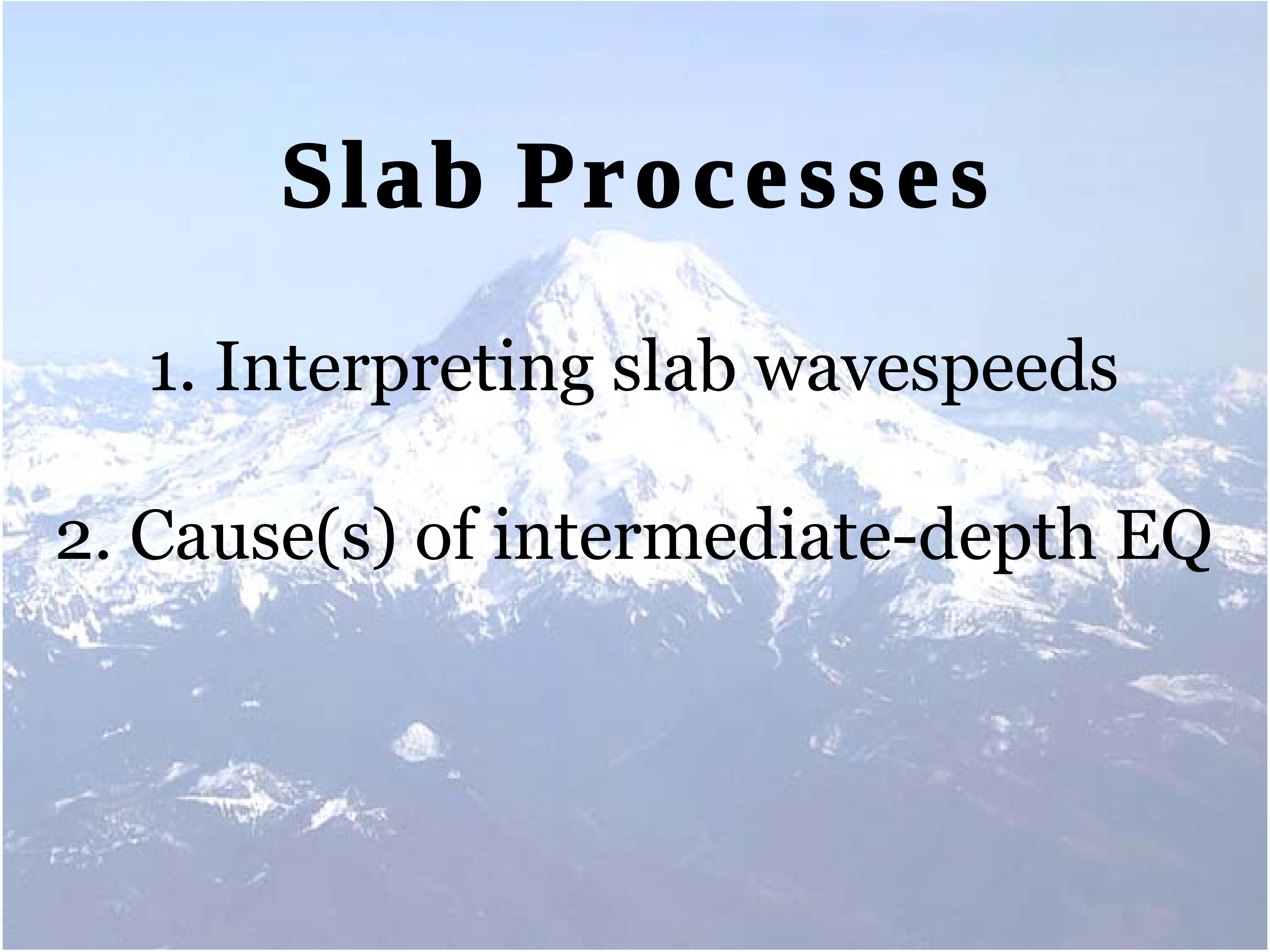

Slab Processes
1. Interpreting slab wavespeeds
2. Cause(s) of intermediate-depth EQ

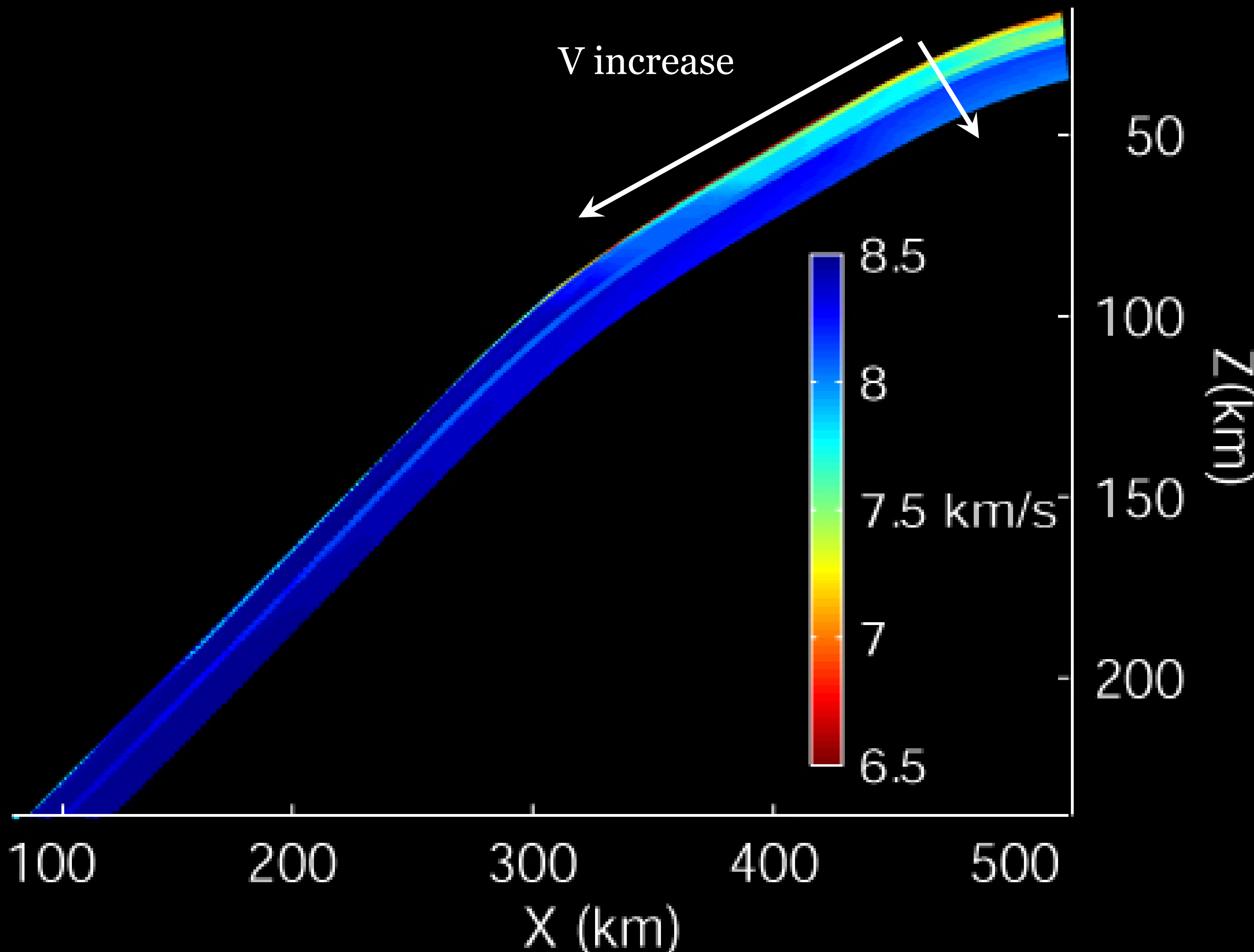
Slab Processes

1. Interpreting slab wavespeeds

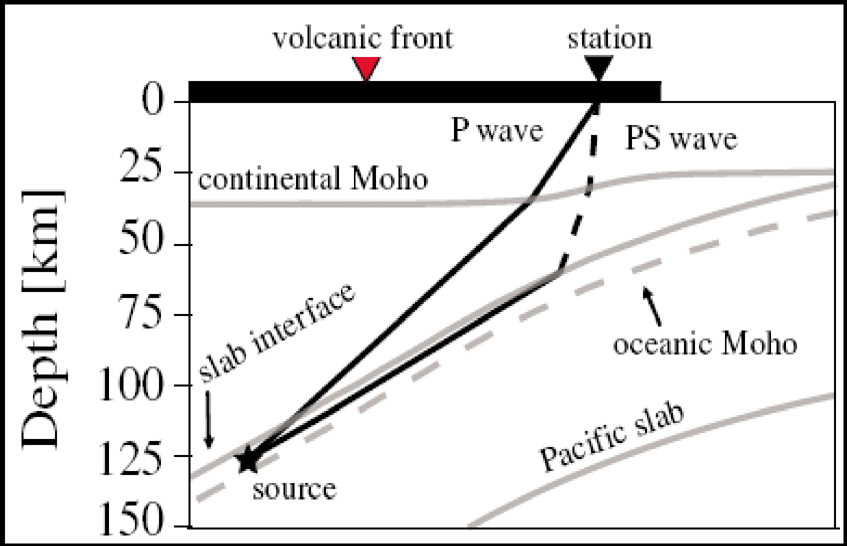
focus on new, recent observations

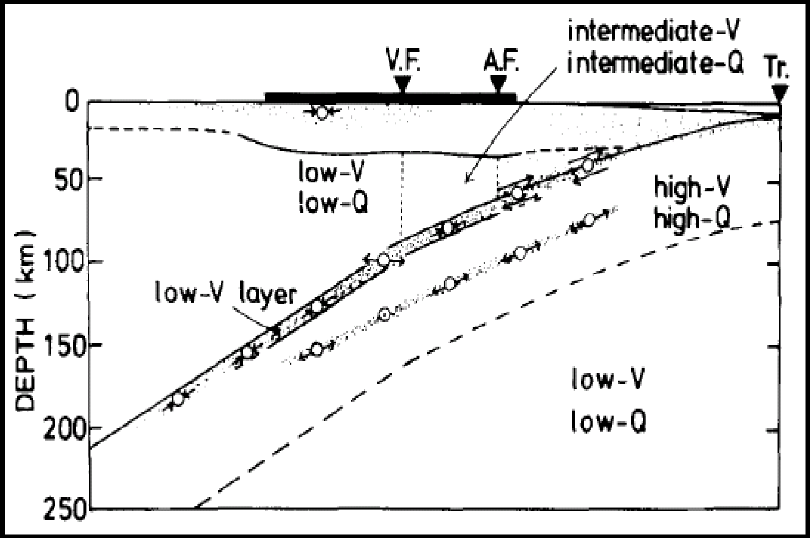
mostly northern Japan

Expected Slab Wavespeeds



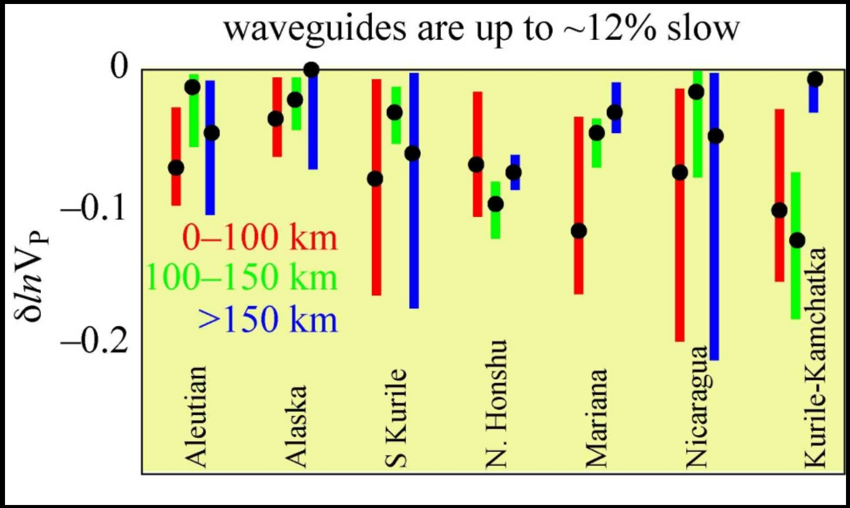
Anomalous Slab Wavespeeds

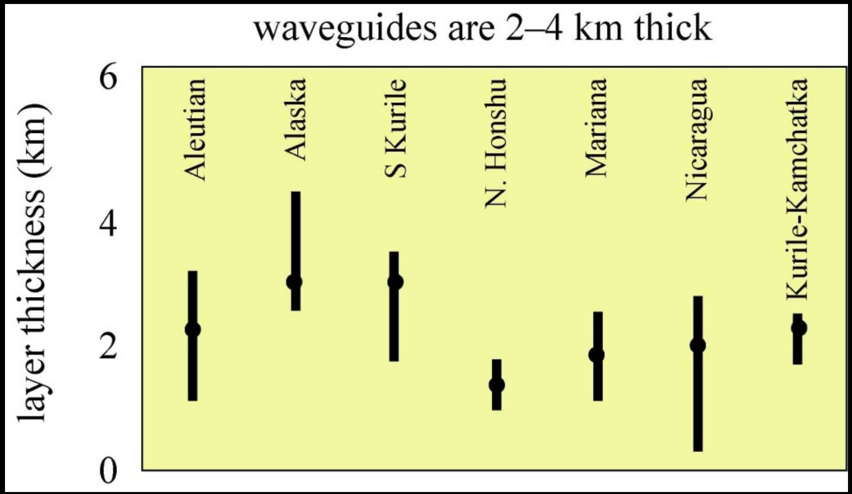




Matsuzawa et al. (1986)

