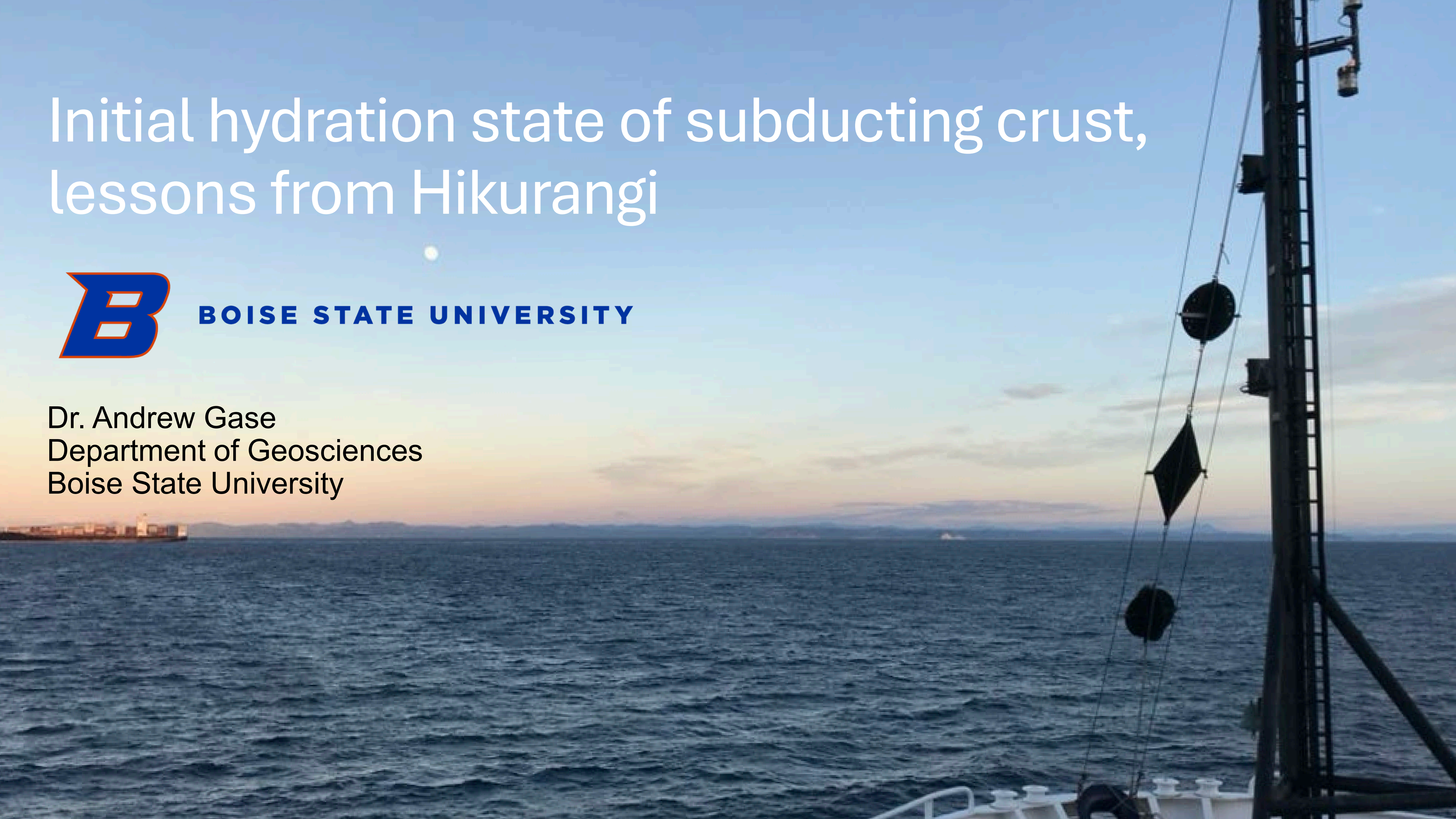
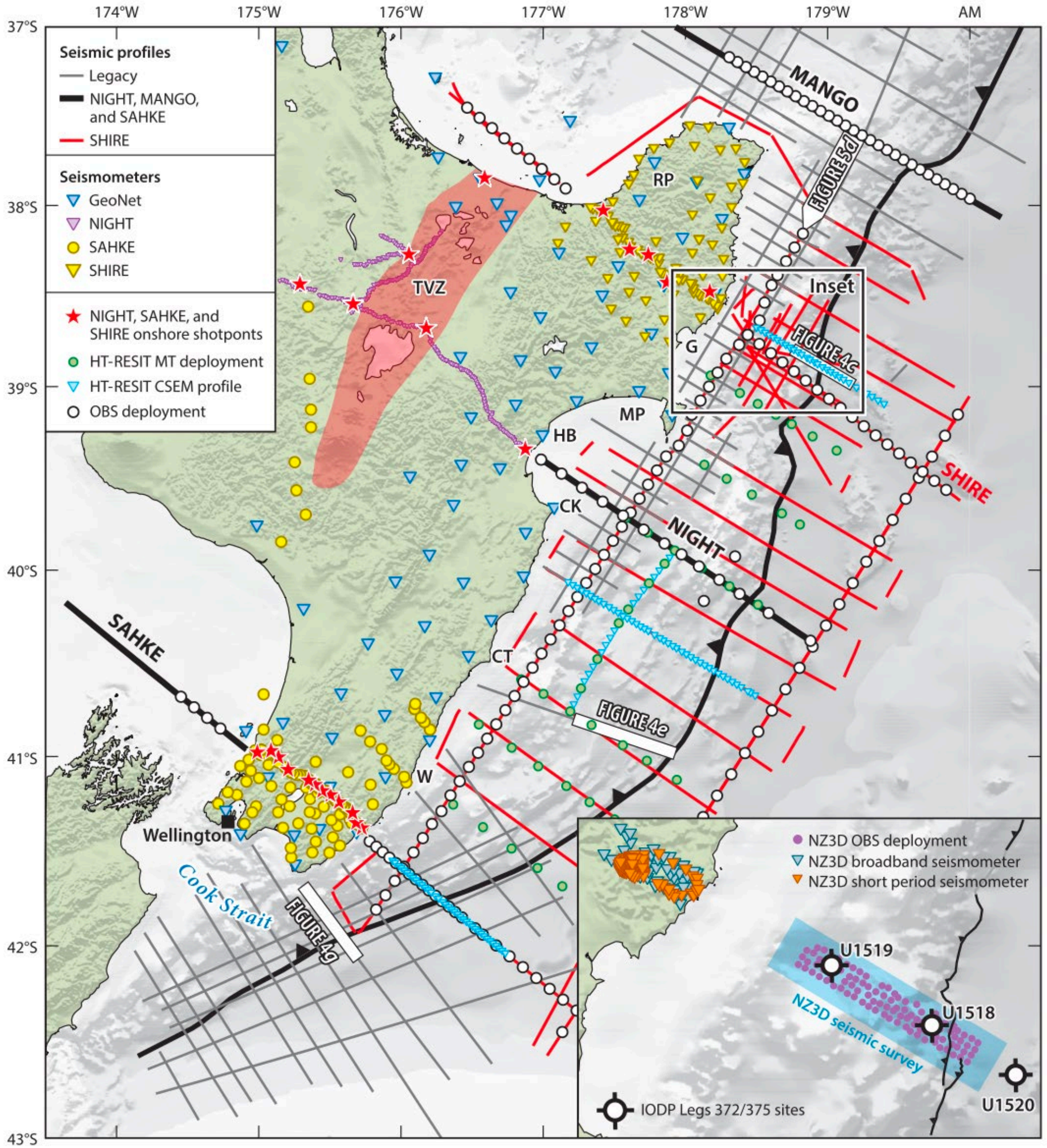
Initial hydration state of subducting crust, lessons from Hikurangi



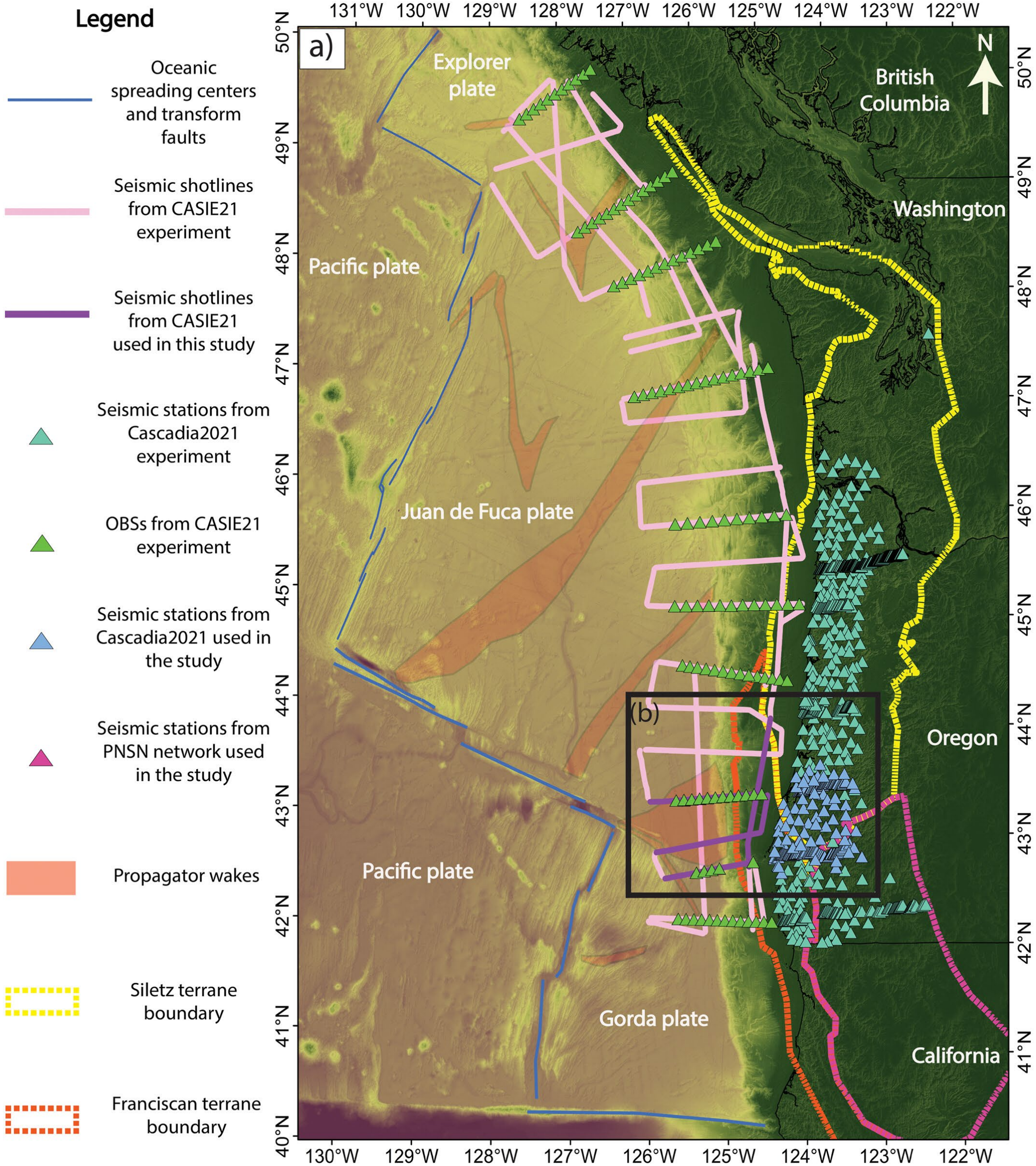
BOISE STATE UNIVERSITY

Dr. Andrew Gase
Department of Geosciences
Boise State University

Similarities: Both New Zealand and Cascadia now have large geophysical imaging datasets, ripe for further investigation

