Up-dip Locking at Cascadia: How far does it go?

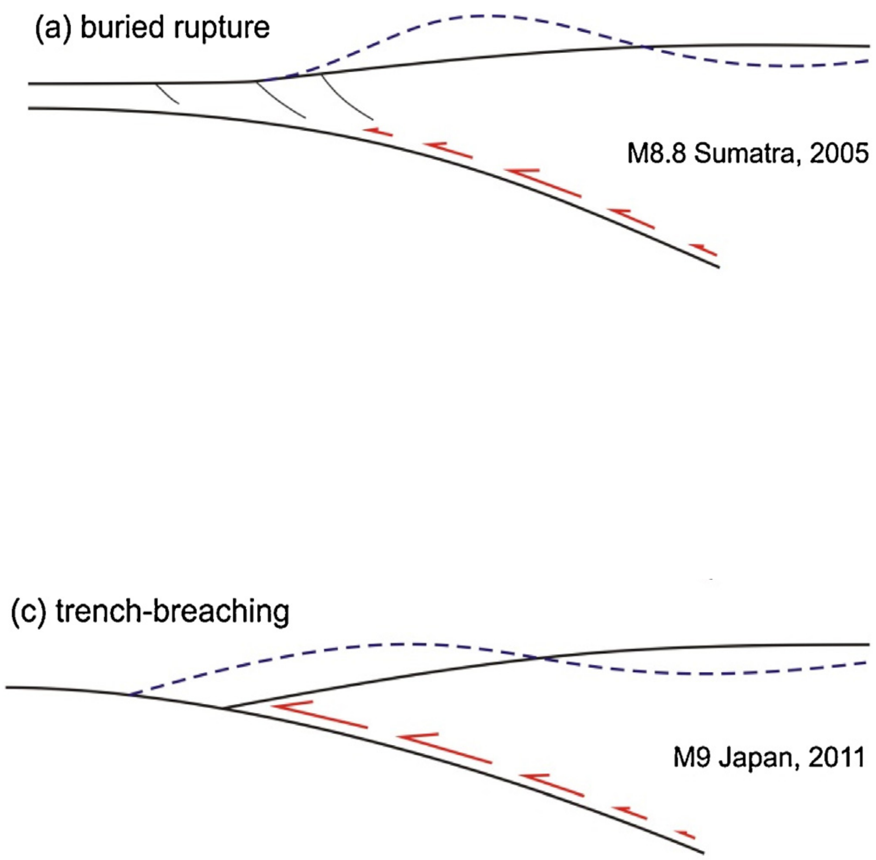
Shallow rupture and locking has implications for both total moment and tsunamigenesis

Questions:

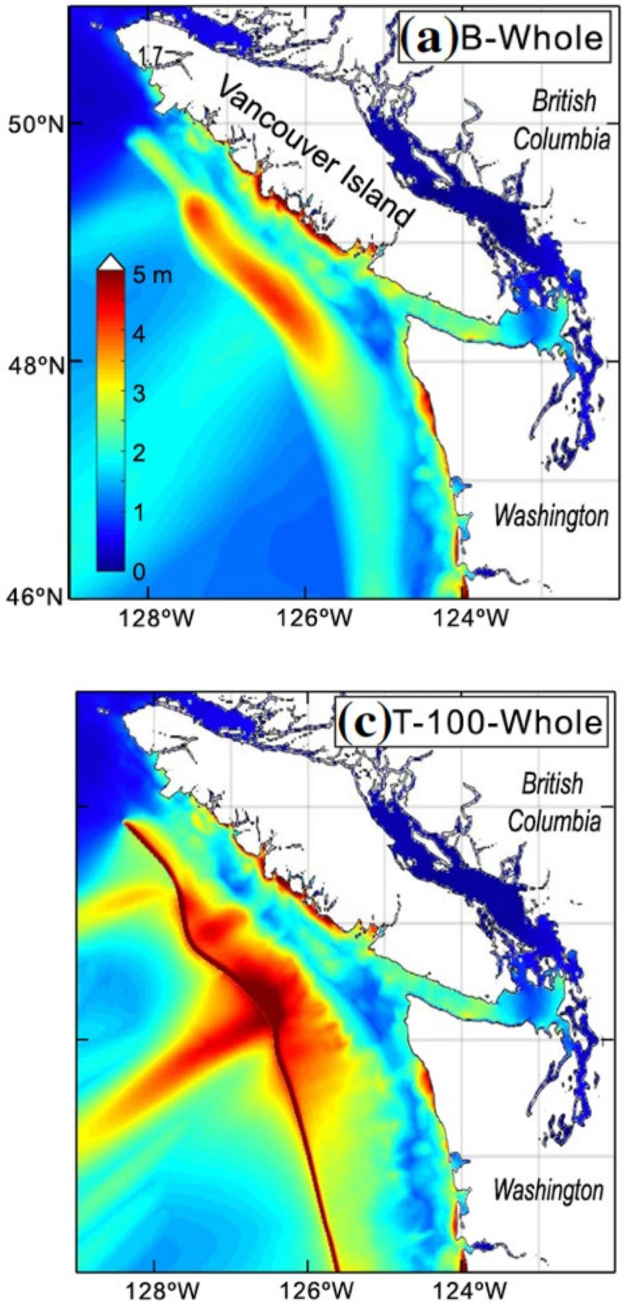
Where is the zone of frictional locking?

What is the up-dip limit of seismogenesis?

What barrier does the up-dip zone present for slip propagation?

