Seismological constraints on the mechanism(s) responsible for intermediate-depth earthquakes

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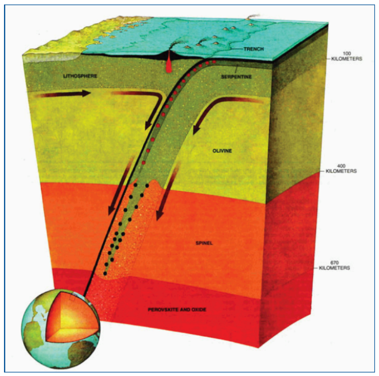
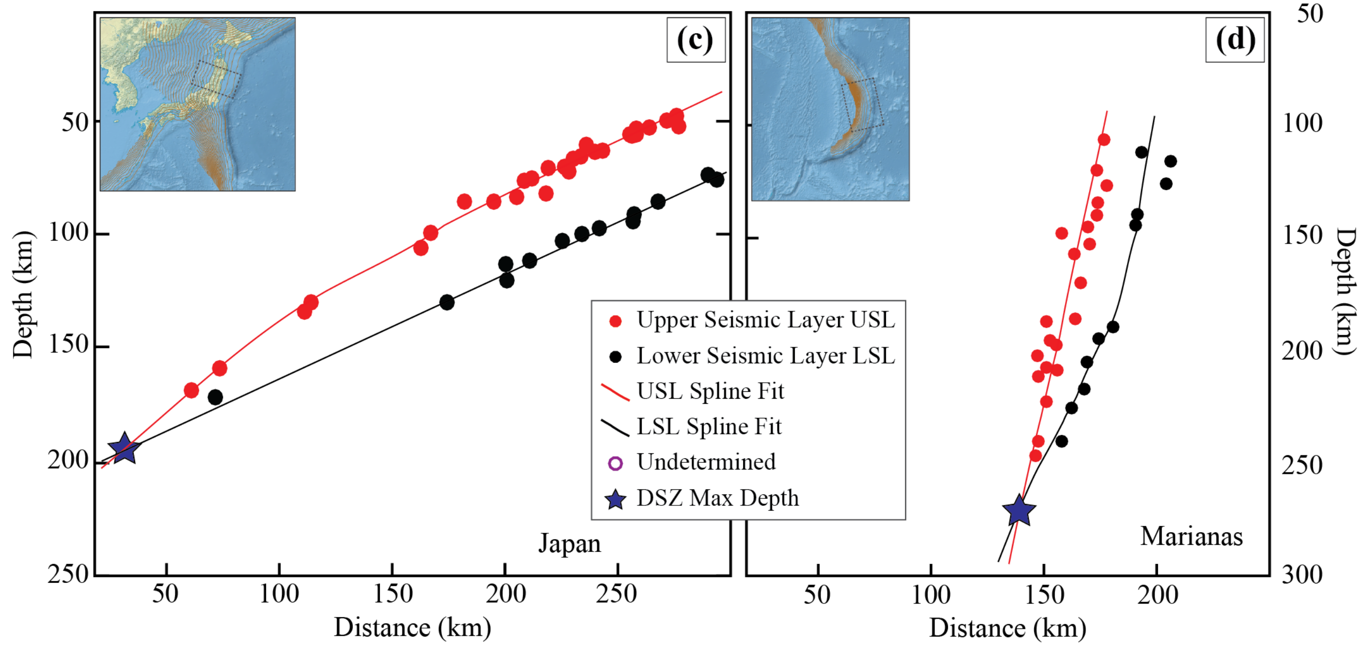


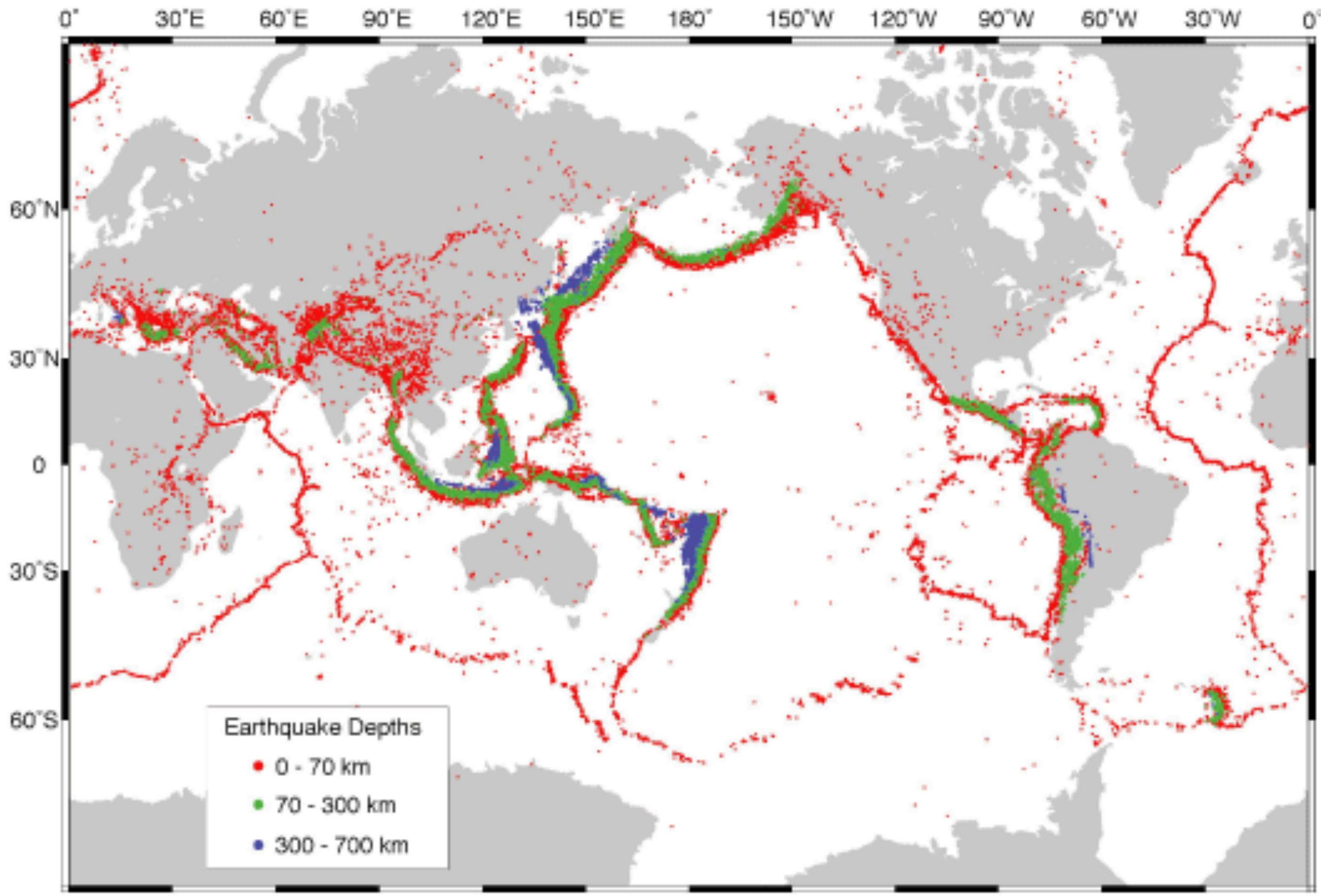


Germán A. Prieto[1] & Manuel Florez[2]

(1) Universidad Nacional de Colombia, (2) EAPS, MIT

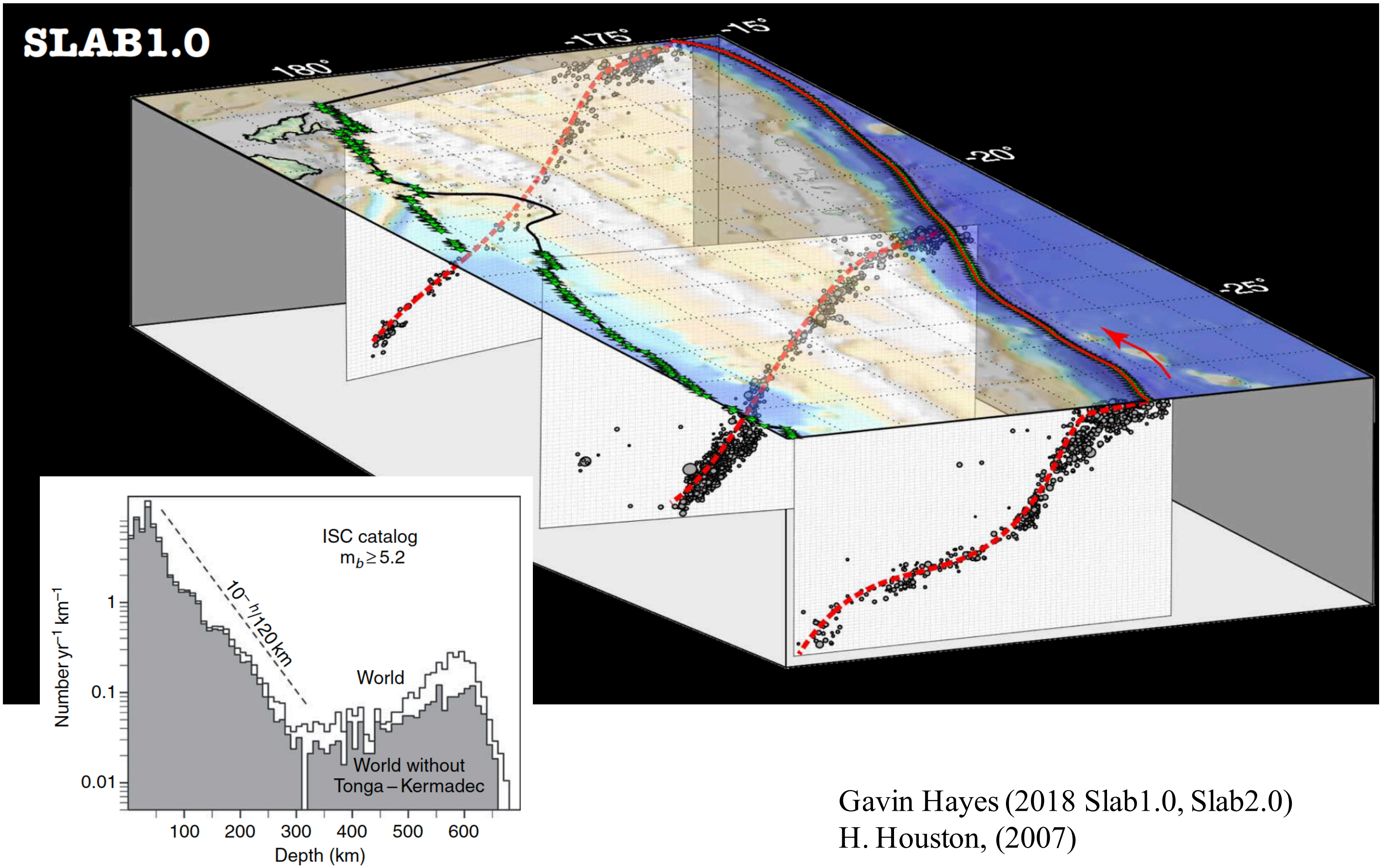
Workshop: Intermediate and Deep Eathquakes: Observation and modeling

Earthquakes around the World



Most **intermediate-deep earthquakes occur along subduction zones**

Mechanism(s) of IDE and deep earthquakes?