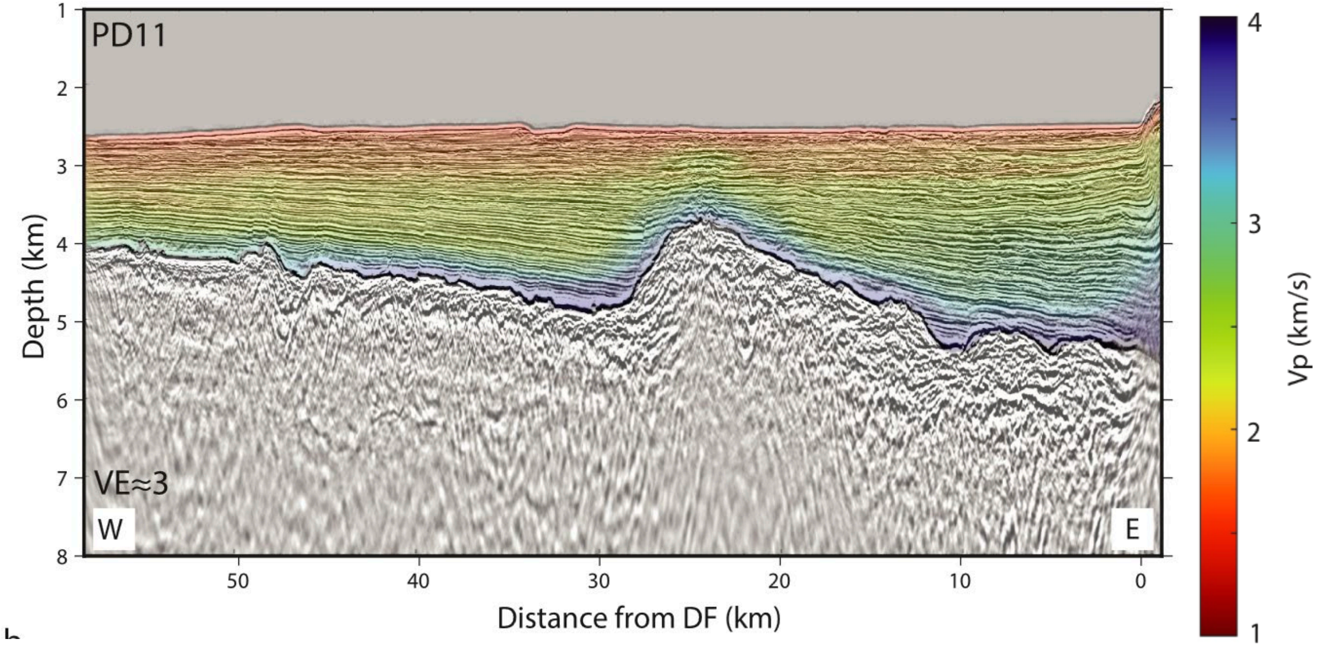


Henrys et al., 2025

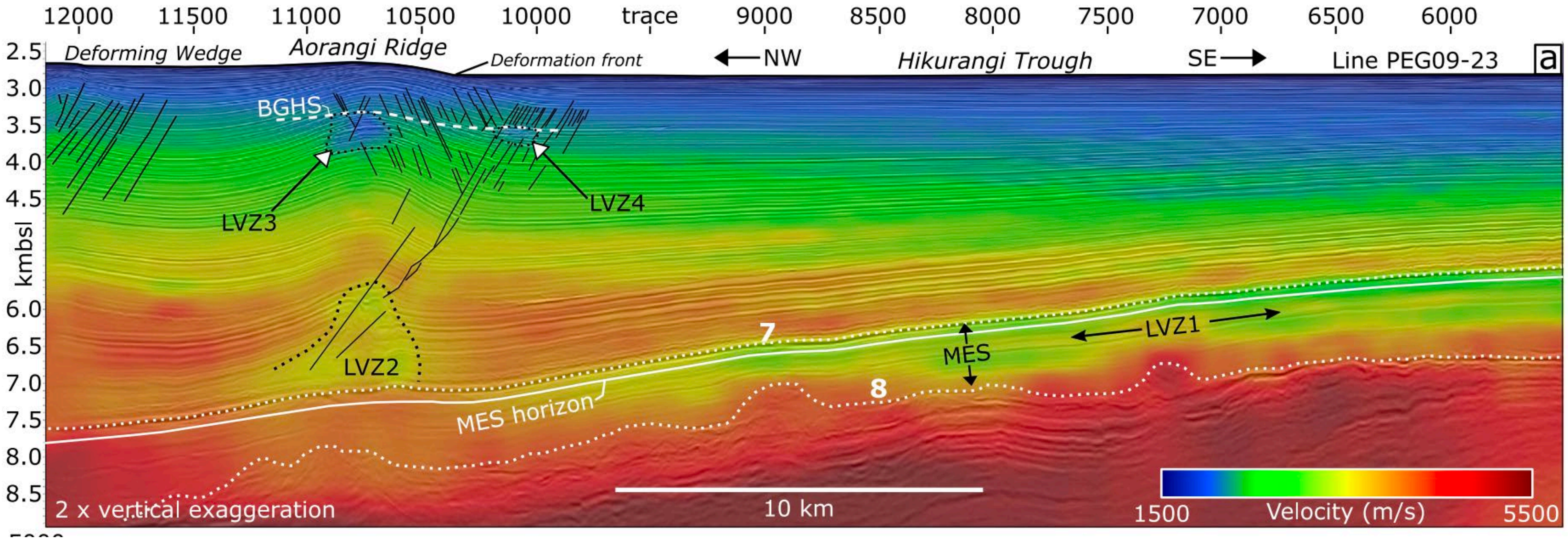


Ashraf et al., 2025

Similarities: Both have thick incoming sediments, most of Cascadia similar to northern Hikurangi sediment thicknesses.



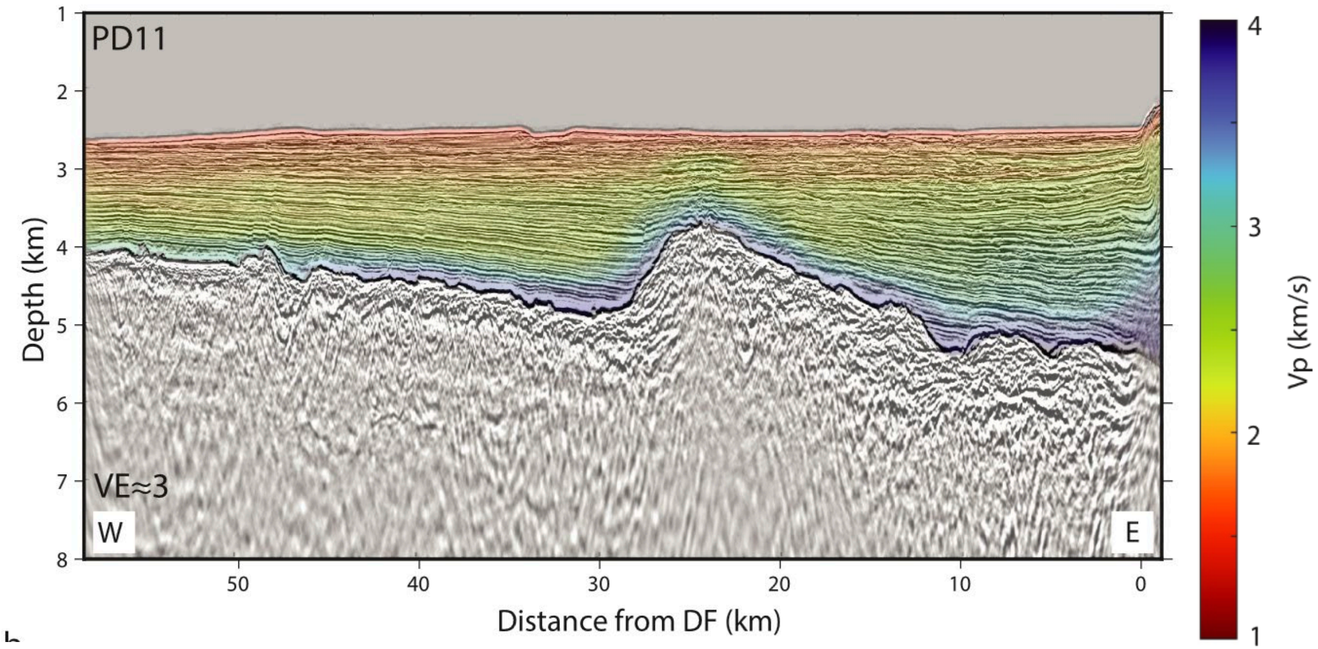
Lee et al., 2024



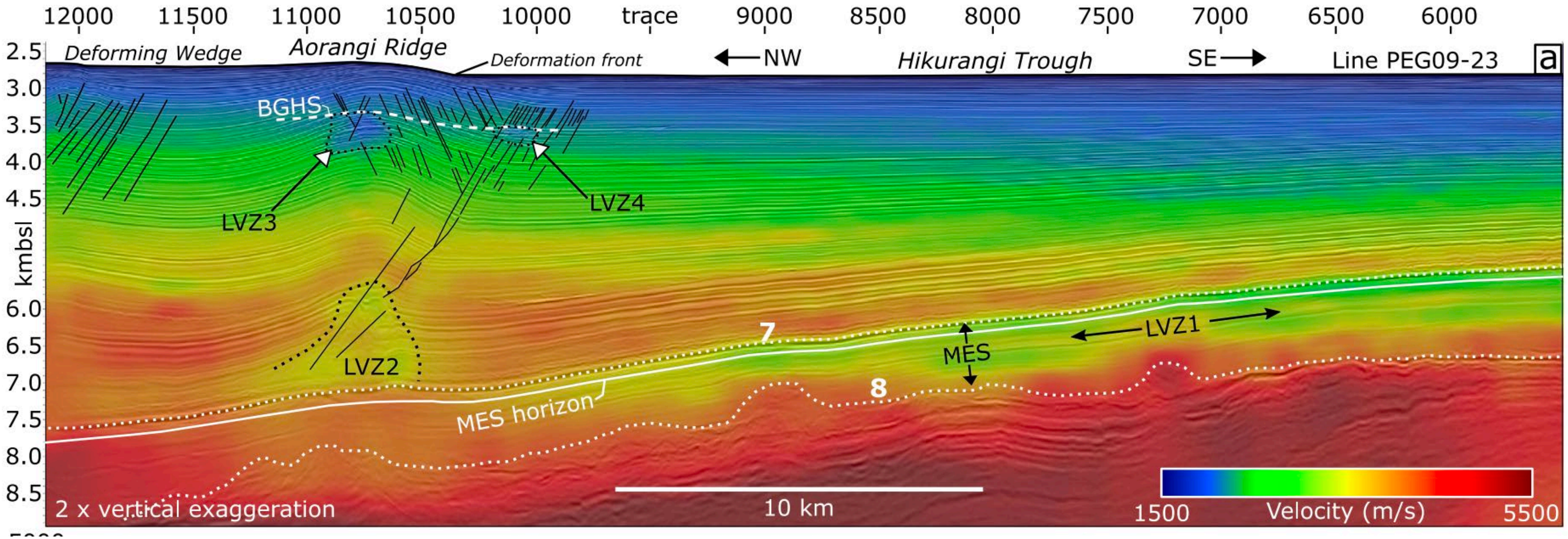
Crutchley et al., 2020

Similarities: Both have thick incoming sediments, most of Cascadia similar to northern Hikurangi sediment thicknesses.

Differences: Hikurangi is considerably more heterogeneous in lithology – contains pelagic carbonates



Lee et al., 2024



Crutchley et al., 2020

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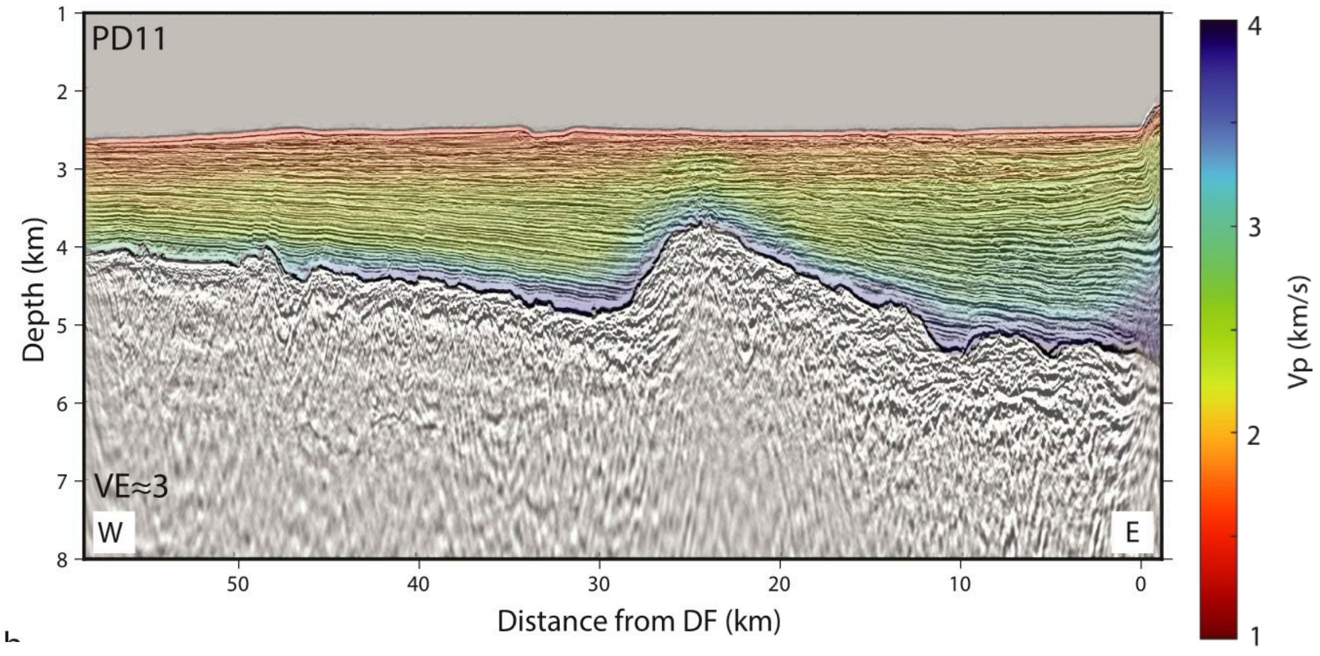
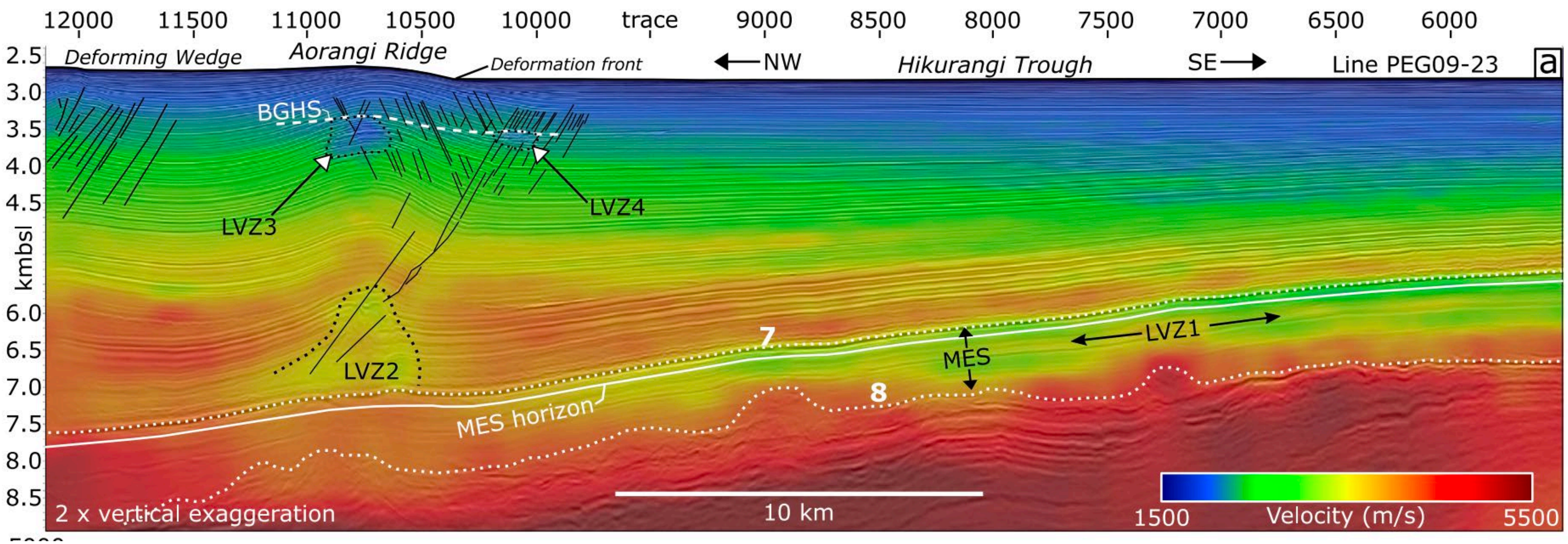