Abers [2000, 2003, 2005]



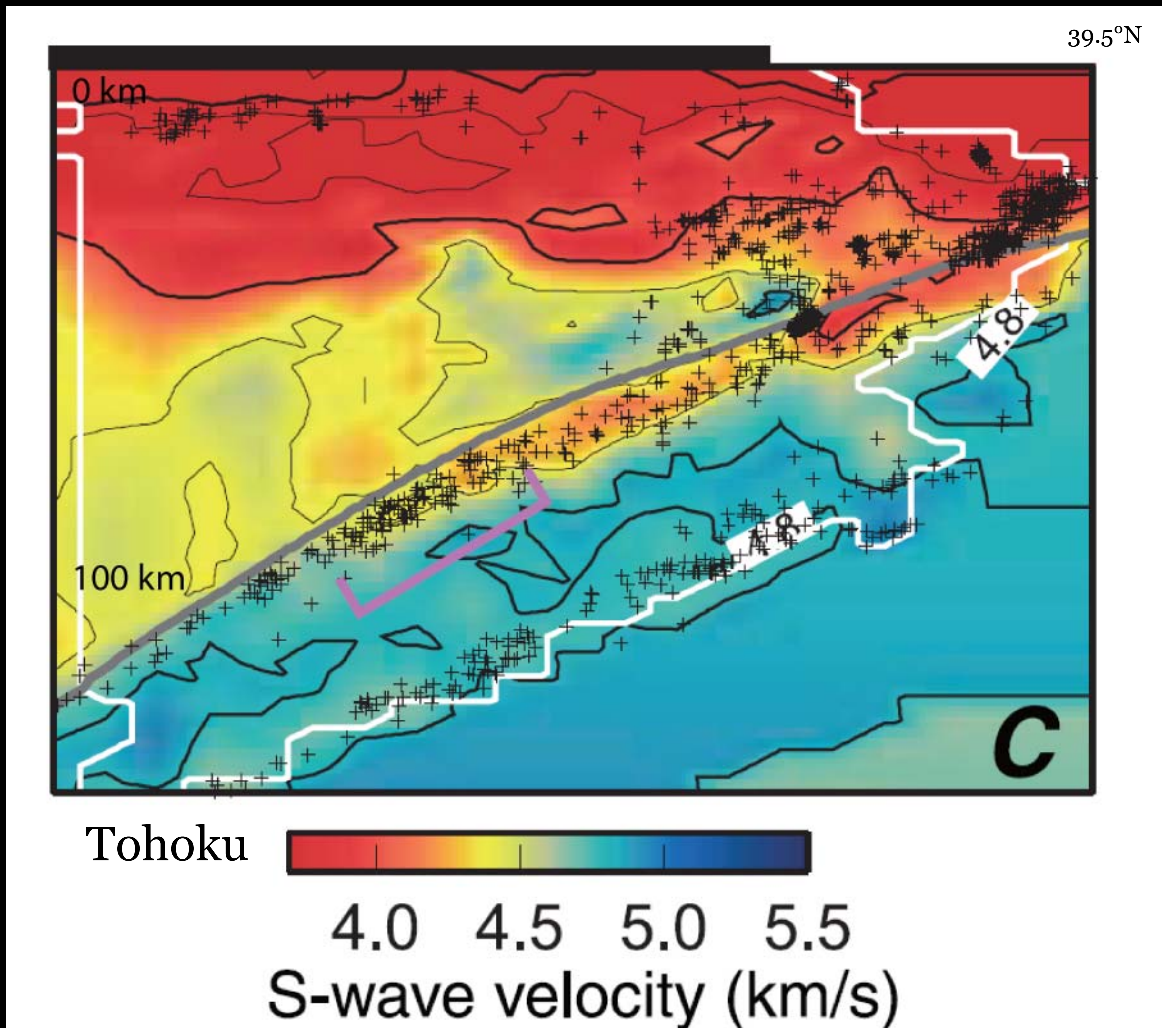


Anomalous Slab Wavespeeds

- hydrous minerals?
- free fluid?
- anisotropy?

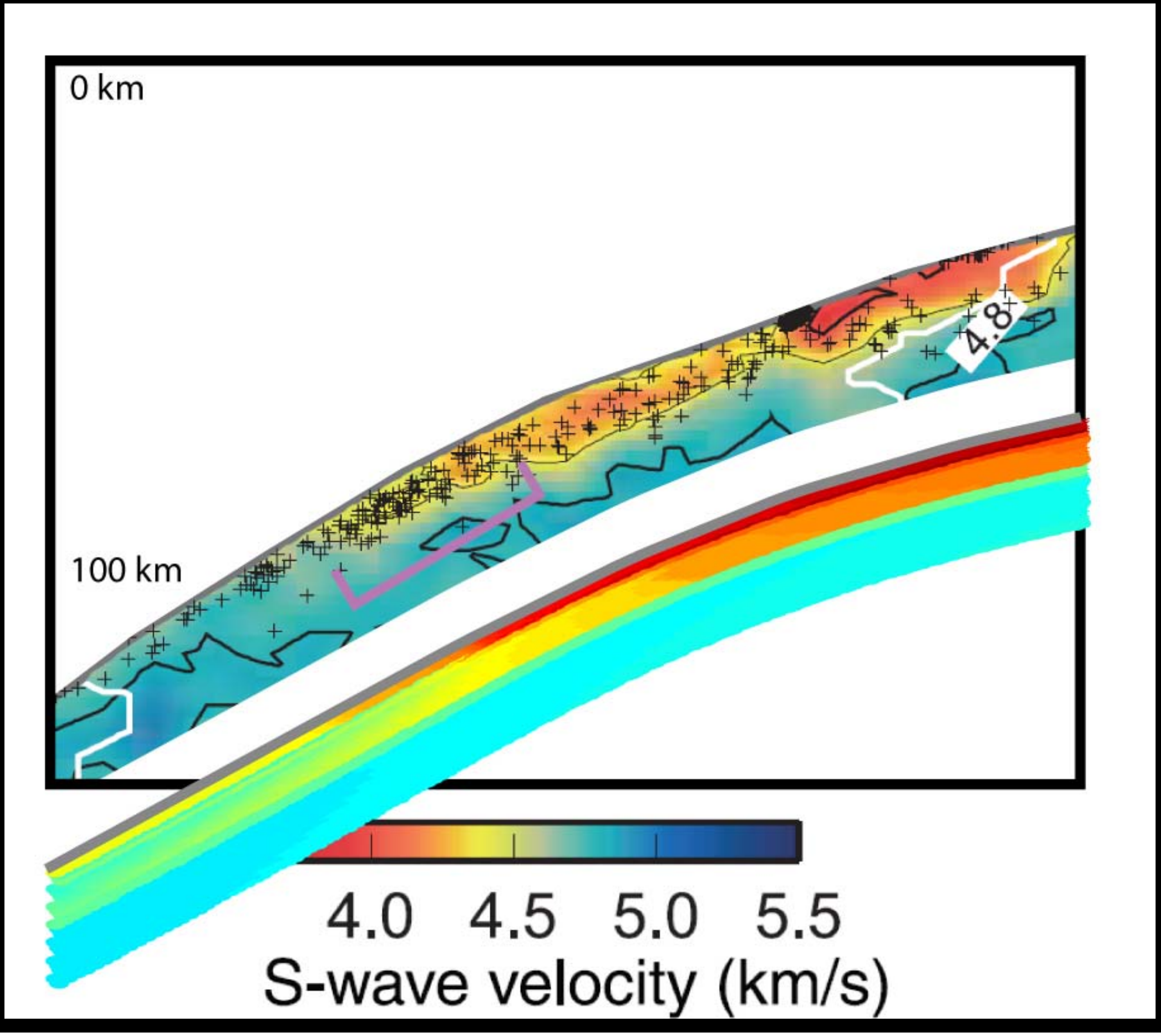
N Japan: Slow V_S

Tsuji et al. (2008): 10-km thick slow layer to 70–90 km.

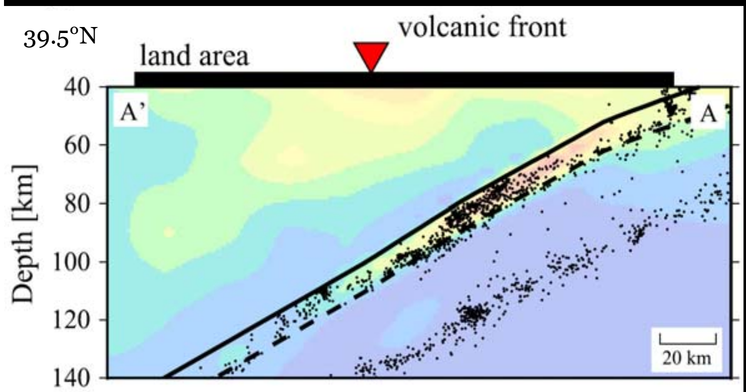


Slow Reaction?

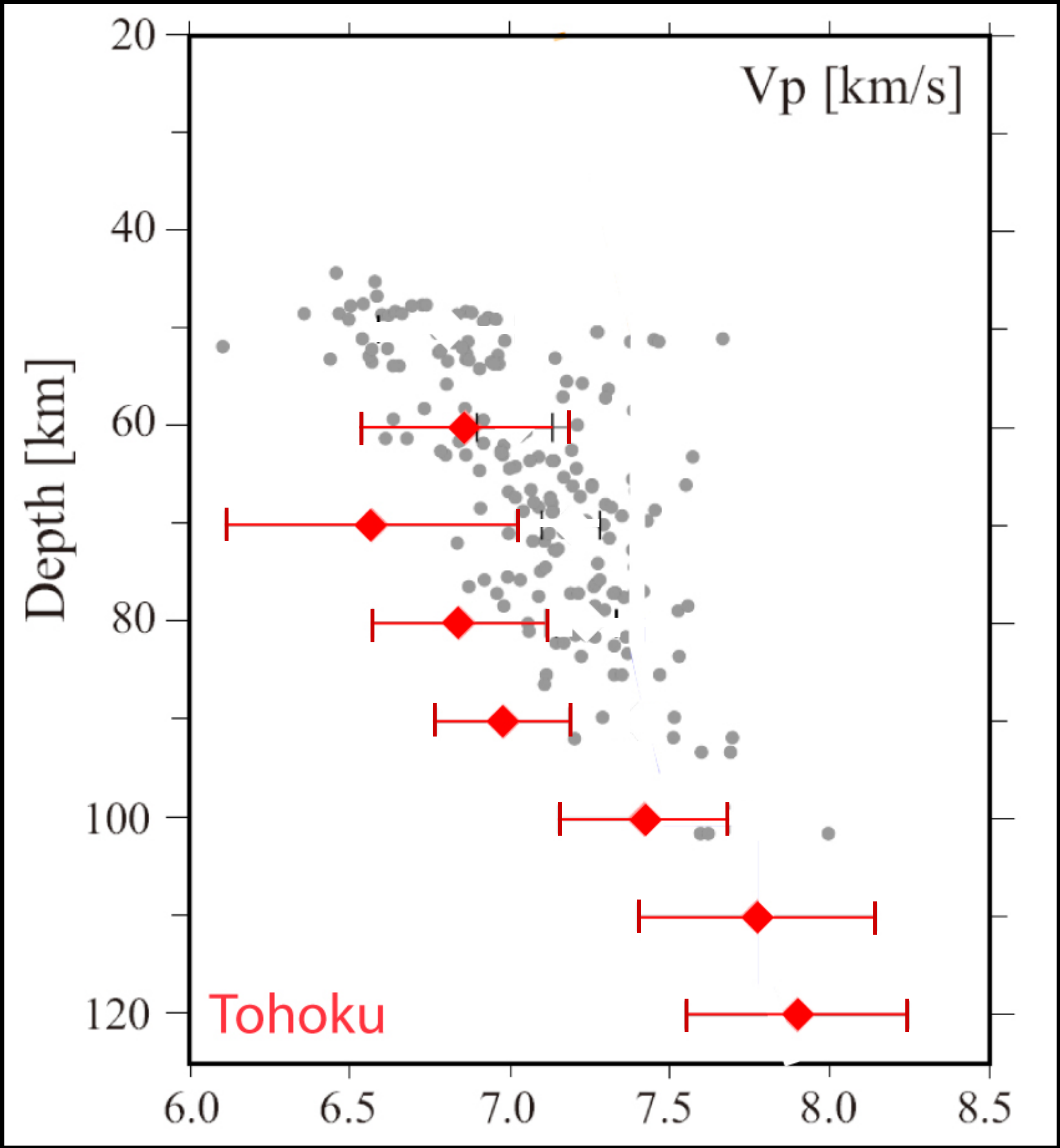
V_S model: progressive reaction from 0°C → 500°C