Gavin Hayes (2018 Slab1.0, Slab2.0)
H. Houston, (2007)

Subduction Zones

Earthquakes between

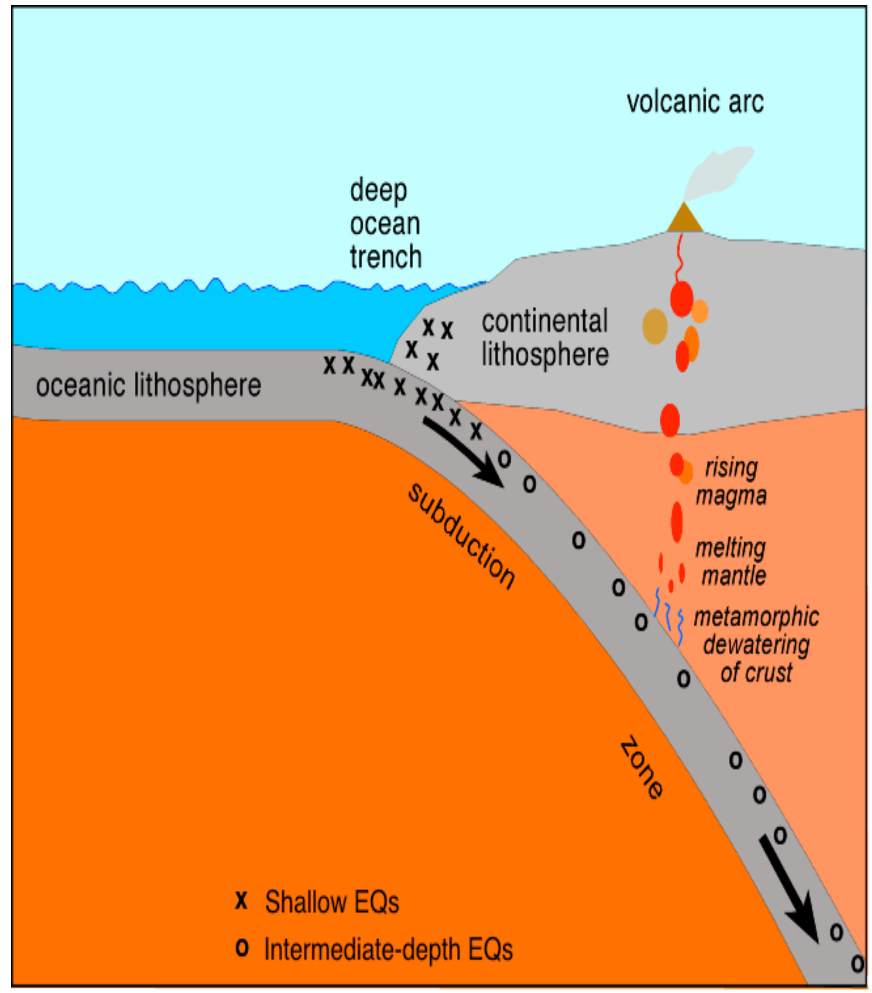
50-300 km IDE

>350-700 km Deep

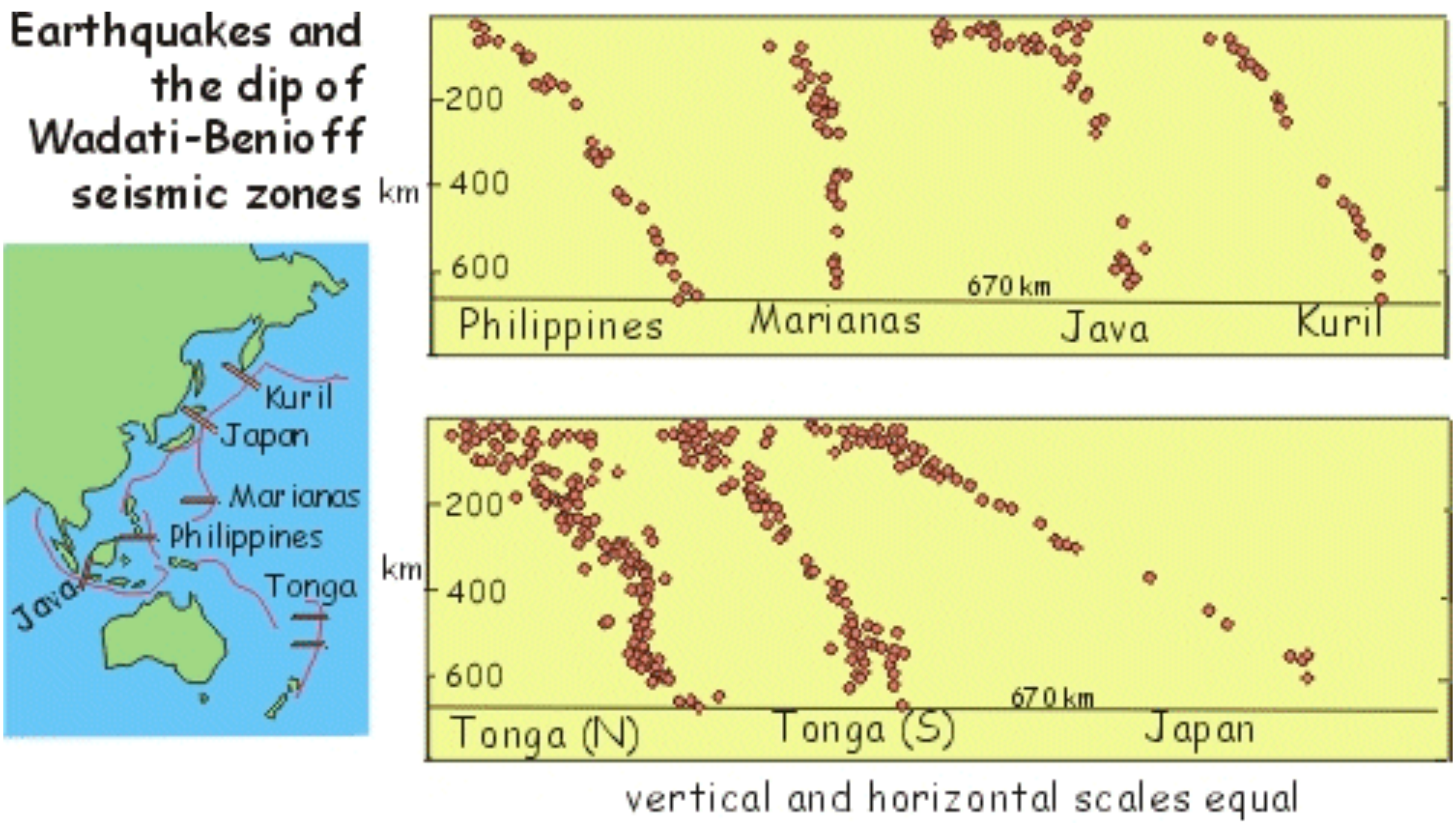
Due to high T-P, brittle rheology is not guaranteed.

Composition?
Phase-transitions?
Water content?
Temperature?

Mechanism is not clear



Wadatti Benioff Zones



Geometric complexity between (along) subduction zones?

Double Wadatti-Benioff Zones

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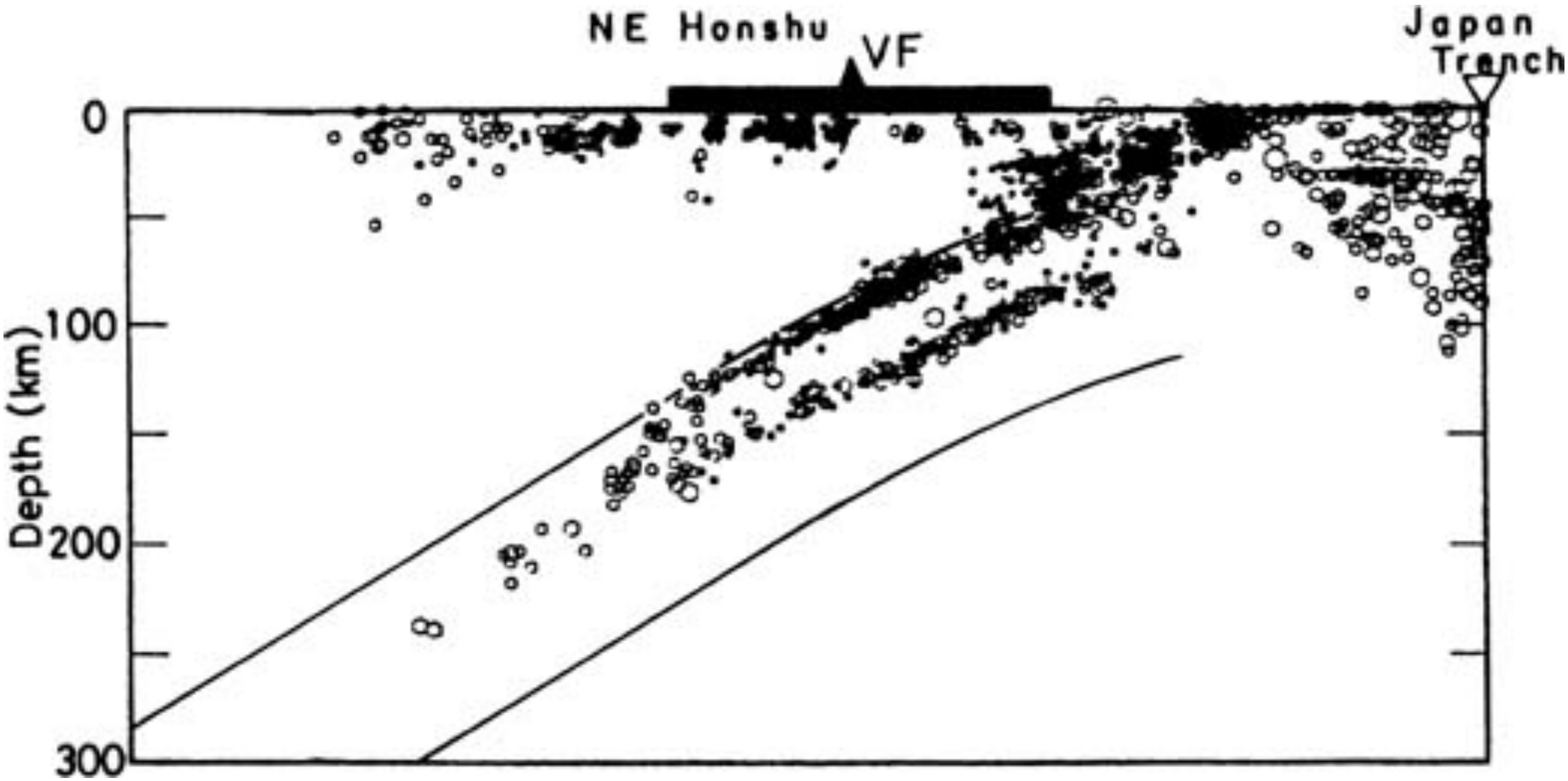
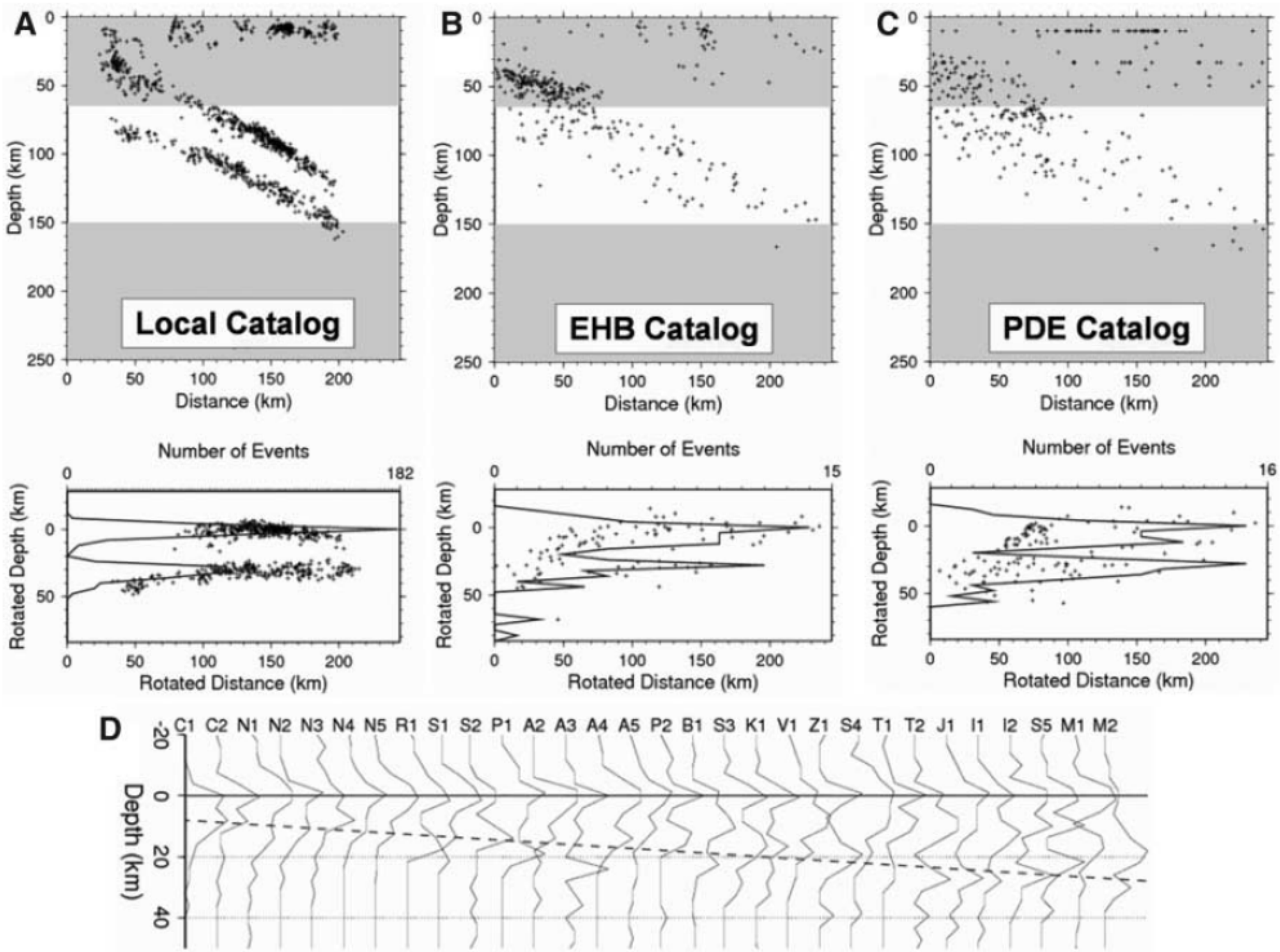
A Hasegawa, 1979



Taking a closer look, IDE locations show more complexity. Double Seismic Zones (DSZ) are observed worldwide.