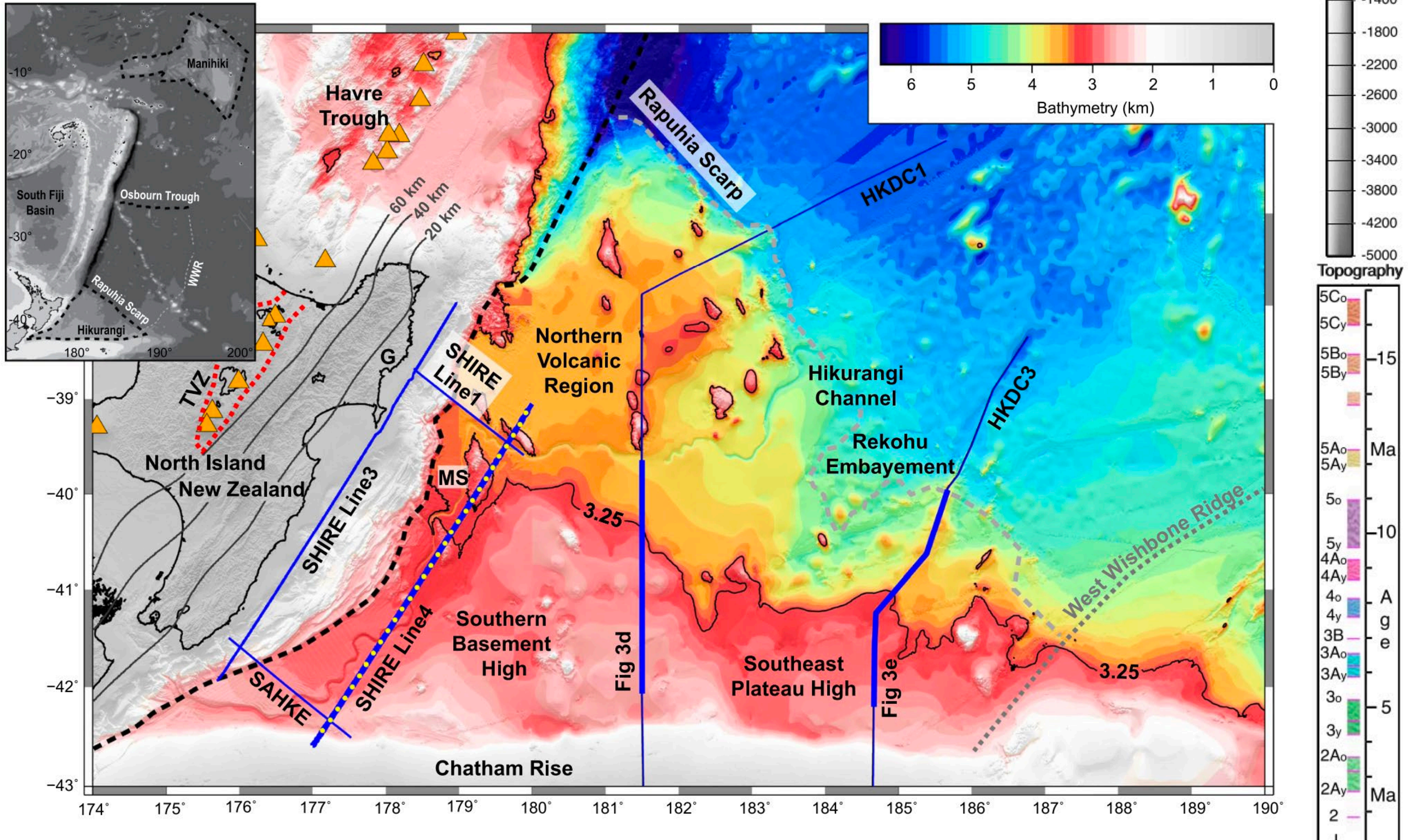
Lee et al., 2024



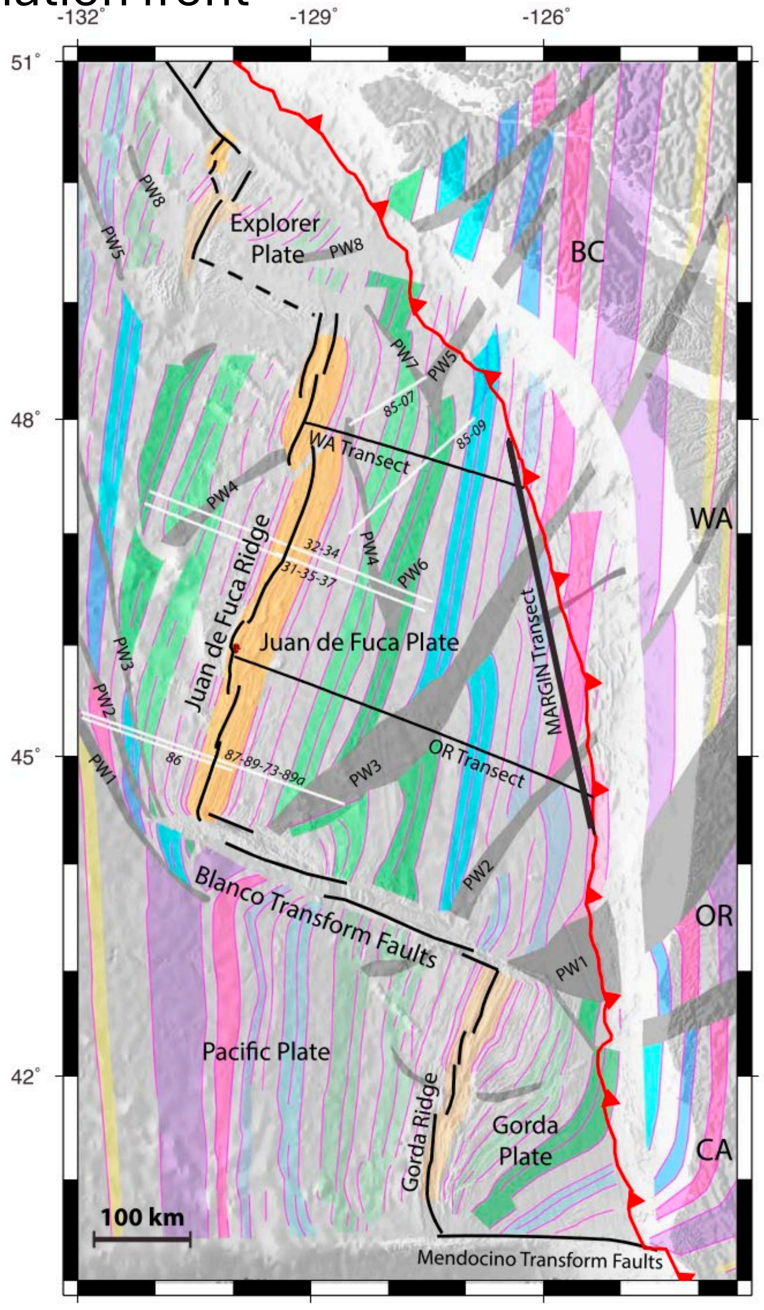
Crutchley et al., 2020

Differences: Cascadia is a young, hot end member ~5-9 Ma at deformation front

Hikurangi is an old, cold end member, ~120 Ma large igneous province with volcanic resurgences