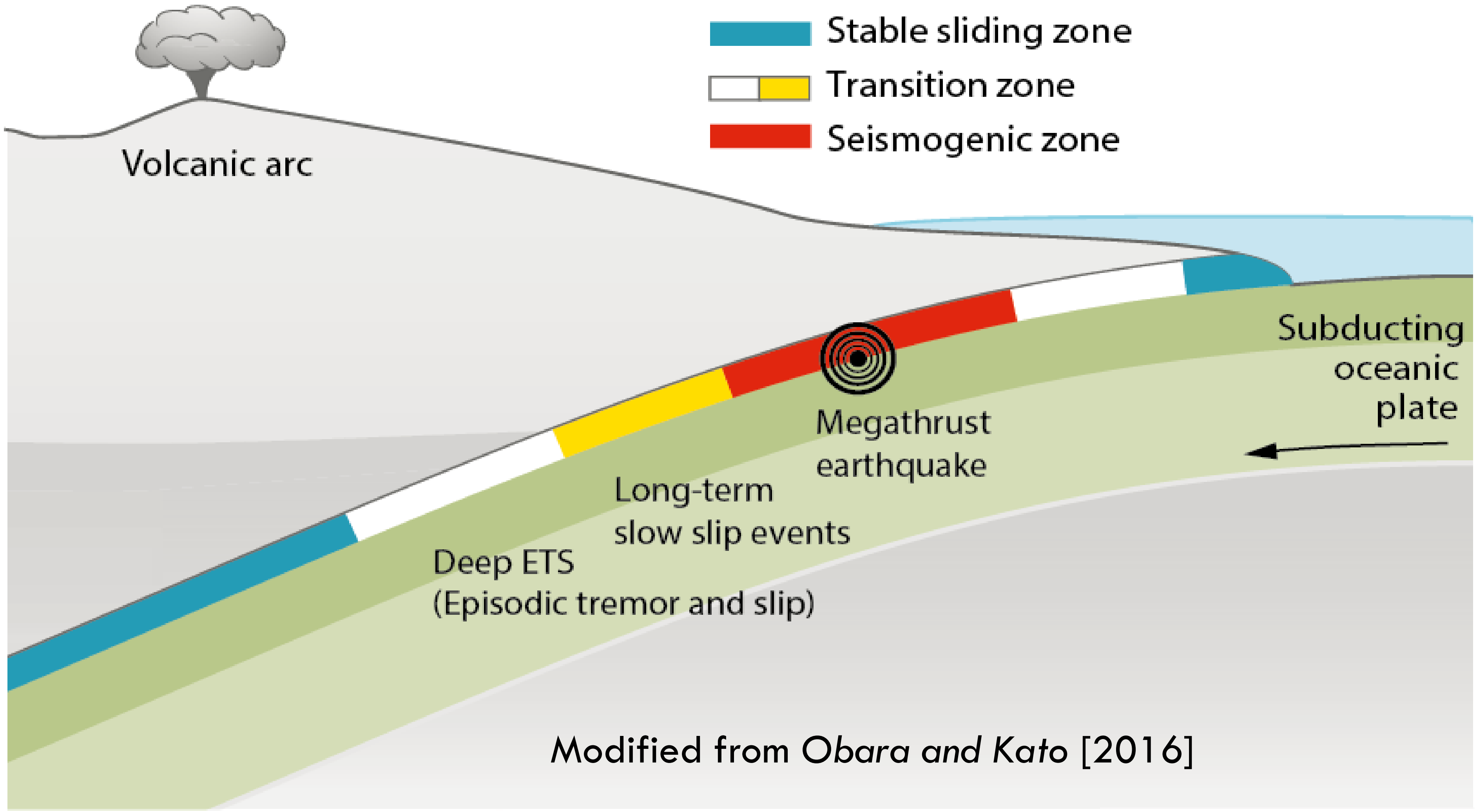


Wang and Trehu, 2016



Gao et al., 2018

Prevailing Paradigm: Seismogenic zone flanked by aseismic, stable slip zones down-dip and up-dip



Modified from *Obara and Kato* [2016]

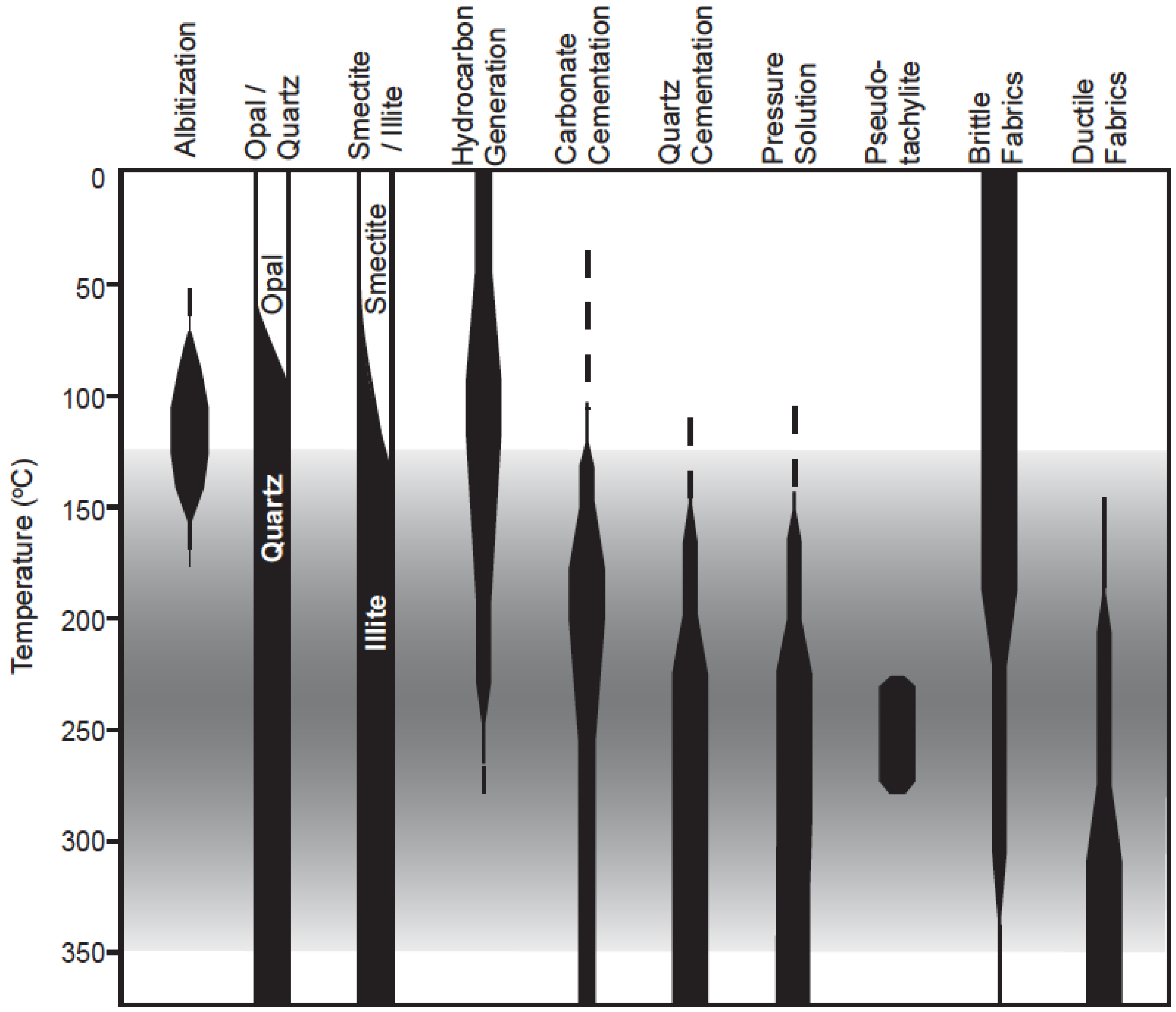
What controls frictional locking behavior of the shallow subduction zone decollement?