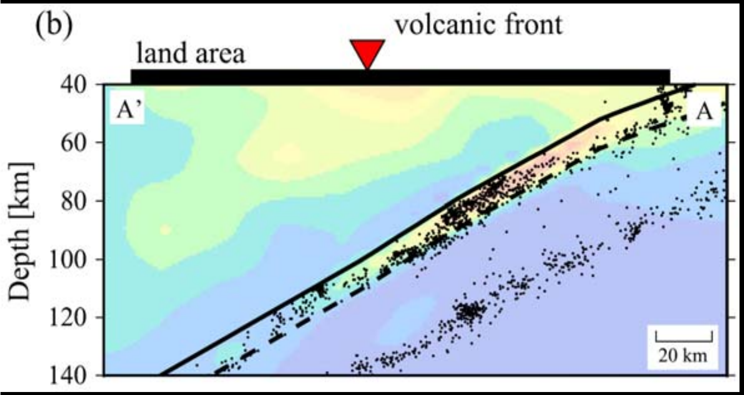
N Japan: Slow V_P



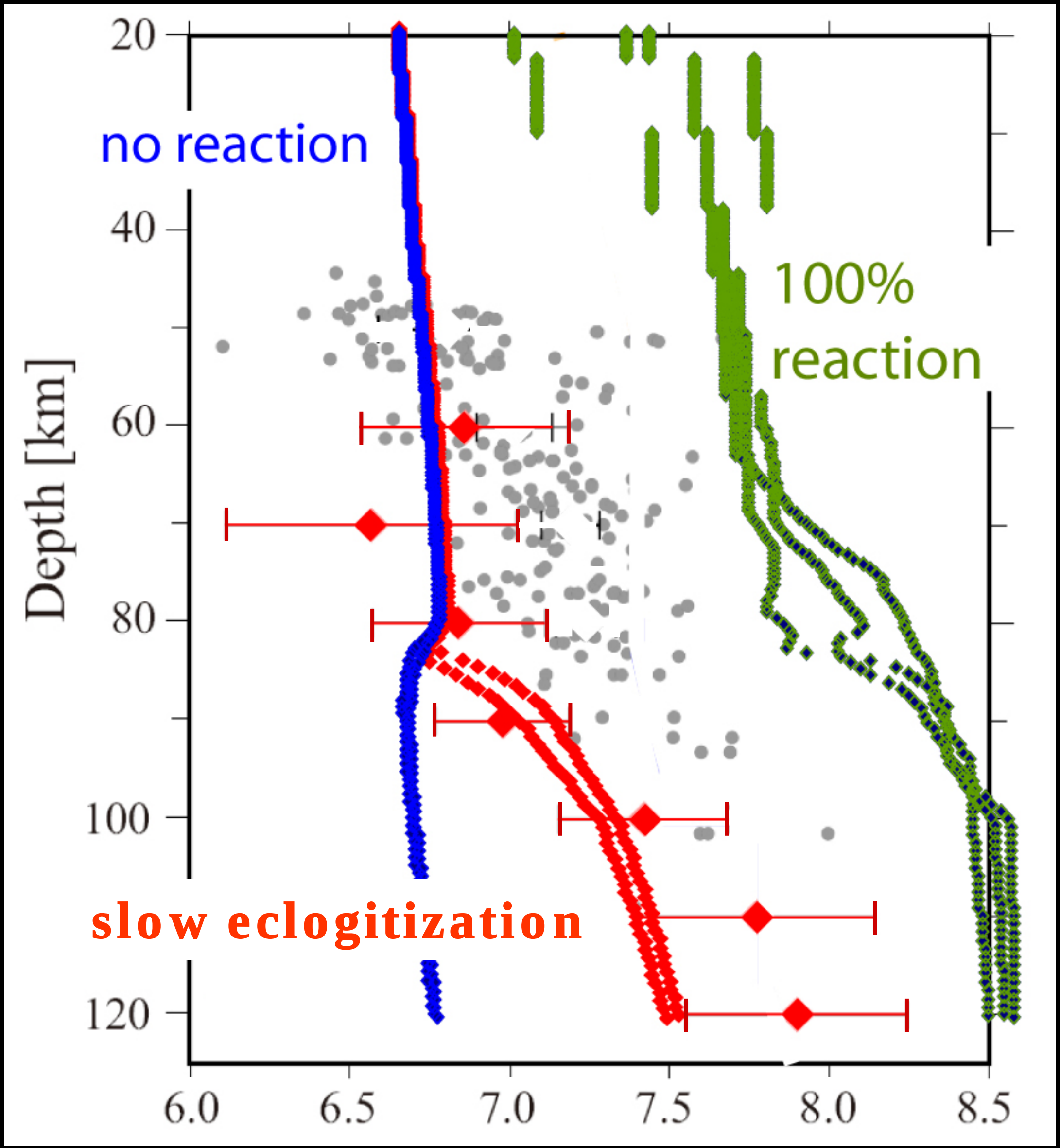
Shiina et al. (2013)



Slow Reaction?



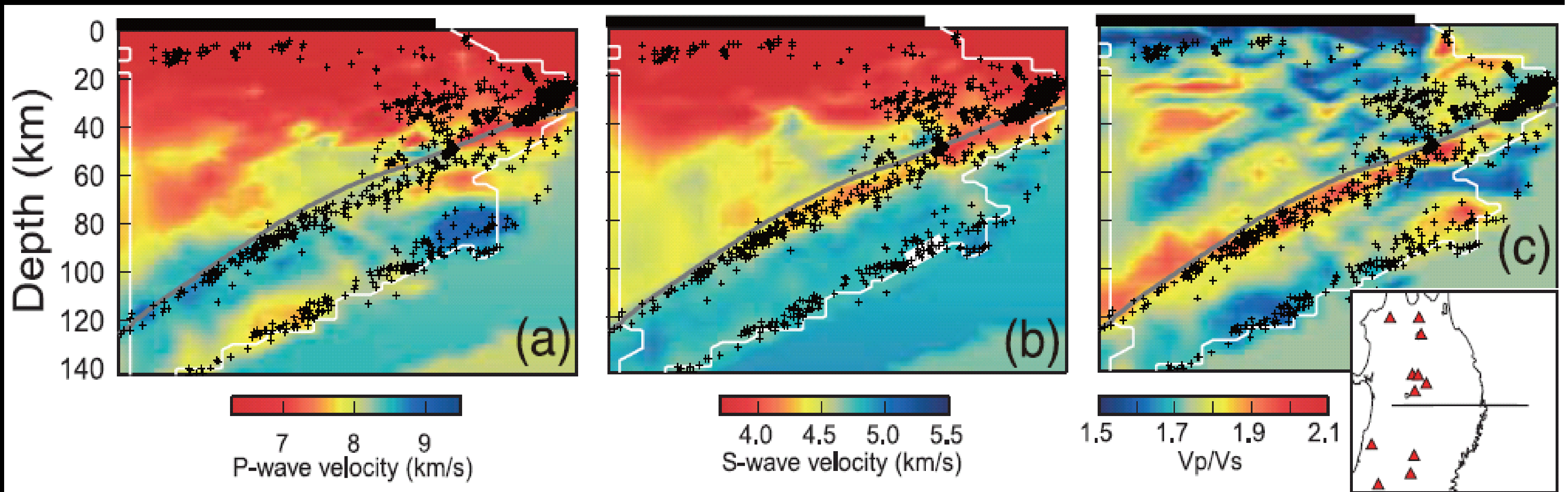
Shiina et al. (2013)



Free H2O

Tsuji et al. (2008)

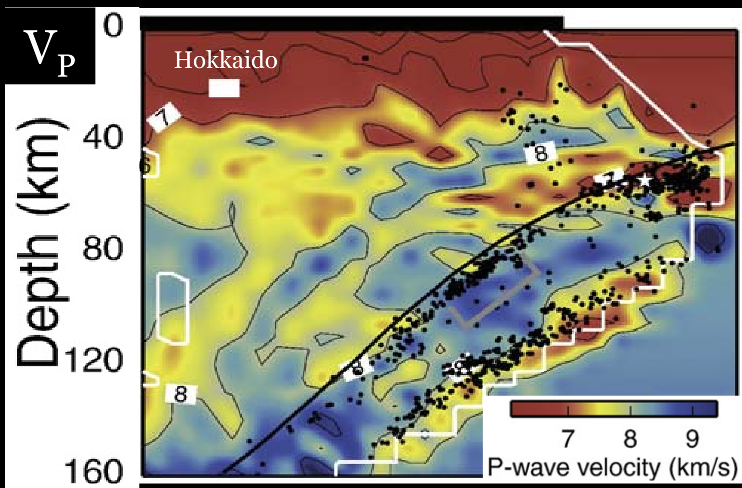
1% fluid-filled pores (*Shiina et al.*, 2013)

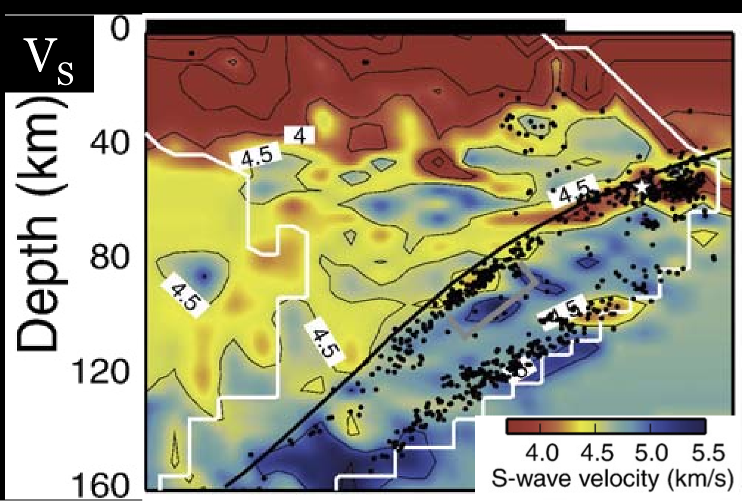


V_P V_S V_P/V_S

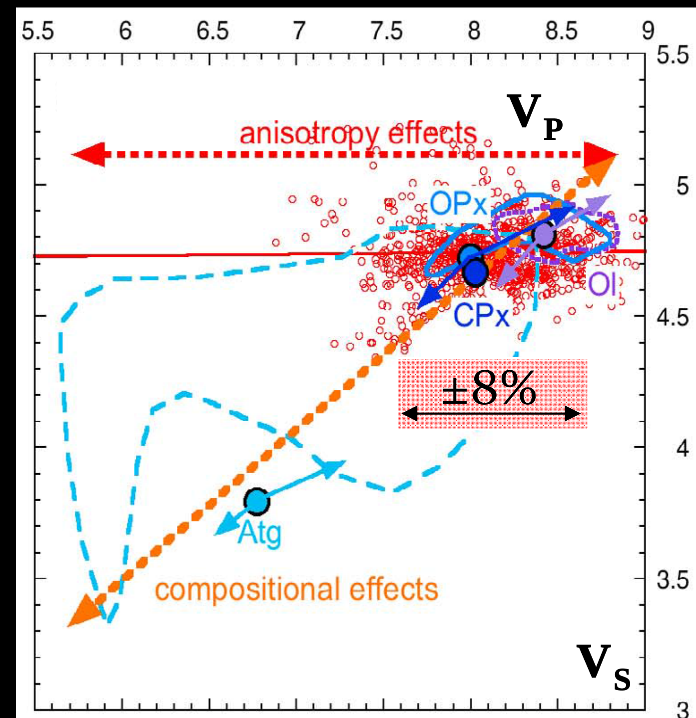
Serpentinite in Lower Seismic Zone?

Nakajima et al. (2009)