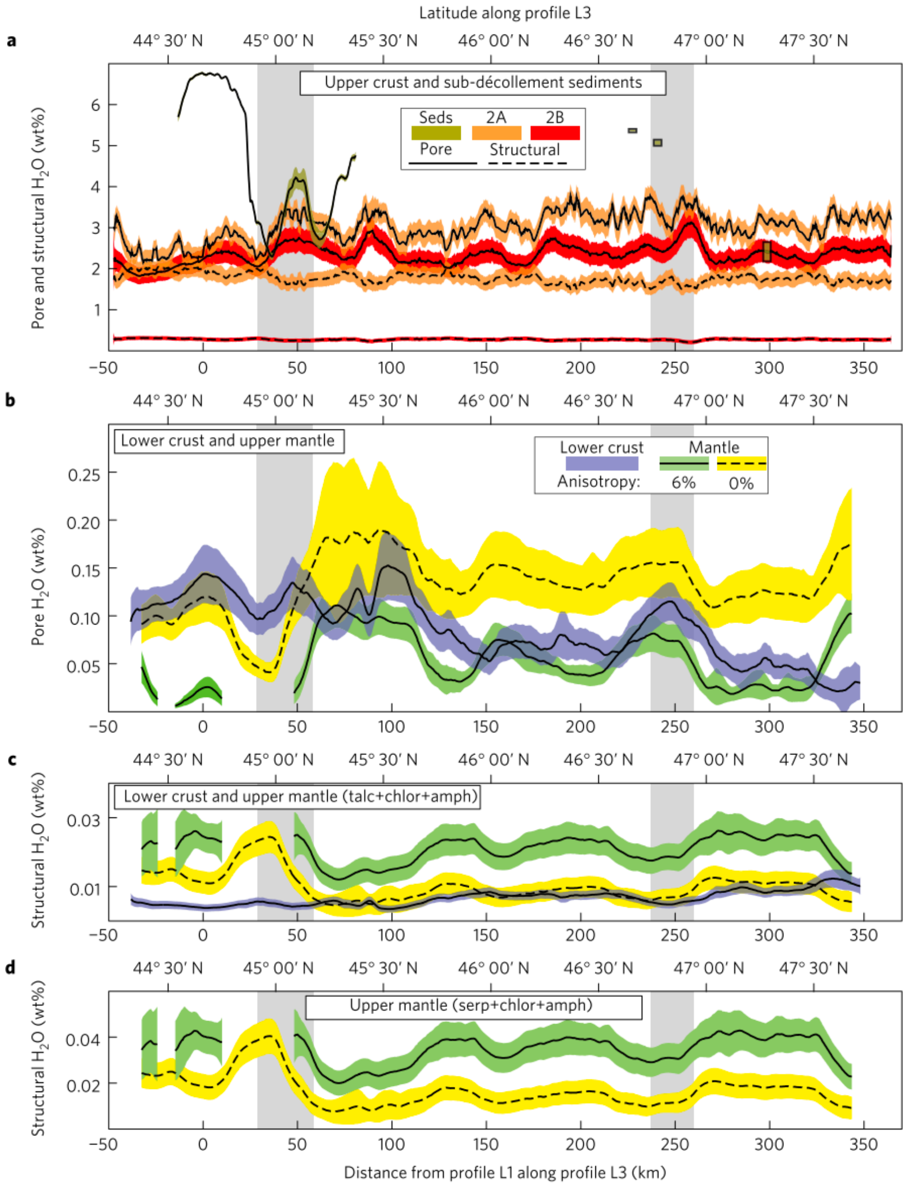


Bassett et al., 2023

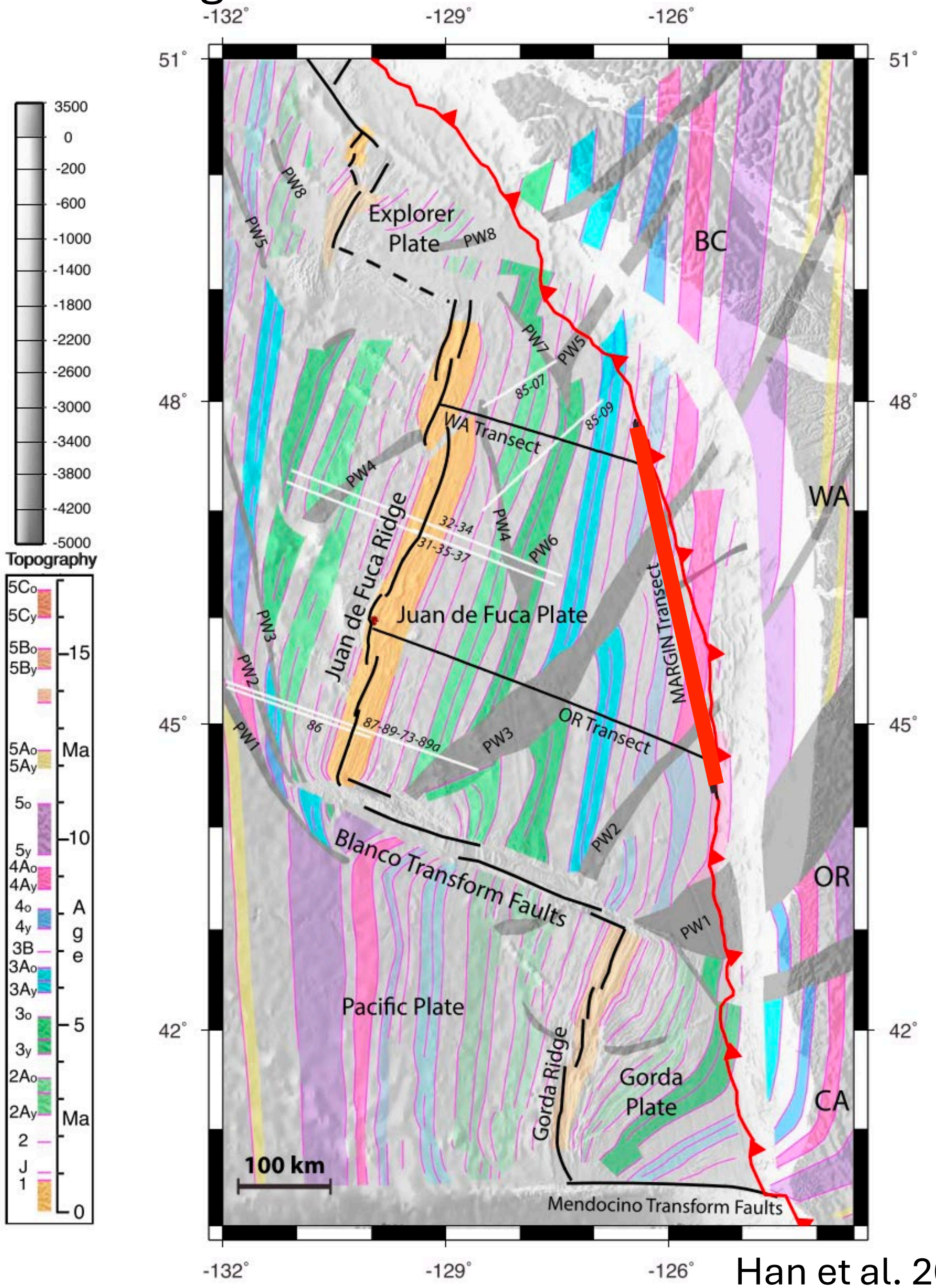


Han et al. 2018

Prior work shows that JDF lower crust and upper mantle offshore Washington and Oregon are dry – upper crust is largest reservoir (~3-4 wt. %)

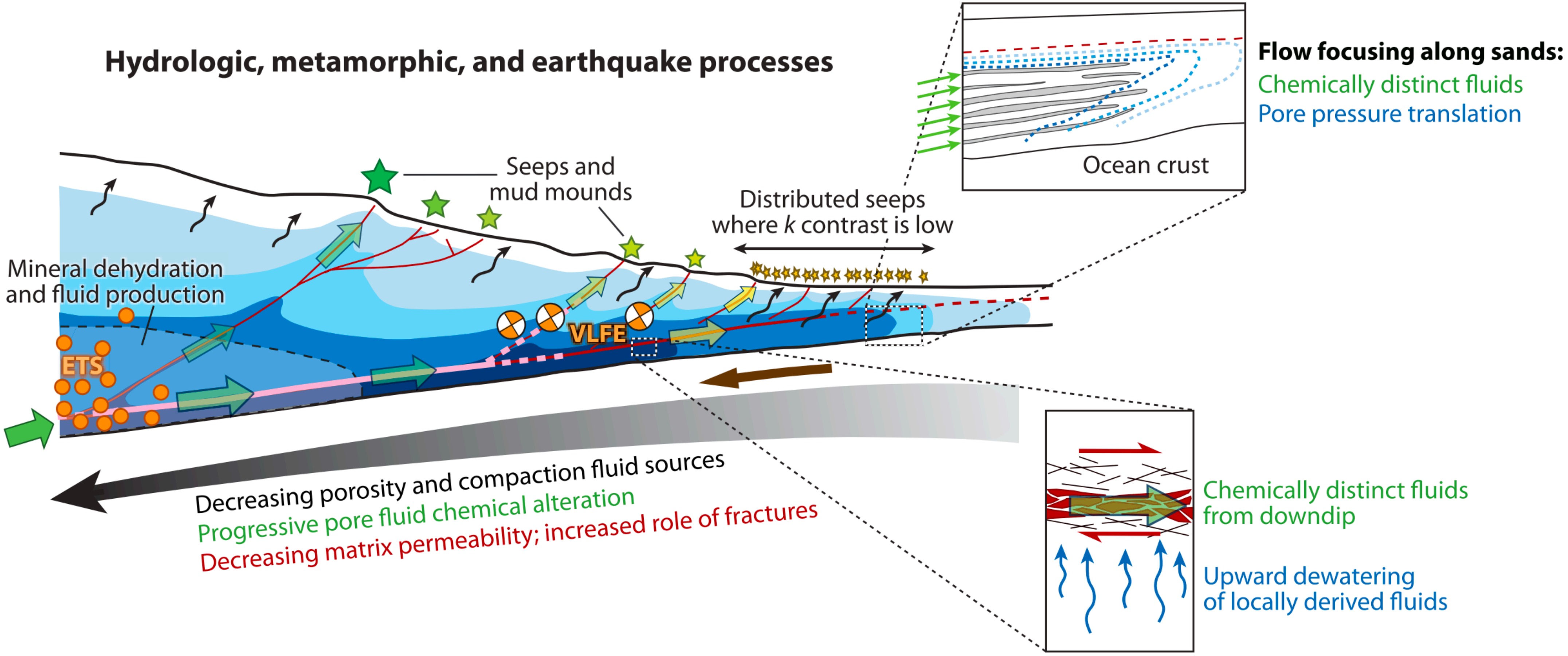


Canales et al., 2017



Han et al. 2018

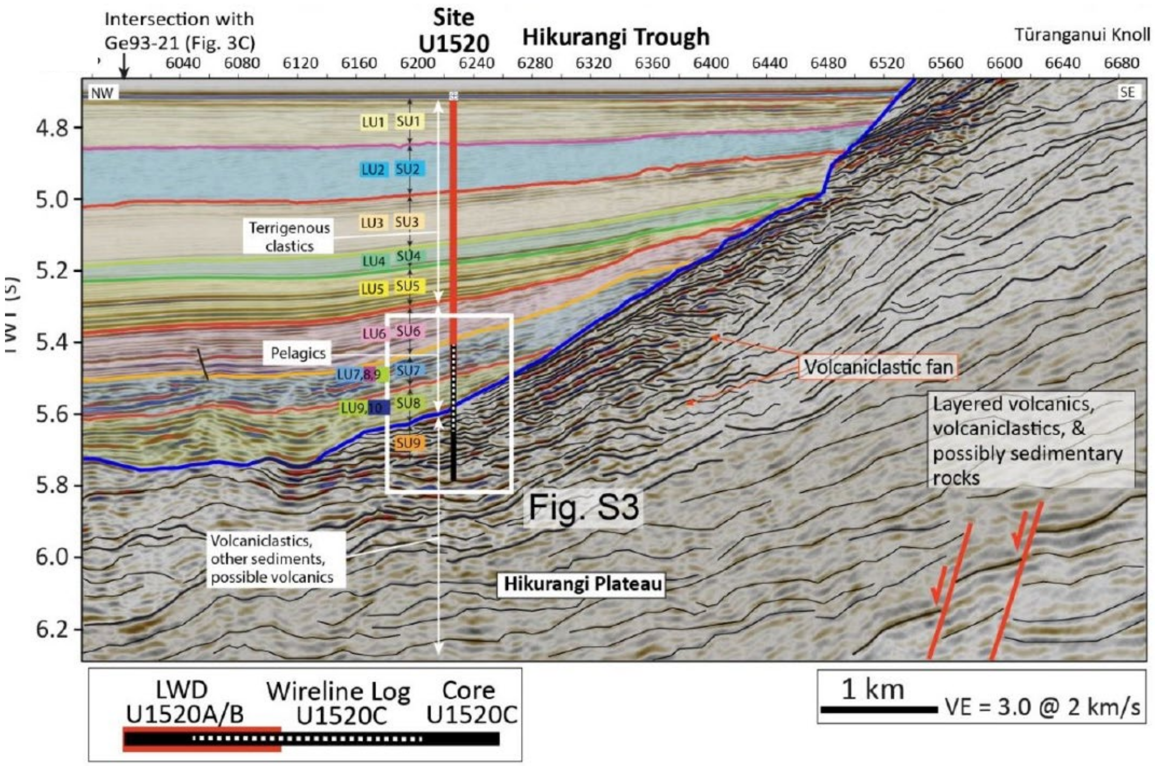
What role does oceanic crust play in supplying fluids to forearc and sub-arc systems?

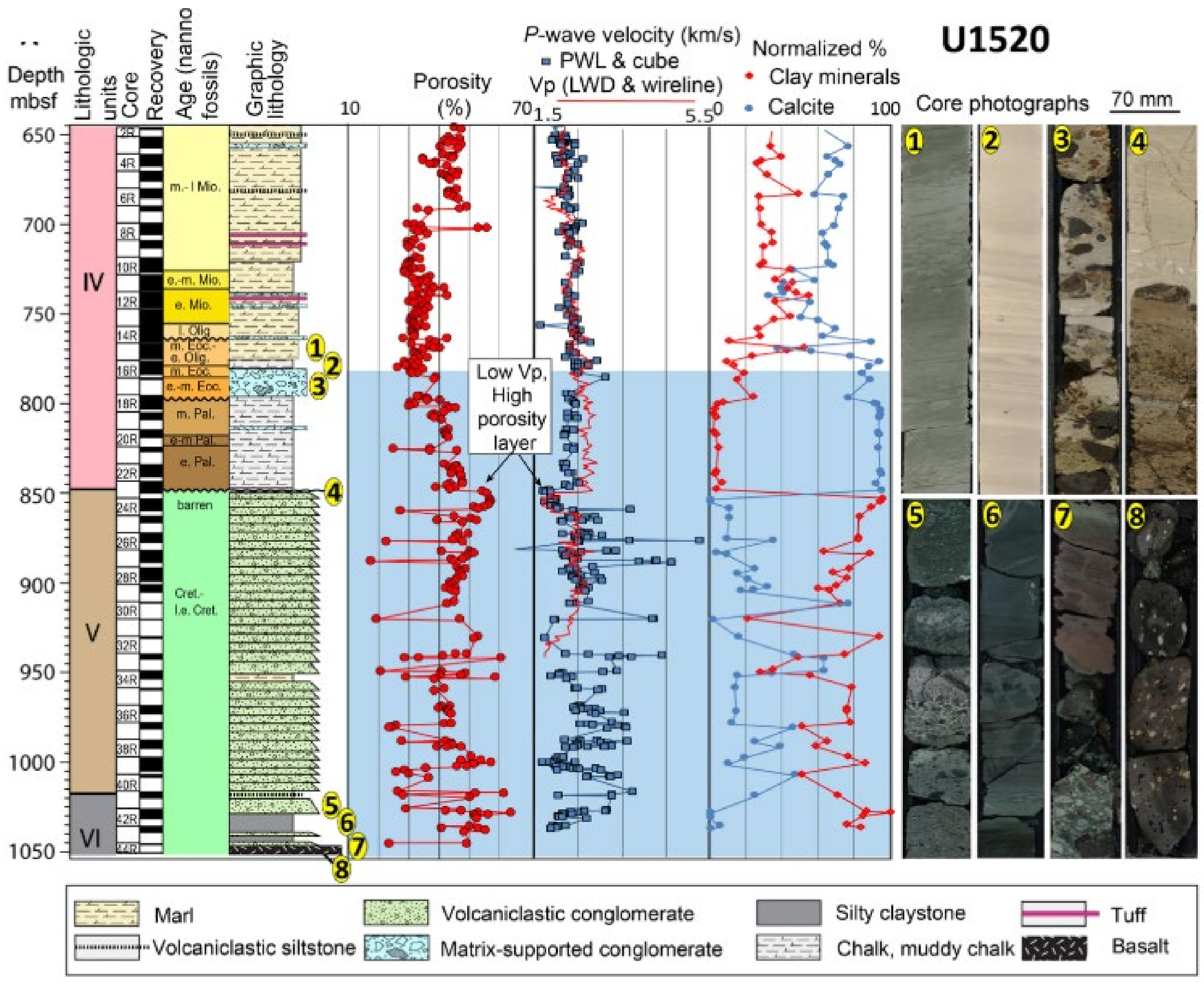


Reconciling these conflicting observations and quantifying the role of the igneous oceanic crust as a potential permeable conduit remain important unresolved questions.