- Lithification and cementation
- Fault-normal stress magnitude (burial)
- Pore fluid pressure
- Wall-rock strength (compliance) especially the upper plate

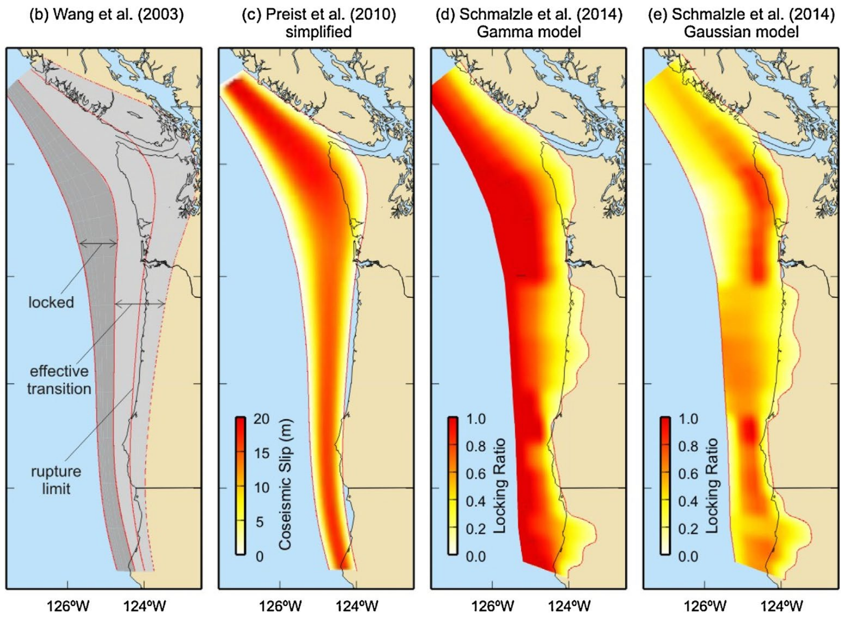
What evidence is there for each in the main locked patch of Cascadia?

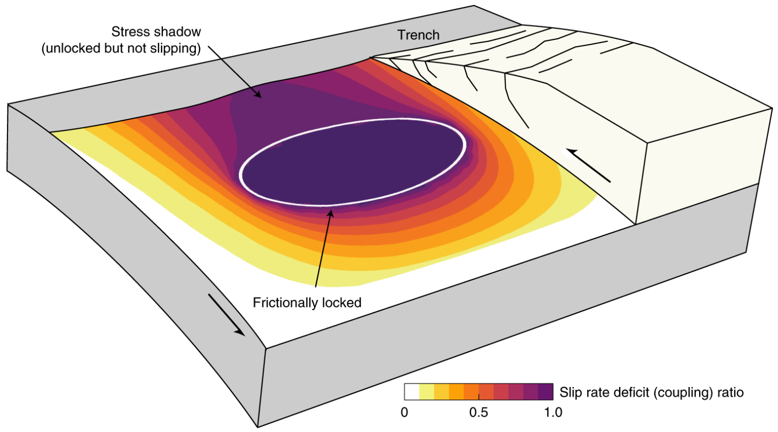
Mineralization and fluid sources change with temperature in typical s.z. sediments

→ *~100 - 150˚ C is a major transition for many processes*



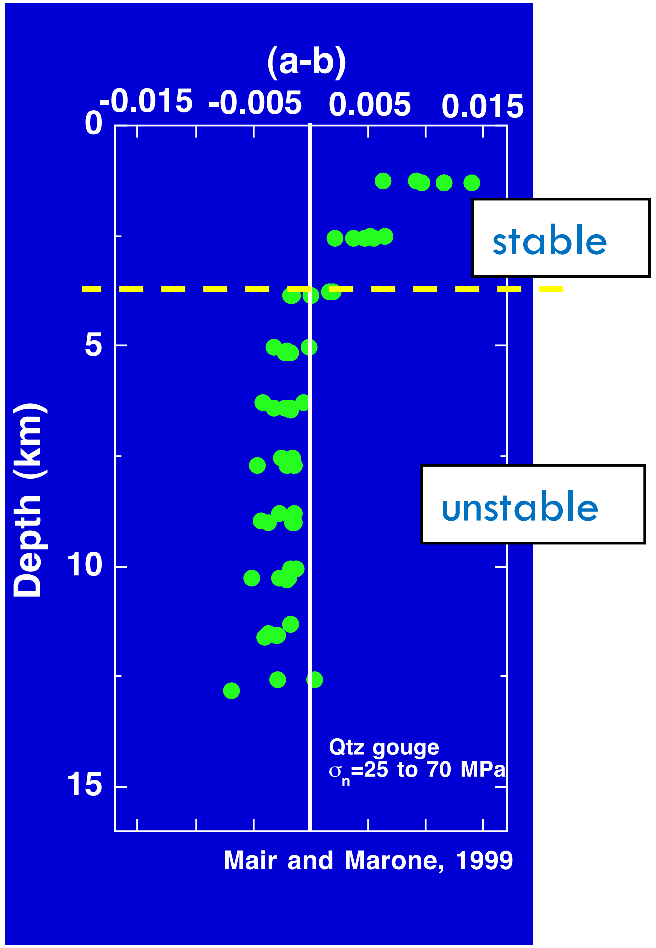
Moore, 2007

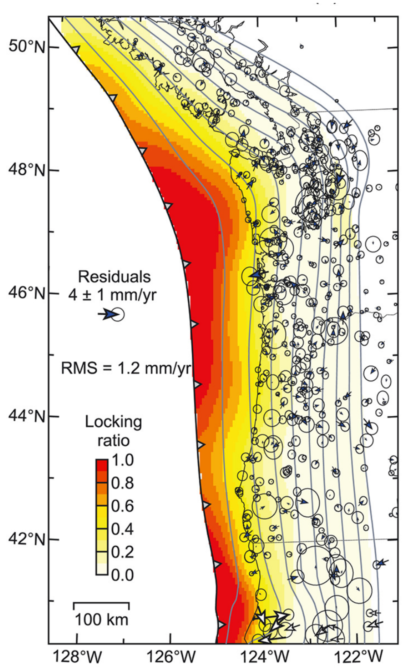




Lindsey et al., 2021

Rate-state friction parameter a-b





Li et al., 2018

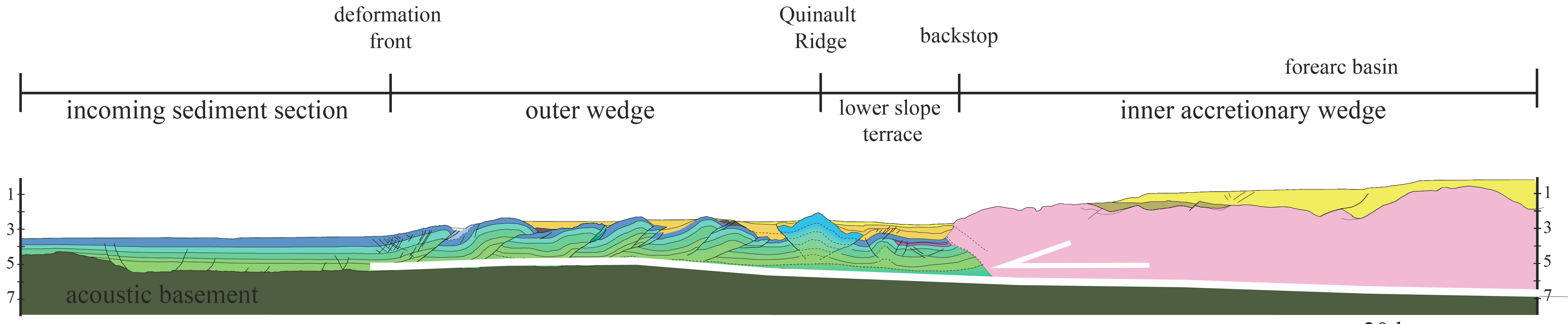
Geodetic locking models to date don't distinguish shallow locking.

