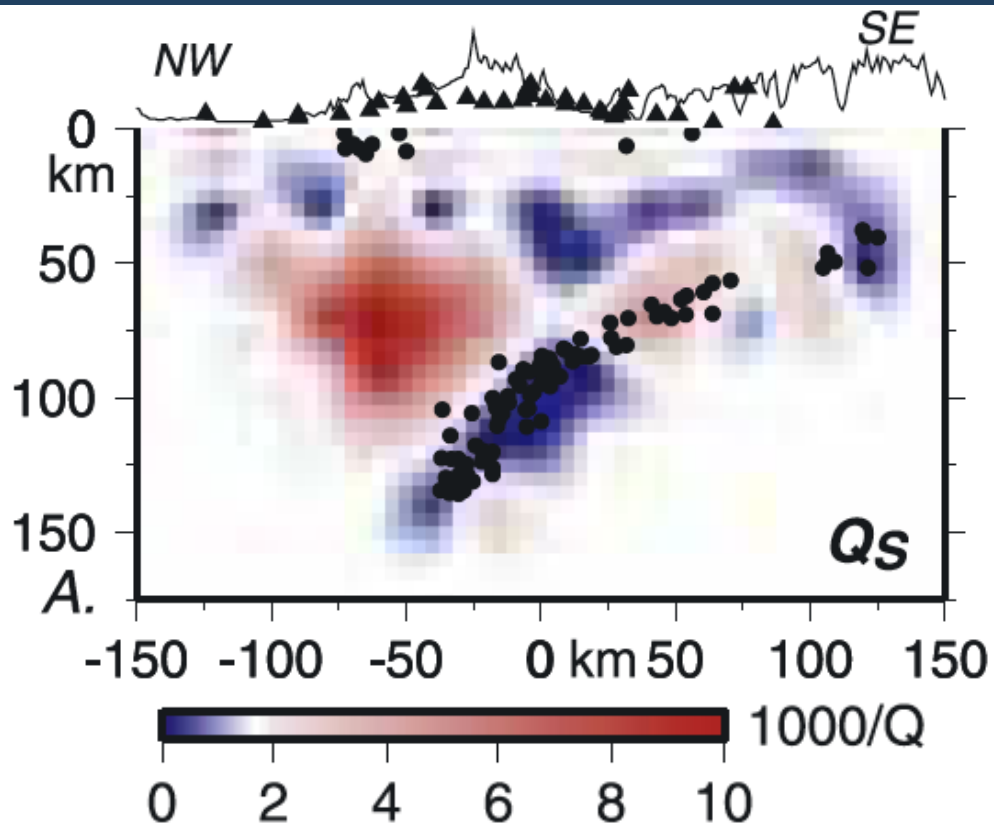
based on Karato, 1993 and
Hammond and Humphreys, 2000

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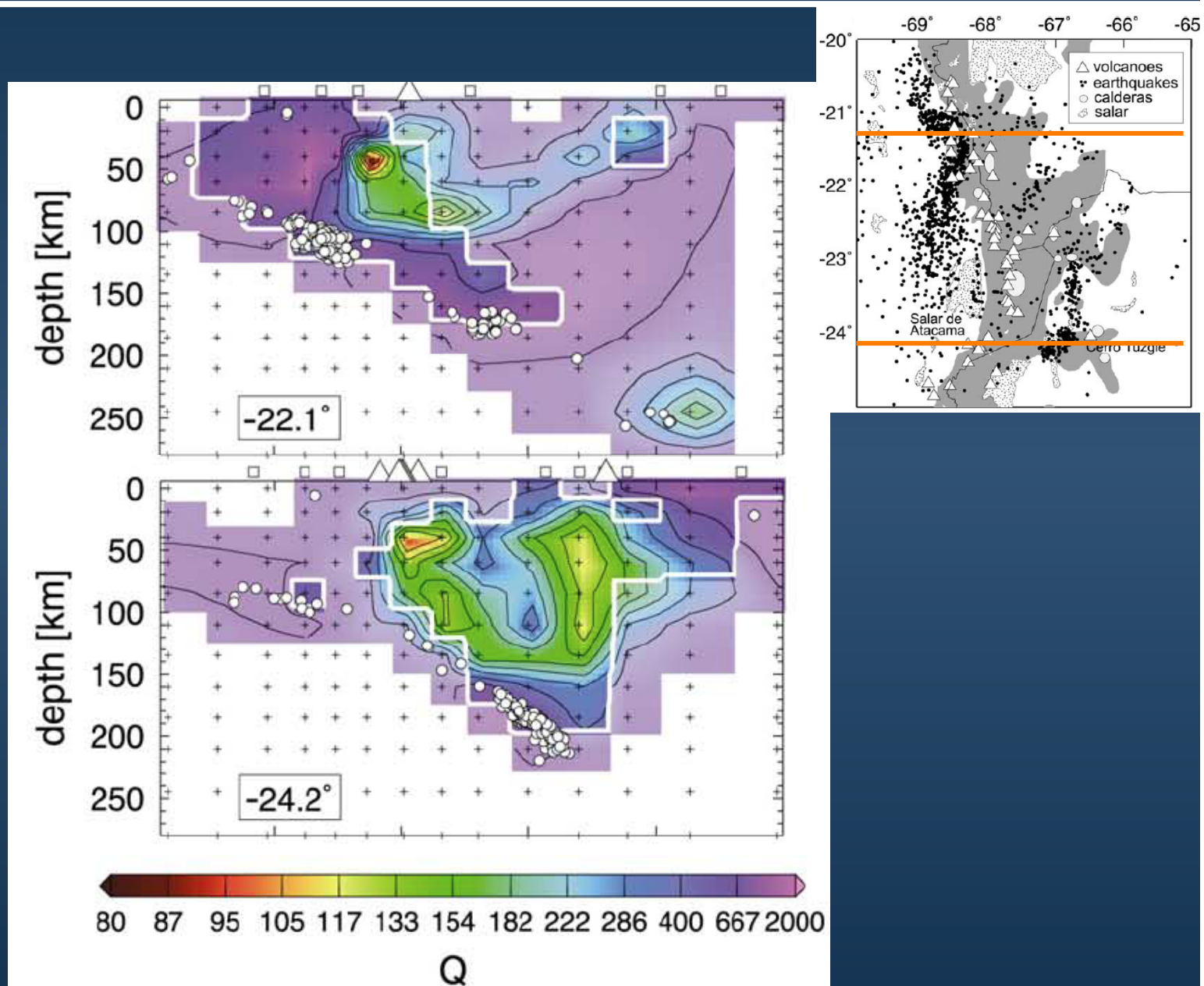
Attenuation tomography

Alaska – nonvolcanic eastern section



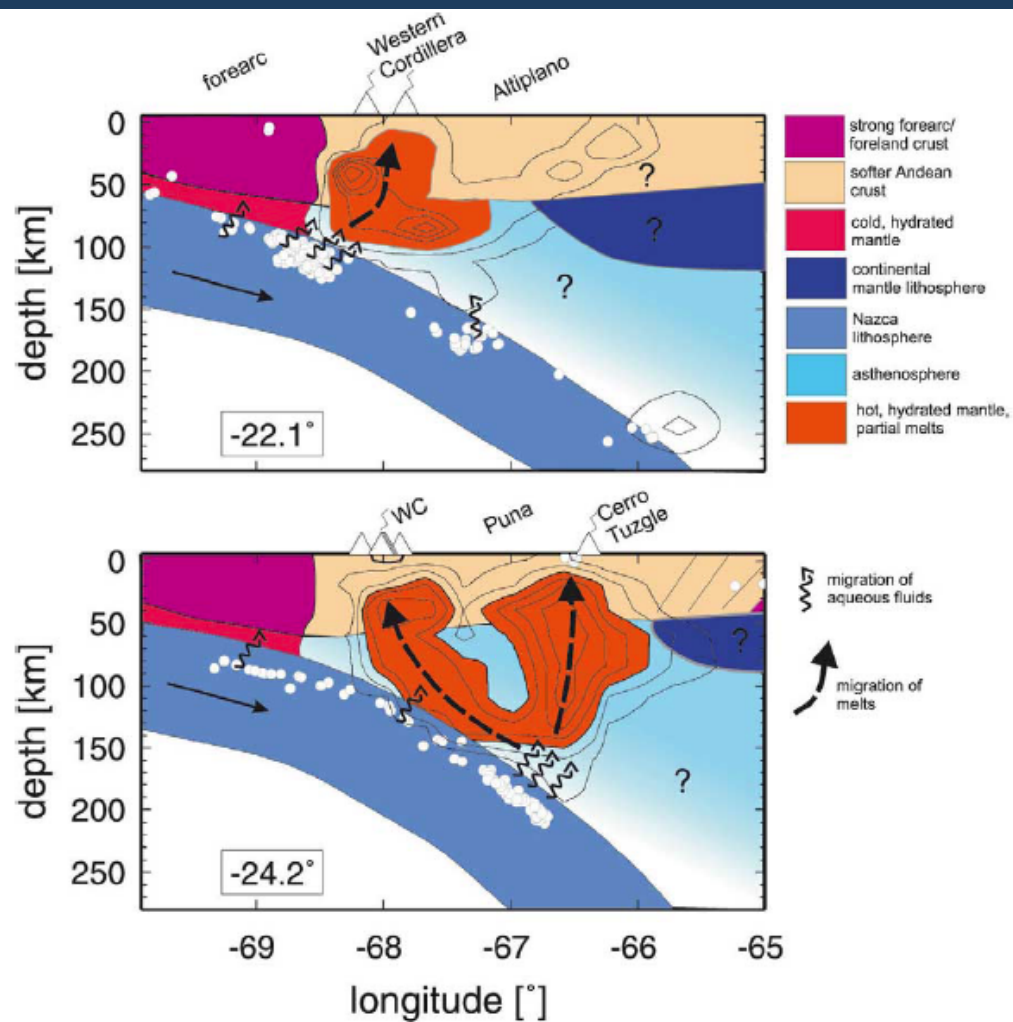
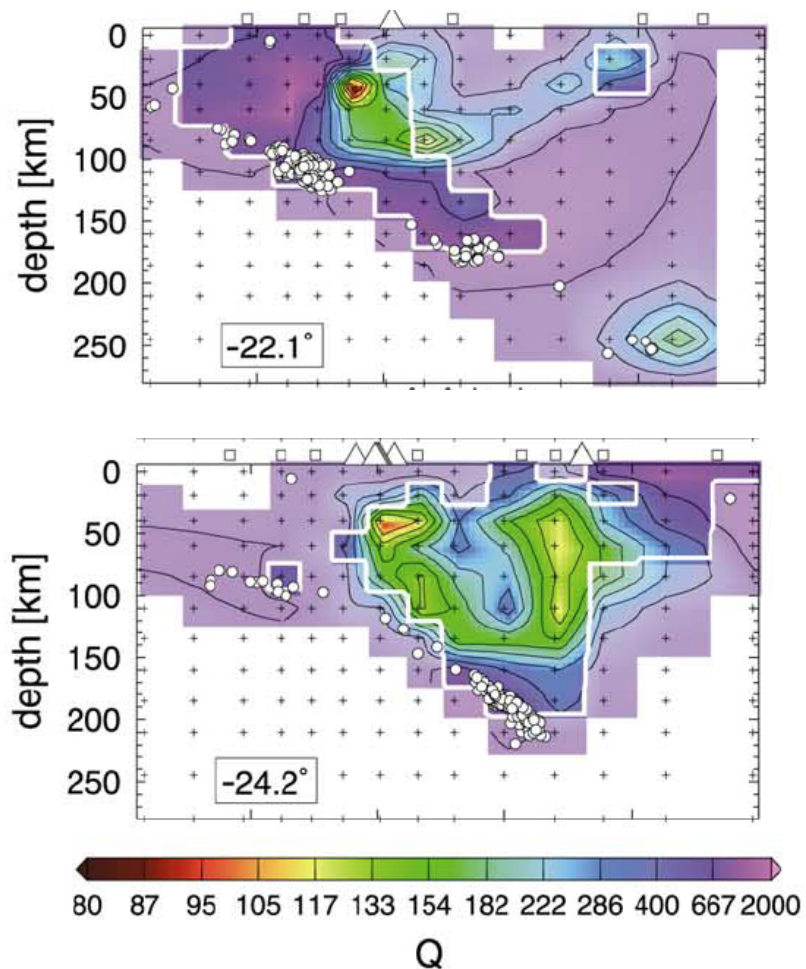
Attenuation tomography