Double Seismic Zones



Brudzinski, Science 2007

Why do we have DSZs?

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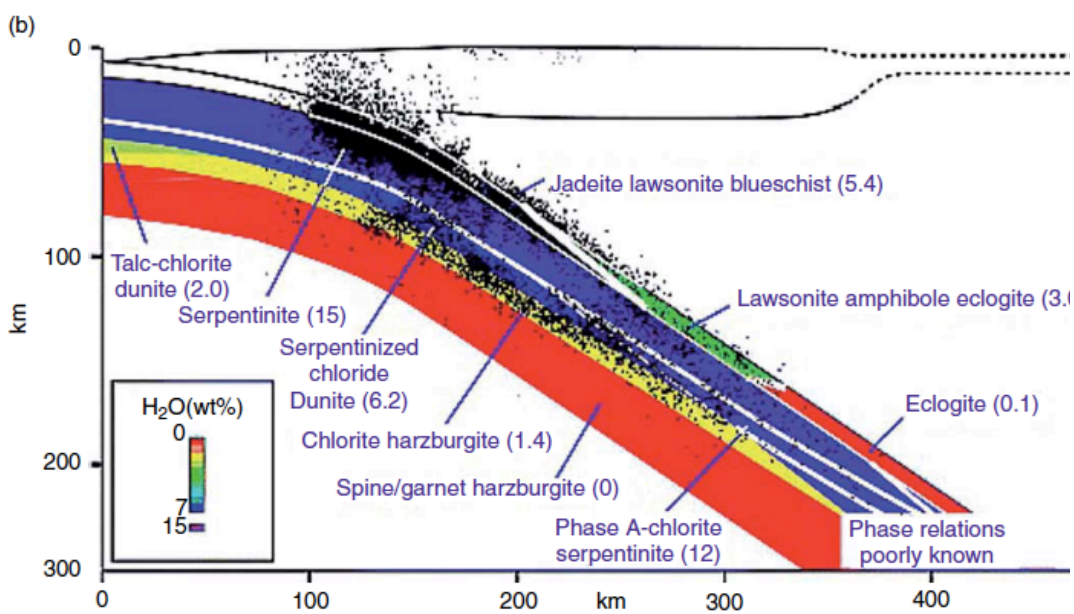
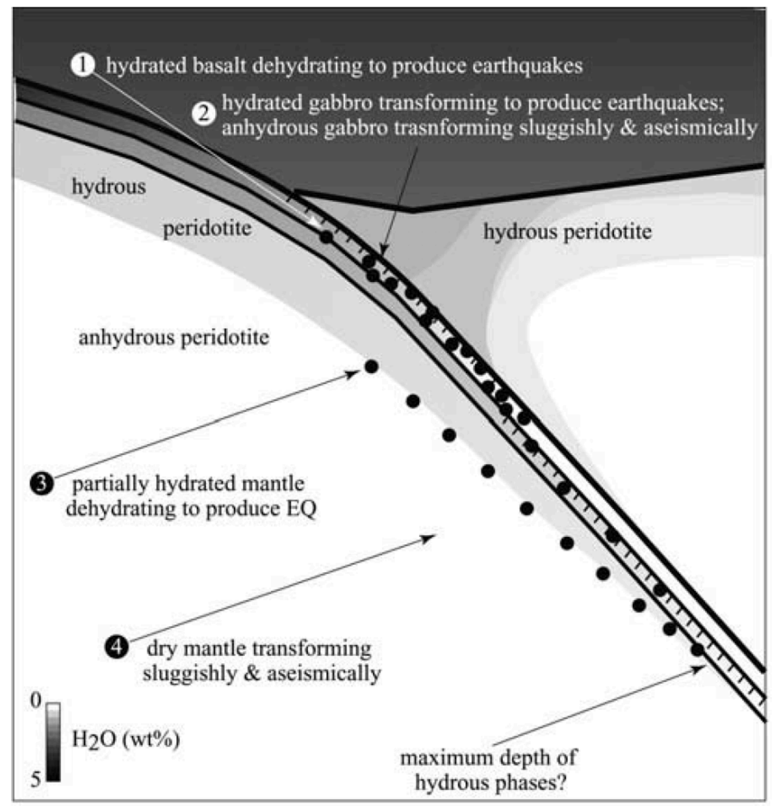
"intermediate-depth double seismic zones consistent with dewatering of hydrous phases predicted from subduction zone thermal structures" (Houston, 2007)

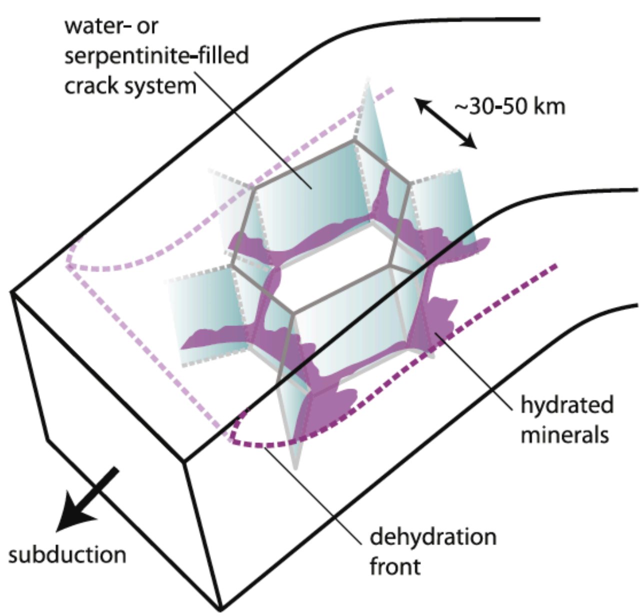


Hacker et al., 2003

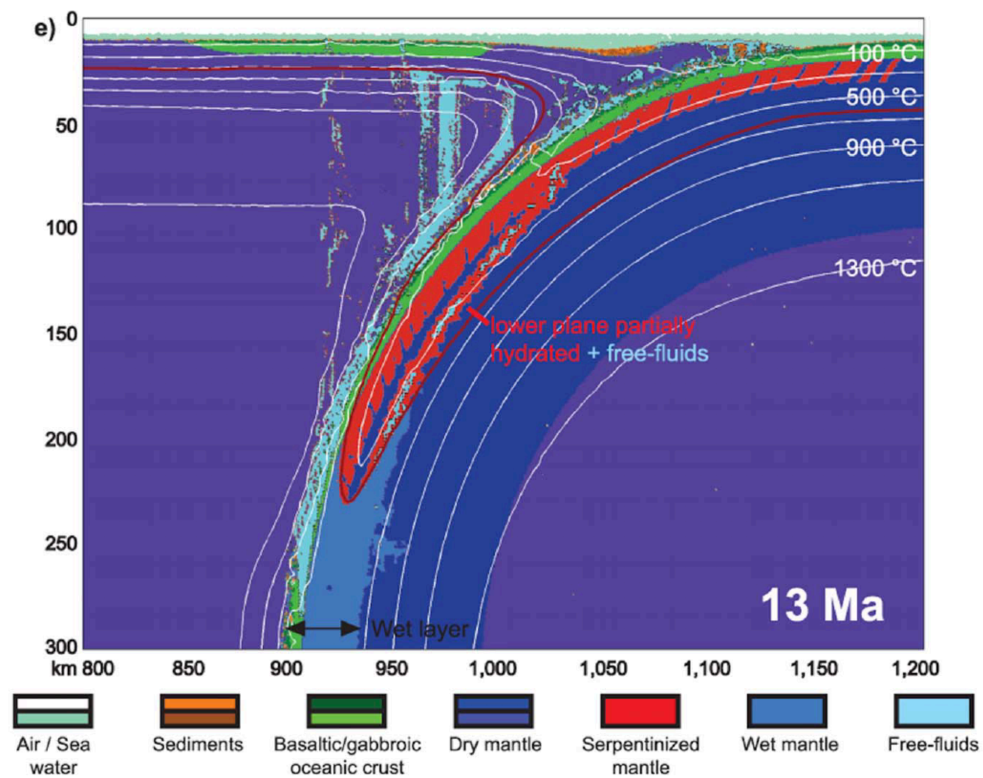


Why do we have DSZs?

“When bent at subduction zones, oceanic plates are damaged by normal faulting, and this bending-related faulting is widely believed to cause deep mantle hydration, down to 20-30 km deep, The buoyancy of water, however, makes it difficult to bring water down even if faulting is deep” *Korenaga, 2017*