Shallow apparent pseudo-locking could be due to the "stress shadowing effect" (see Lindsey et al., 2021).

Addressing this from a frictional stability perspective:

How likely is the fault near and at the deformation front to be locked and accumulating strain?

What do we mean by "slip to the trench?"

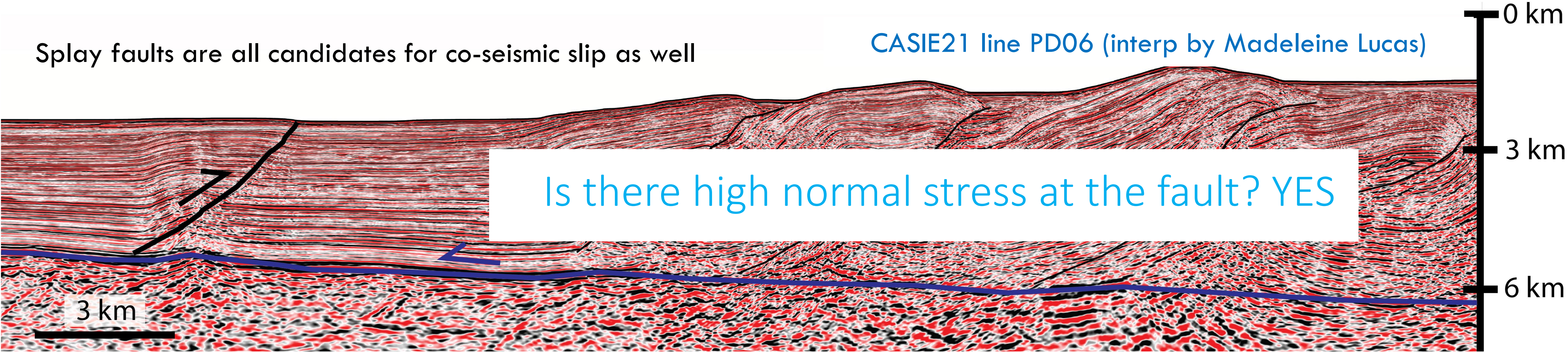


COAST line 4 off Grays Harbor region (Webb, 2017)

Decollement is the plate boundary, and lies **~3 km** below the surface <u>right at the deformation front</u>

Splay faults are all candidates for co-seismic slip as well

CASIE21 line PD06 (interp by Madeleine Lucas)