Saffer and Tobin, 2011

In NZ, IODP Exp. 372B/375 drilled upper LIP crust

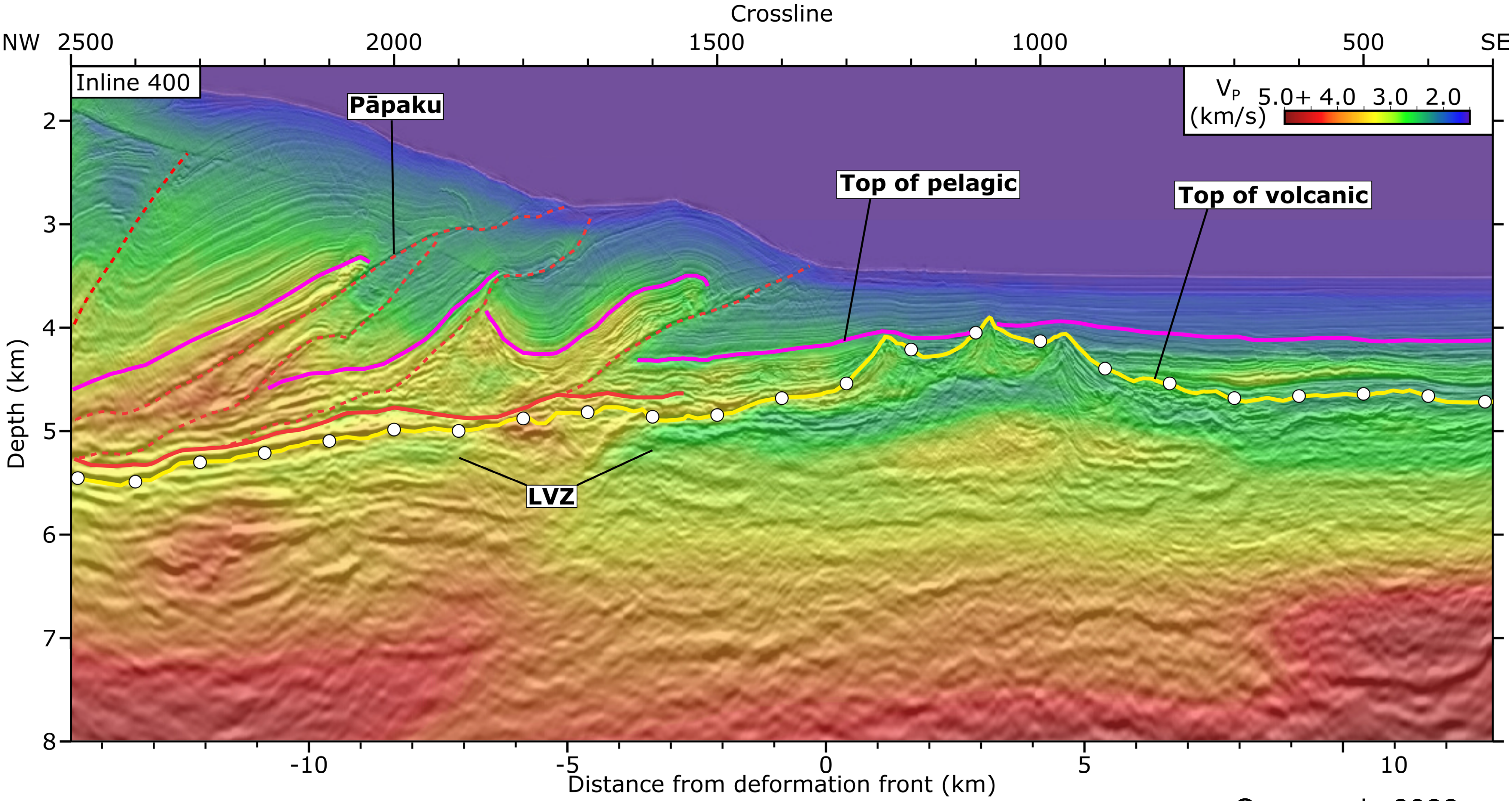




- Volcaniclastics are altered to water-rich clay
- High interstitial and mineral bound water

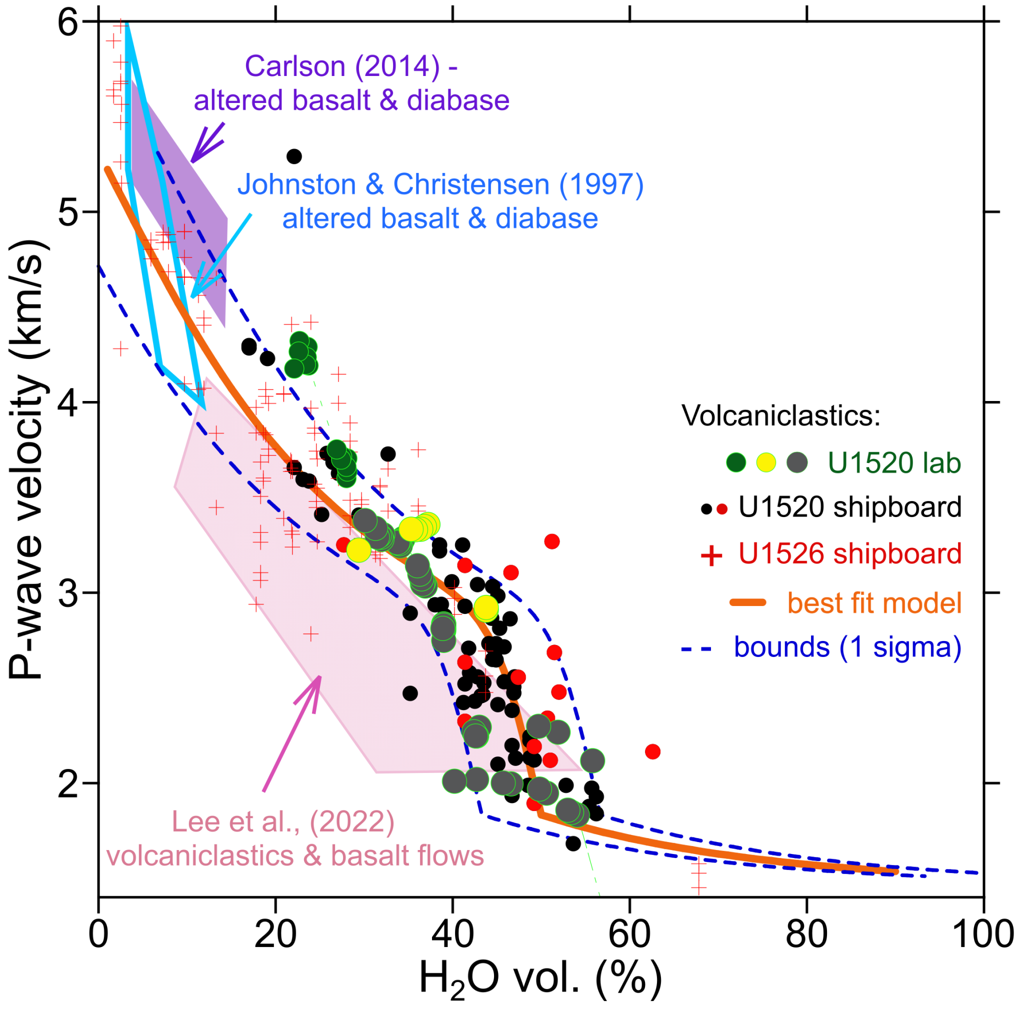
Barnes et al., 2020

Little sediment subducts at N. Hikurangi, largest shallow fluid reservoir is upper volcanic crust