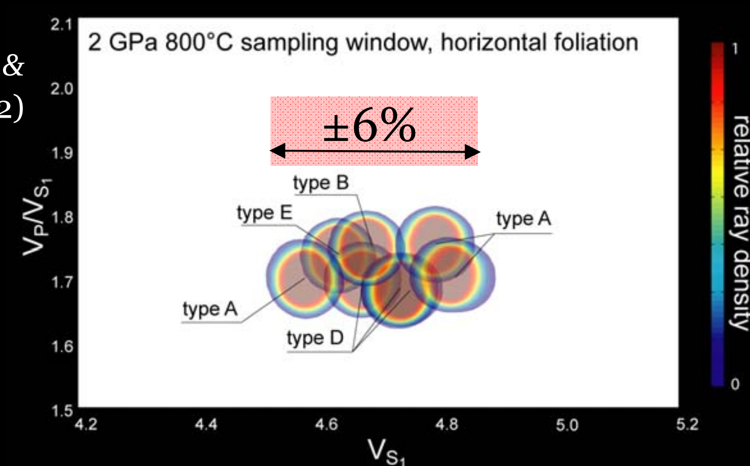




Reynard et al. (2010): result of ray geometries + anisotropy

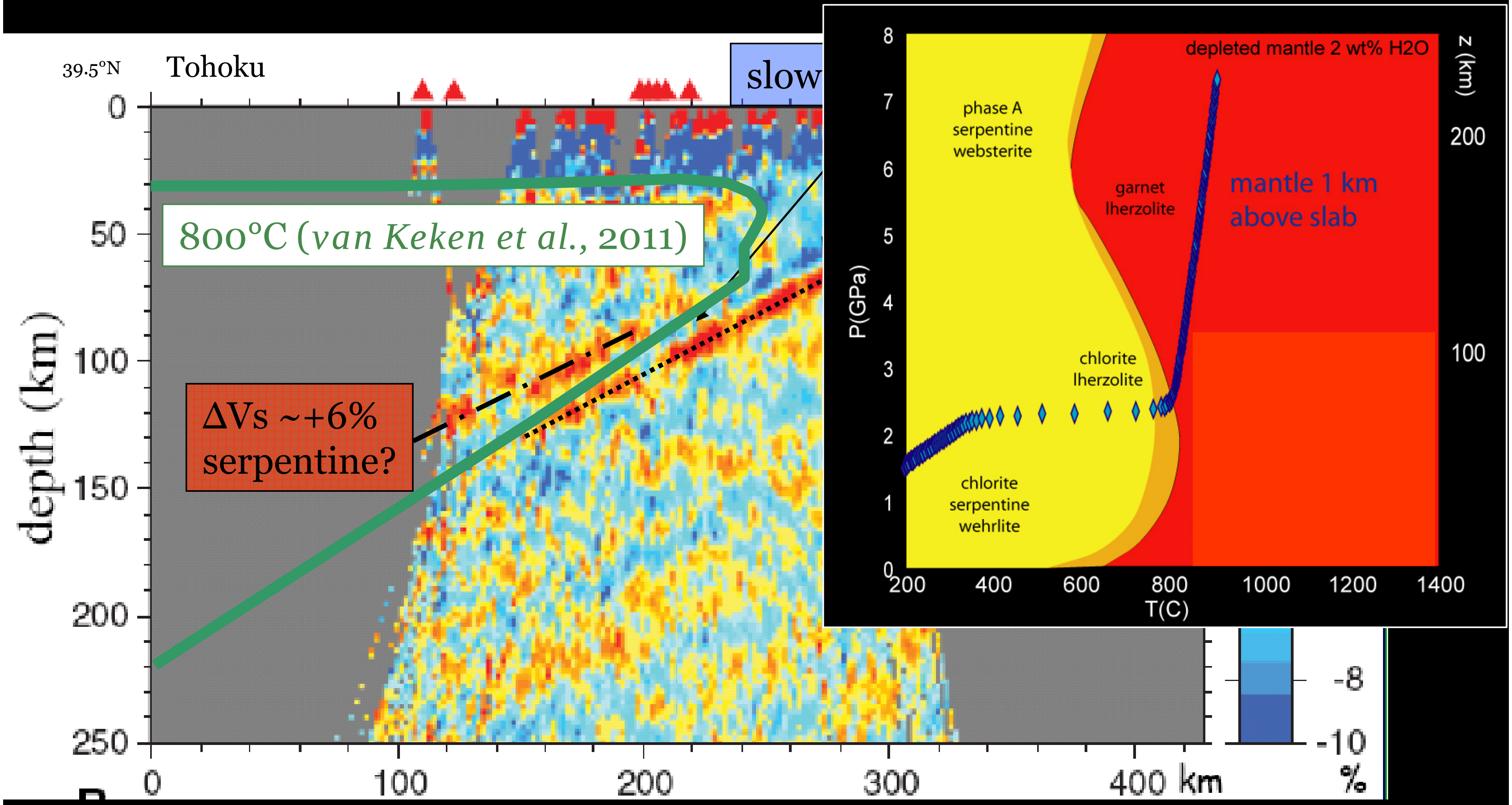


Hacker & Abers (2012)



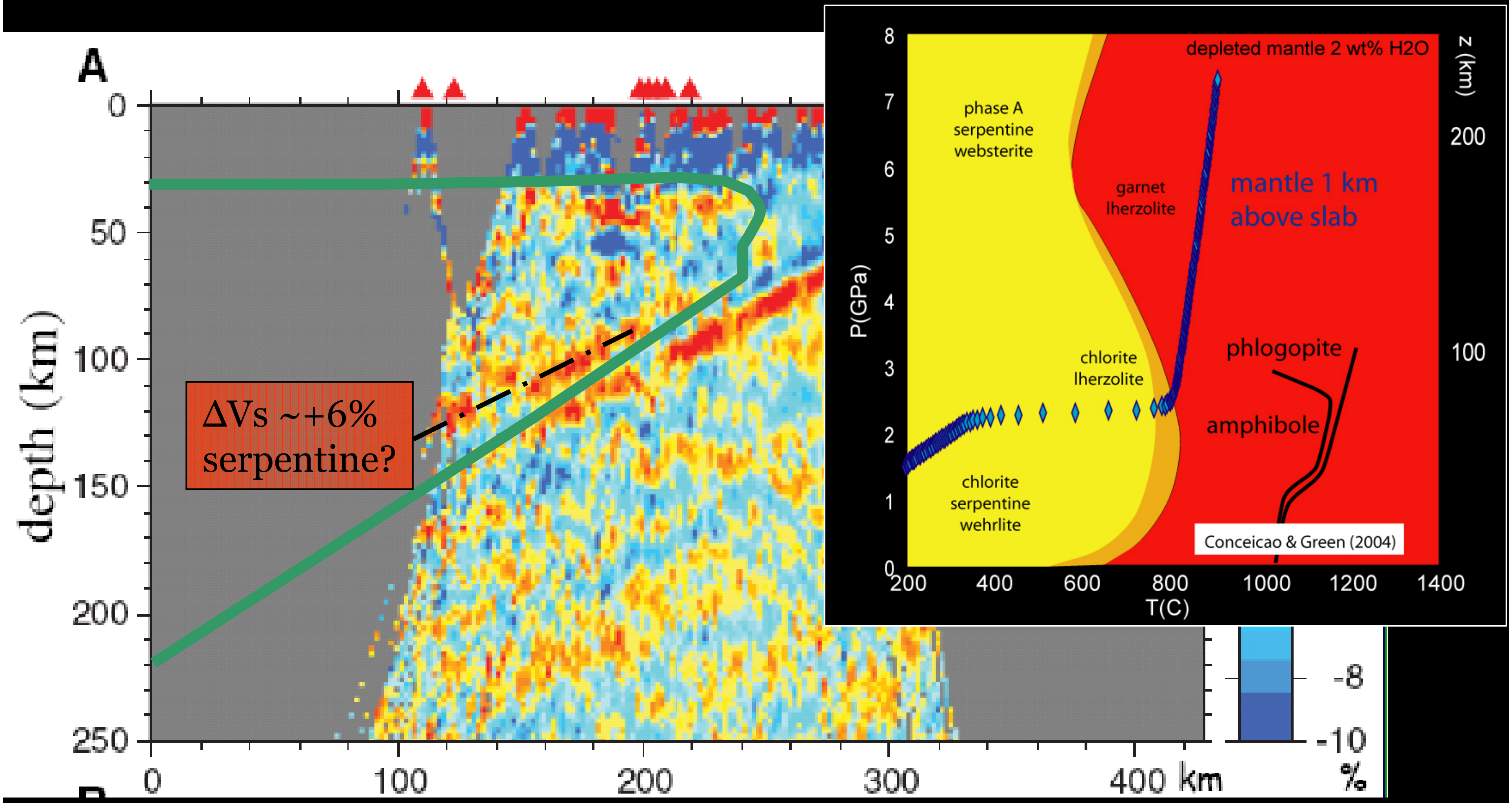
Serpentinite Above Slab?

V_S RF reflectivity (*Kawakatsu & Watada*, 2007): serpentine?



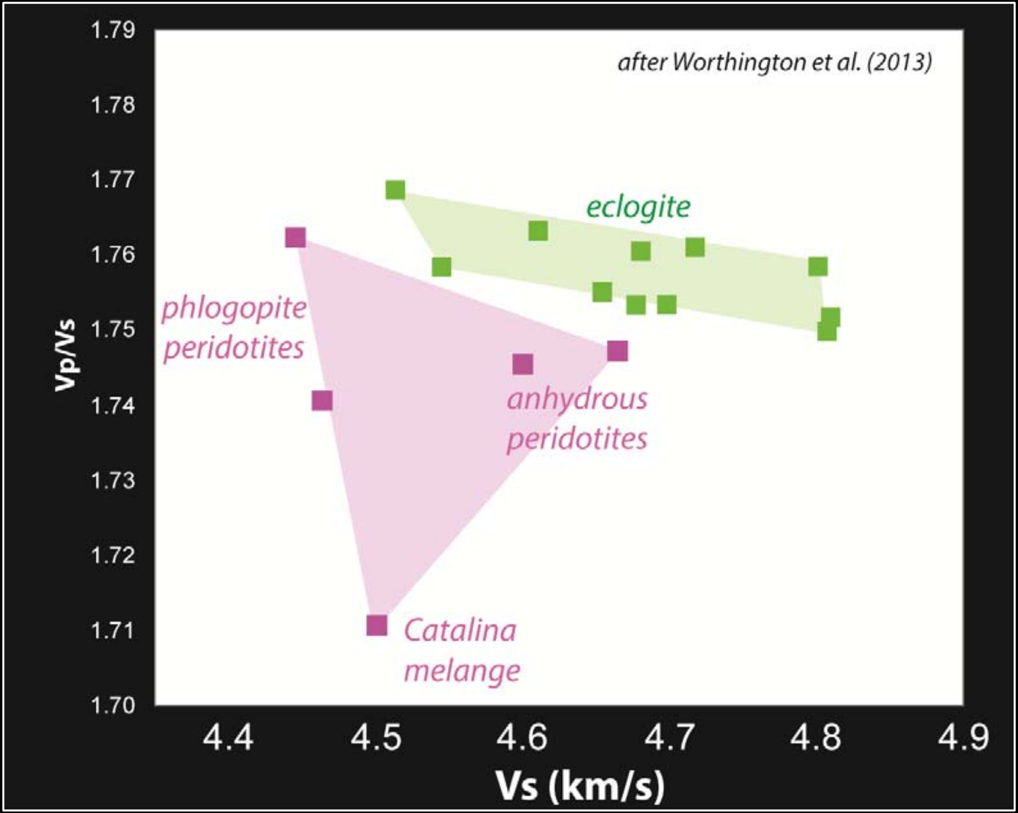
Hydrous Peridotite Layer?

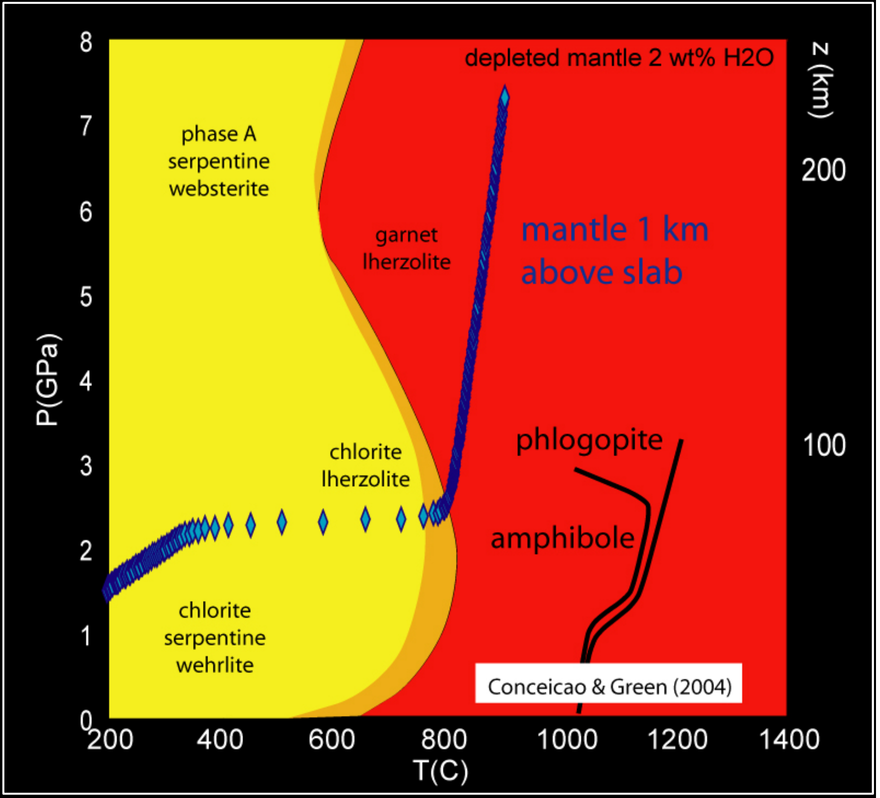
serpentinite improbable, but why not phlogopite?



Hydrous Peridotite Layer?

serpentinite improbable, but
shouldn't hydrous high-*T* peridotite be present beneath every arc?