Is there high normal stress at the fault? YES

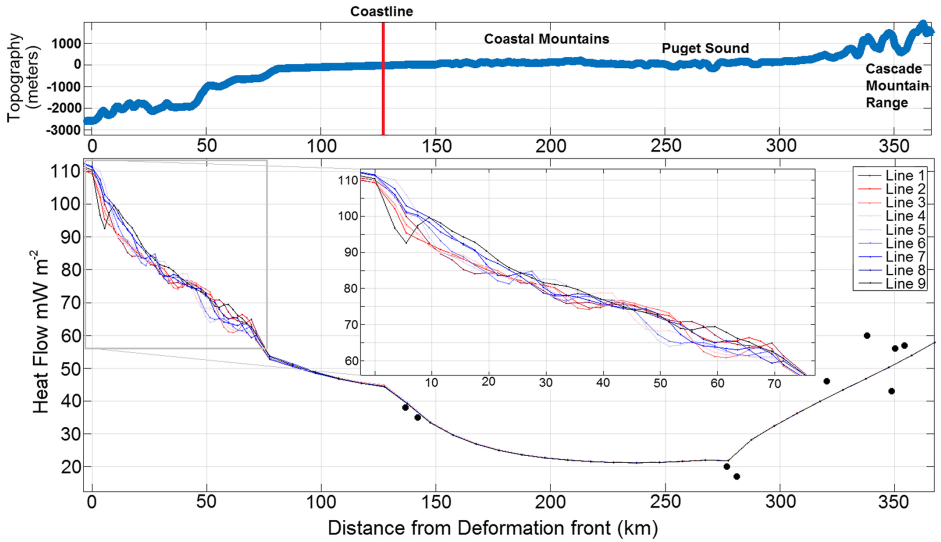
Is it hot? *YES*

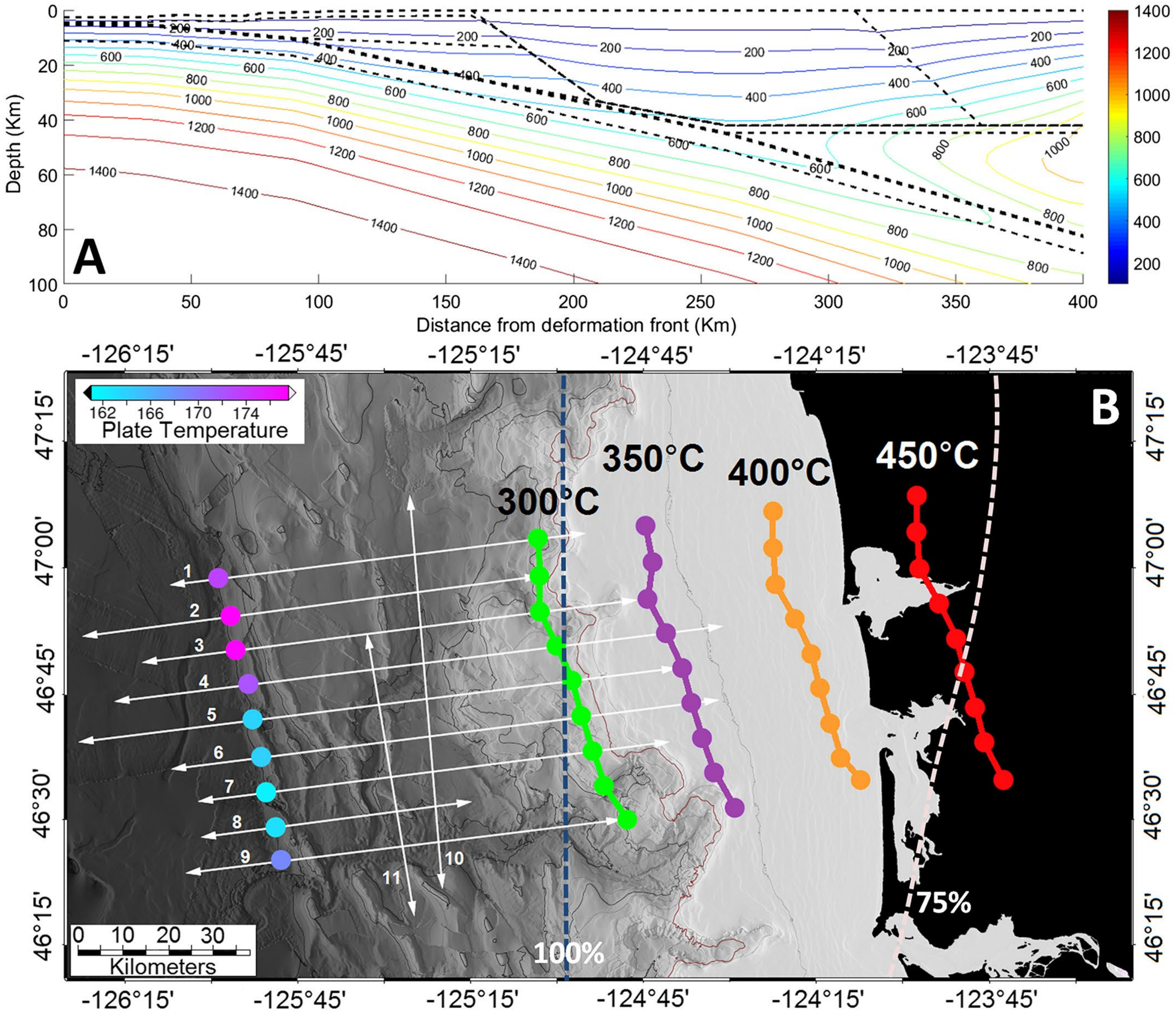
Cascadia thermal models agree that the temperature at the base of the sediment section at the front exceeds ~150°C

Salmi et al. (2017) heat flow data and BSR derived temperature gradient estimates to constrain a thermal model

→ At the DF, **T = ~170°C**

→ Heat flow = **110 mW/m^2**

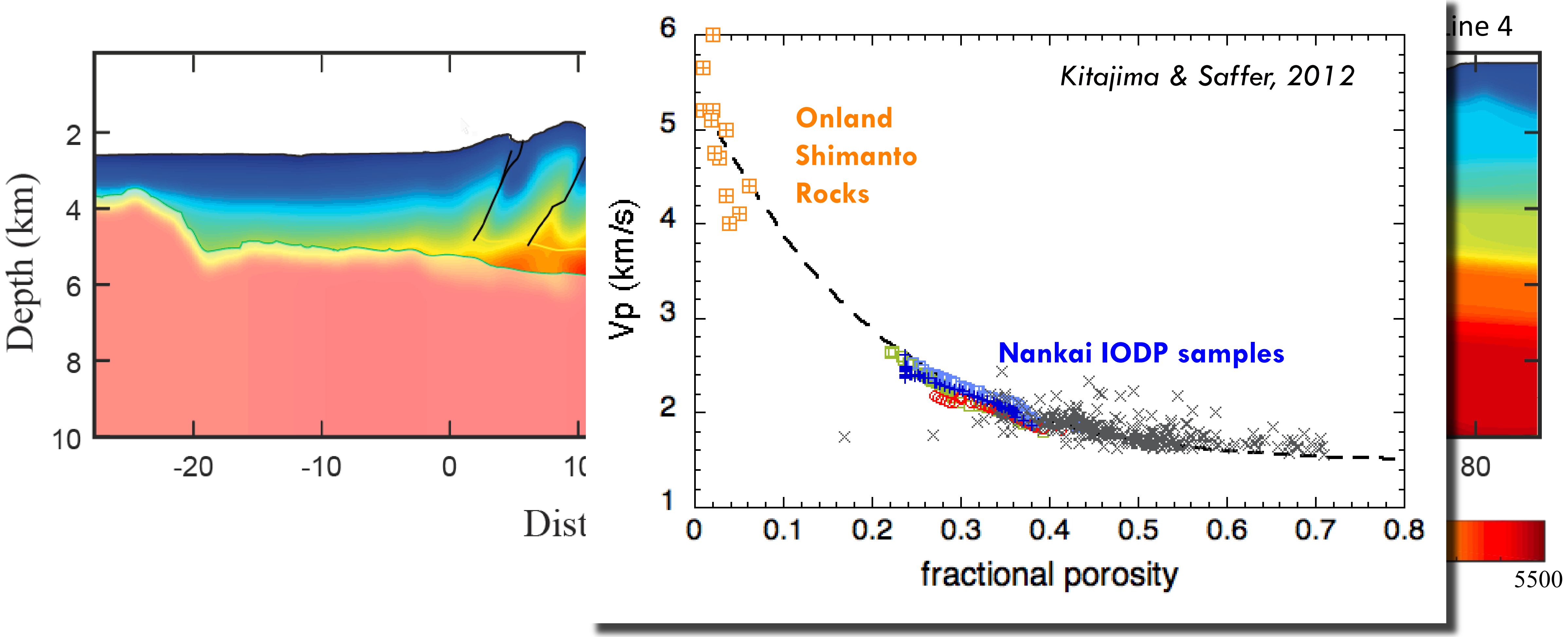




Salmi et al., 2017

Are the rocks lithified? *YES*

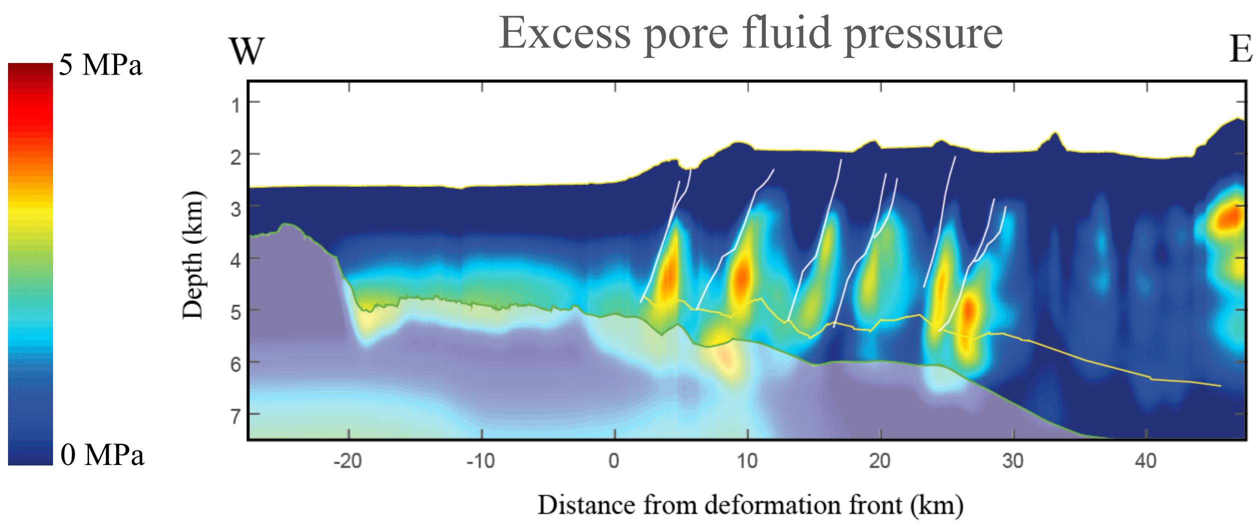
Seismic interval velocity from horizon-based tomography for Prestack Depth Migration