Korenaga, 2017



Faccenda et al., 2012

Characterizing Seismicity along DSZs

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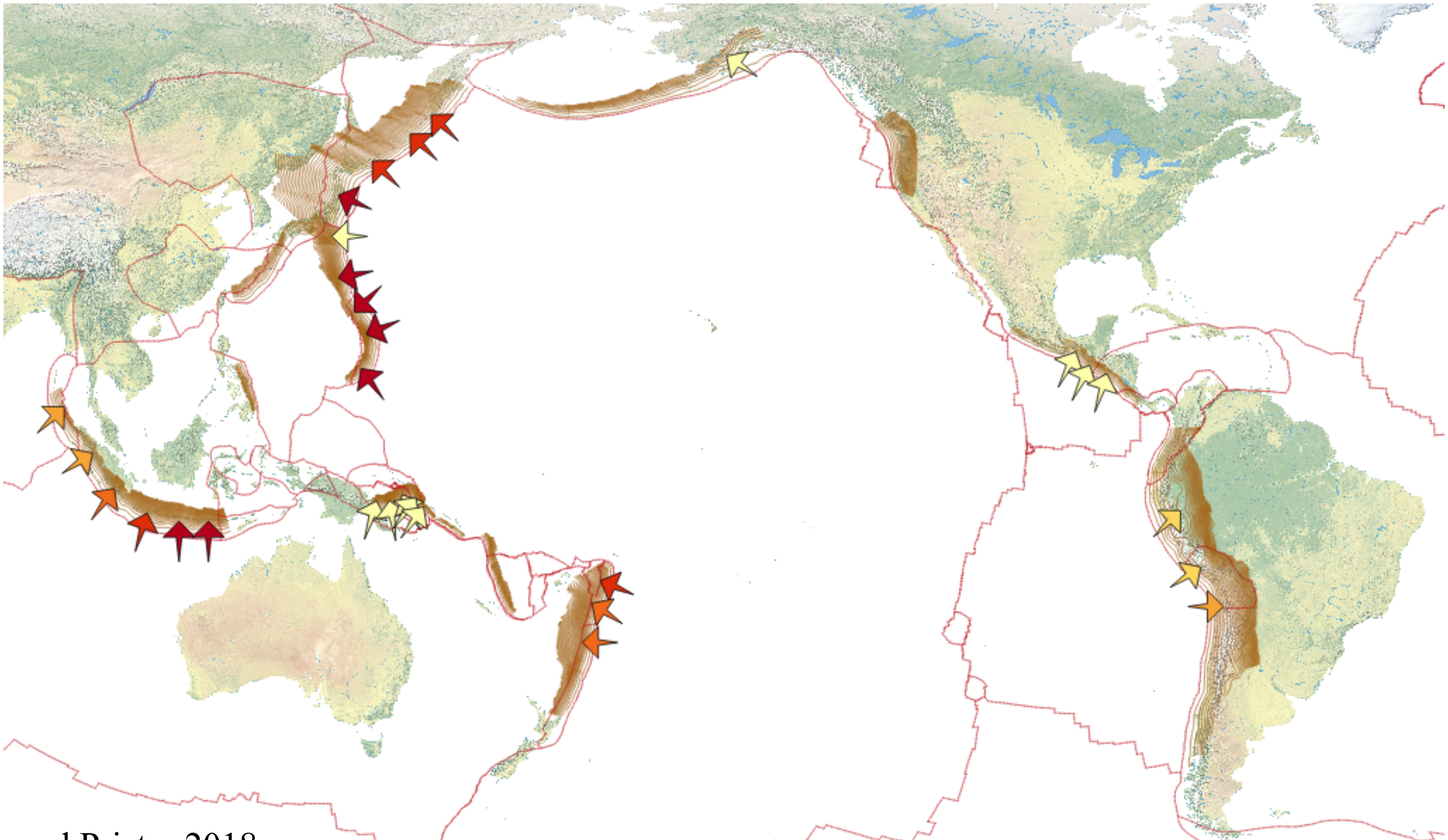
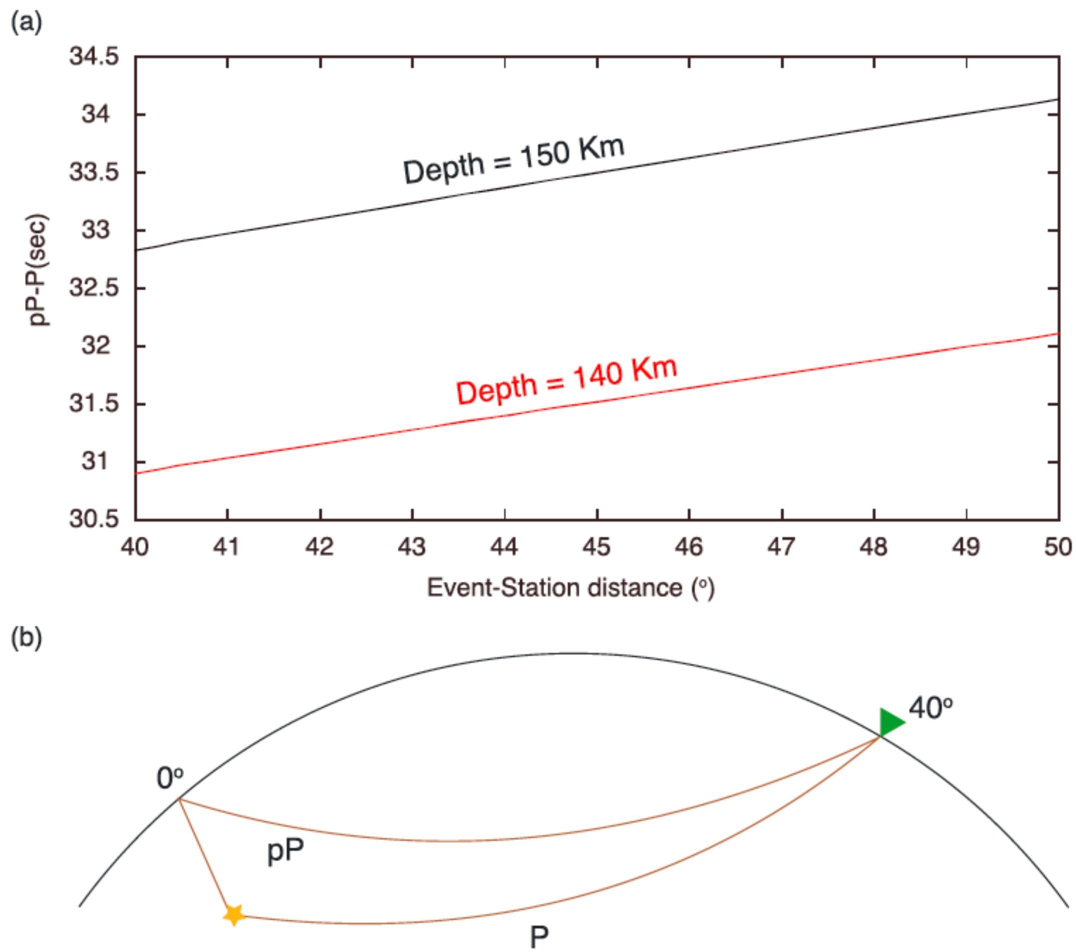


Florez and Prieto, 2018

Characterize DSZ width and maximum depth

Seismicity behavior (*b*-values, aftershock productivity, …)

Relocation of teleseismic DSZ catalog



Florez and Prieto, 2017

Use of depth-phases for precise depth determination

Relocation of teleseismic DSZ catalog

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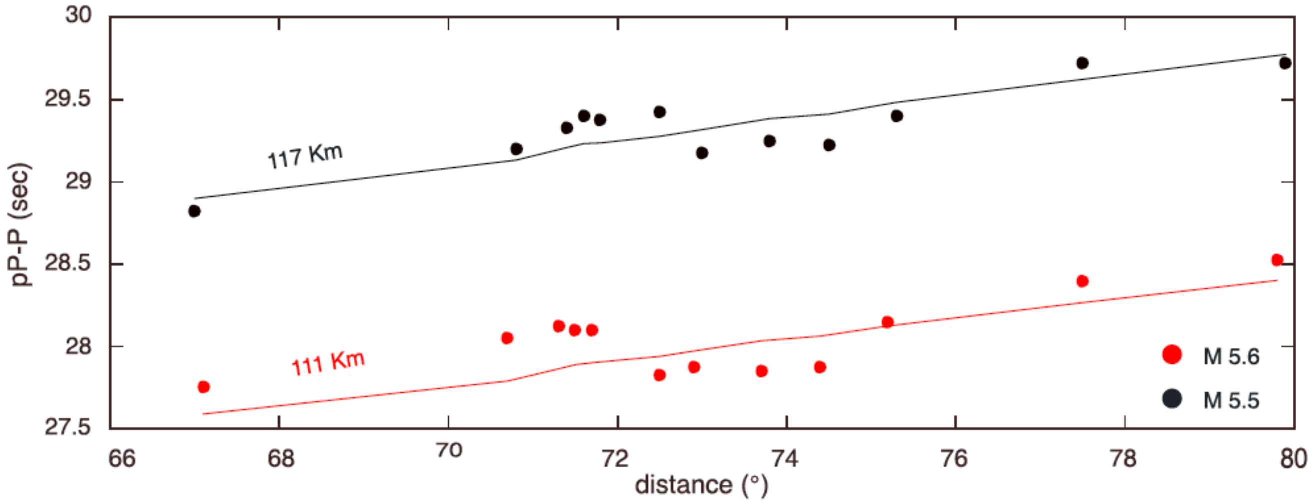
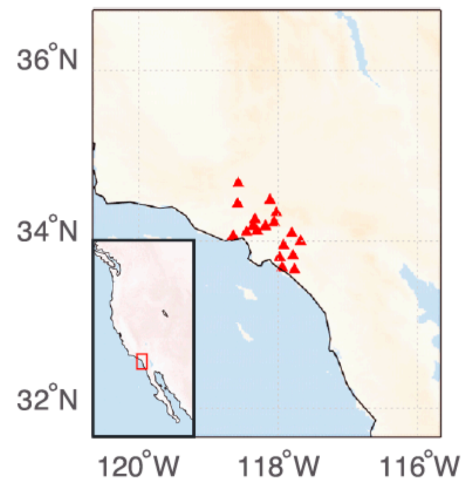
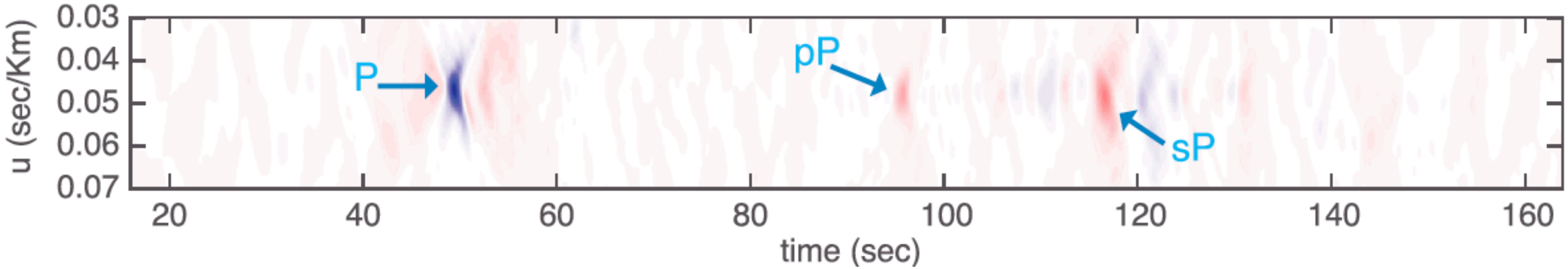




Florez and Prieto, 2017



Use of depth-phases for precise depth determination

Array based *pP-P* relative arrival times

Characterizing Seismicity along DSZs

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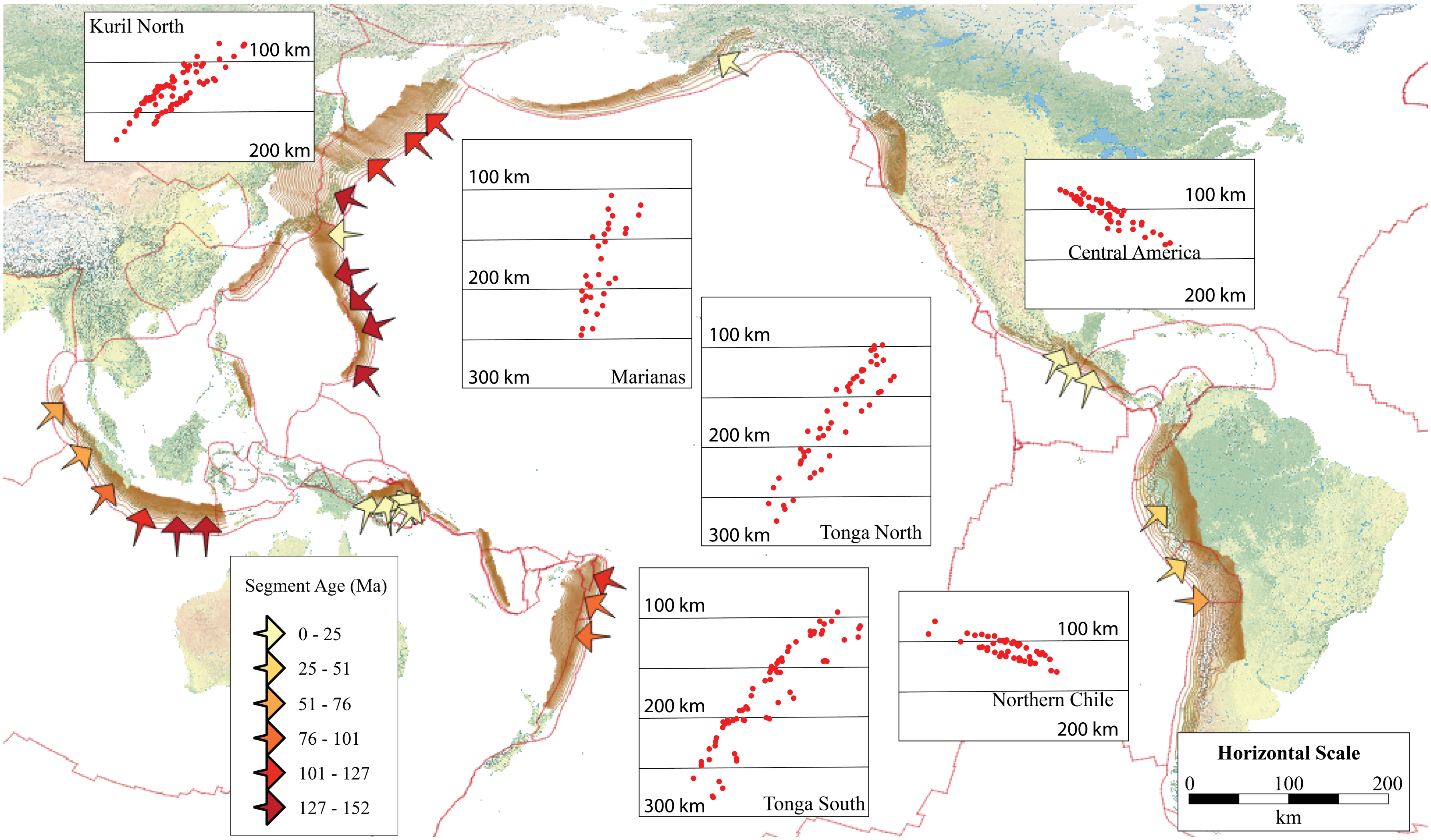