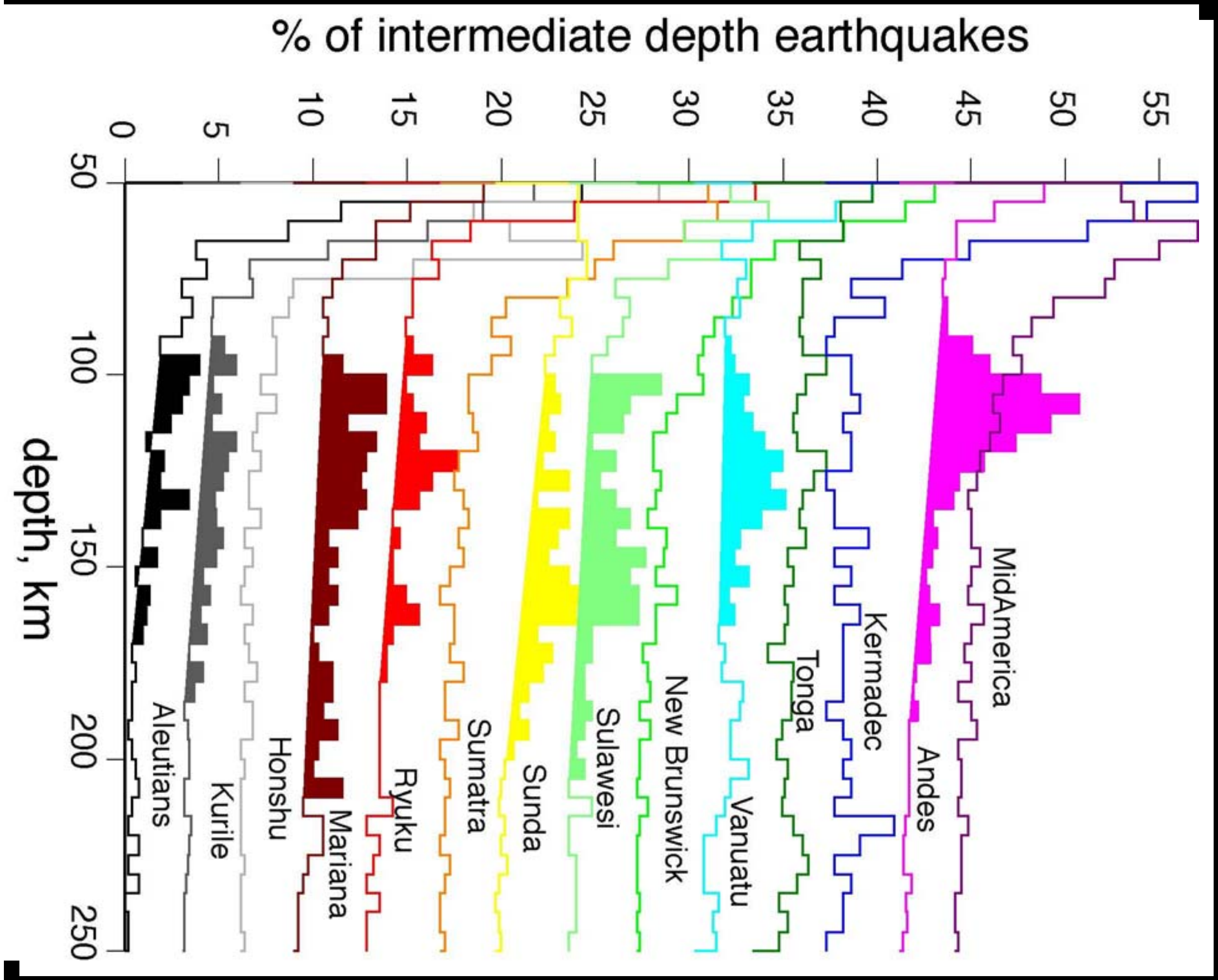


Slab Processes

1. Interpreting slab wavespeeds

2. Cause(s) of intermediate-depth EQ

Intermediate-Depth EQ

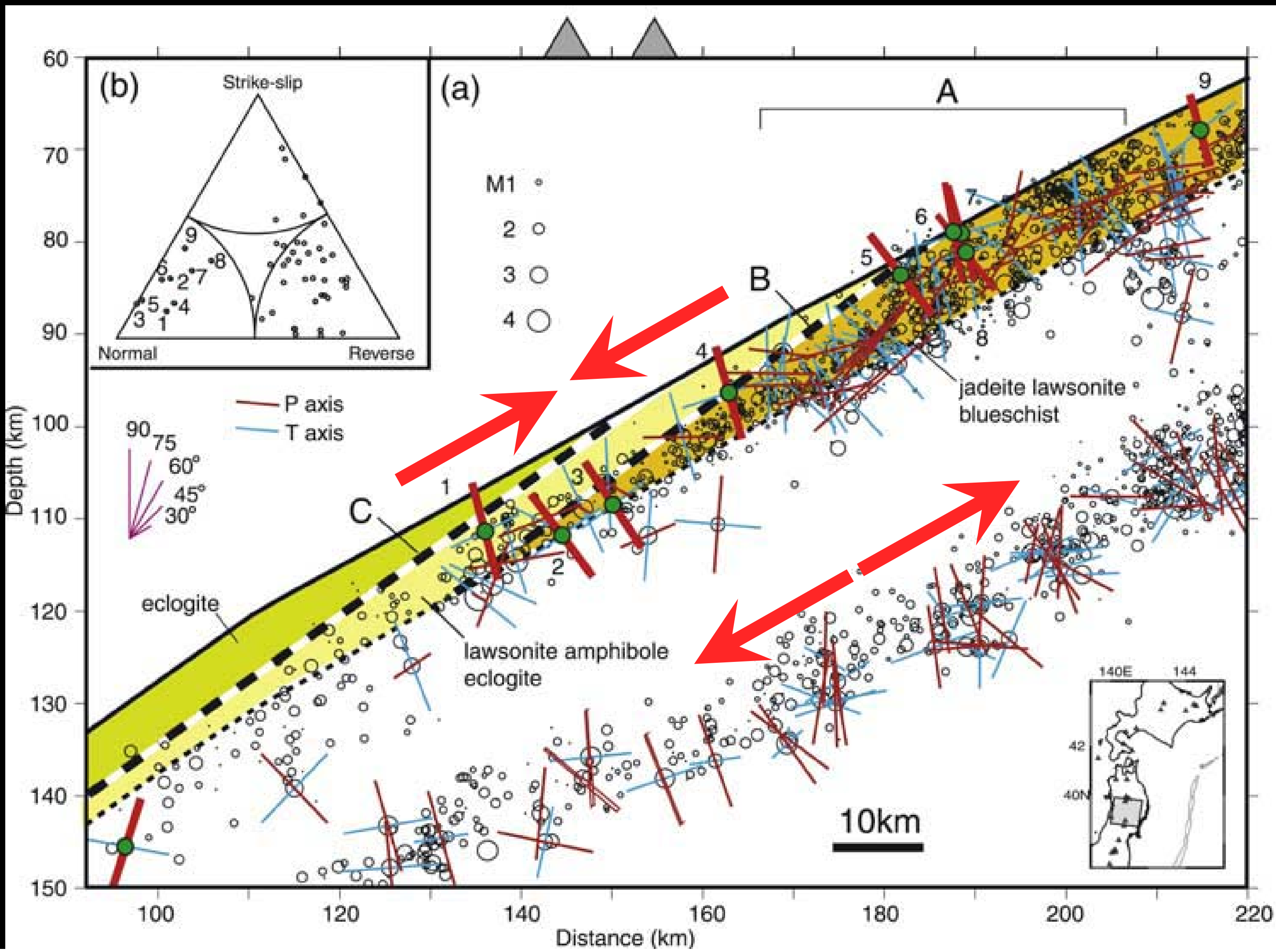


- 70–300 km depth
- only in subduction zones
- intraplate, not interplate

from Geoff Abers: catalog of *Engdahl et al.* [1998],
m_b>4.5 & >2 depth phases reported

Intermediate-Depth EQ

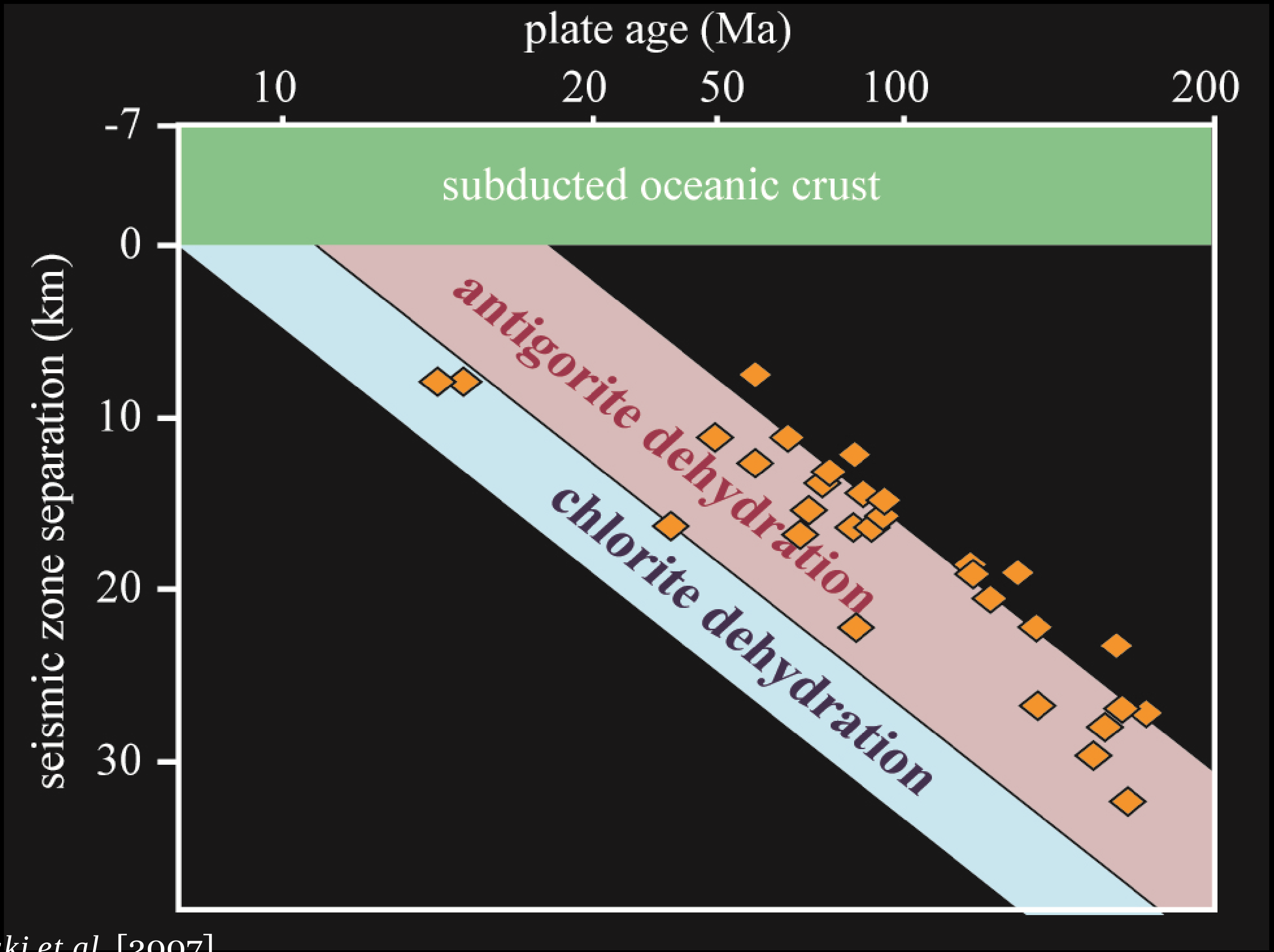
• *many* in DSZ with downdip P over downdip T



Kita et al. [2006]

Intermediate-Depth EQ

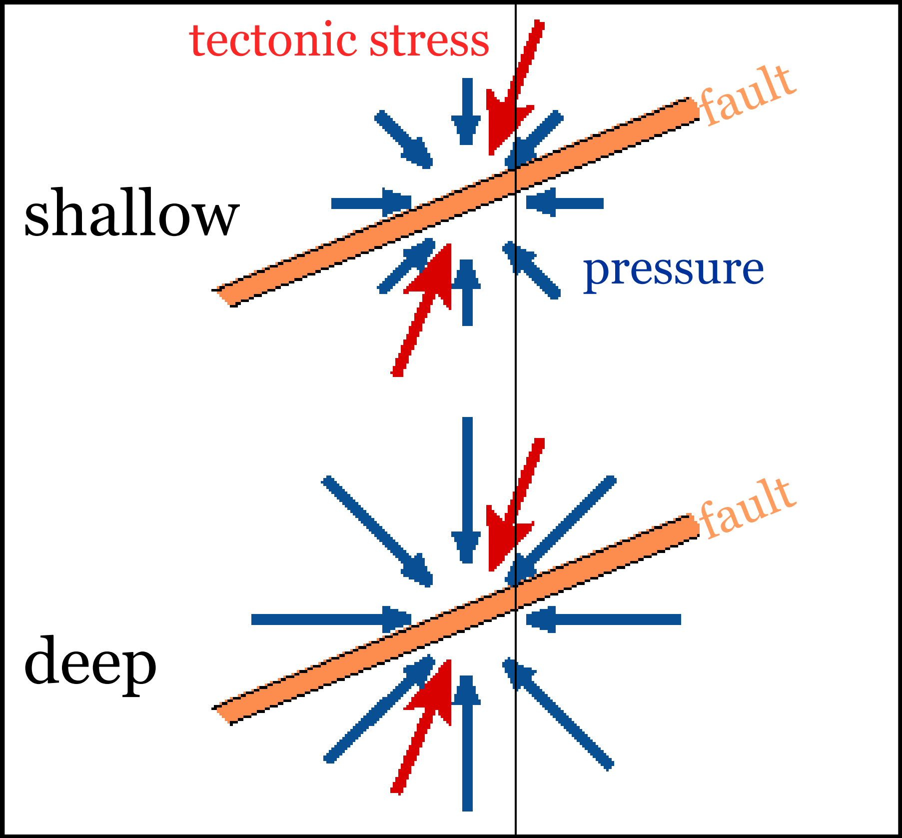
• double seismic zones separation ≤ 30 km scales with plate age



after *Brudzinski et al.* [2007]

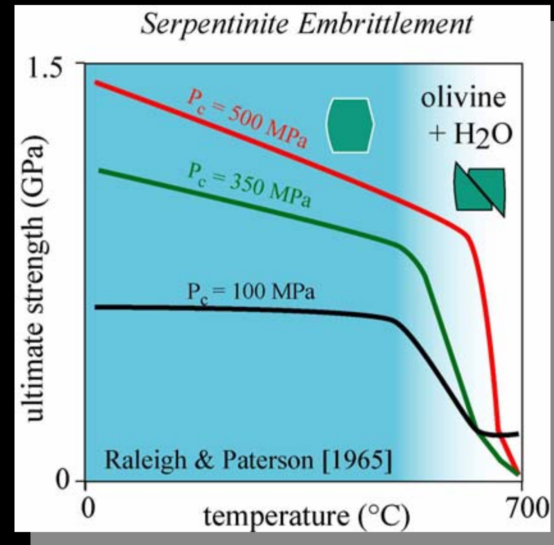
How to Explain IDE When "Normal" Faulting is Inhibited at Depth?