Central Andes



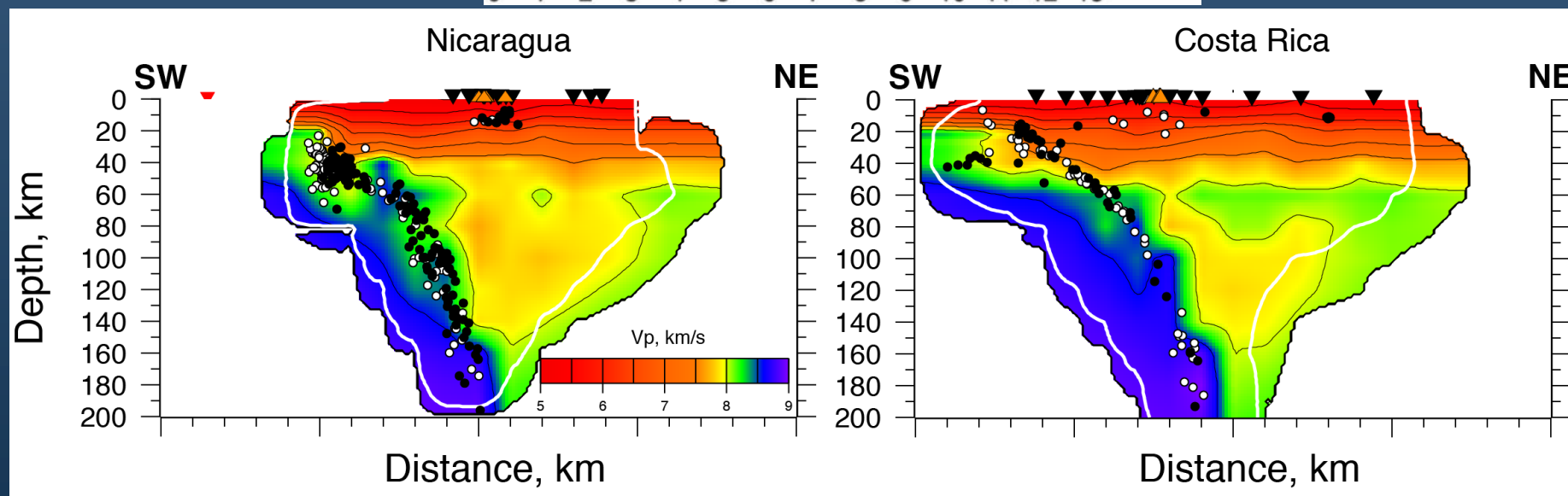
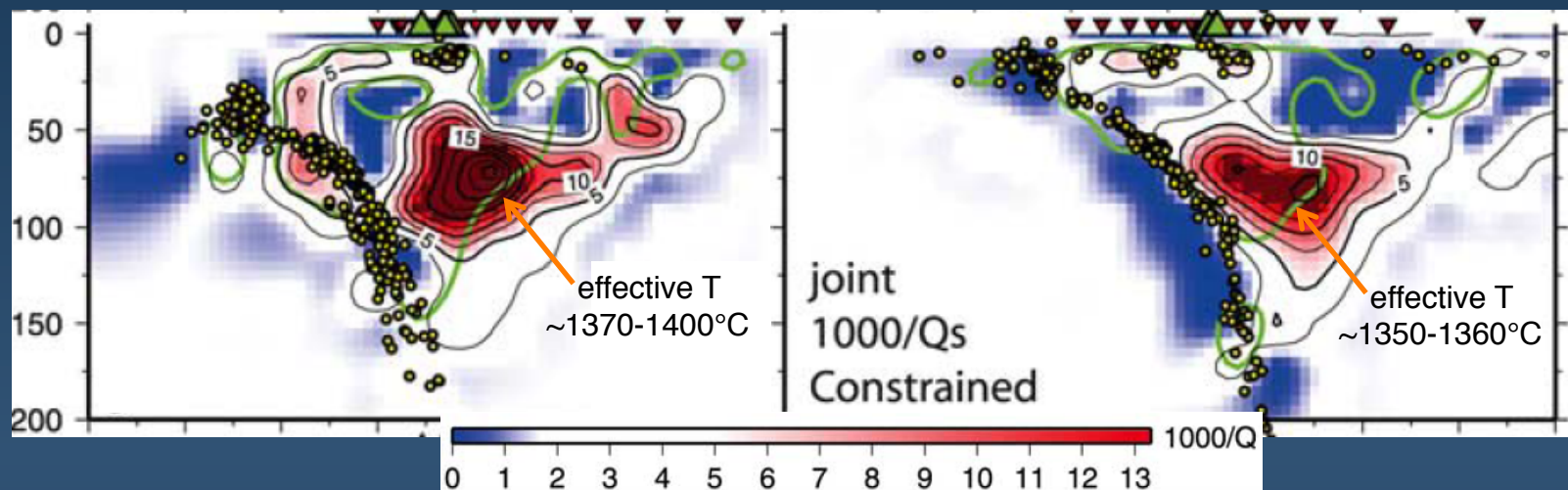
Attenuation tomography

Central Andes

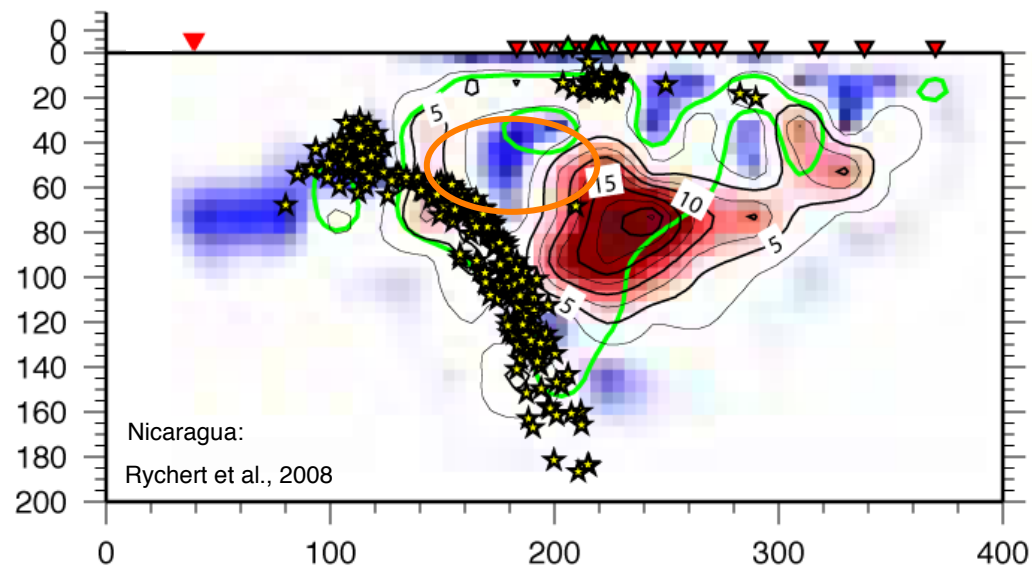
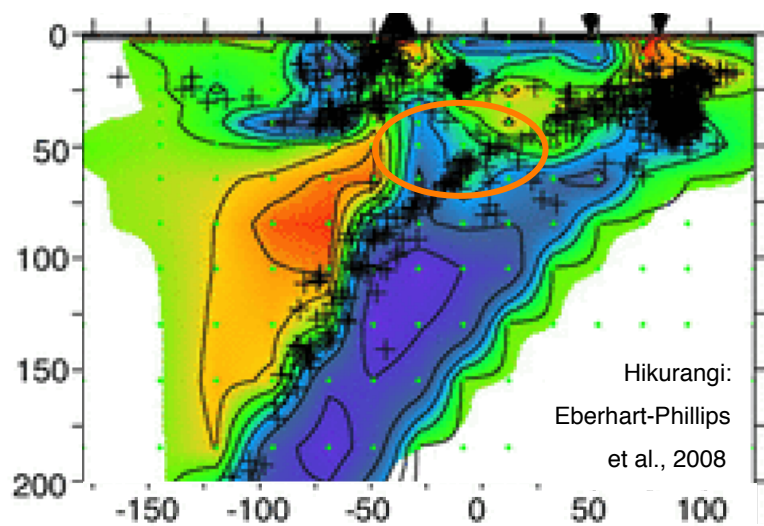
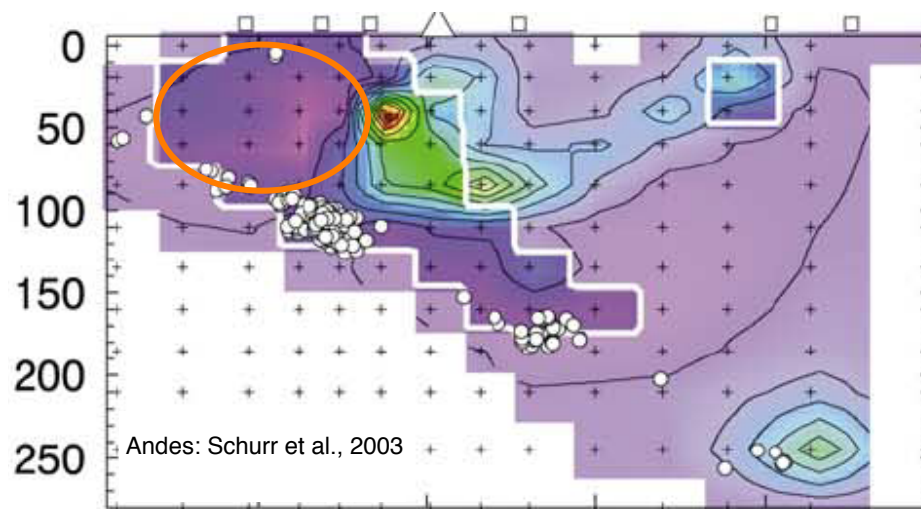
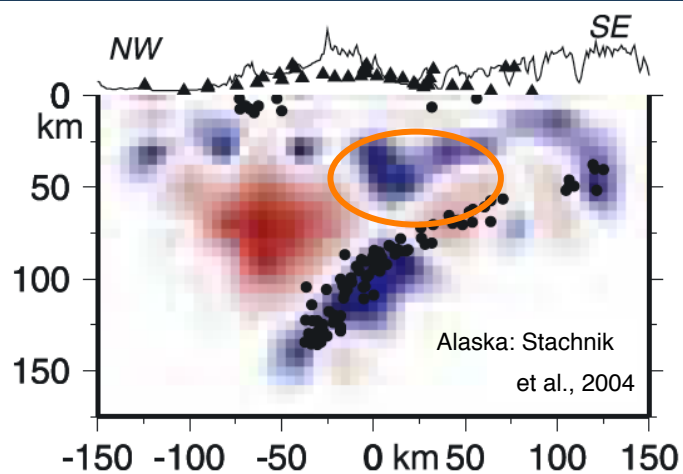