Florez and Prieto, 2018

Largest DSZ catalog

32 slab segments, 10-150 Ma. DSZ everywhere

Characterizing Seismicity along DSZs

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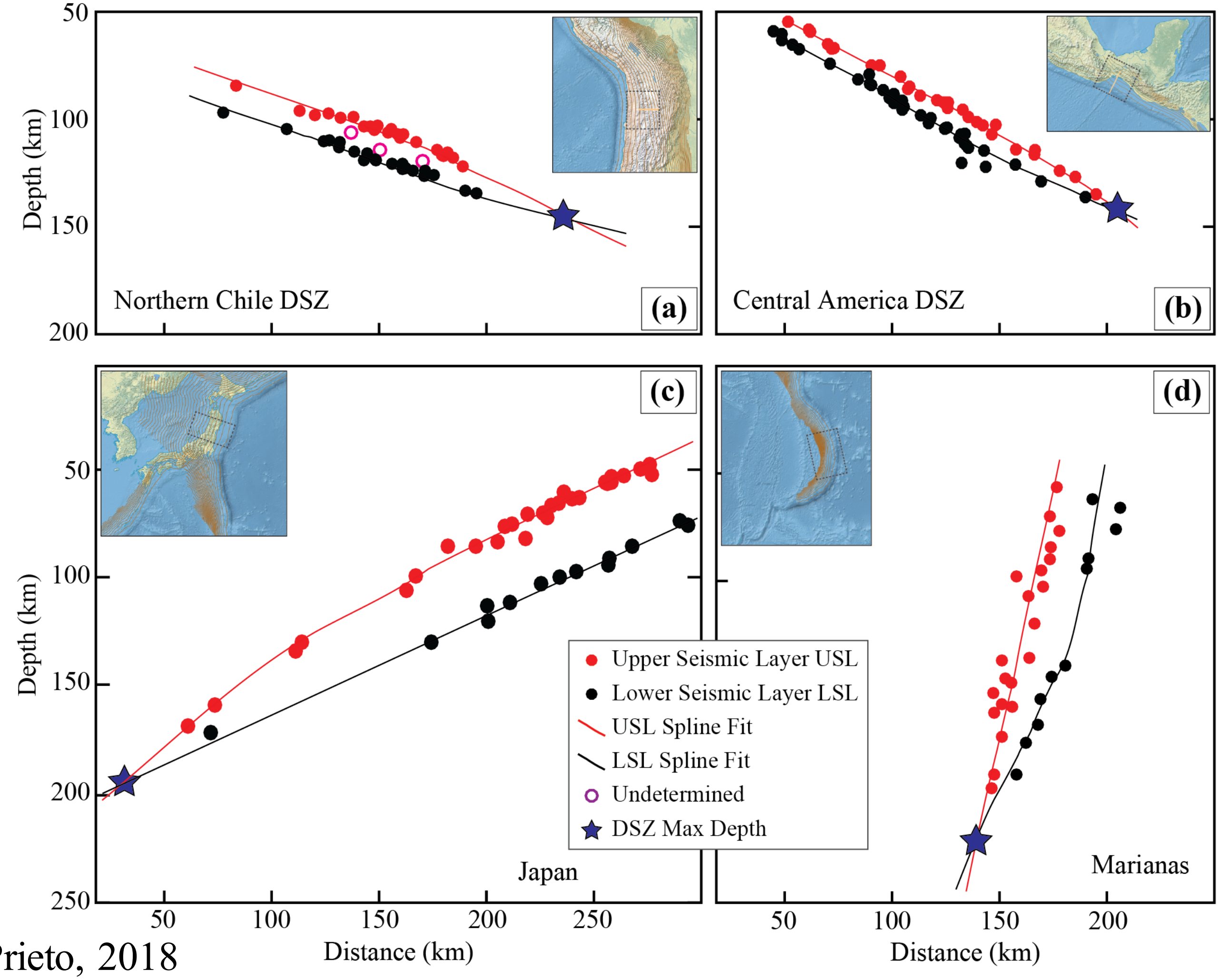

Florez and Prieto, 2018

Spline fit for Upper and Lower layers

Curve extrapolation for defining *closing depth* of DSZ

Characterizing Seismicity along DSZs

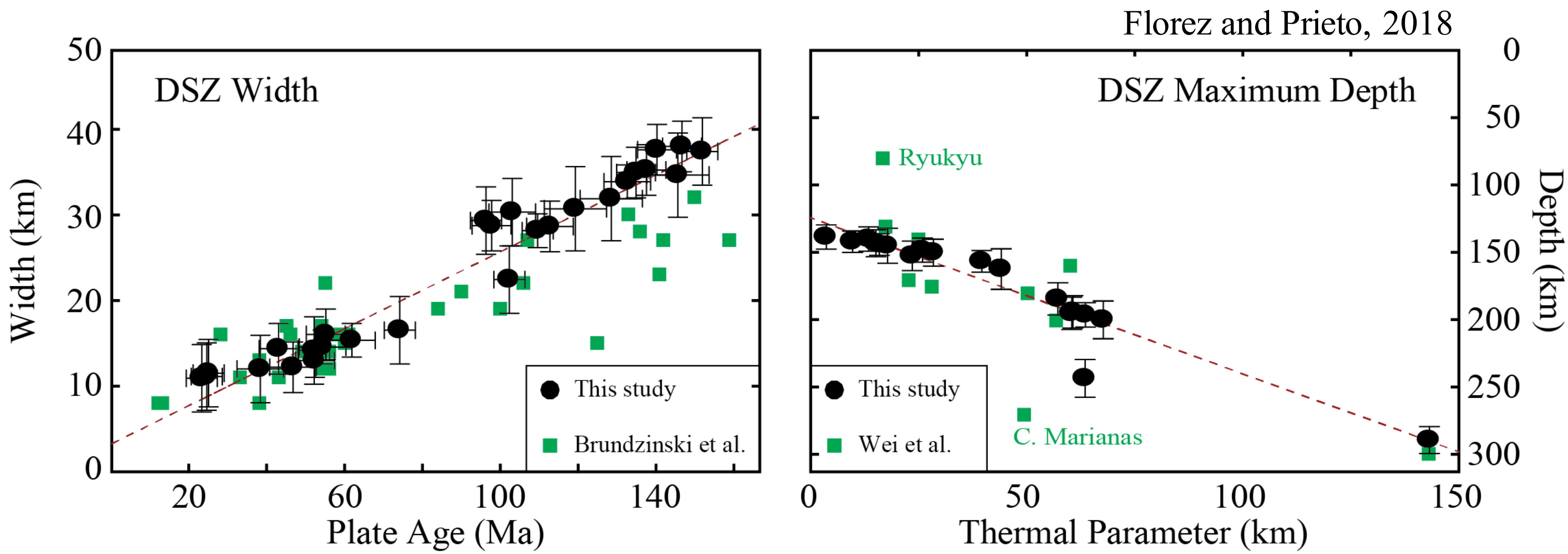

Plate age correlated with DSZ width

- Similar to Brudzinski, but wider for old plates.
- Suggest chlorite not antigorite dehydration?

Thermal parameter correlates with maximum depth

- Deeper DSZ in colder slabs
- Slab temperature controls dehydration?

Characterizing Seismicity along DSZs

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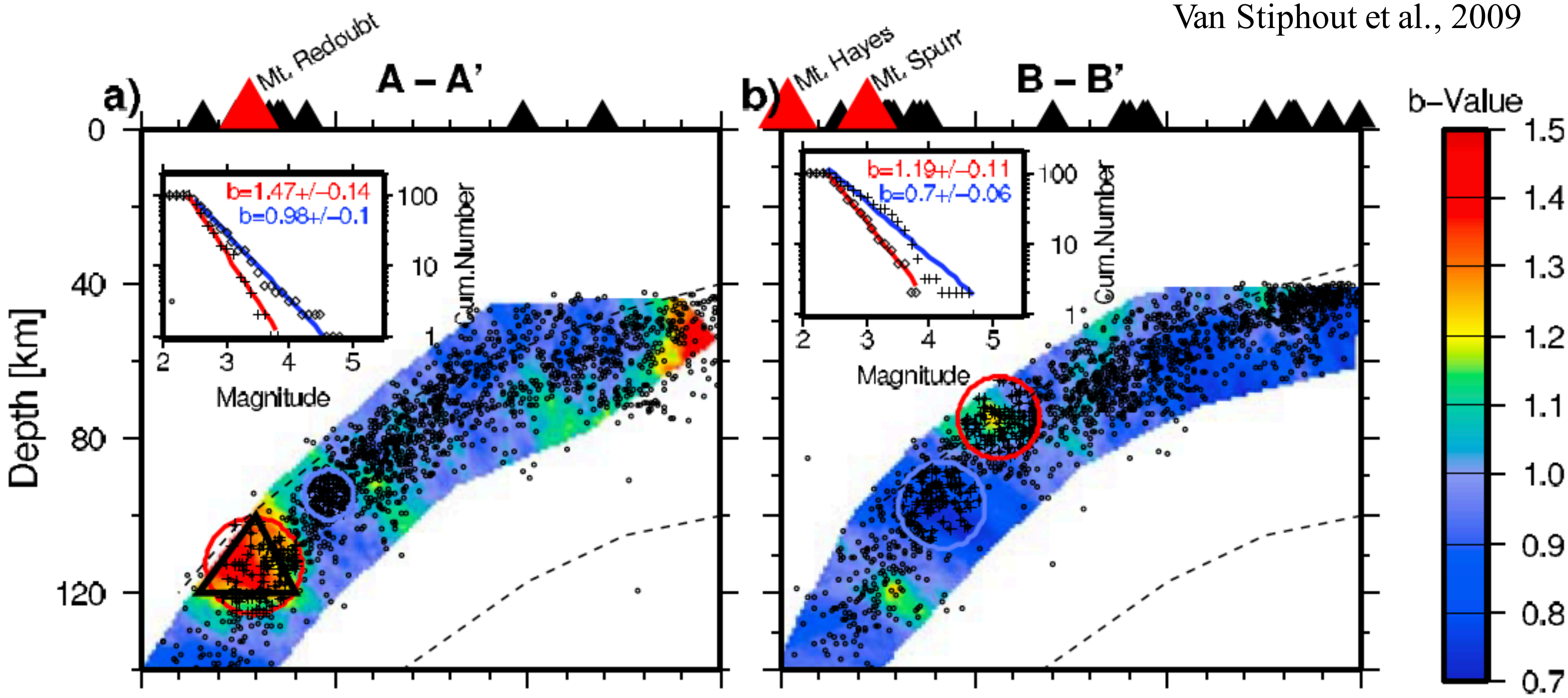
Seismicity, b-value, and water content

- ***b***-value characterizes the relative number of small compared to large earthquakes and *correlates* negatively with *differential stress*.
- Along subduction zones, b-value anomalies interpreted as regions with active dehydration.