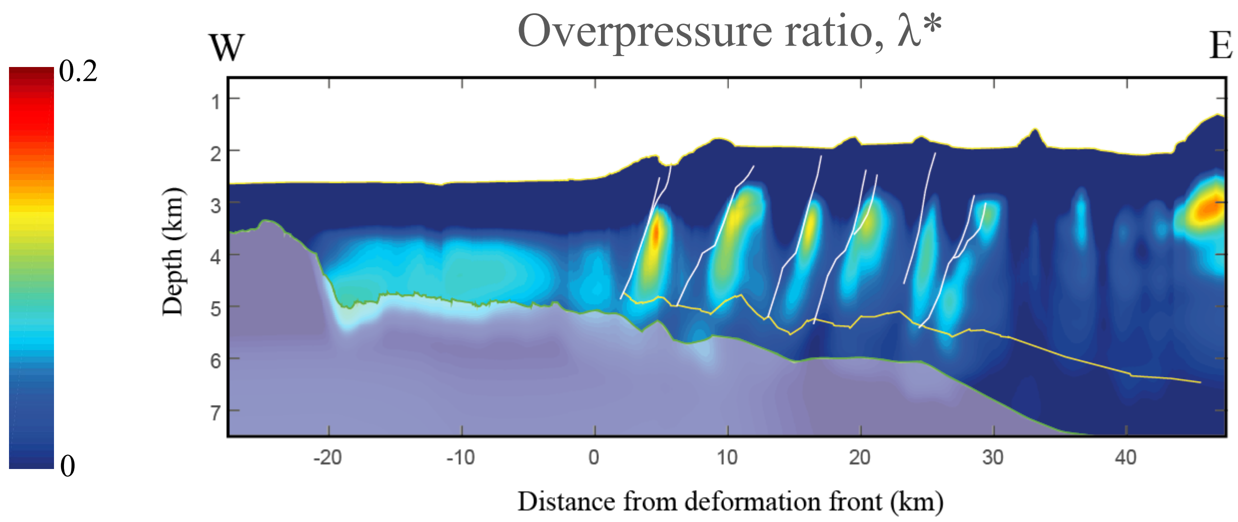
Decollement at the front is high Vp: $\geq 4000\ m/s$

PSDM by Susanna Webb, 2017

Is there pore fluid overpressure? *NO*



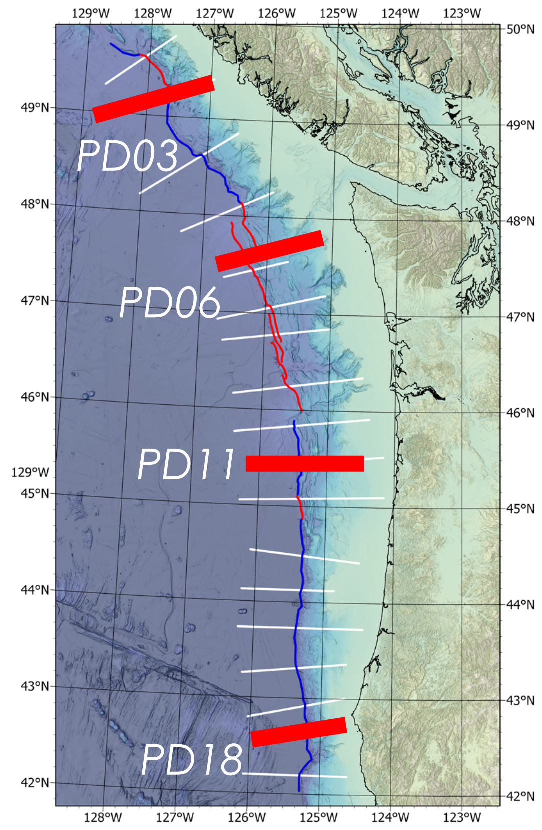
Evidence for only <u>very minor</u> overpressure at depth – close to hydrostatic