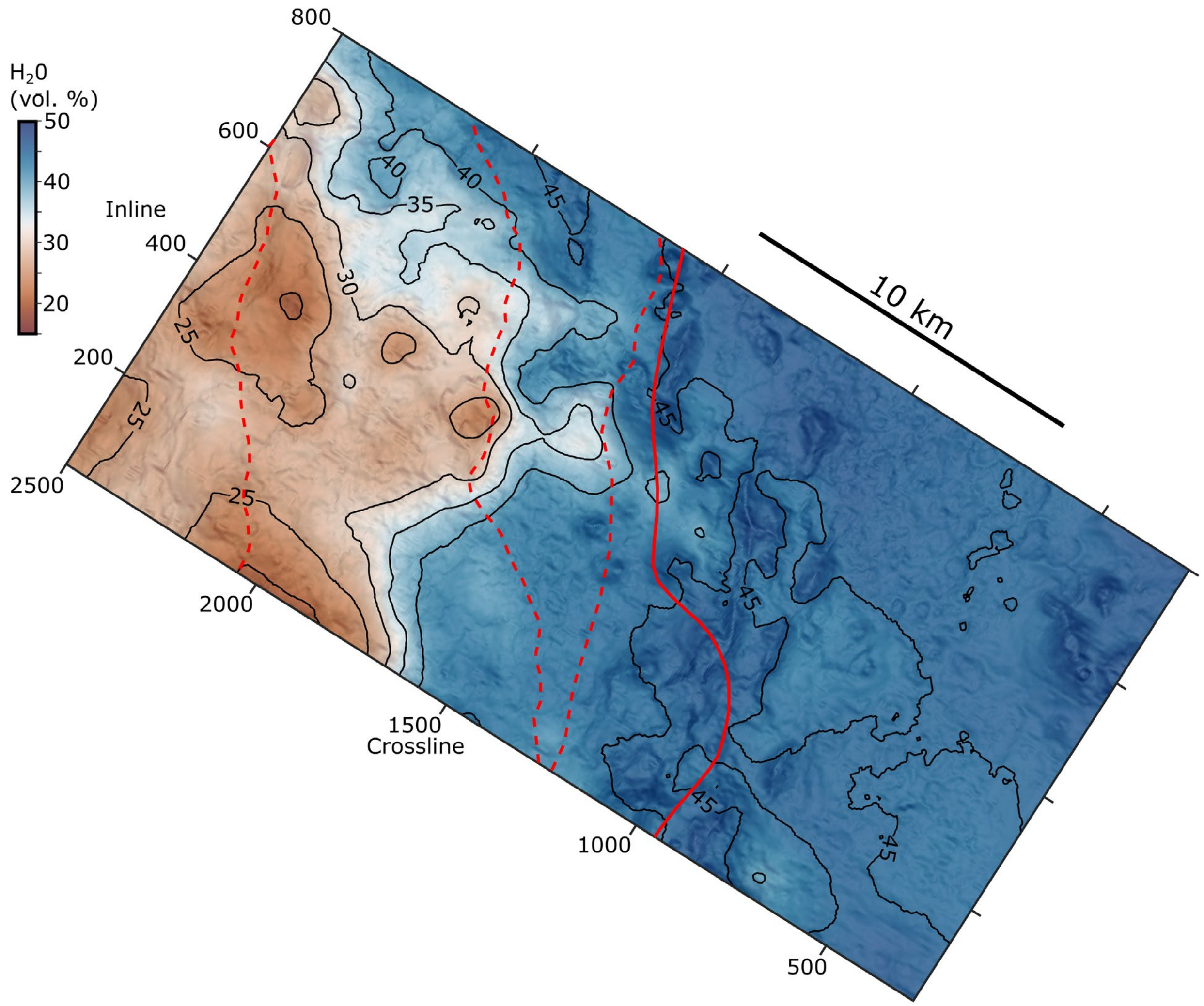


Gase et al., 2023

Estimate water content of volcaniclastics from P-wave velocity and drilling data

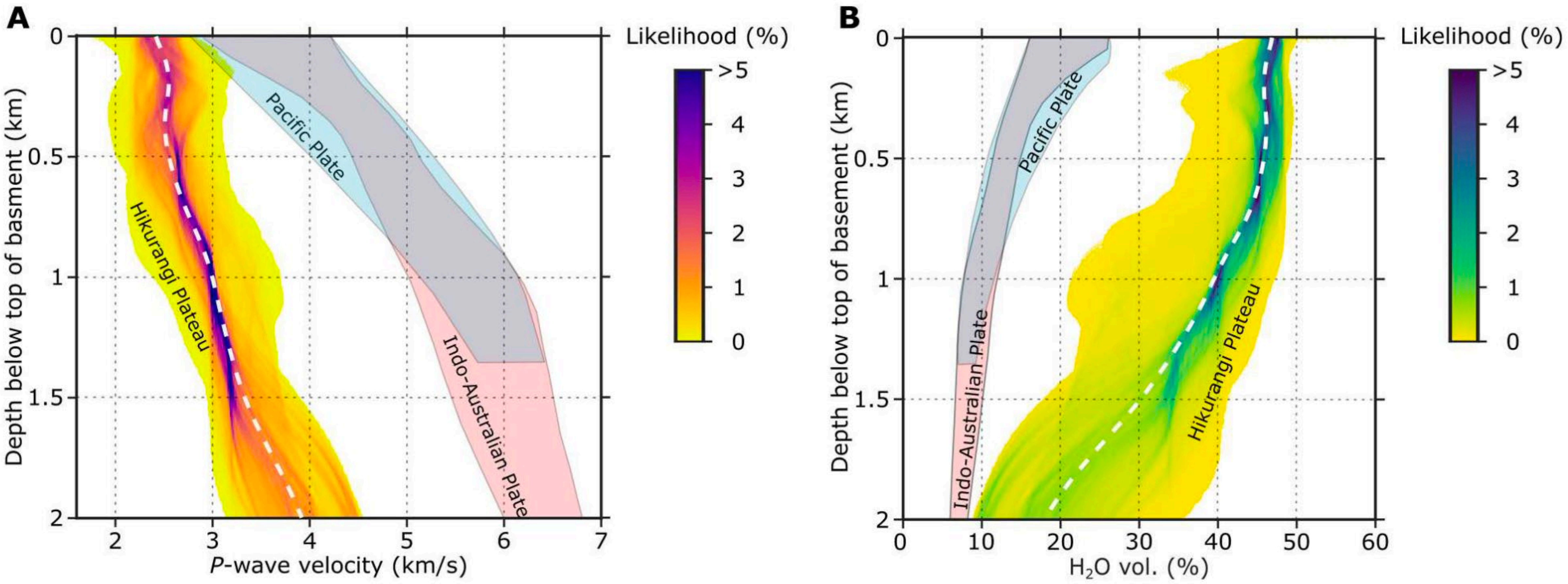


Average water content in upper 1 km of volcanic crust



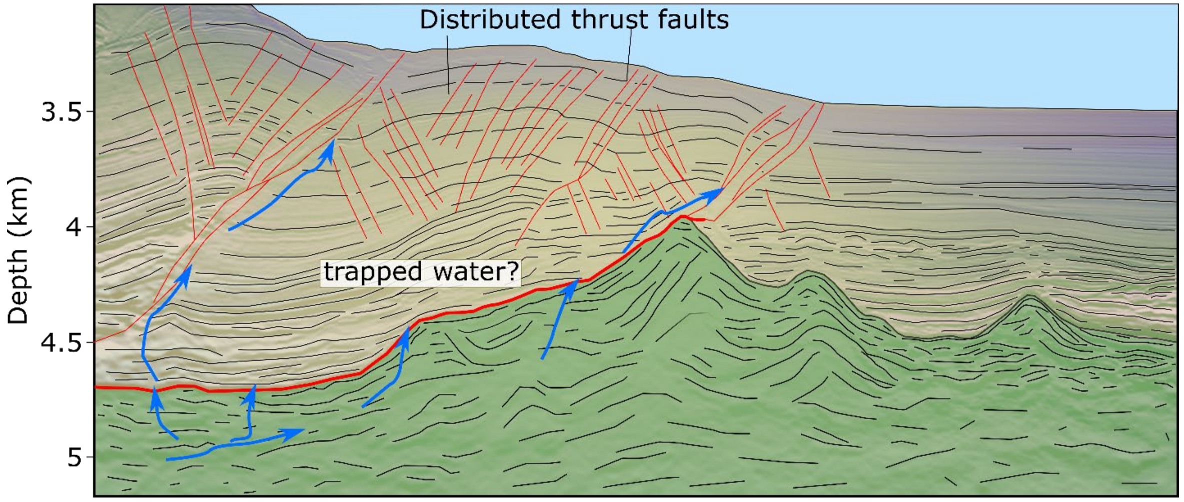
Gase et al., 2023

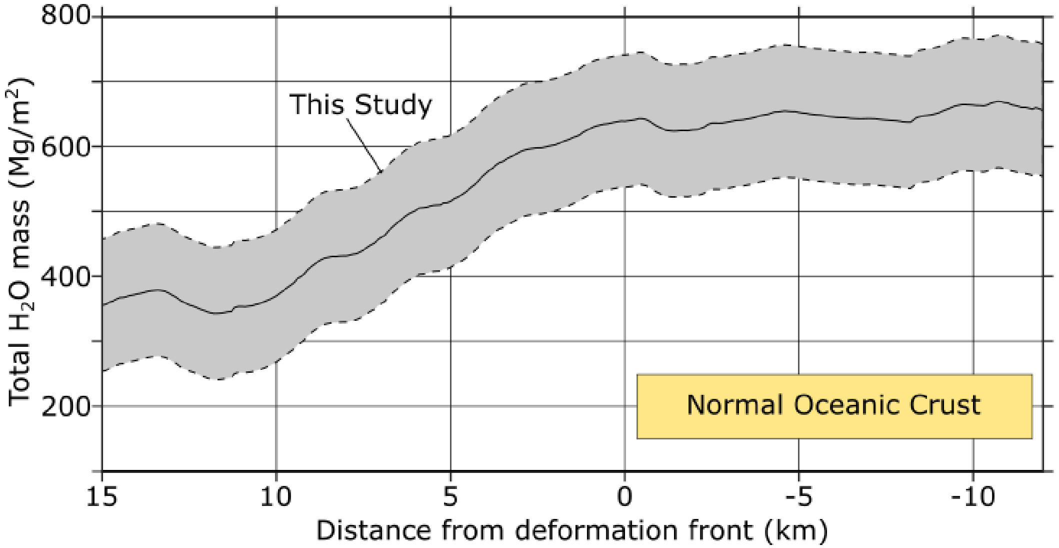
Incoming fluid contribution from Hikurangi Plateau upper crust is much larger than normal oceanic crust



Gase et al., 2023

Volcaniclastics can dewater substantially within the shallow subduction system





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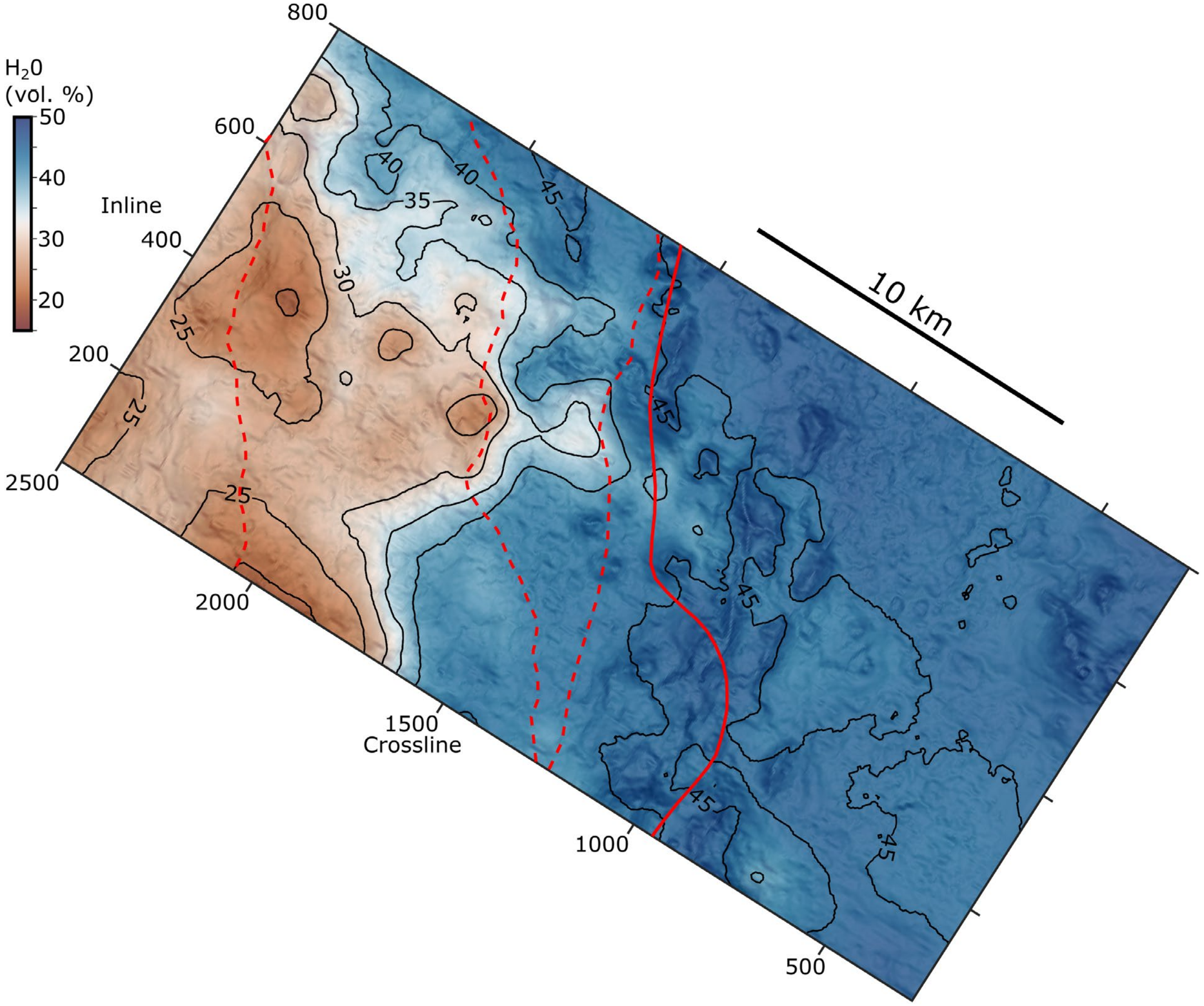

Gase et al., 2023

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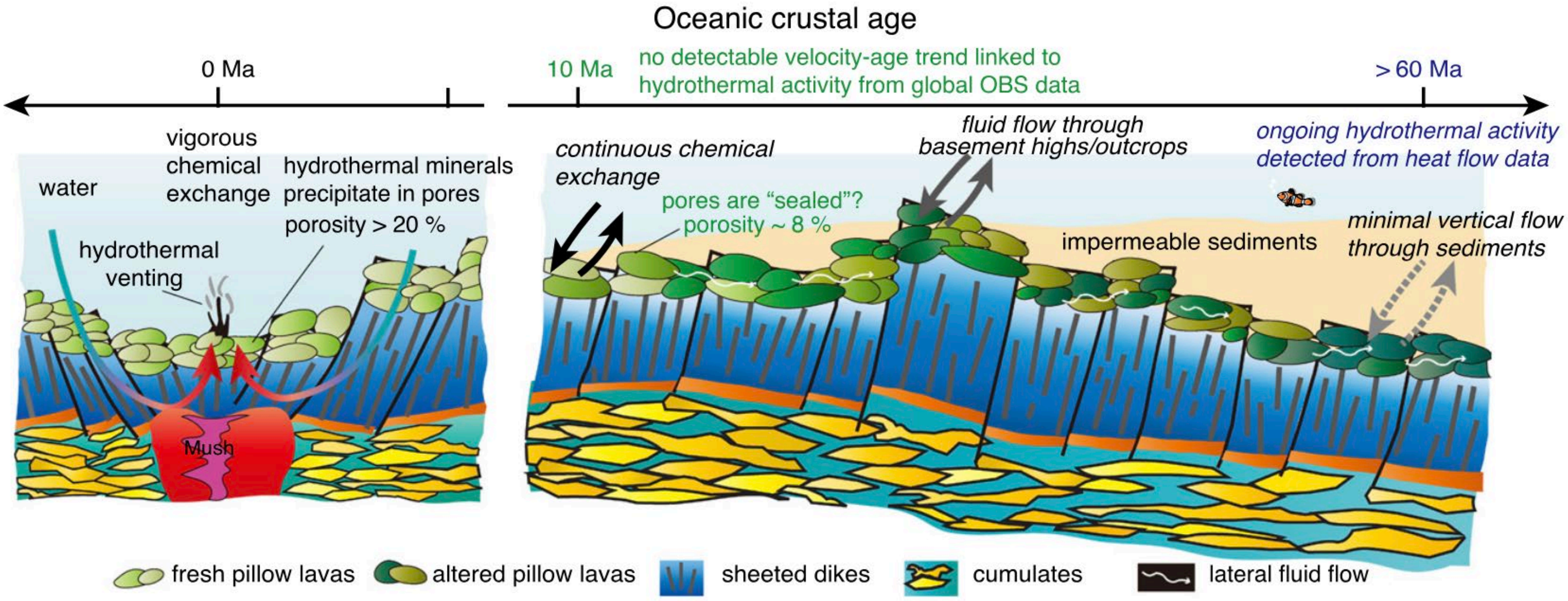
Upper oceanic crust evolves with time – largest change in 0-10 Ma