Attenuation tomography

Central America



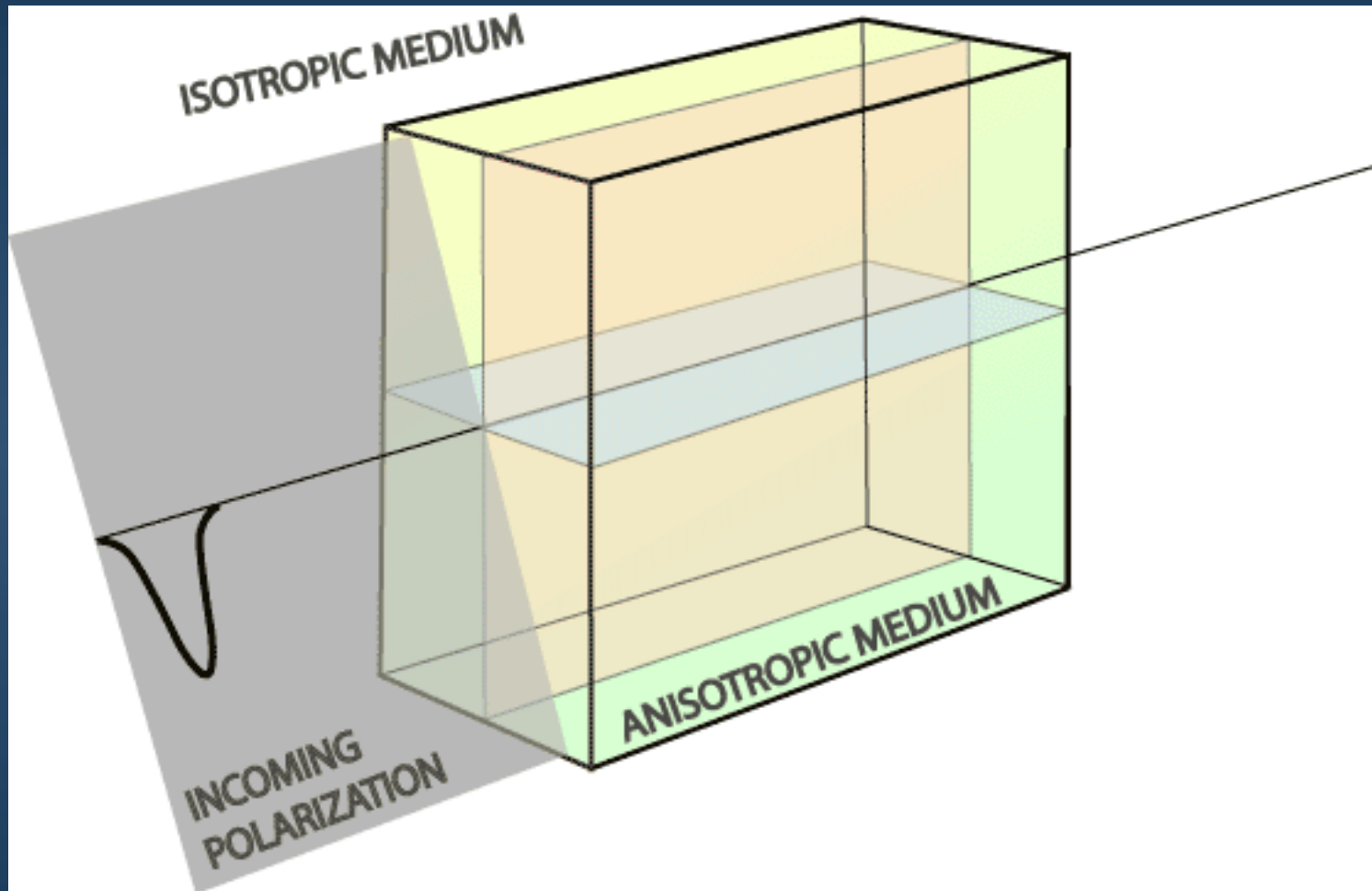
Attenuation tomography



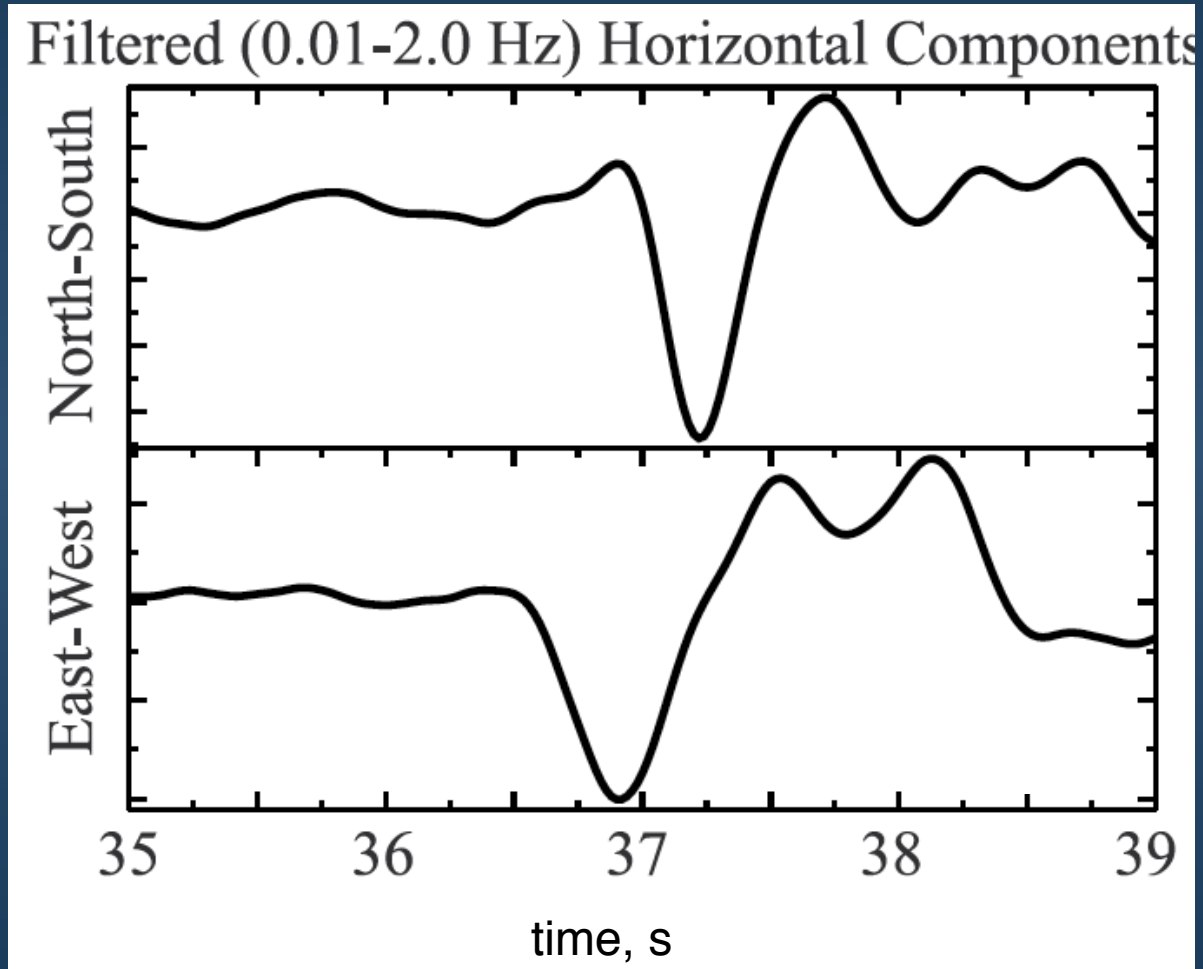
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- 2D thermal and mineralogical modeling