Van Stiphout et al., 2009



Alaska

Characterizing Seismicity along DSZs

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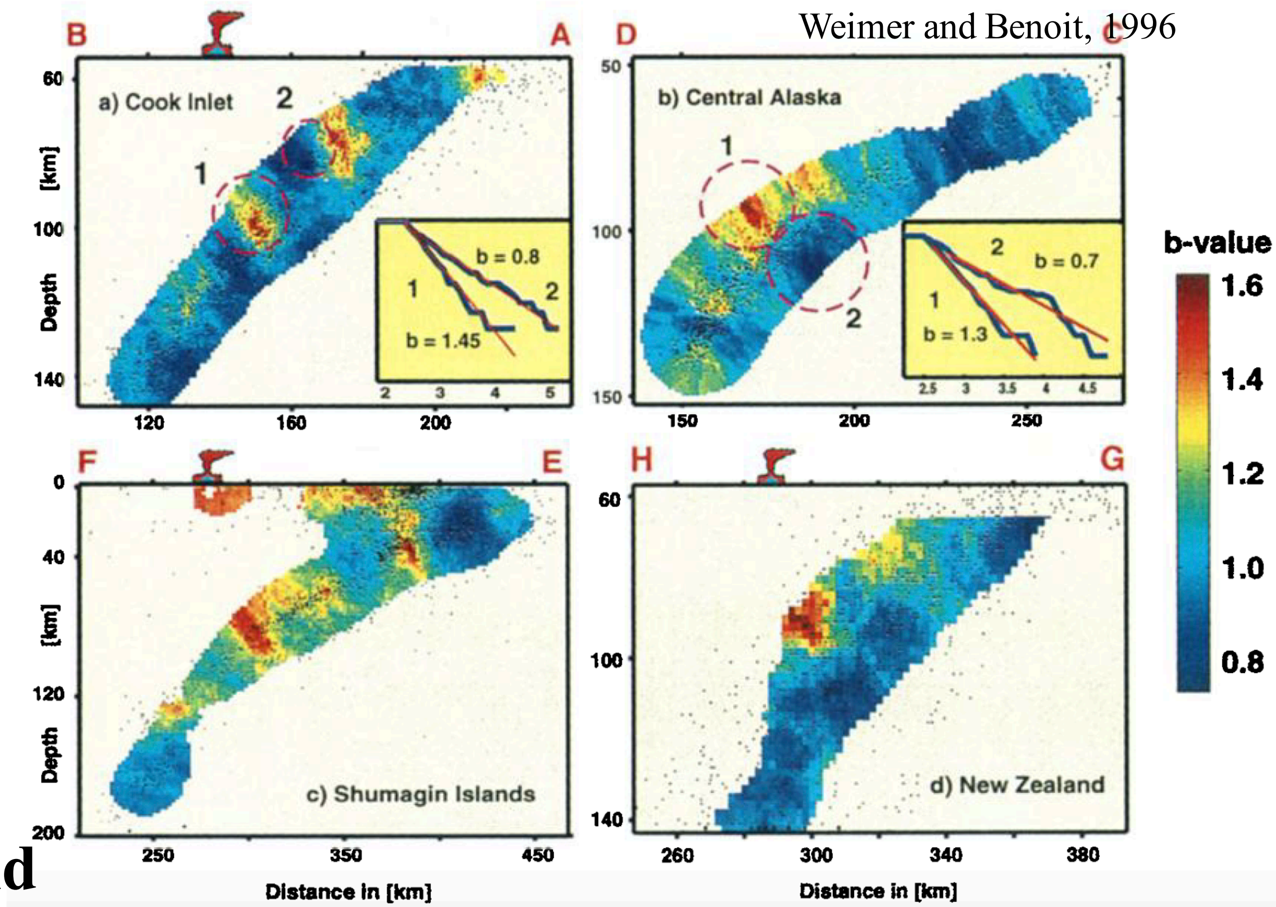
Weimer and Benoit, 1996



Alaska & New Zealand

Characterizing Seismicity along DSZs

Seismicity, b-value, and water content

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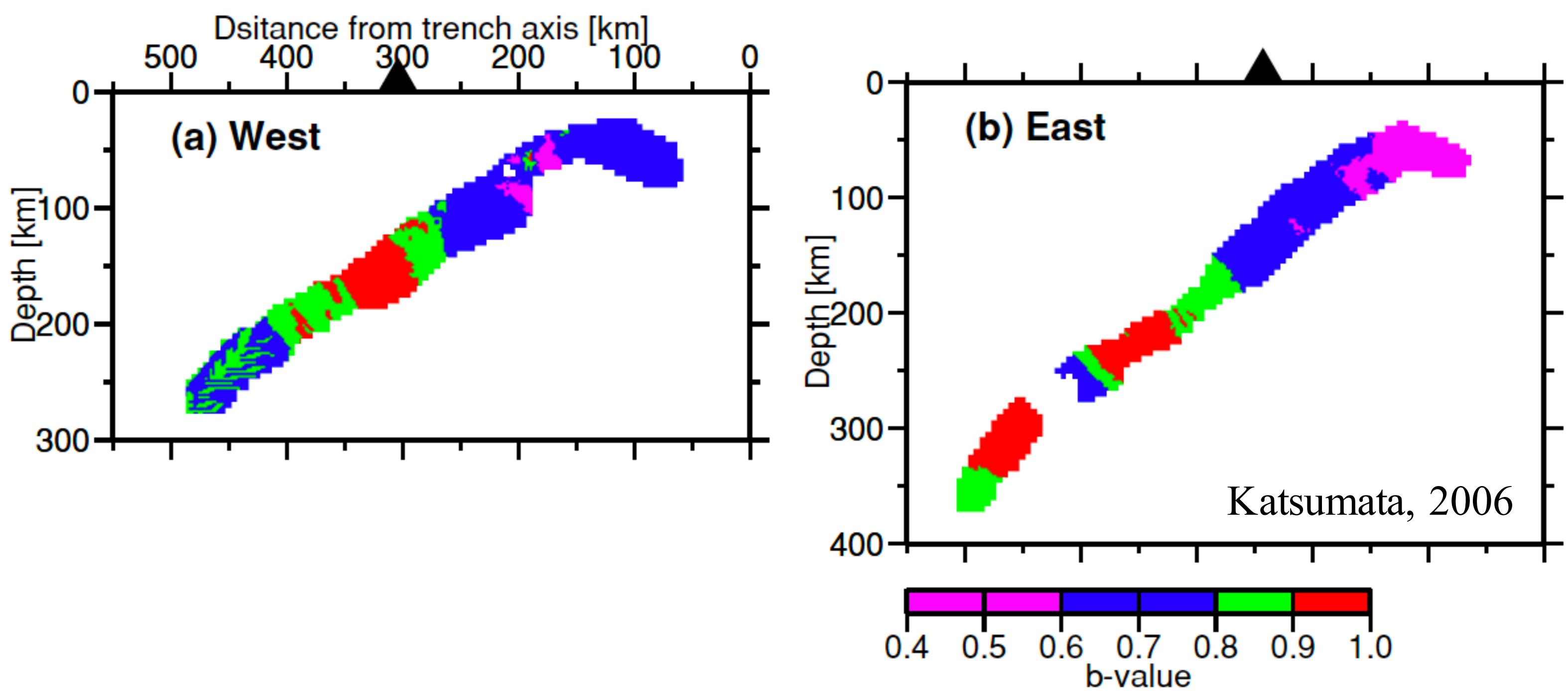

Hokkaido

Characterizing Seismicity along DSZs

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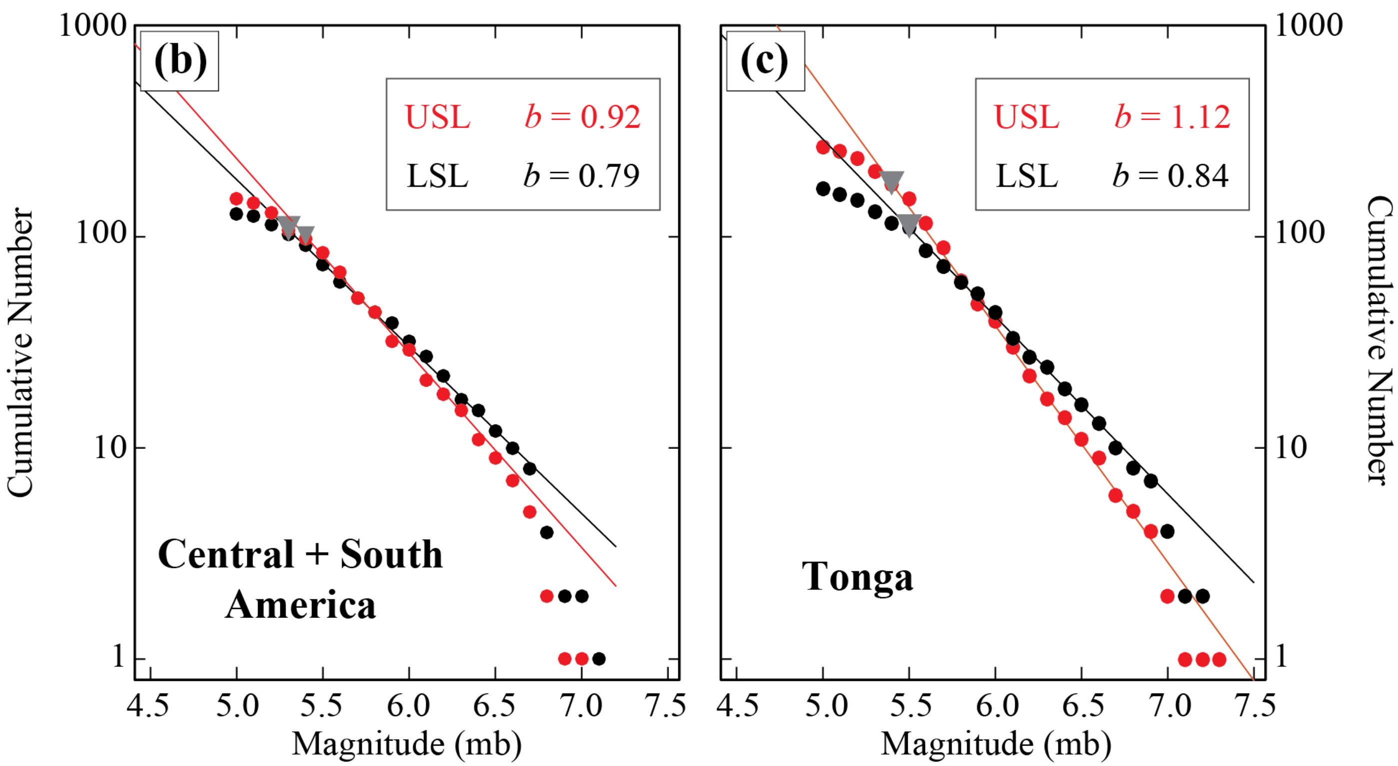
Seismicity, b-value, and water content

- We calculate *b*-values for upper (USL) and lower (LSL) seismic layers separately in each slab segment



Florez and Prieto., 2018

Characterizing Seismicity along DSZs

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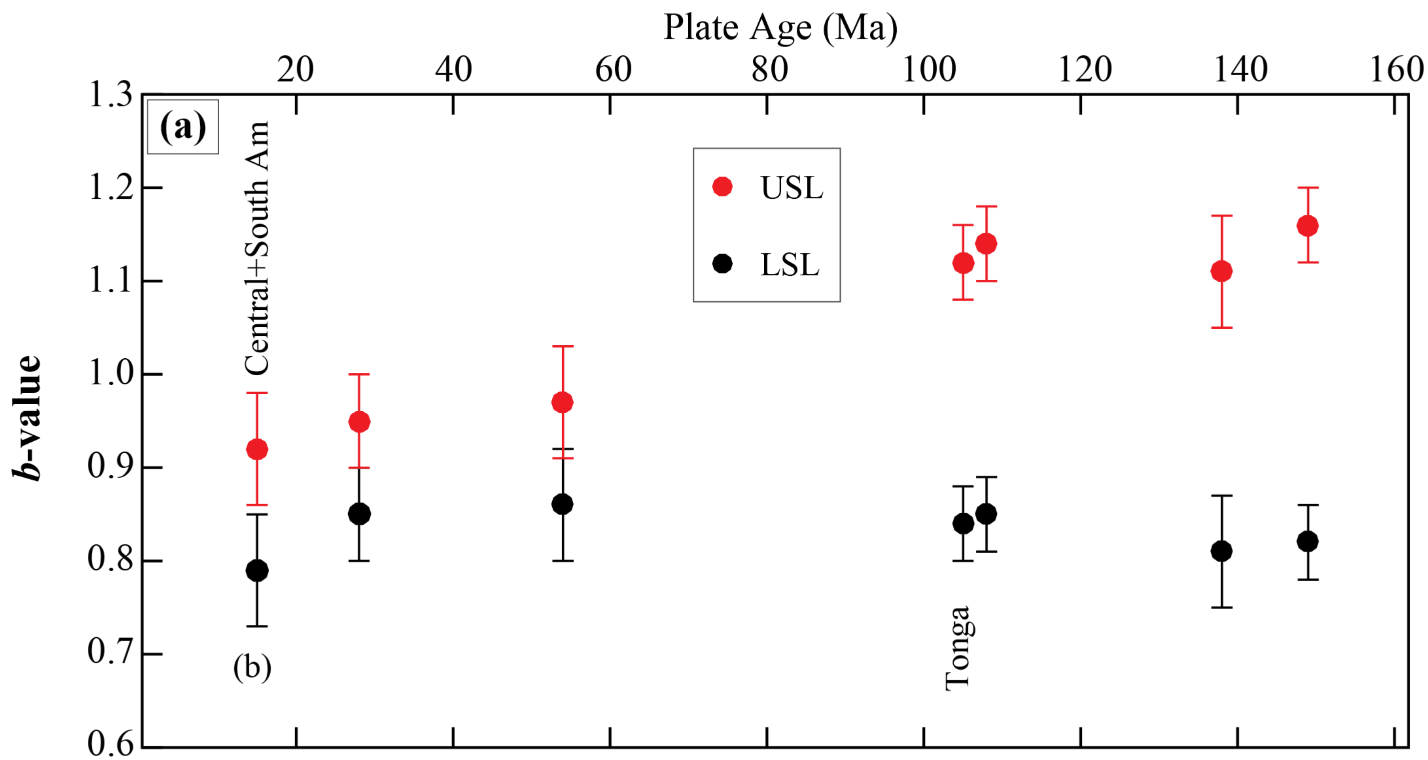
Seismicity, b-value, and water content