Jeffreys [1929] recognized need for fluid or another mechanism to overcome normal stress



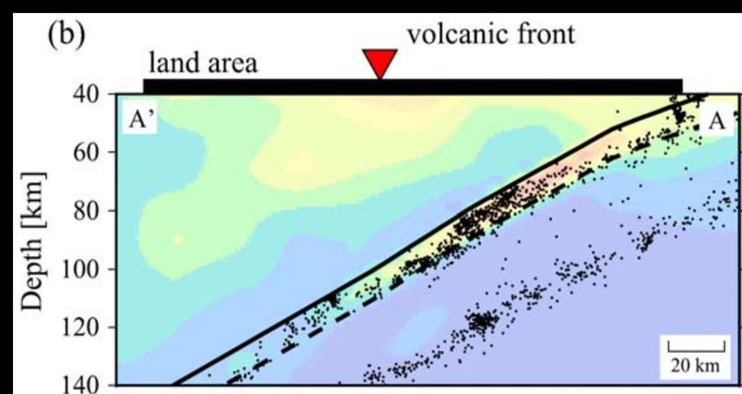
Intermediate-Depth EQ Mechanisms

1. dehydration embrittlement (DE)



- sample scale
- only some materials: poster by Keishi Okazaki
- can sample-scale behavior be extrapolated?

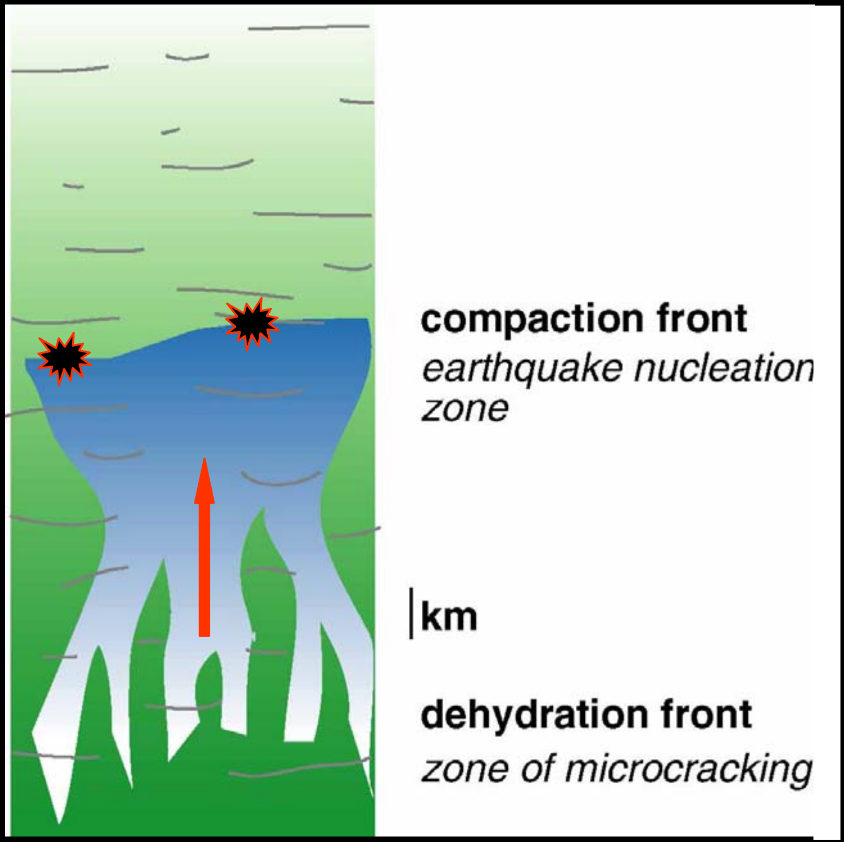
x 10^7



Intermediate-Depth EQ Mechanisms

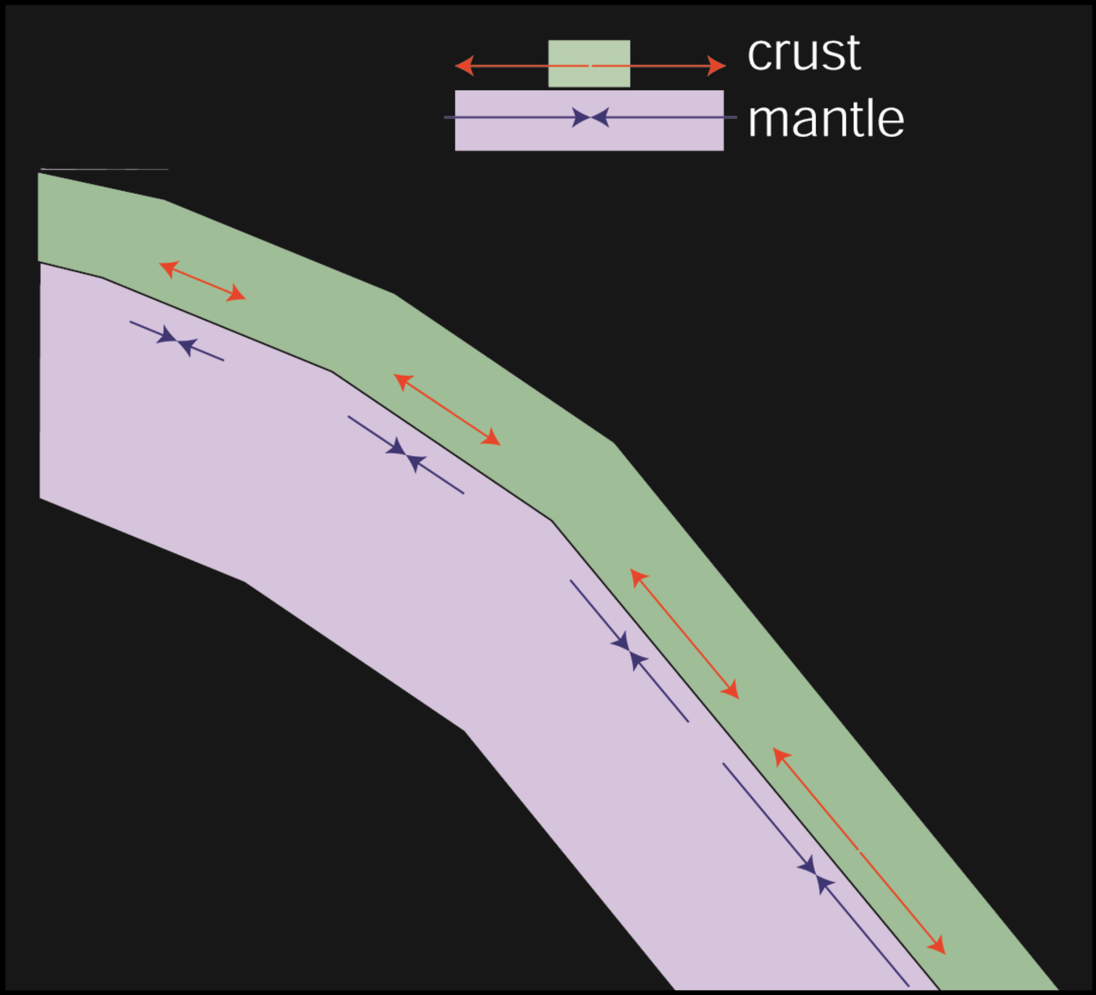
2. hydration embrittlement (HE)

   - lithostatic fluid pressure

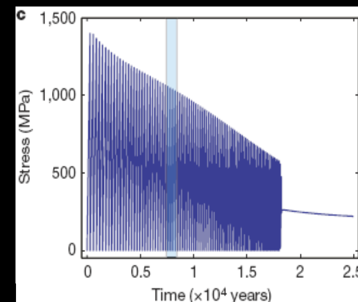


Intermediate-Depth EQ Mechanisms

3. ΔV eclogitization [*Goto et al.*, 1987; *Kirby et al.*, 1996]



Intermediate-Depth EQ Mechanisms



4. thermal shear instability (TSI)

- at strain rate > diffusion, heating decreases viscosity, generating feedback & self-localization that can lead to faulting (*Ord & Hobbs*, 1986)
- peridotite: 600–800°C & >500 MPa σ drop (*Kelemen & Hirth*, 2007)
- gabbro: 680°C & 750 MPa σ drop (*John et al.*, 2009)

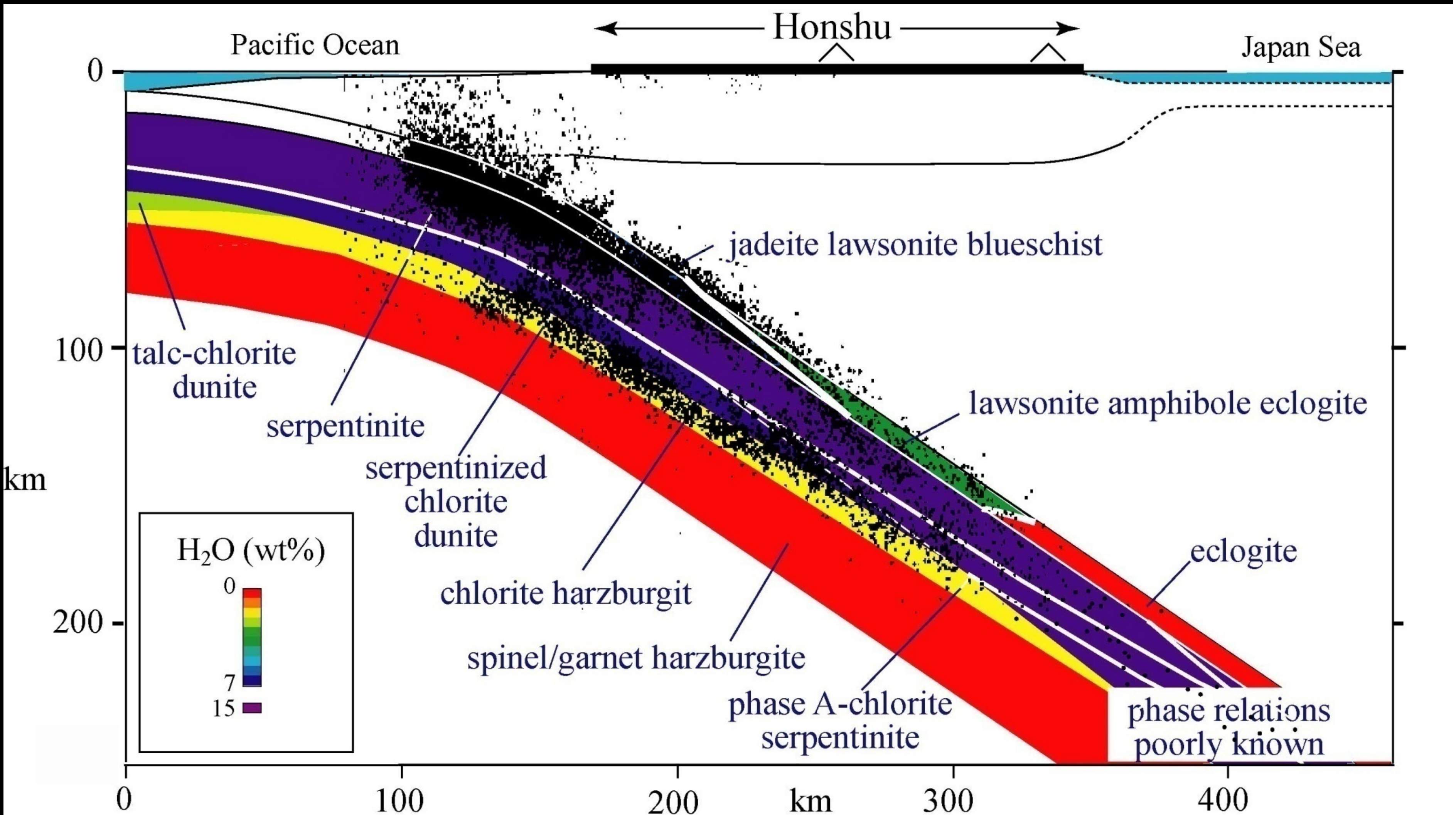
Intermediate-Depth Earthquakes

predictions of the four hypotheses

	1 DE	2 HE	3 TSI	4 ΔV
EQ & mineralogy (wavespeed) correlated	Y	Y	N?	Y
>500 MPa σ drops	N	N	Y	N
only 600–800°C	N	N	Y	N
fluid present	N	Y	N?	N
dehydration ongoing	Y	N	N	N
correlation to Clapeyron slope	Y	N	N	N
correlation to eclogitization	N	N	N	Y