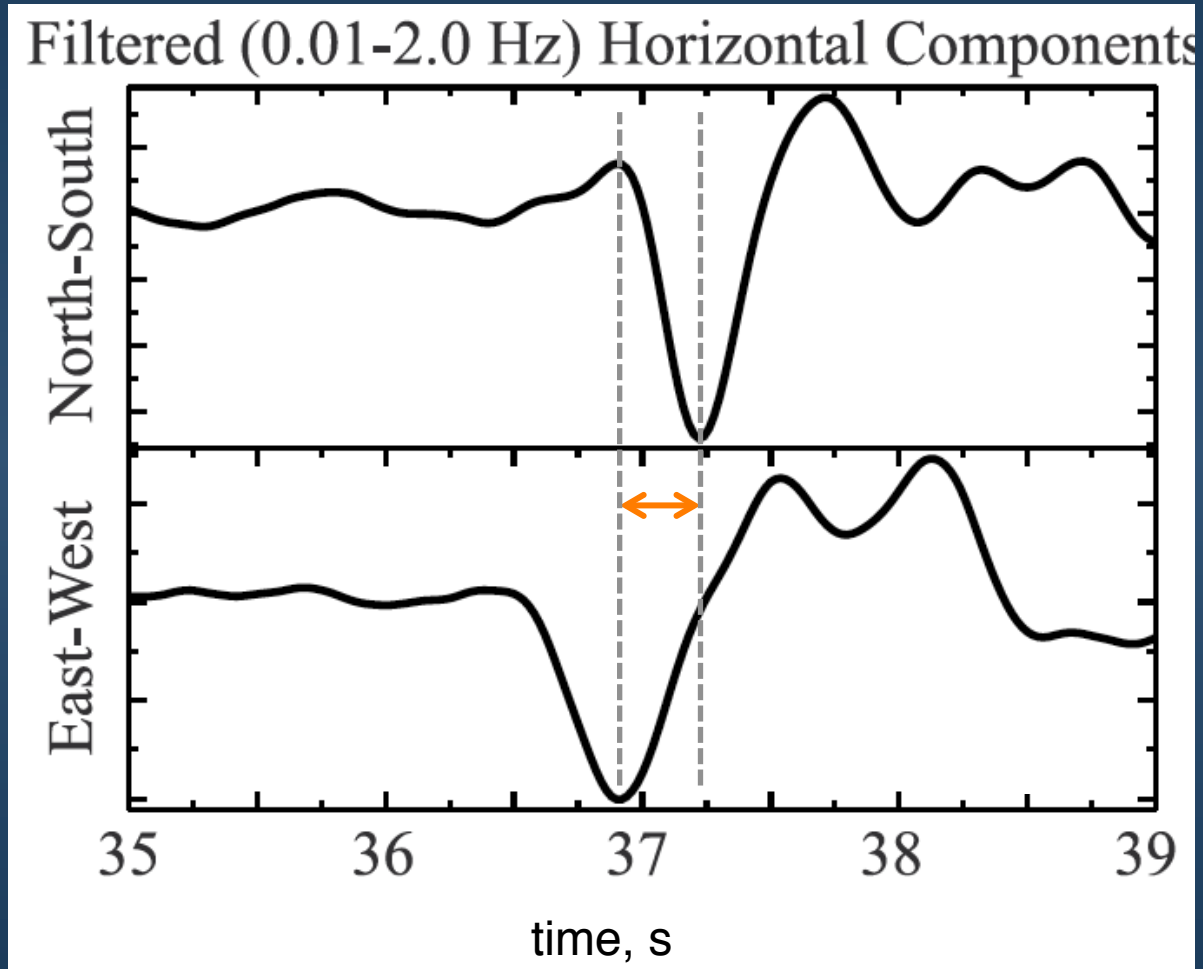
Shear-wave splitting



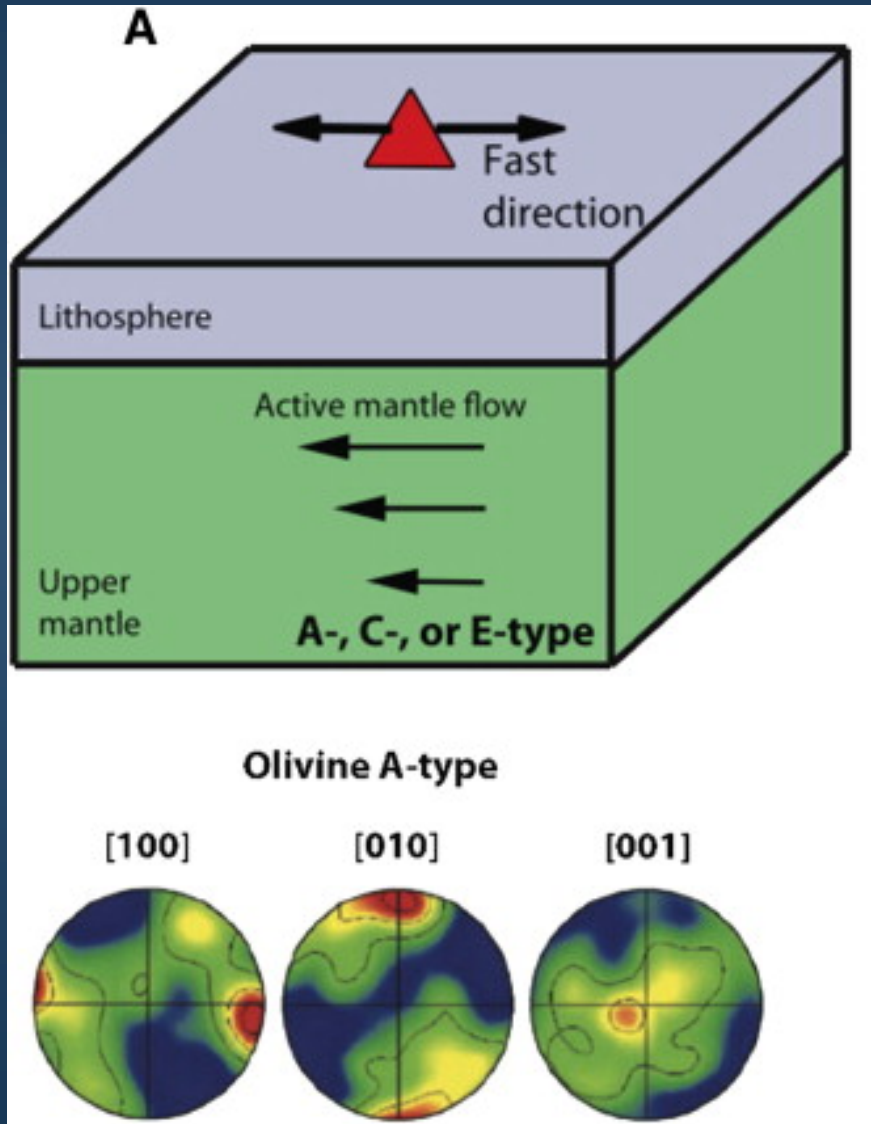
Shear-wave splitting



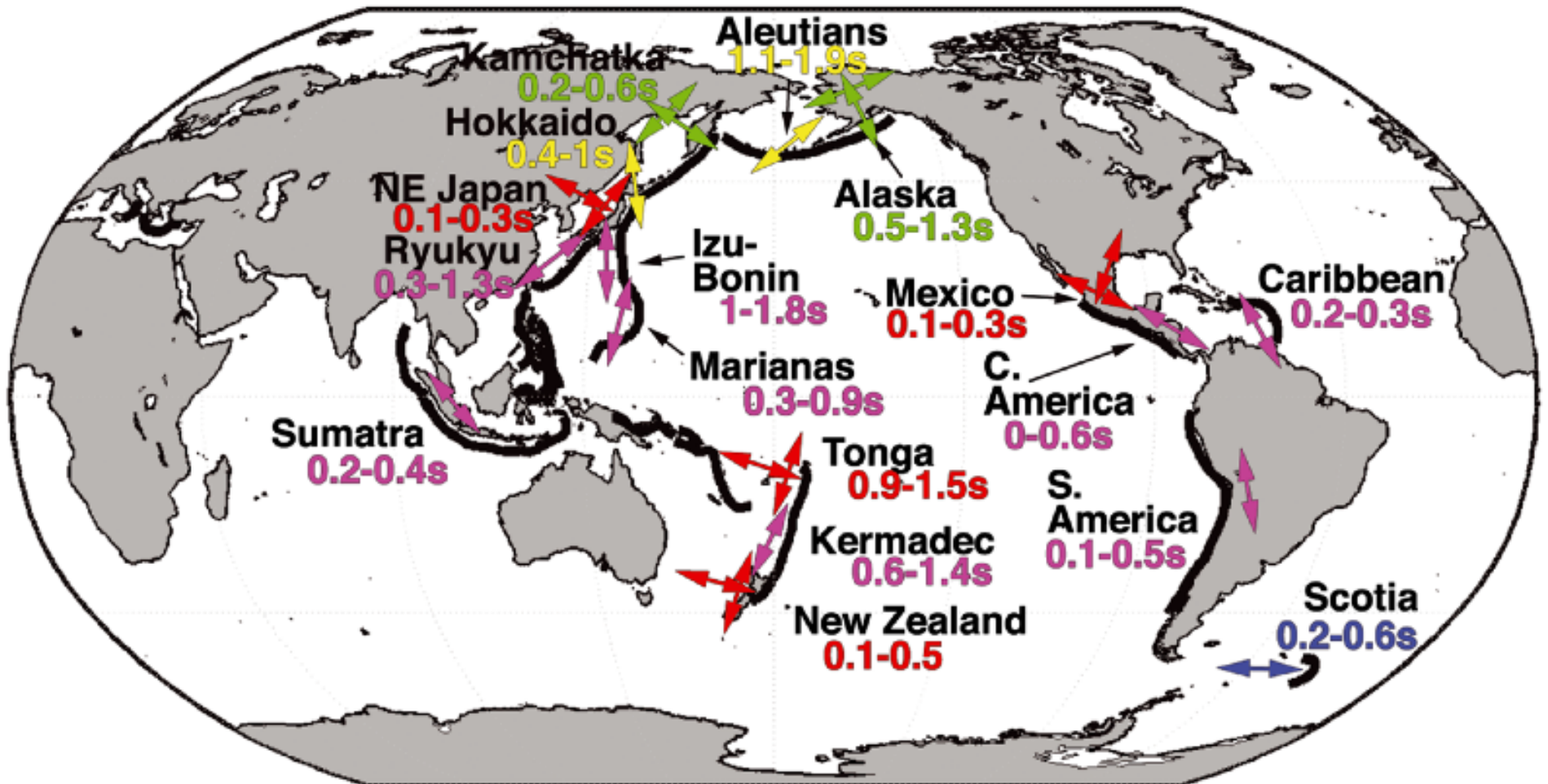
Shear-wave splitting