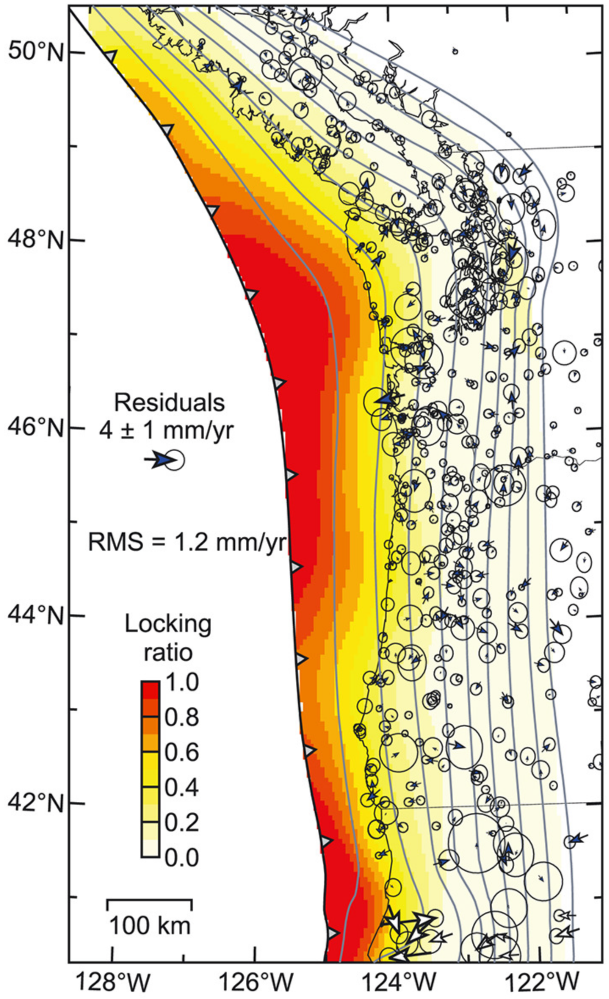


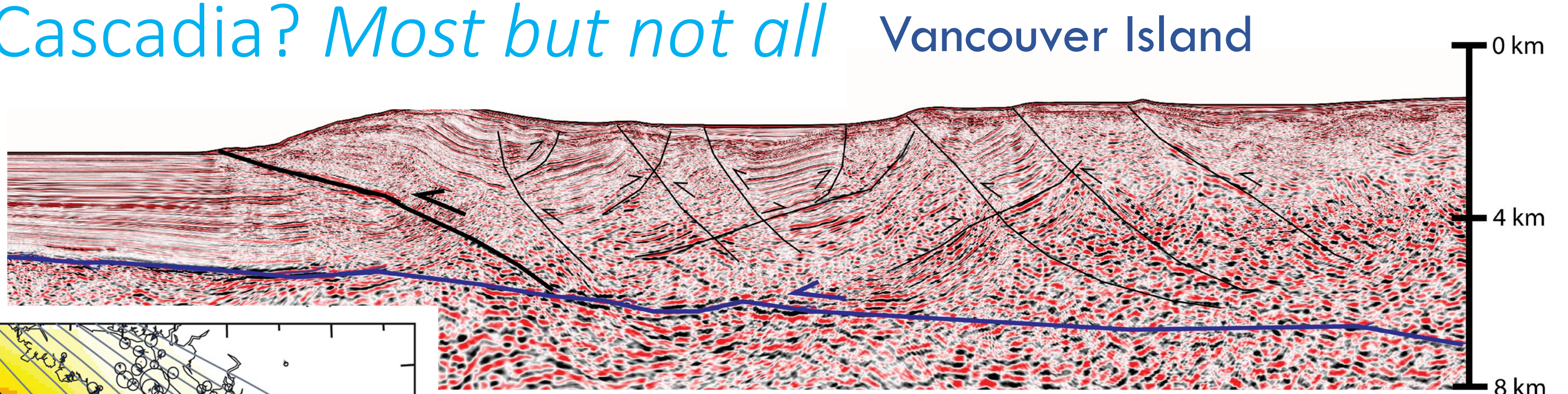
High seismic velocity, deep burial, normal pore pressure imply a <u>strong</u> wedge environment