Florez and Prieto., 2018



USL has consistently higher *b*-values, age dependent

Our results are consistent with **dehydration operating in the upper layer**, but point to a relatively **dry lithospheric mantle**

Characterizing Seismicity along DSZs

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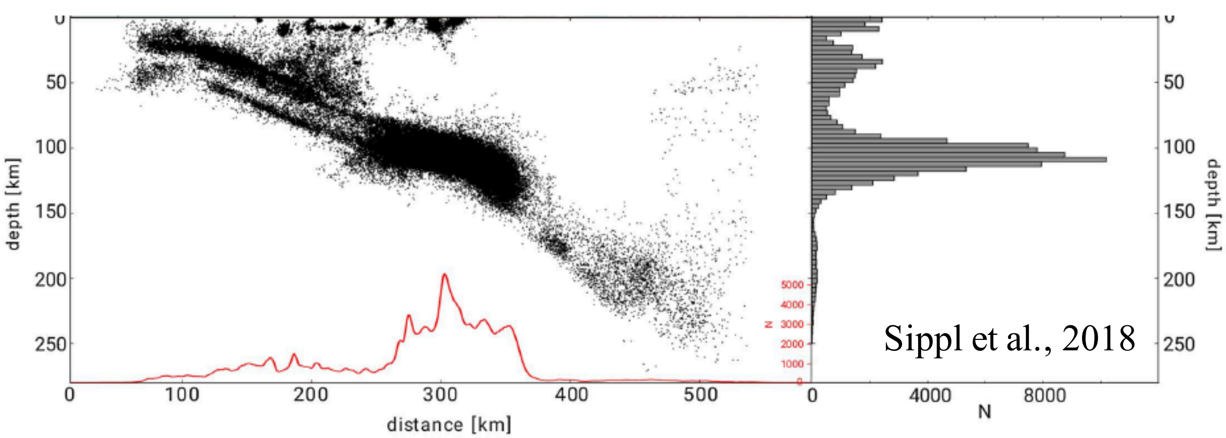
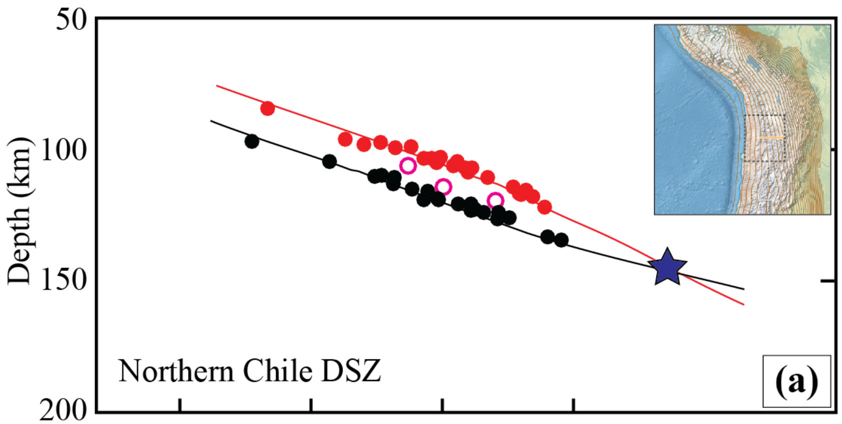
Seismicity, aftershocks and aftershock productivity

- ***Aftershocks are less common in intermediate-depth earthquakes (Bucaramanga, Hindu-Kush, Wyoming, …)***
- Is aftershock behavior different in USL and LSL?





Characterizing Seismicity along DSZs

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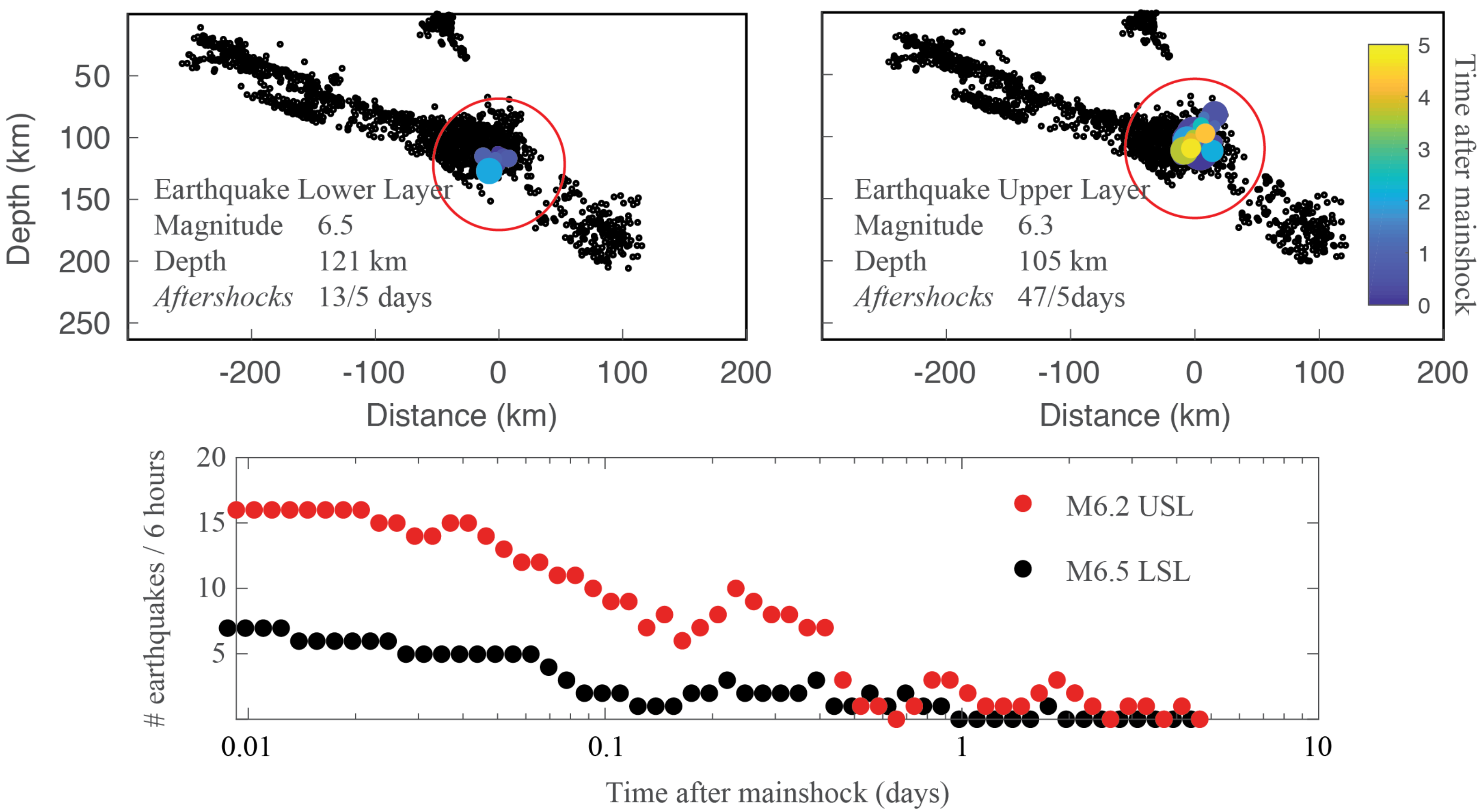

Characterizing Seismicity along DSZs

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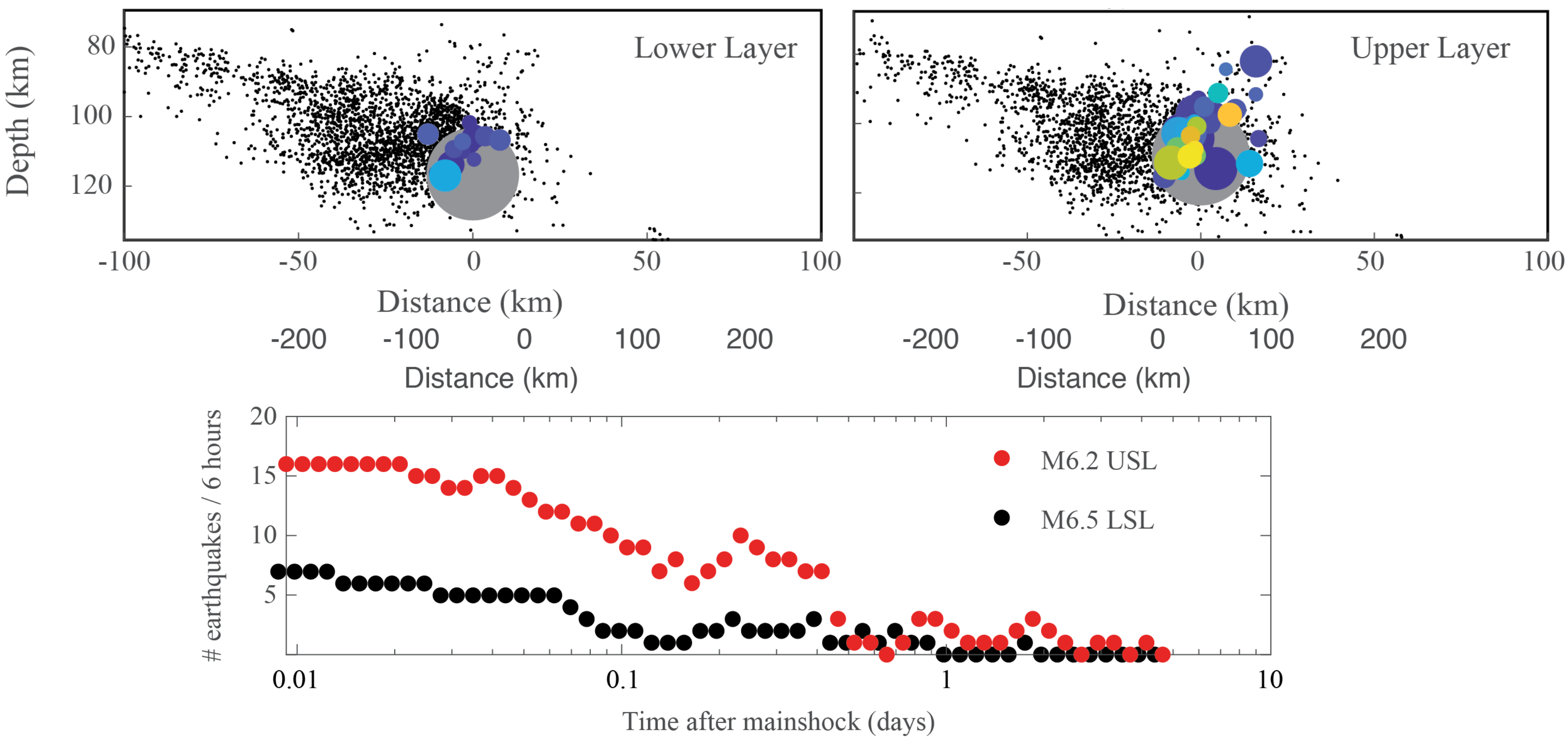