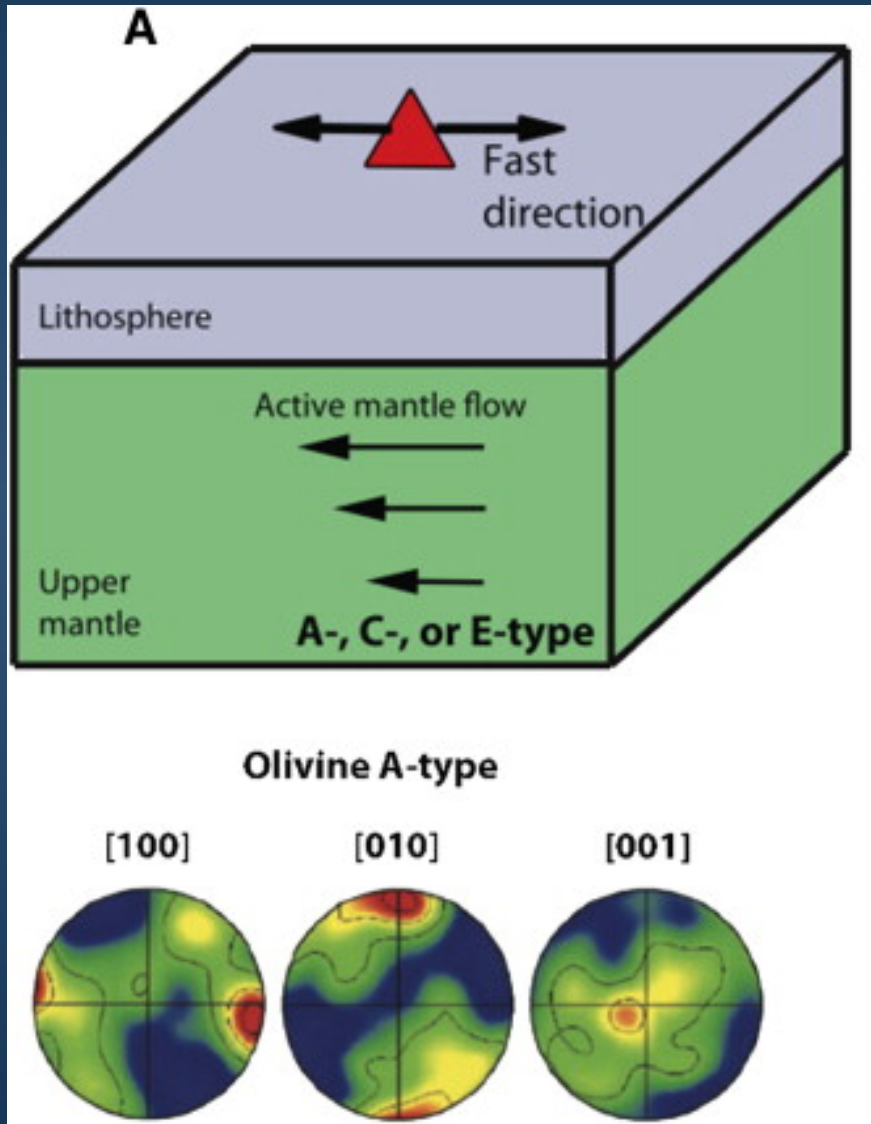
Shear-wave splitting



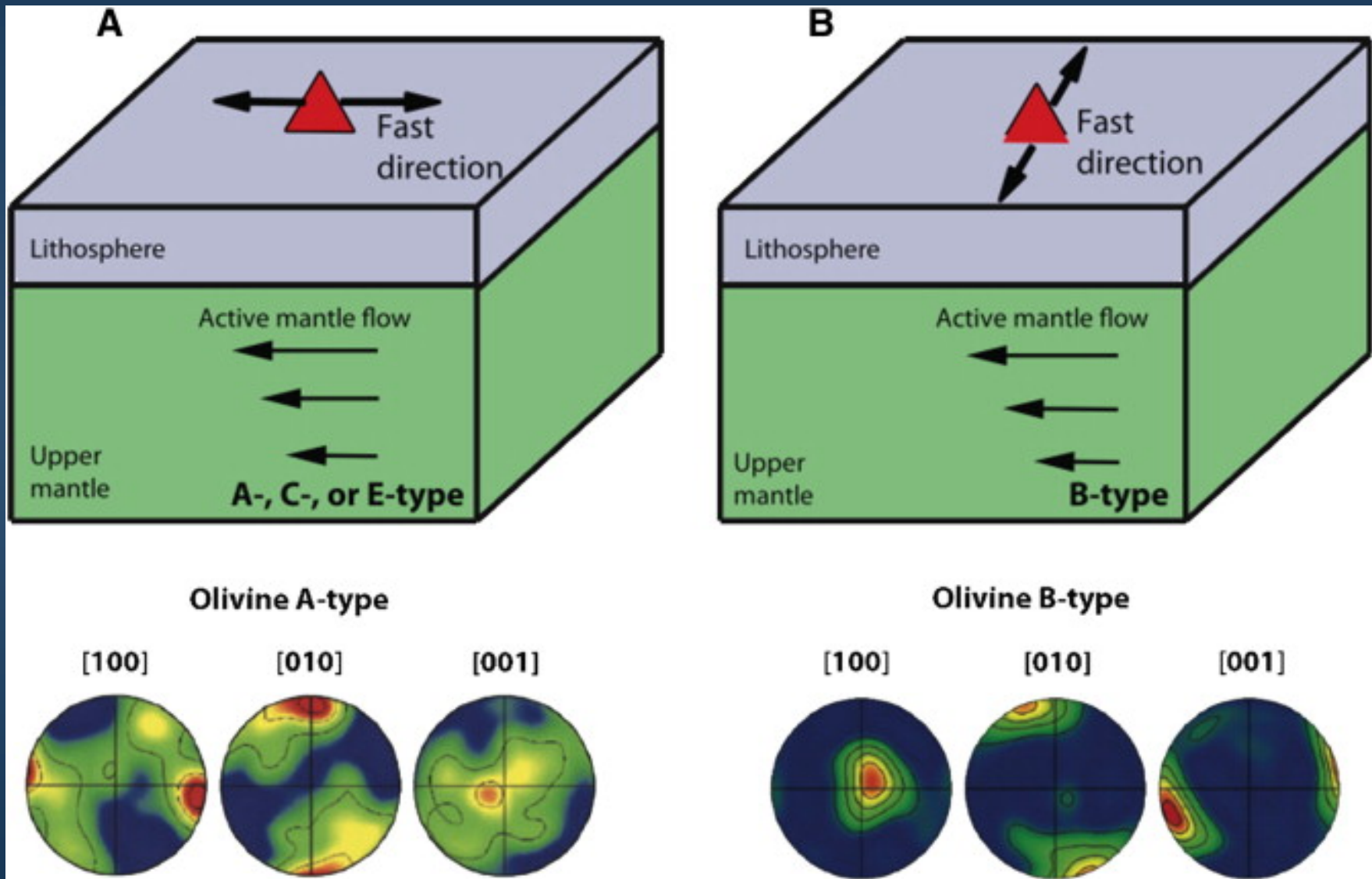
Shear-wave splitting



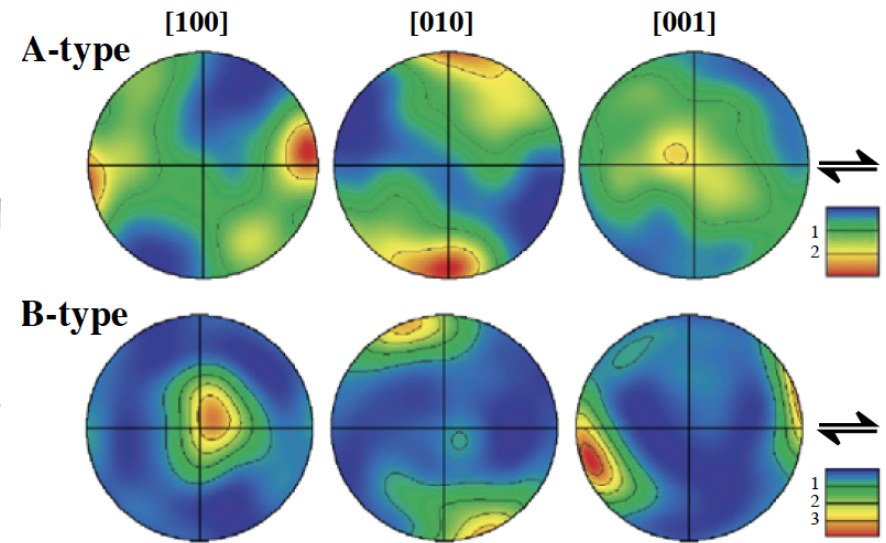
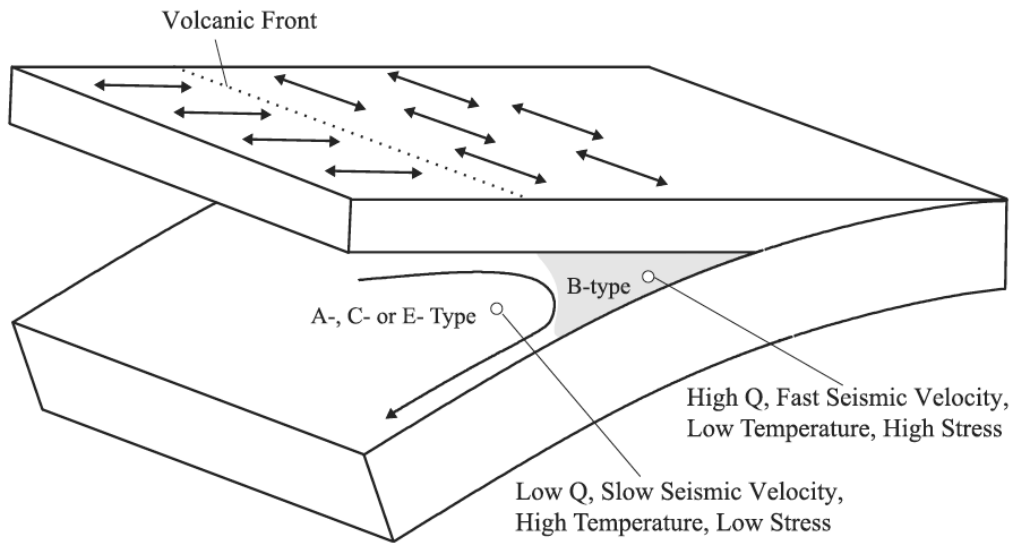
Shear-wave splitting