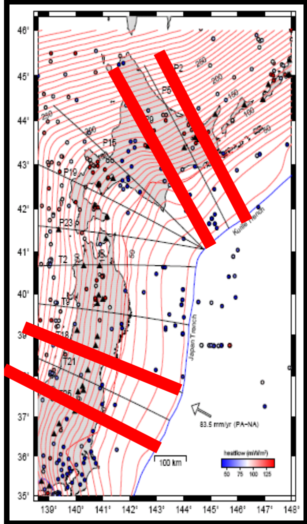
Hydration & Seismicity

favors (de)hydration embrittlement; compatible with TSI

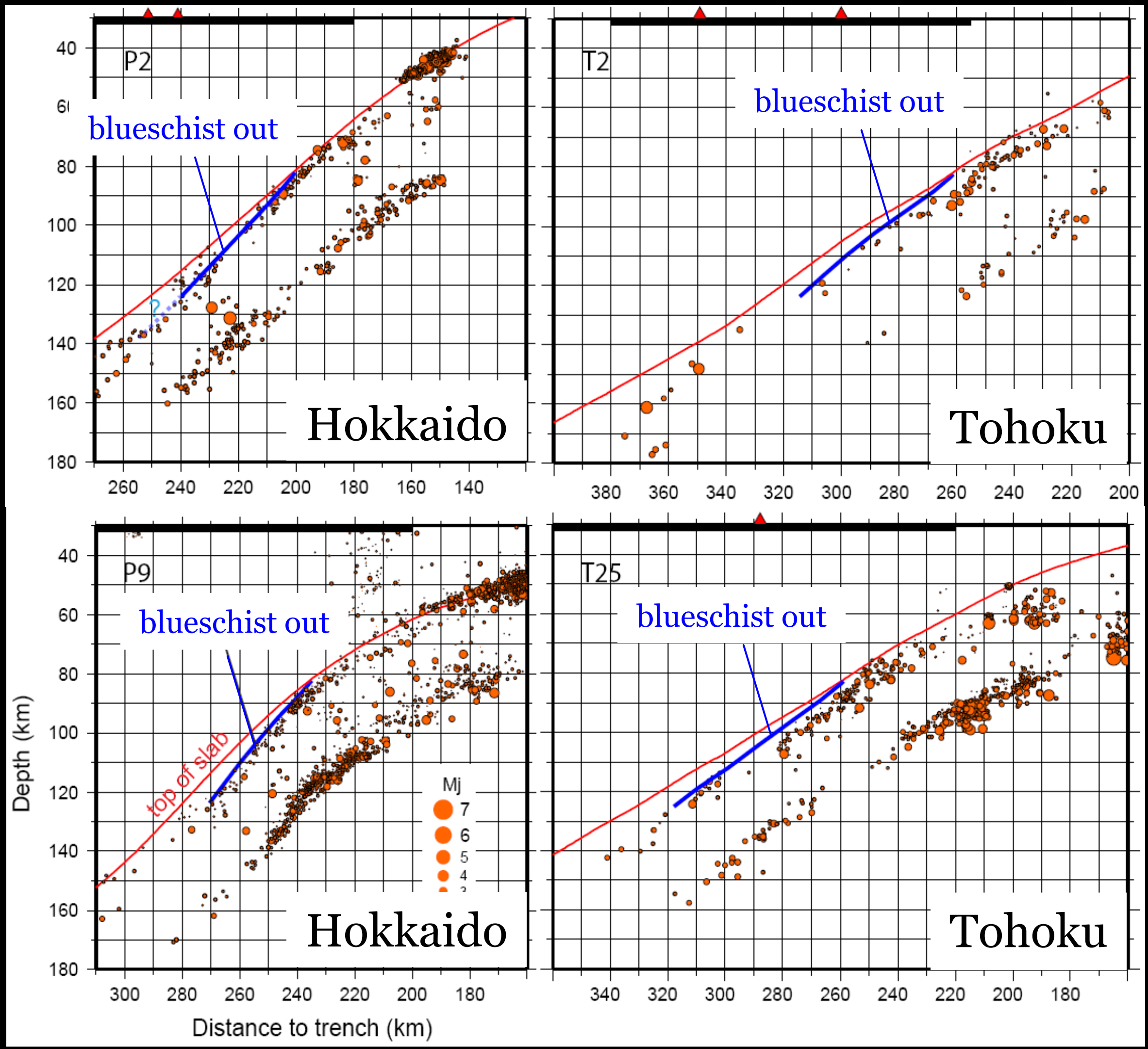


Hacker et al. [2003]

Blueschist-Out Limits Upper Seismic Zone



compatible with (de)hydration embrittlement

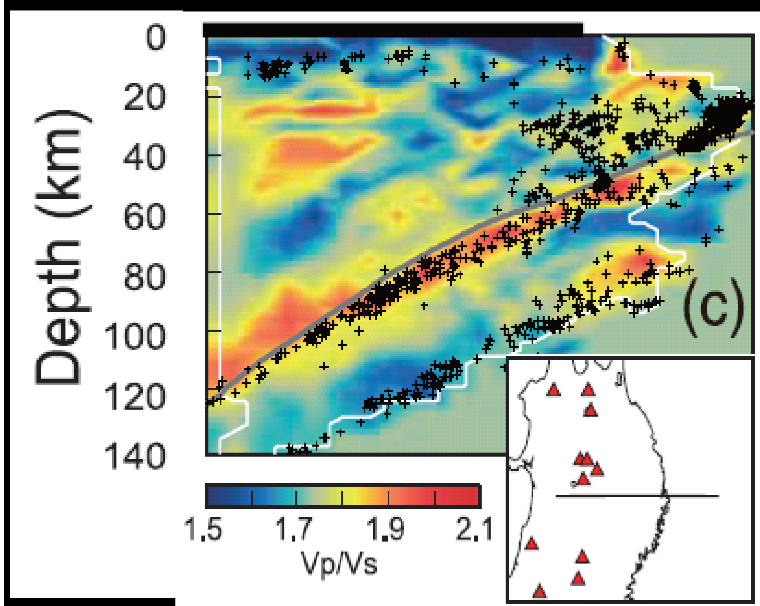


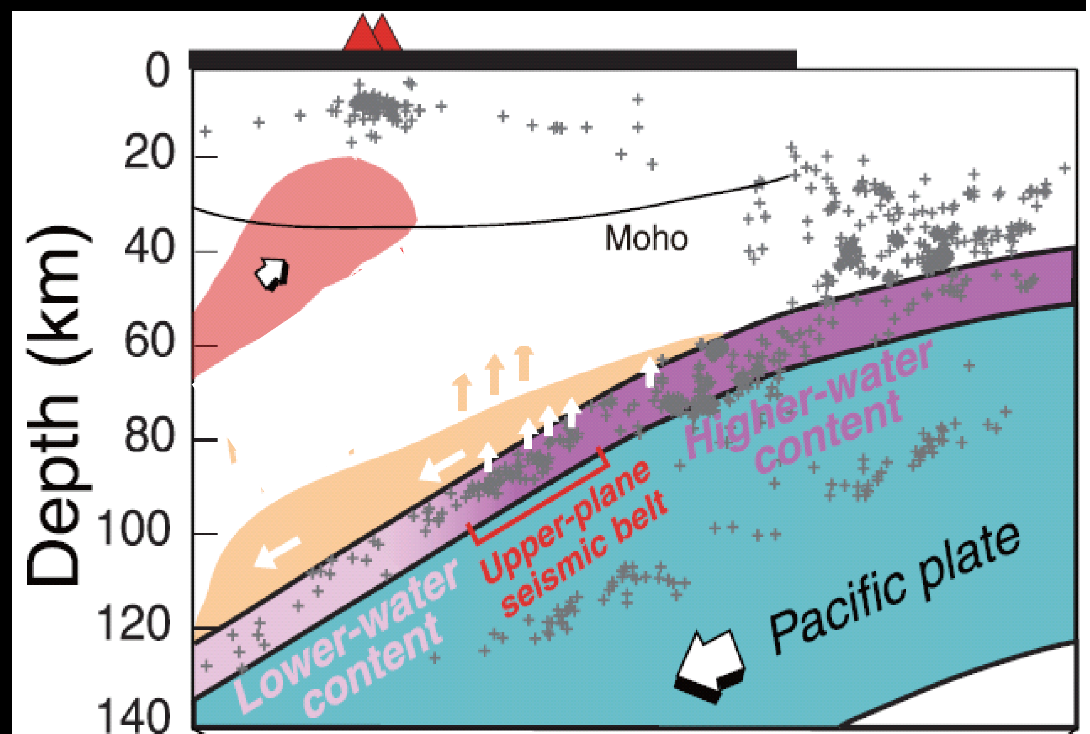
van Keken et al. [2012]

EQ Associated with Slow V, High Vp/Vs

H2O ± hydrous minerals;

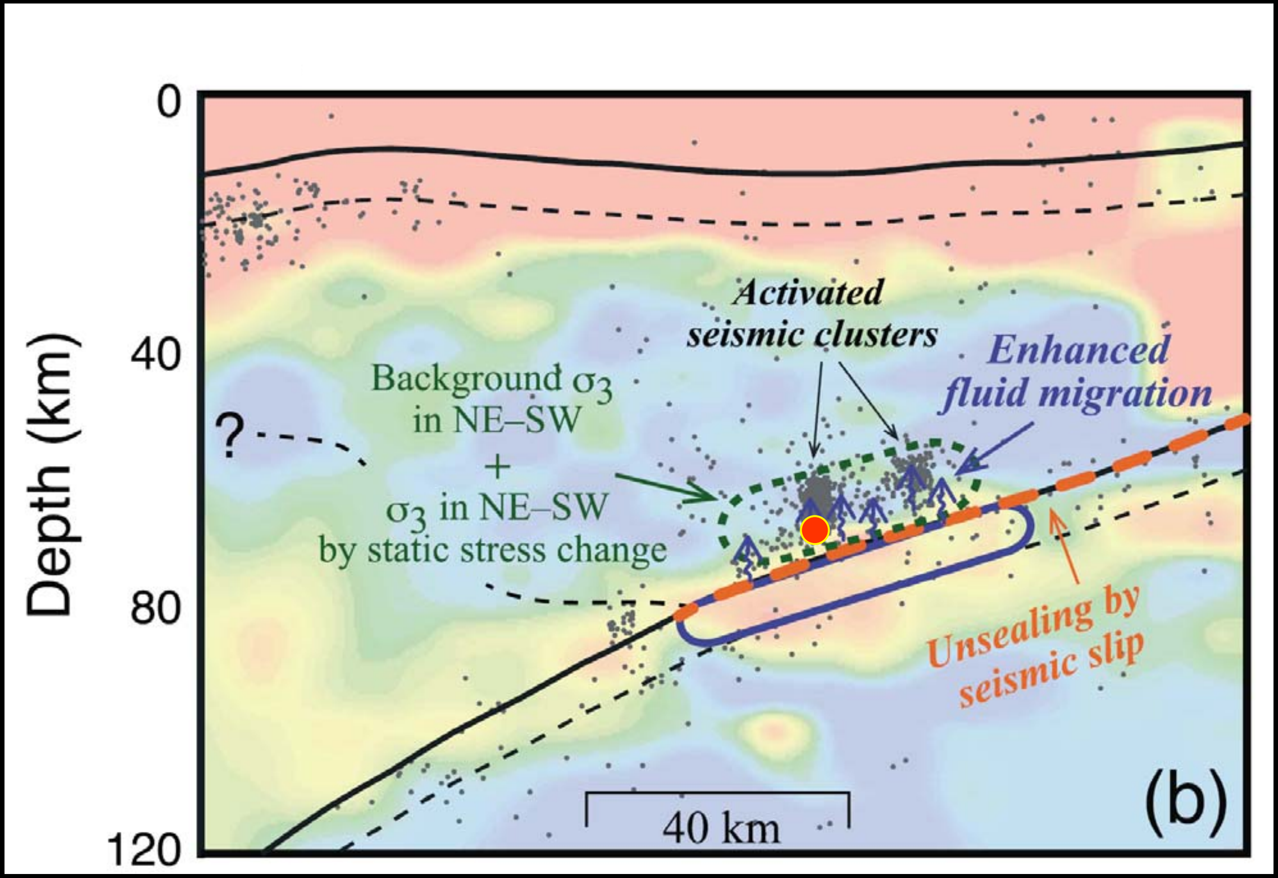
compatible with (de)hydration EQ (*Tsuji et al.*, 2008; *Nakajima et al.*, 2009; *Shiina et al.*, 2013)





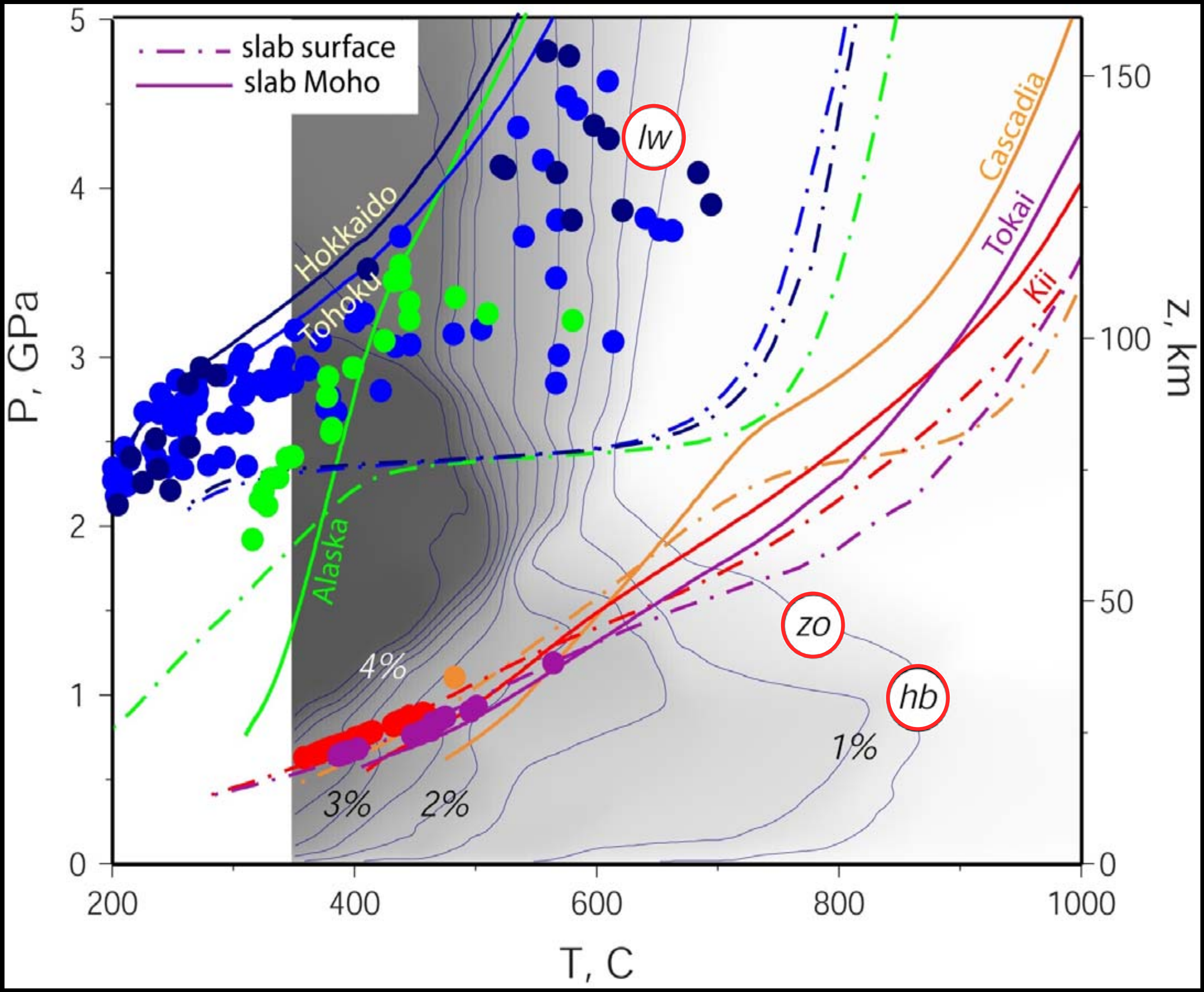
Supraslab EQ Propagation

propagation over dimension much larger than initial rupture, suggesting fluid involvement (*Nakajima et al.*, 2013)