Characterizing Seismicity along DSZs

Seismicity, aftershocks and aftershock productivity

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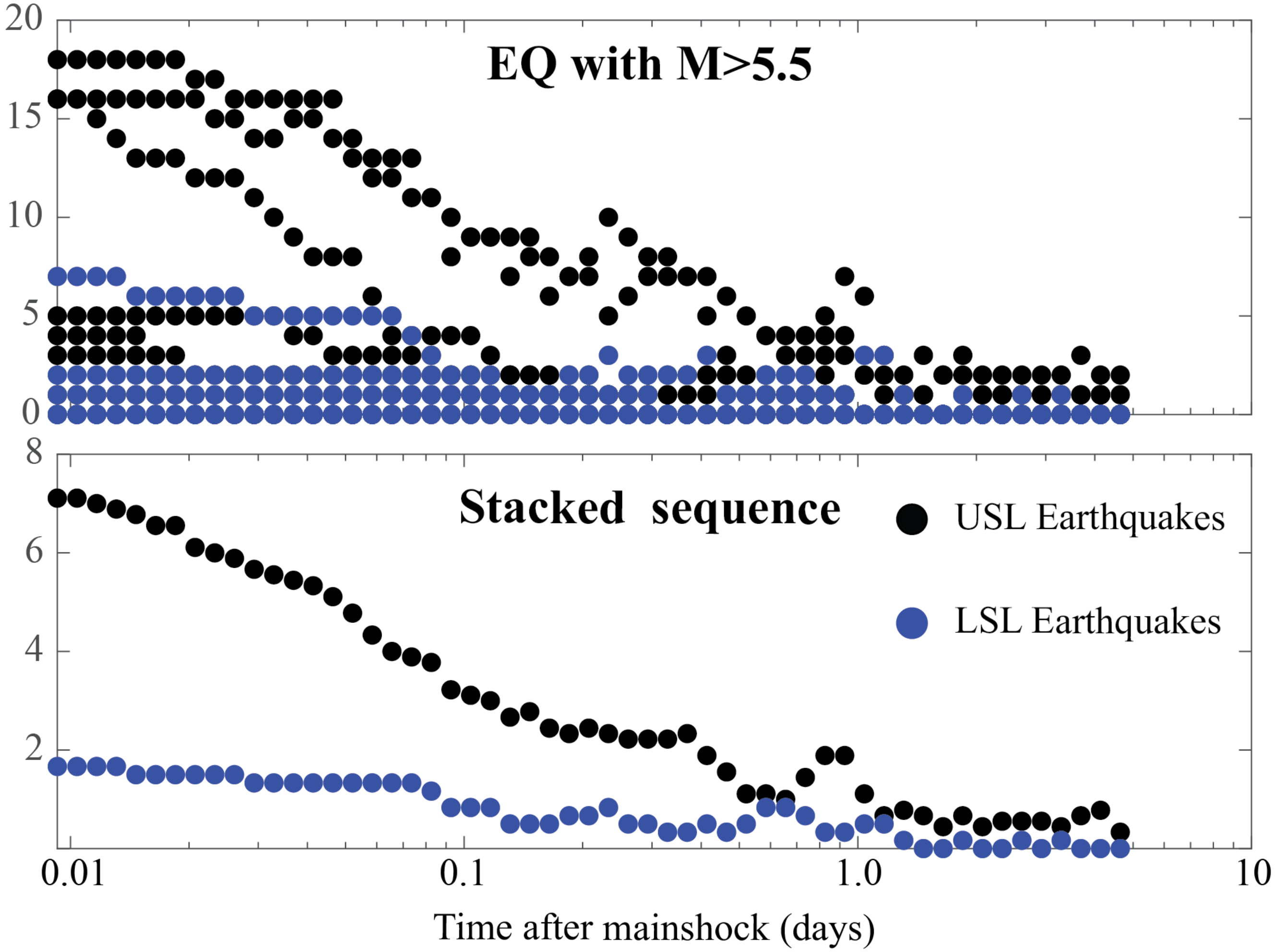
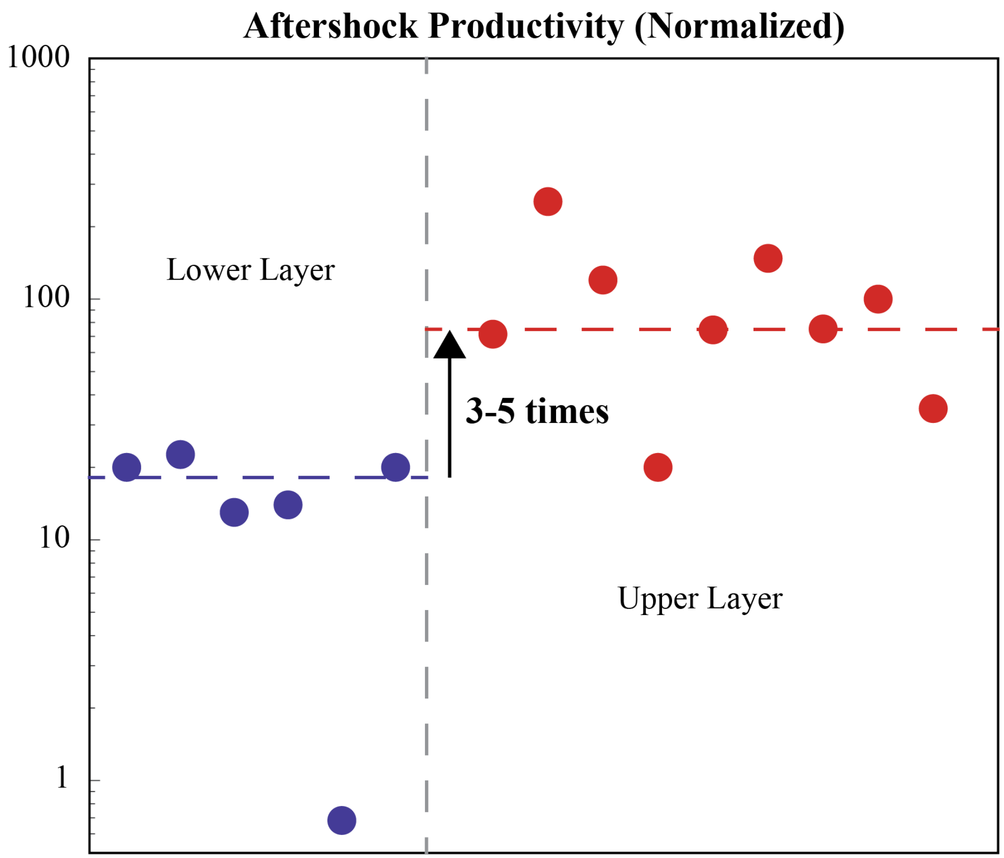


Most LSL earthquakes have no or few aftershocks.

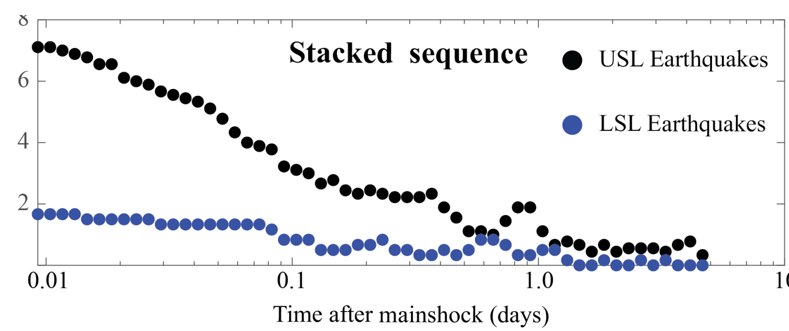
USL aftershock sequences are more clear and more productive.

Seismicity, aftershocks and aftershock productivity



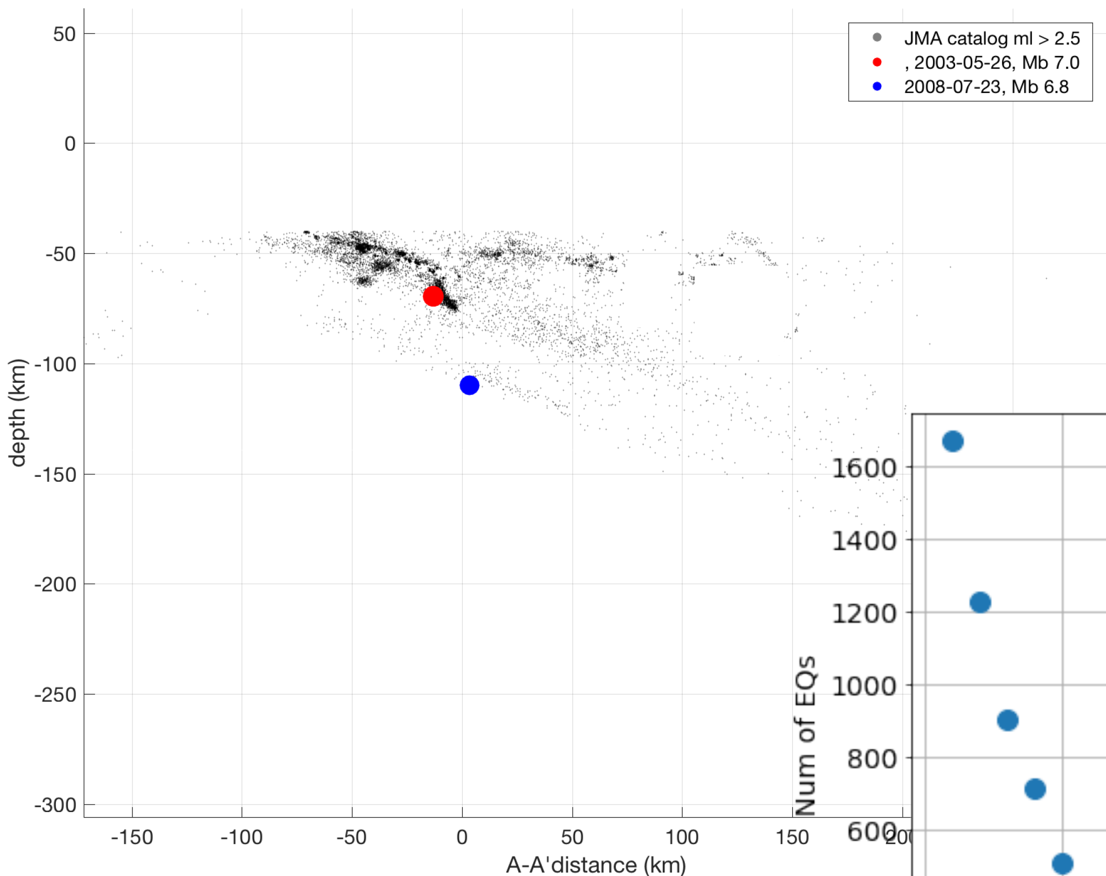
Aftershock productivity normalization

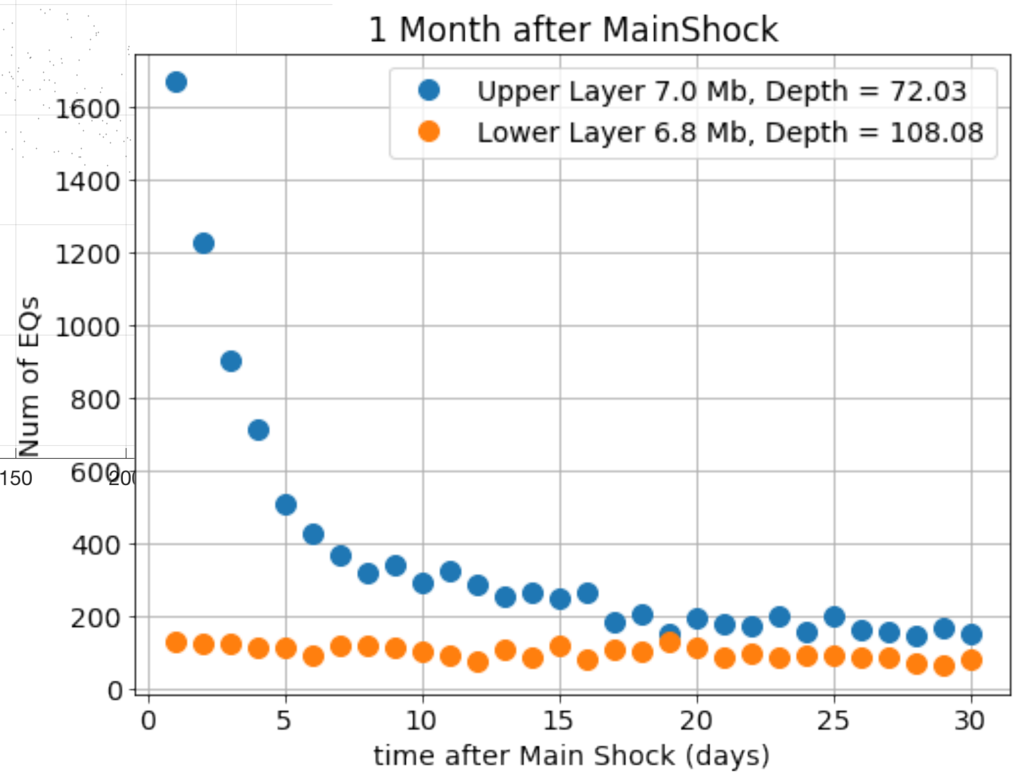
$$\log N_{\mathrm{norm}} = \log N_{\mathrm{obs}} + 8.2 - M_{\mathrm{W}},$$



Aftershock sequences and productivity are higher in USL.
Agreement with b-value results, mechanism is different.

An example from Japan





Conclusions

Seismicity behavior along DSZ points towards different mechanism in crustal and mantle earthquakes

- ***b*-values** consistently different. Dehydration in upper layer, dry mantle.
- ***Aftershock sequences*** with lower productivity in LSL. Sequences are not as clear.

- **What other seismic observables** may provide a constrain on the mechanism?
  - Are stress drops different? (Japan, Katsumata, 2015)
  - STF differences (e.g., SCARDEC)
  - Rupture velocity? Rupture directivity?

Other examples

Thank you