Shear-wave splitting



Shear-wave splitting

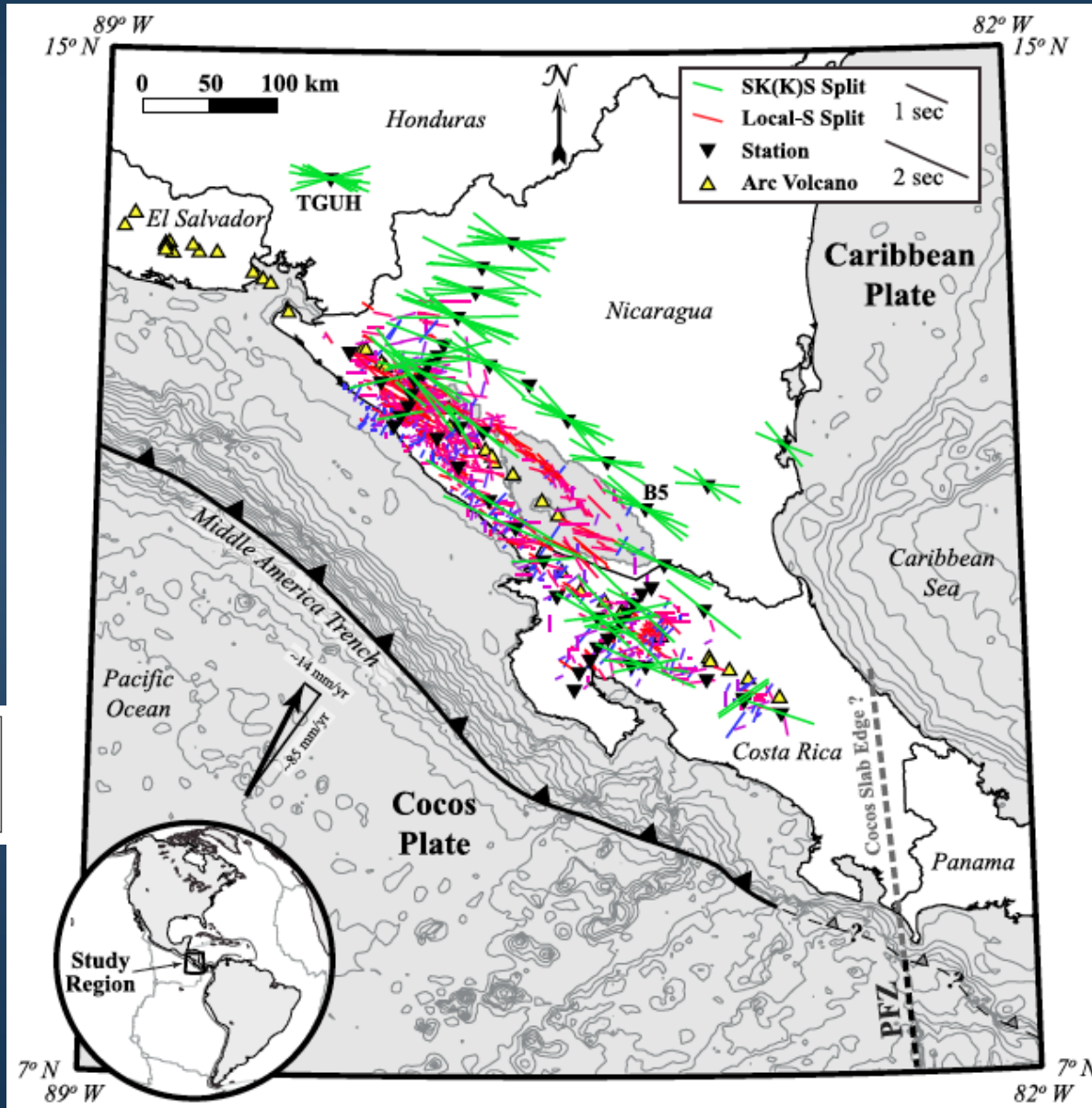


Kneller et al., 2007

Kneller et al., 2005

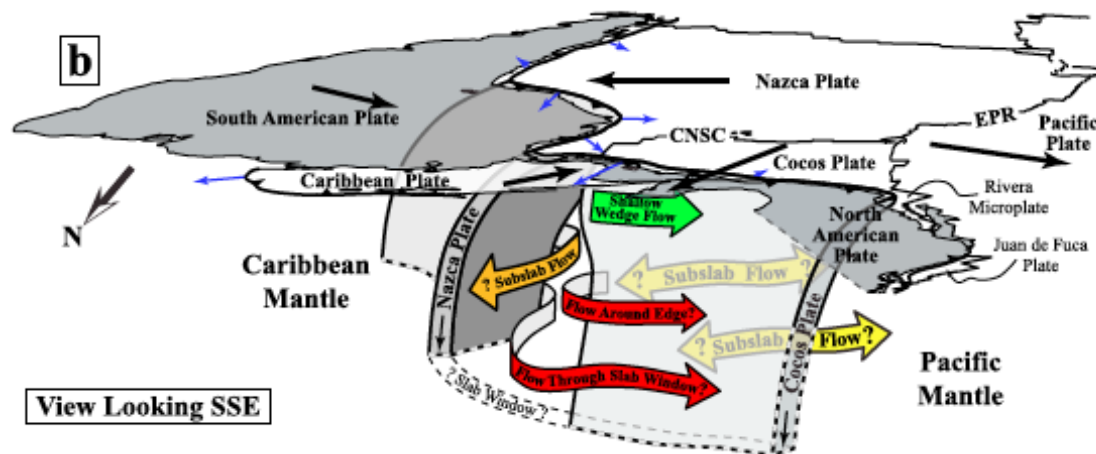
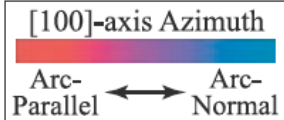
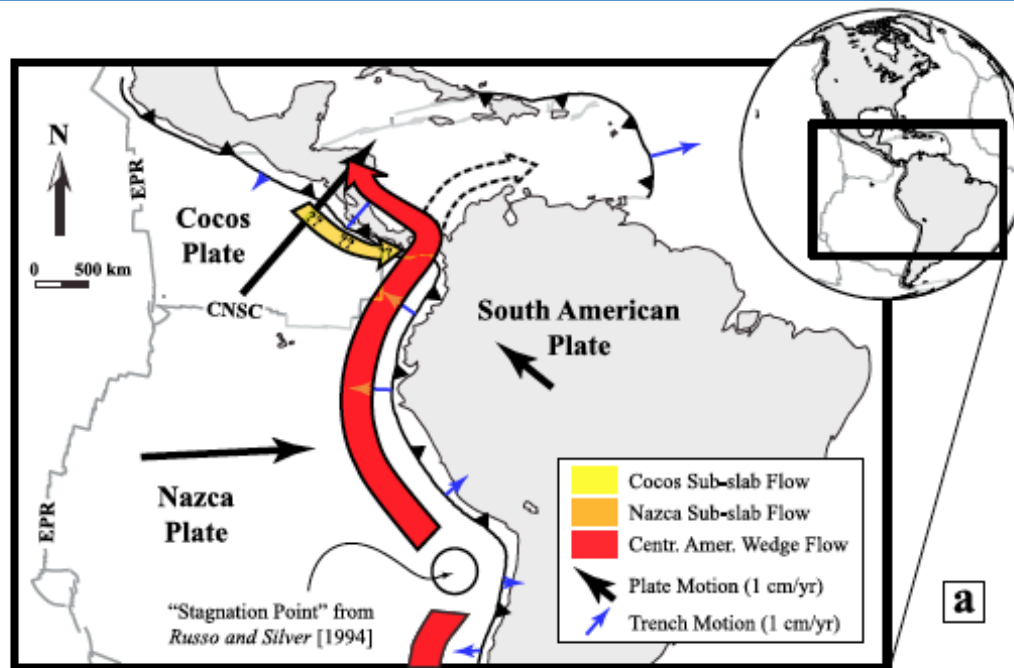
Shear-wave splitting