Li et al., 2024

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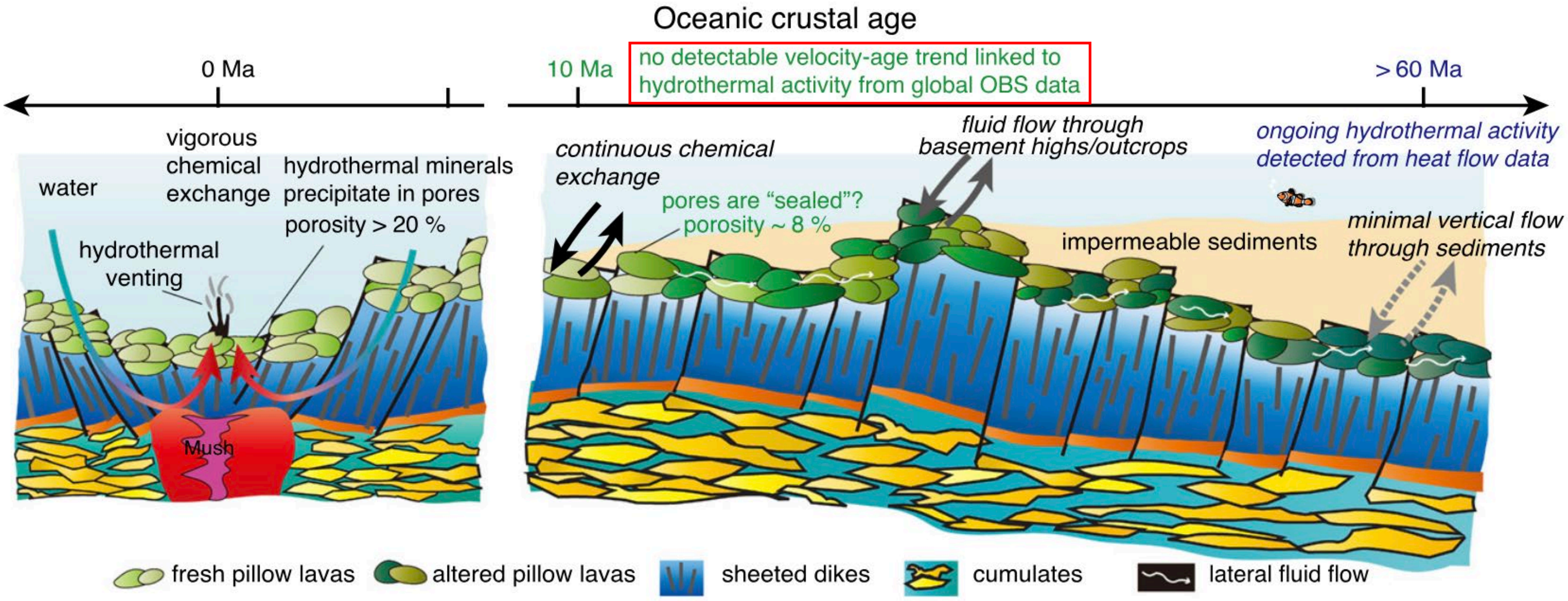
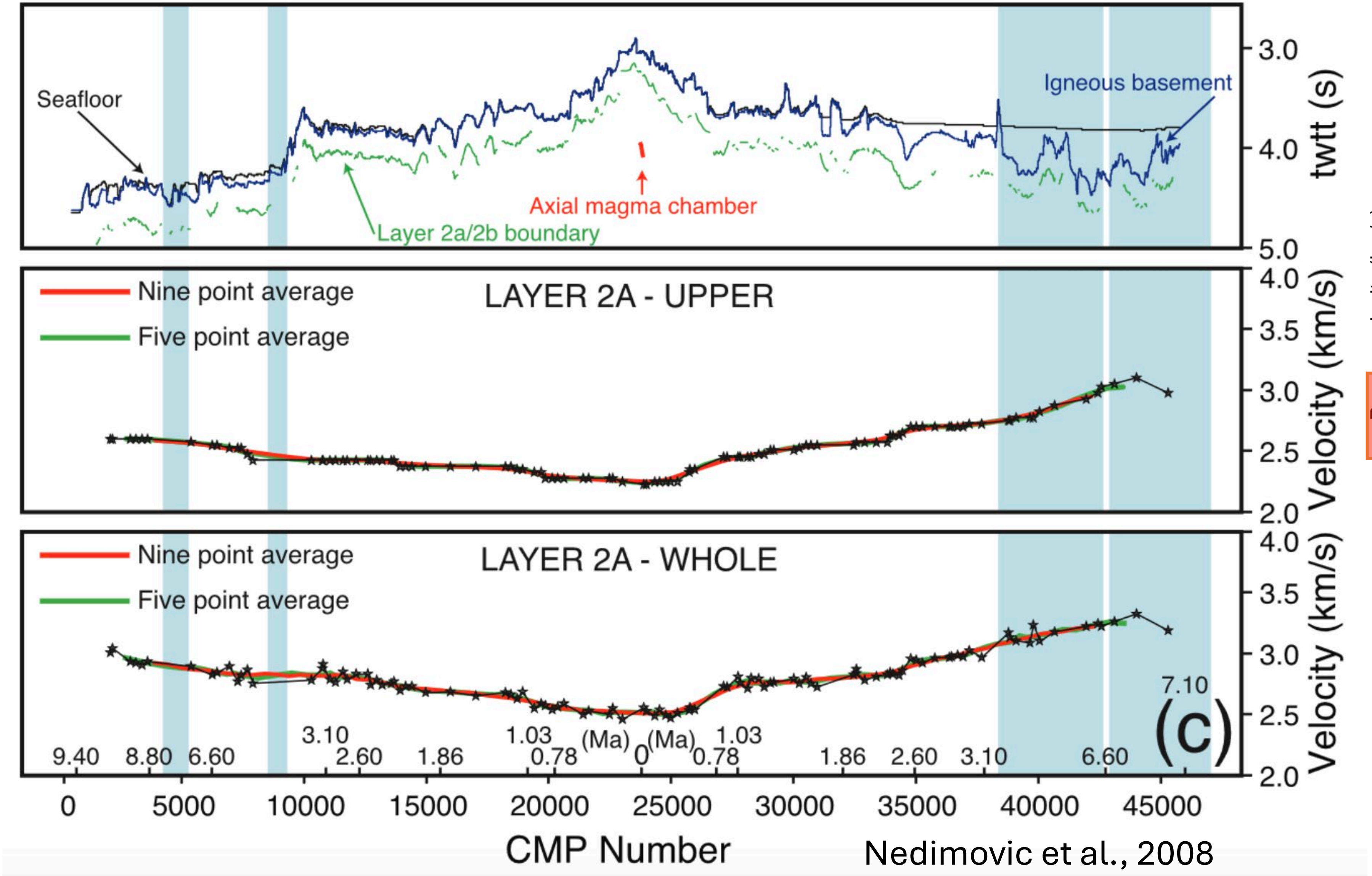


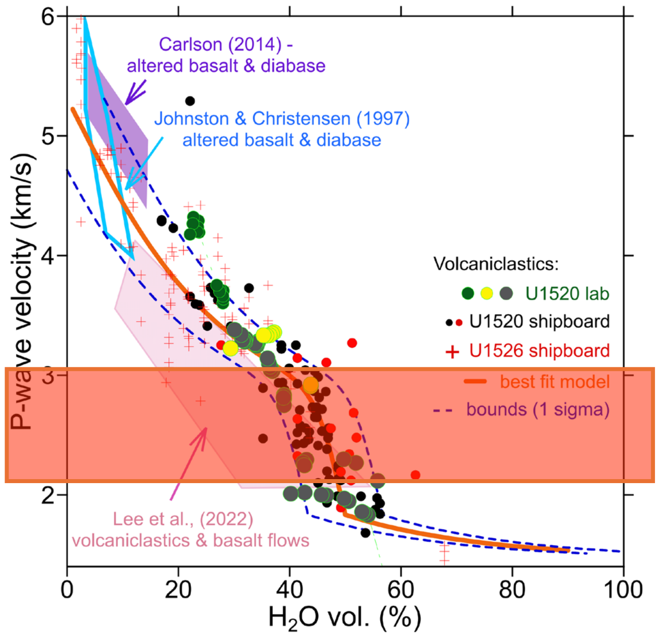
Li et al., 2024

Near ridge seismic velocity estimates from seismic reflection data confirm exceptionally low VP – high volumetric water content near ridge



Nedimovic et al., 2008

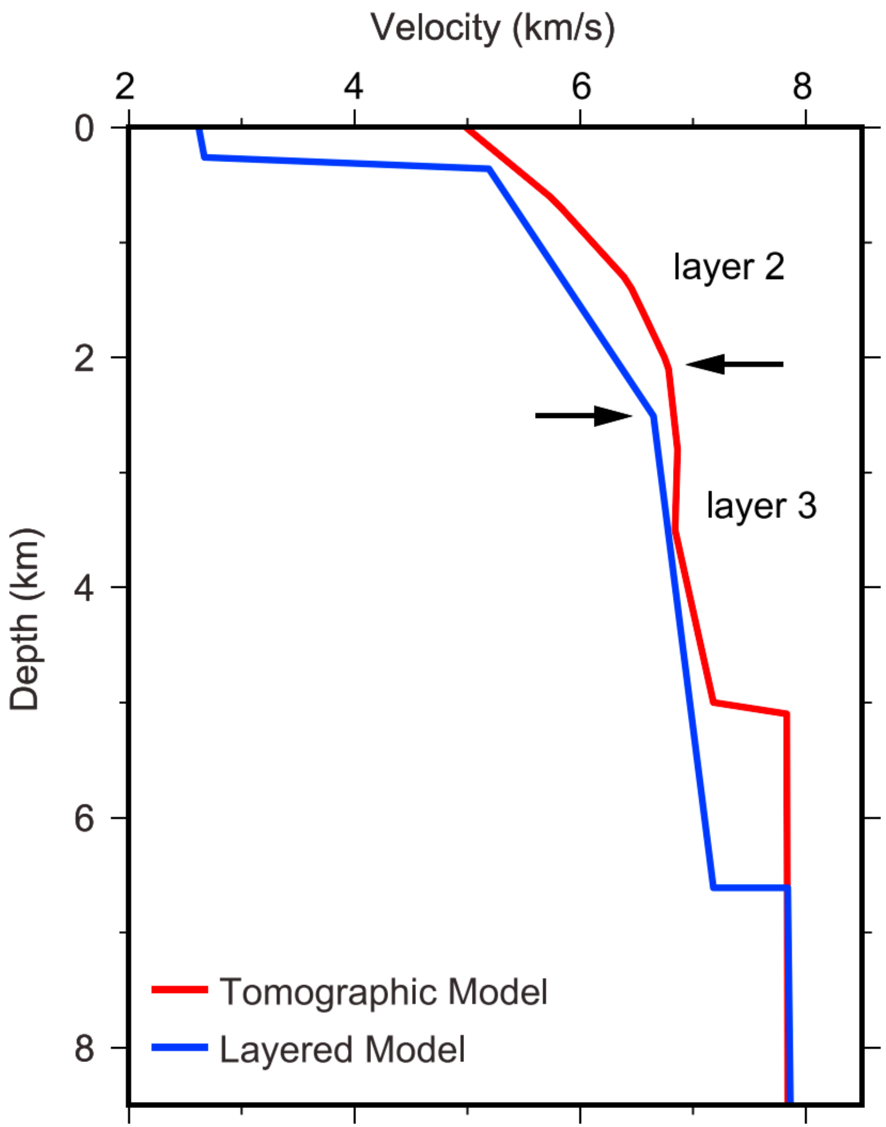
Gase et al., 2023



~50% vol. H_2O at 0 Ma

~20-40% vol. H_2O at 3-9 Ma

For wide-angle seismic data, wildly different upper crustal models can be retrieved from different inversion schemes