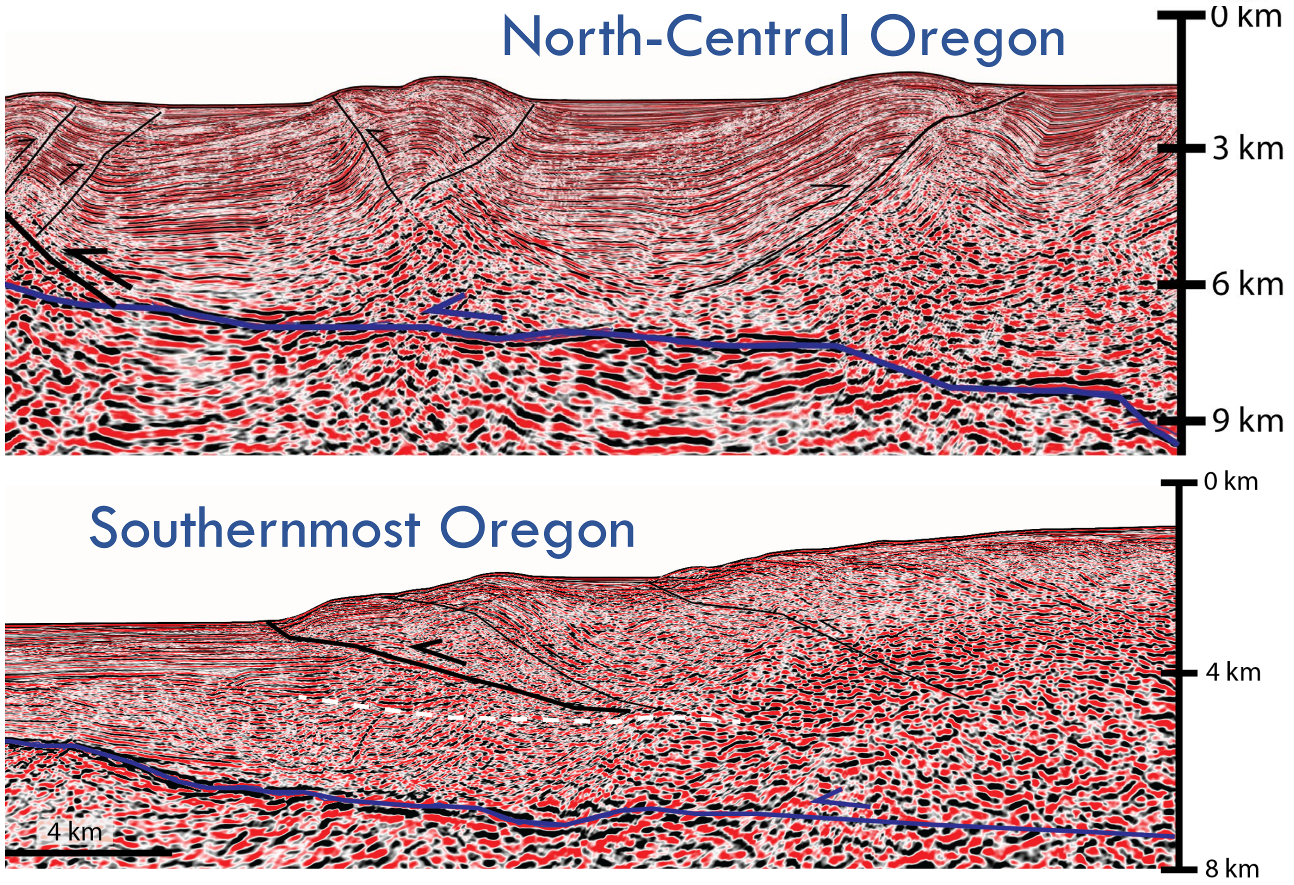
Consolidation analysis by S. Webb, 2017

Is this true for all of Cascadia? *Most but not all*

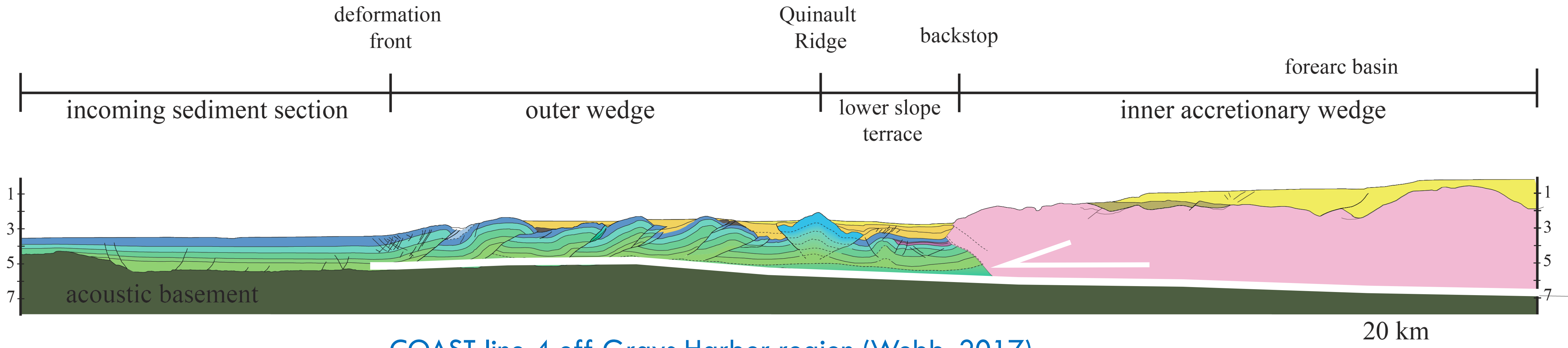








Strong rocks, high T, low pore pressure: *it quacks like a duck….*



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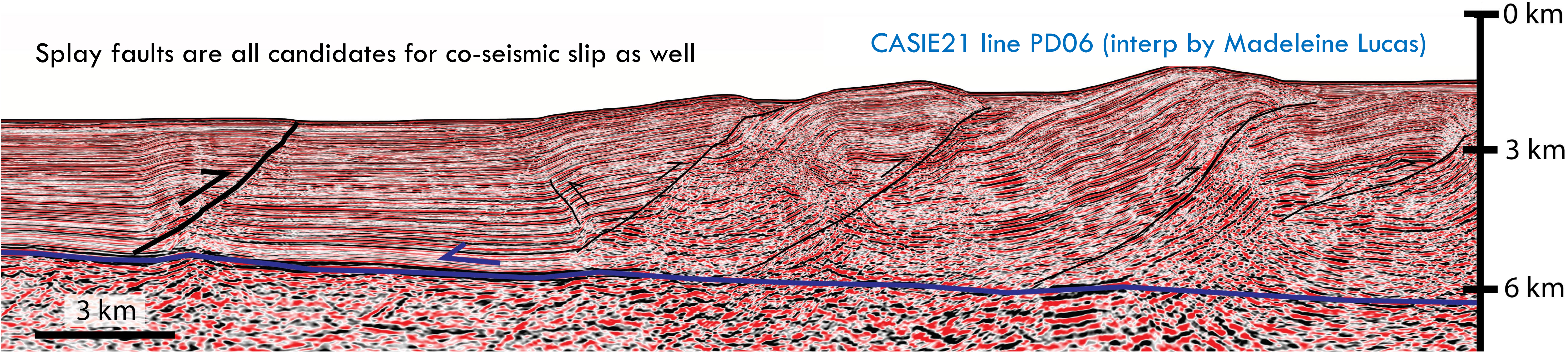
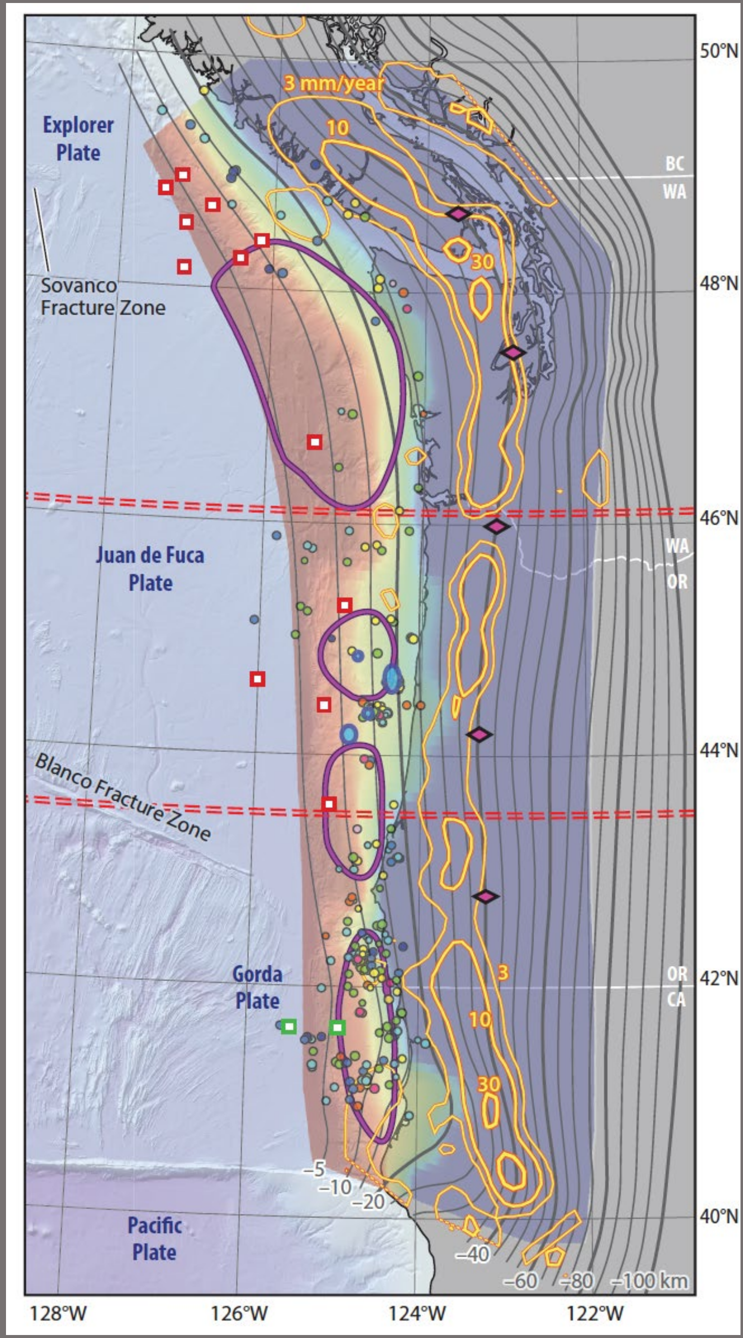


Takeaways

- At the deformation front, the Cascadia megathrust in the main apparent asperity is ~3 kilometers deep and at 170° C or more.
- There's little to no evidence for elevated pore pressure, seismic velocity is high, and porosity is low. It's rock, not sediment.
- For the quartz & feldspar (+clay) dominated lithology, conditions are therefore clearly met for likely frictional locking and rate-state instability.
- This is true of conditions on the splay faults at depth as well.
- Locking to the "trench" is much more likely than not … and slip to the "trench" is extremely likely.
- **Models that anticipate an up-dip stable or aseismic zone can be discounted.**



Walton et al., 2021