Central America



Shear-wave splitting

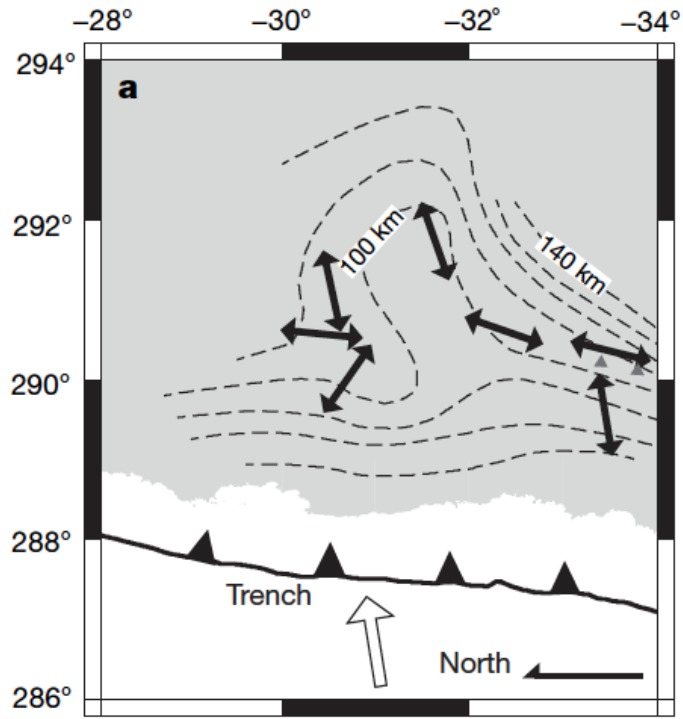
Central America



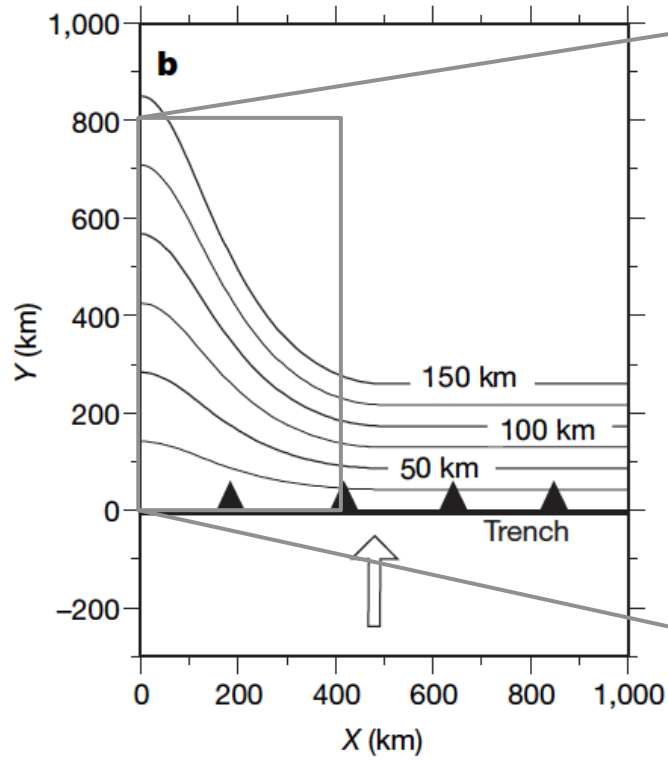
Shear-wave splitting

Andes

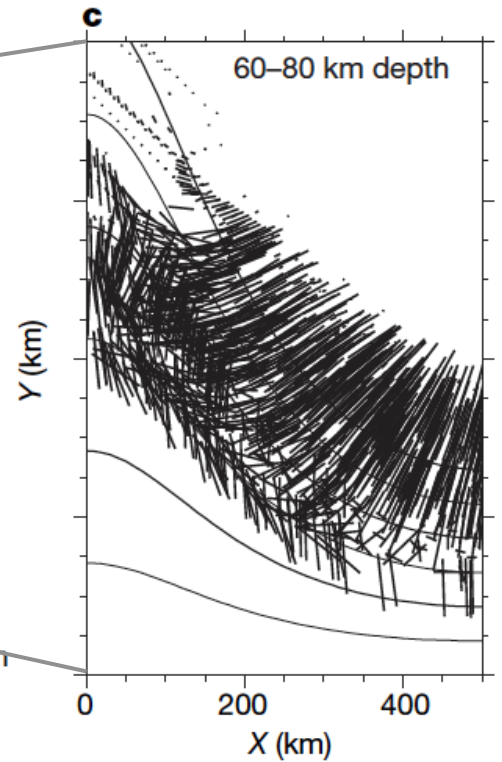
seismic observations



model input



maximum strain direction



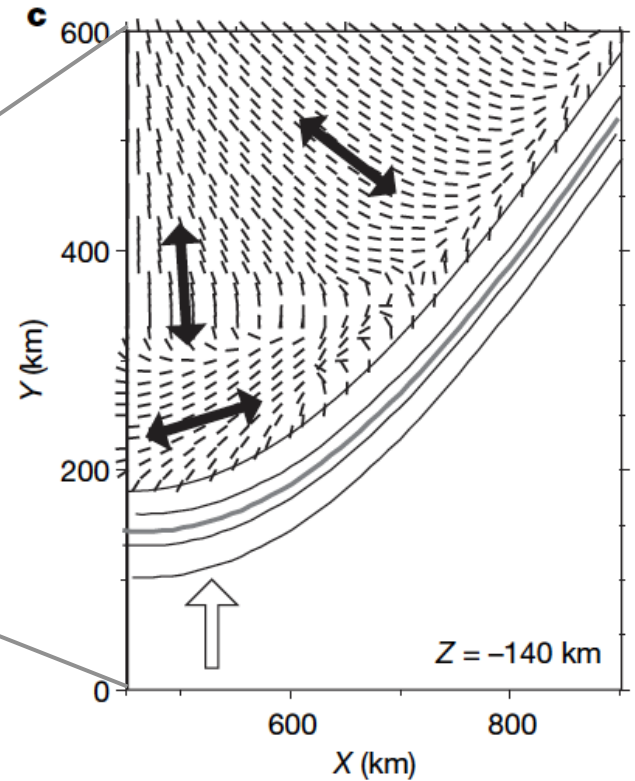
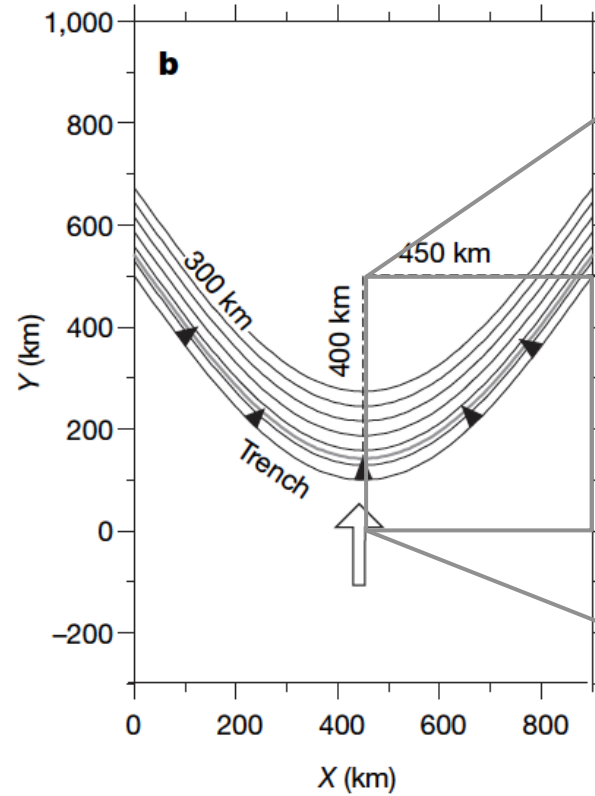
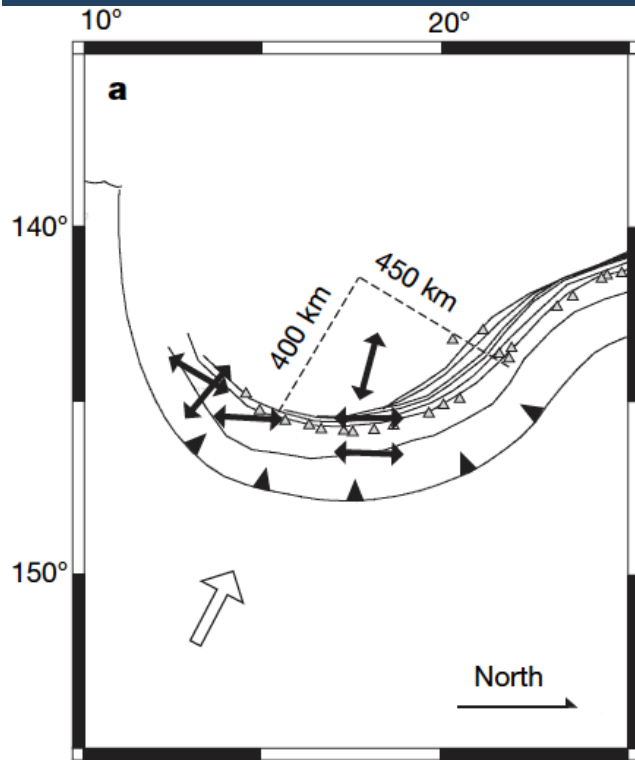
Shear-wave splitting

Marianas

seismic observations

model input

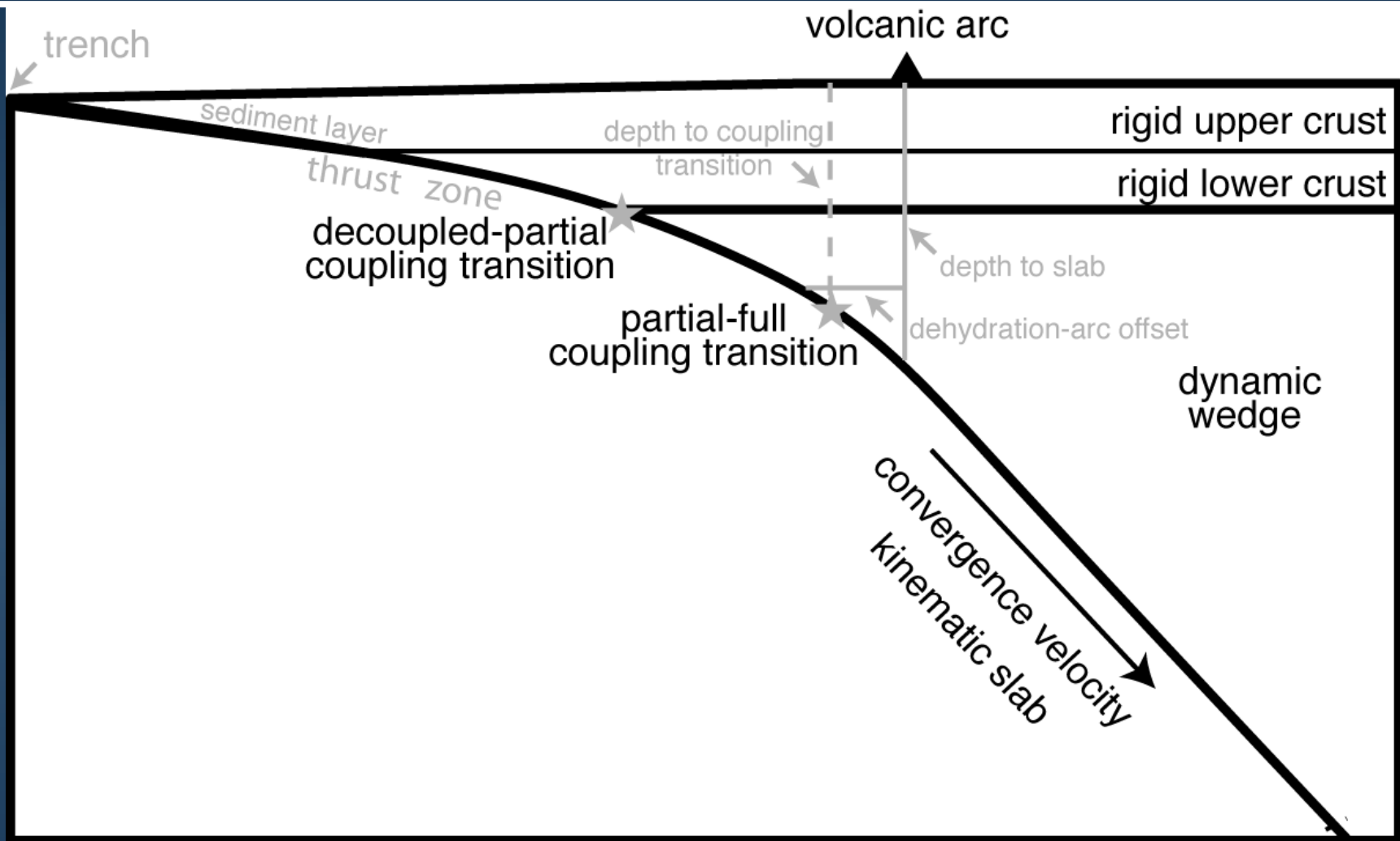
maximum strain direction



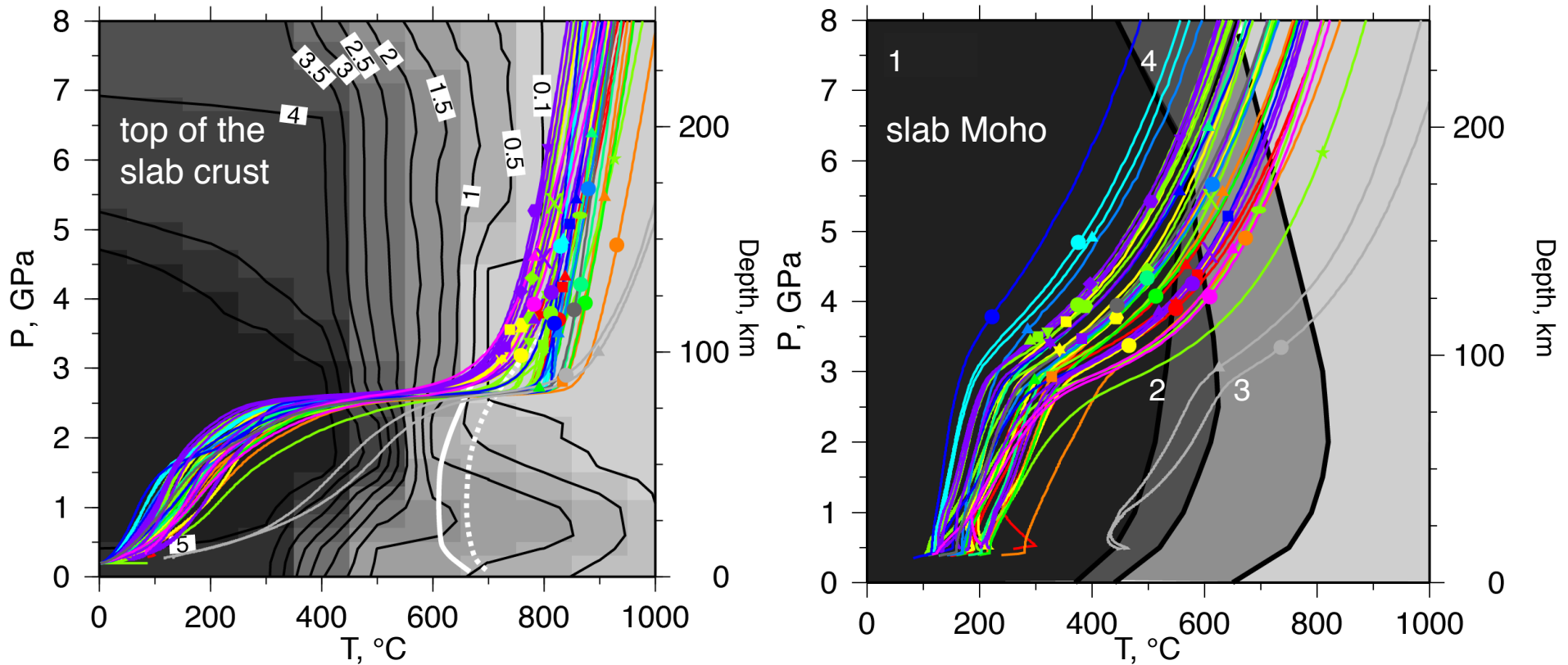
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2D thermal modeling