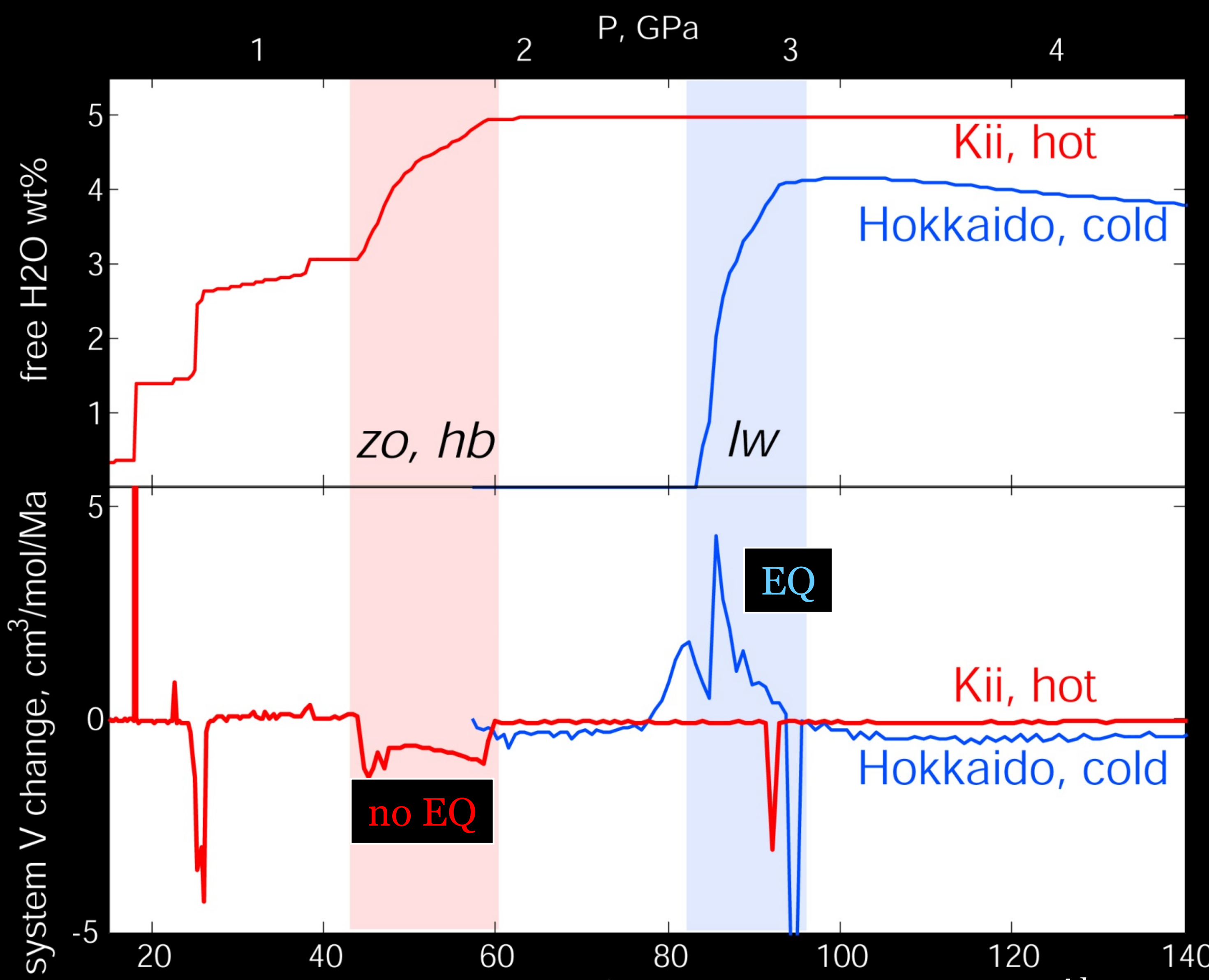


EQ Where Clapeyron Slope > 0

compatible with dehydration-induced seismicity (*Abers et al.*, 2013)



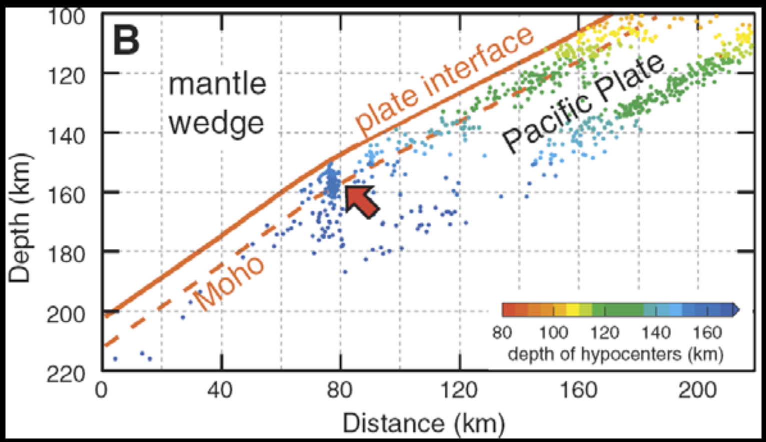
EQ if ΔFluid > ΔPorosity



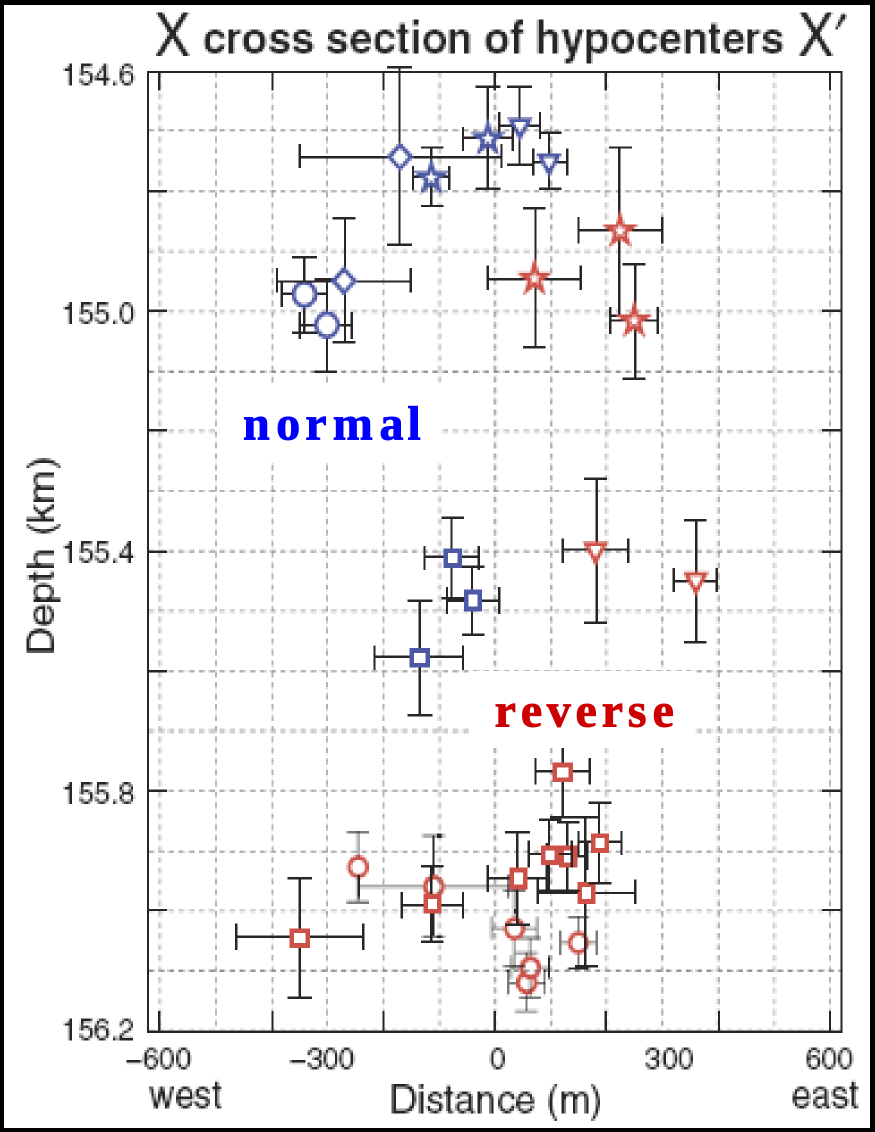
Abers et al. [2013]

Eclogitization-Driven EQ?

compatible with ΔV reaction

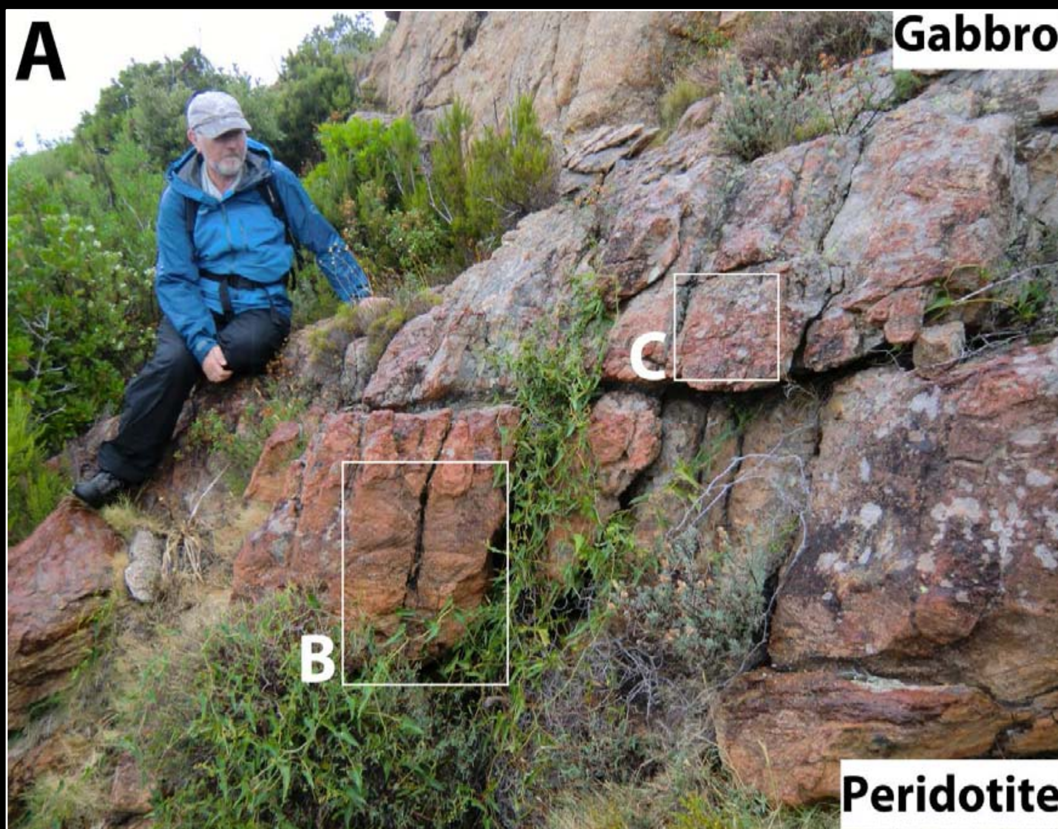


Nakajima et al. (2013)



Evidence of TSIs

- *Deseta et al.* (2014): pseudotachylites in blueschist–eclogite-facies gabbro & peridotite
- postdate greenschist-facies alteration (amphibole, sericite, serpentine in gabbro, & amphibole, chlorite in peridotite)



Andersen et al. (2014)

Intermediate-Depth Earthquakes

predictions of the four hypotheses

	1 DE	2 HE	3 TSI	4 ΔV
EQ & mineralogy (wavespeed) correlated	Y	Y	N?	Y
>500 MPa σ drops	N	N	Y	N
only 600–800°C	N	N	Y	N
fluid present	N*	Y*	N*	N
dehydration ongoing	Y	N	N	N
correlation to Clapeyron slope	Y	N	N	N
correlation to eclogitization	N	N	N	Y*

Summary 1/2

- many potential causes of slow wavespeeds
  – need directed studies with V_P, V_S, V_P/V_S & anisotropy

- arcs should be underlain by high-T hydrous mantle
  – is this seen in seismology?
  – is this seen in arc petrology?

Summary 2/2

- likely multiple cause(s) of intermediate-depth EQ
  - TSI: exist in outcrop, but σ drop too high, T bound too narrow; may require hydrous minerals
  - DE: where Clapeyron slope > 0, but only seen at sample scale
  - DE & HE: EQ associated with slow speeds/hydrous minerals
  - HE: propagating EQ over large, cold areas
  - ΔV: local correlation to eclogitization