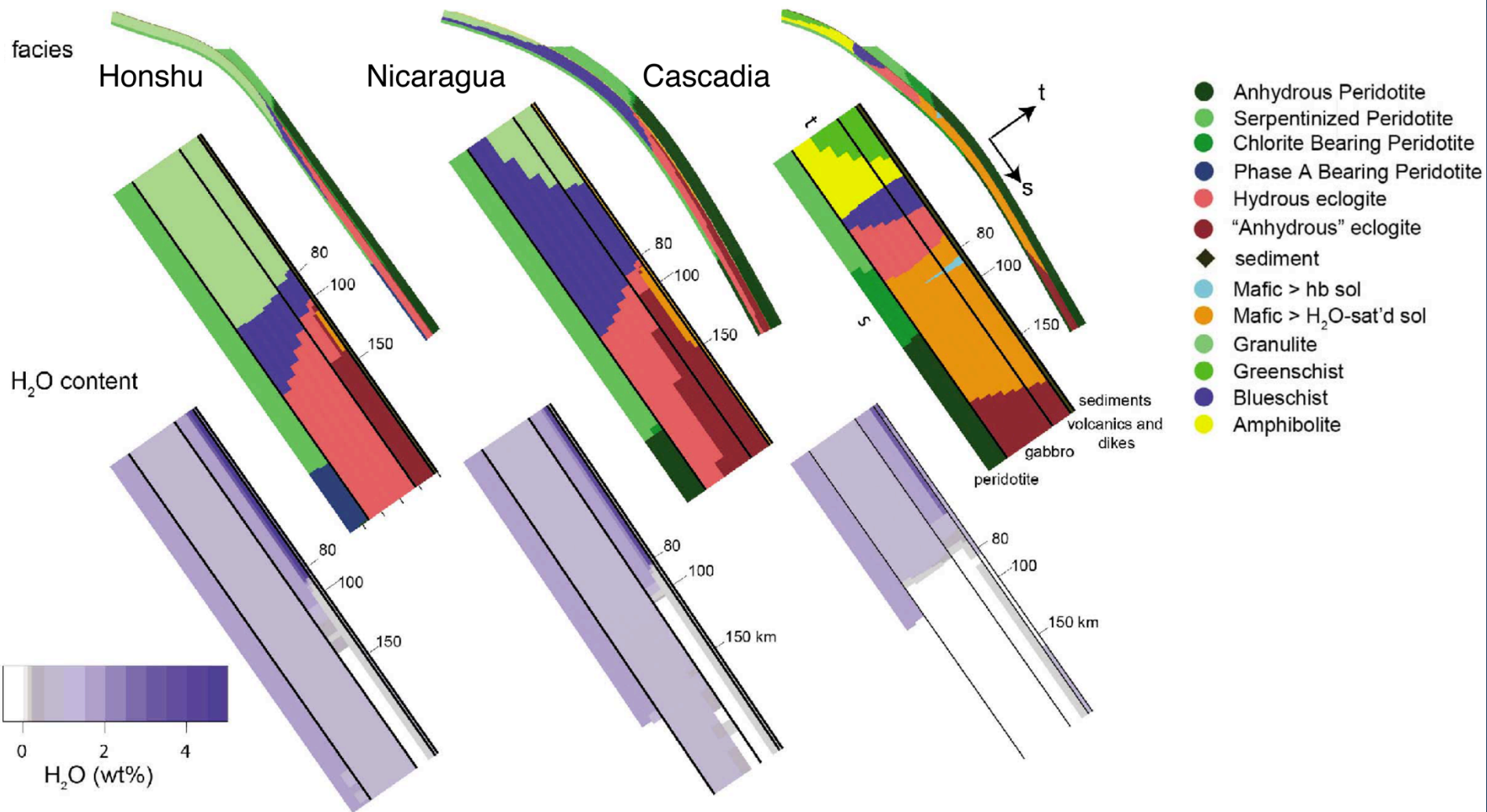
2D thermal modeling



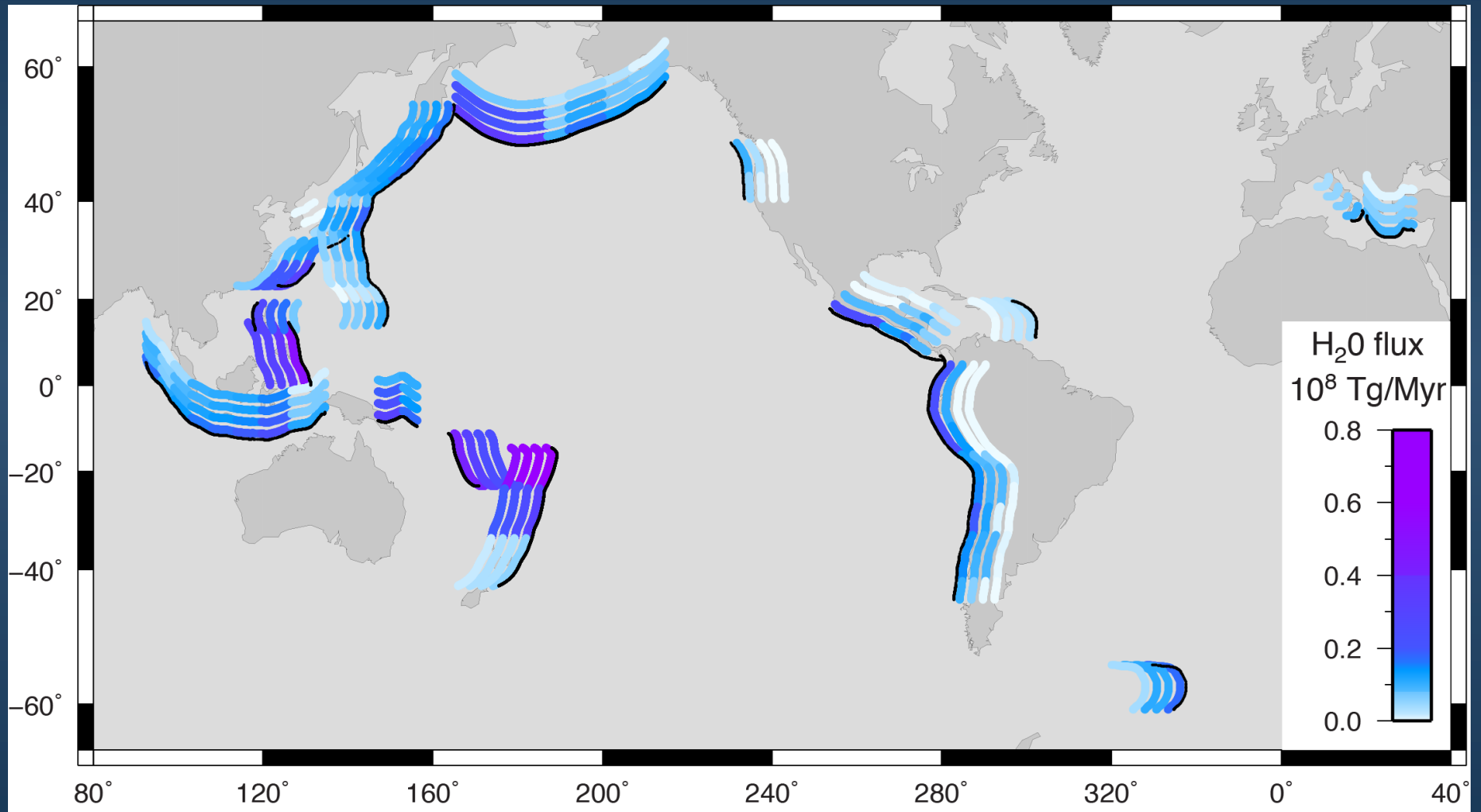
- Andes
- Central America
- Alaska/Aleutians
- Kamchatka-IBM
- Ryukyu/Kyushu
- Philippines
- N. Britain/Solomon
- Vanuatu
- Tonga-N. Zealand
- Indonesia
- Lesser Antilles
- Scotia
- Cascades

- 1: serpentine/chlorite/brucite (14.8 wt% H₂O)
- 2: serpentine/chlorite/dunite (6.2 wt% H₂O)
- 3: chlorite/harzburgite (1.4 wt% H₂O)
- 4: phase A (6.8 wt% H₂O)

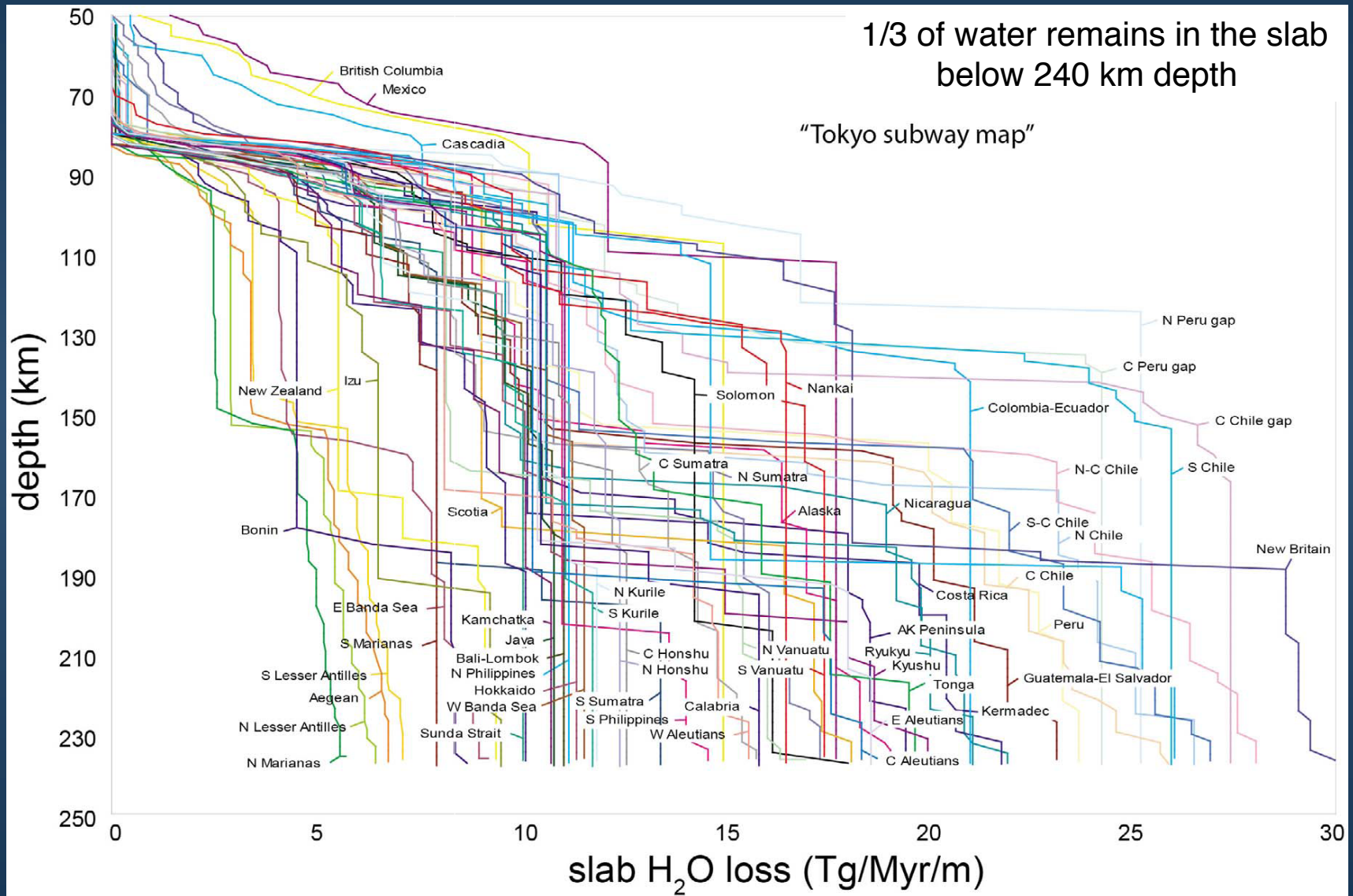
2D mineralogical modeling



Global water-release budgets



Global water-release budgets



Summary

- Seismology provides a variety of geodynamical constraints on subduction
 - shapes of subducting slabs, from trench to below transition zone
 - temperature and melt distributions of the mantle wedge
 - hydration state of slabs and wedges
 - flow patterns of mantle wedges
- Complex 3D patterns are observed in all types of seismic results, indicating a need for geodynamical models to account for and help explain these features