Christeson et al., 2019

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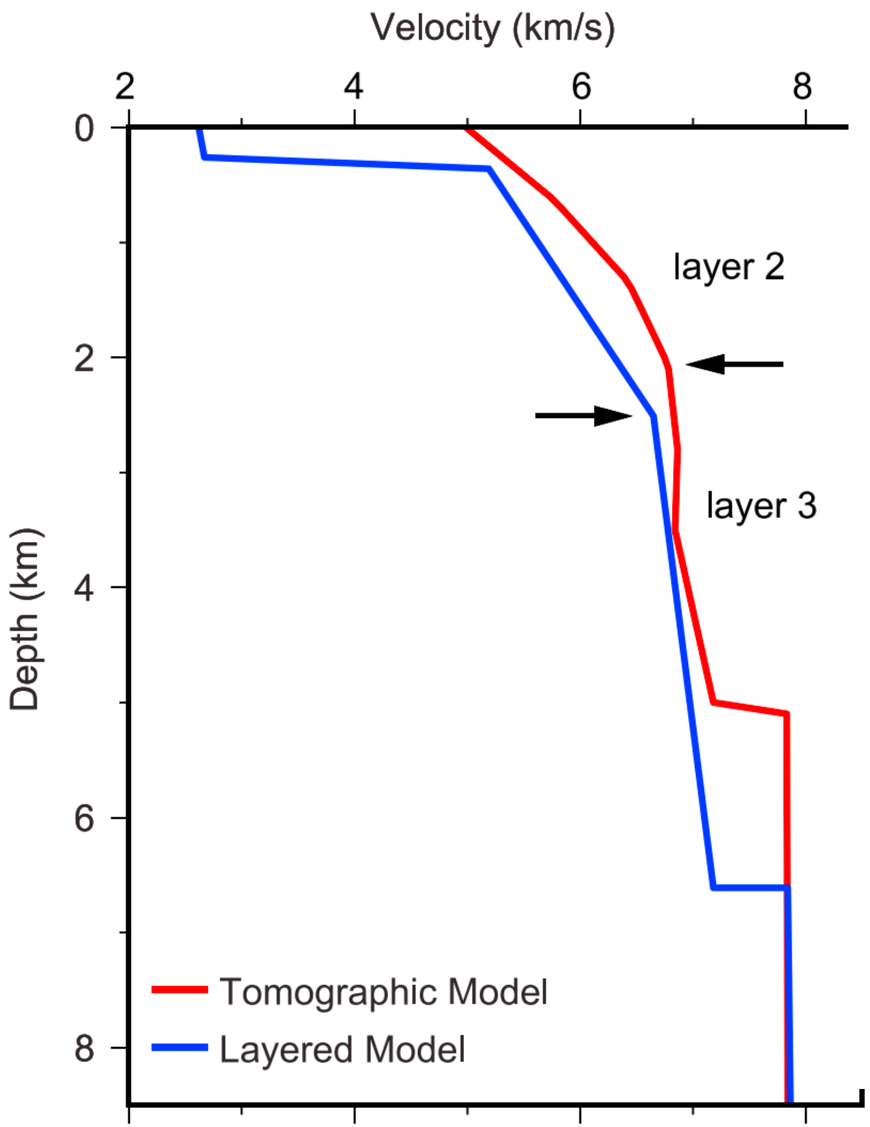
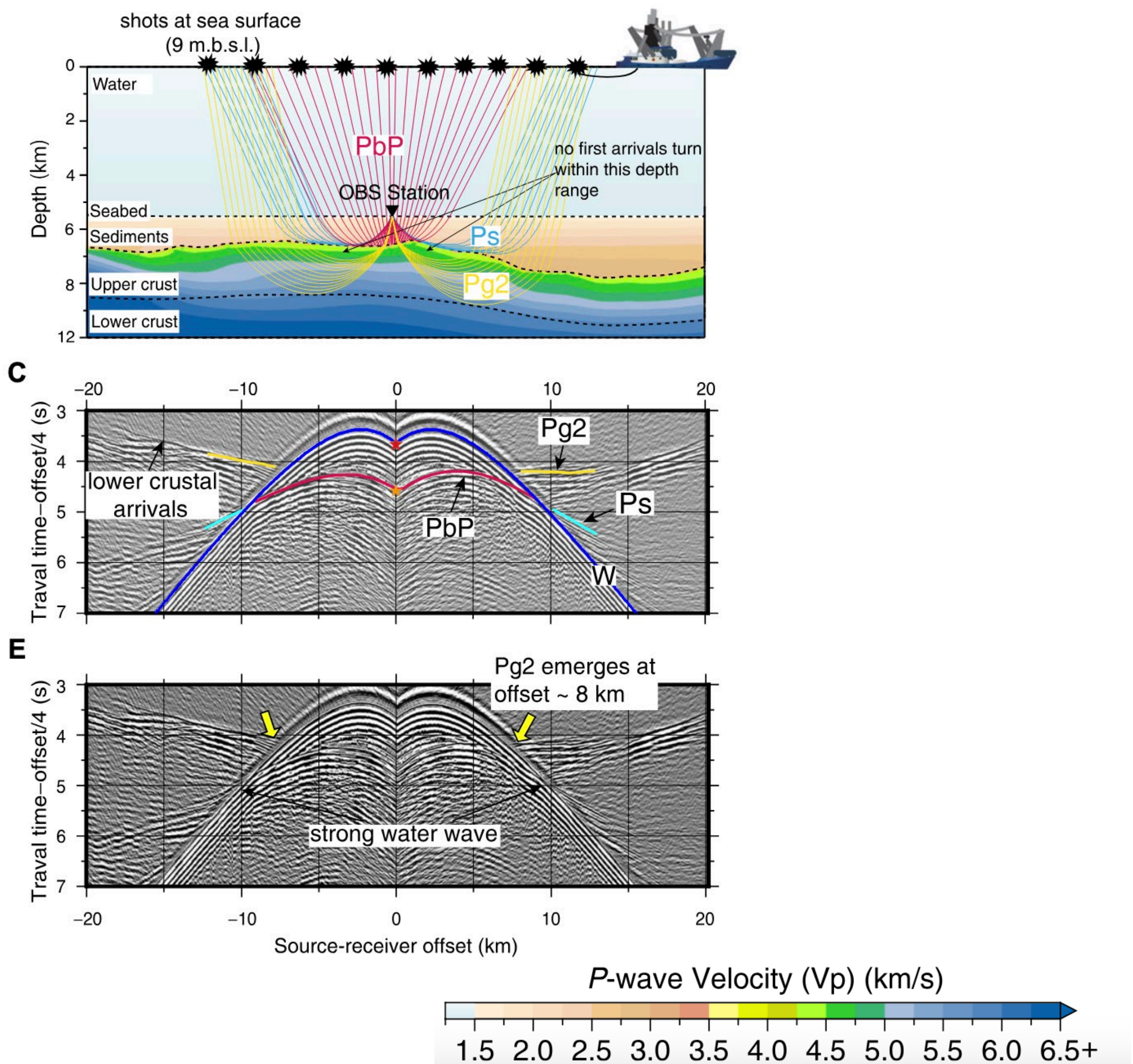


Christeson et al., 2019

Seafloor reflection masks Layer 2A refraction



Li et al., 2024

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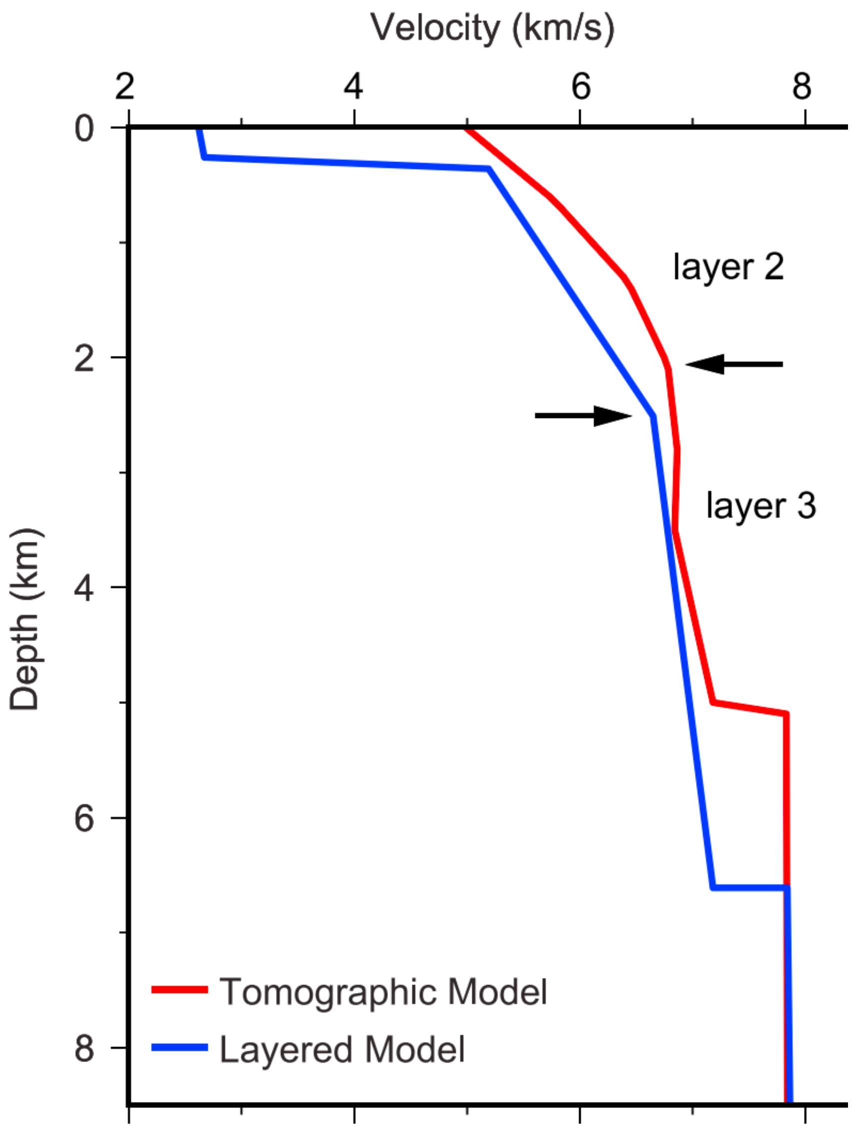

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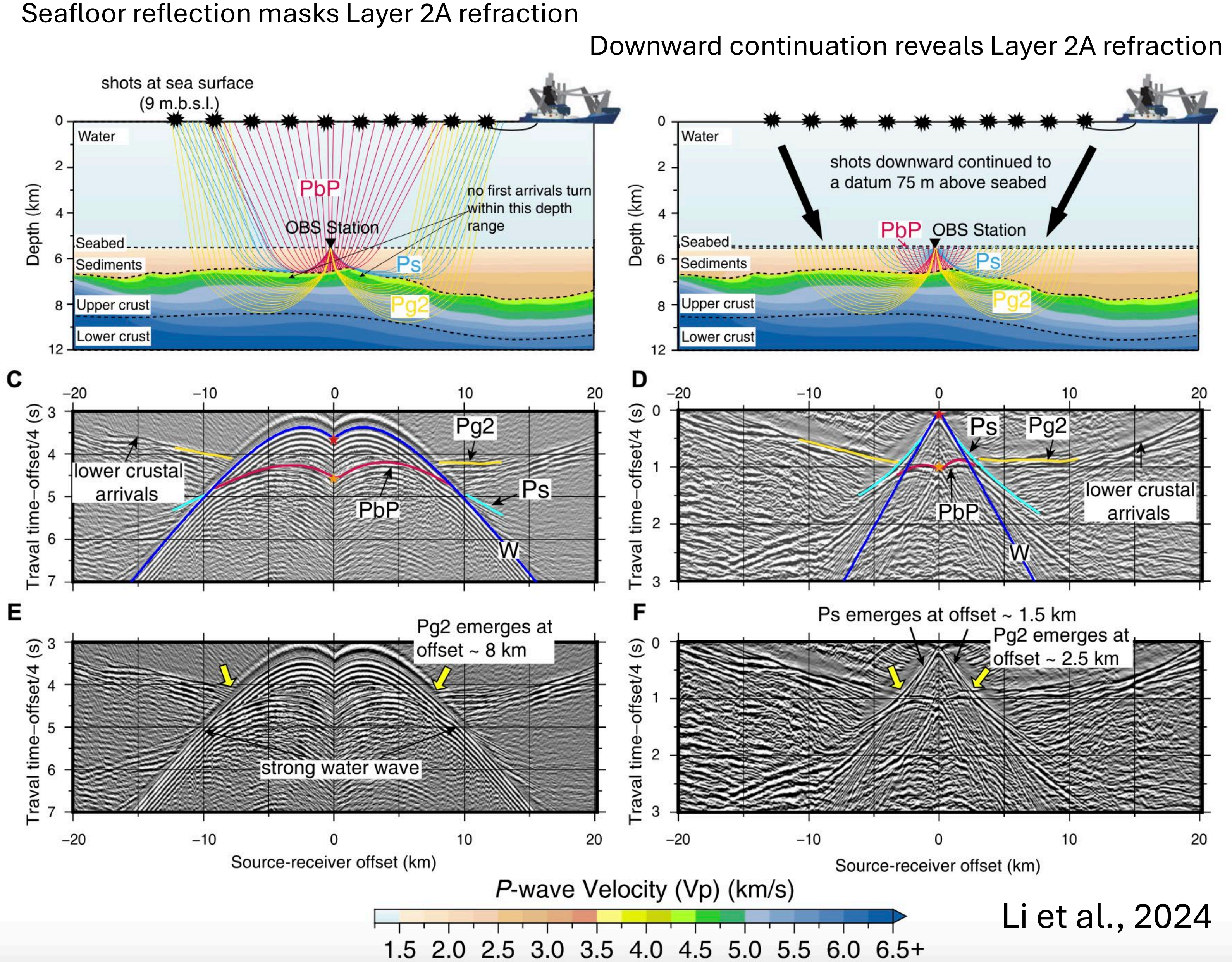
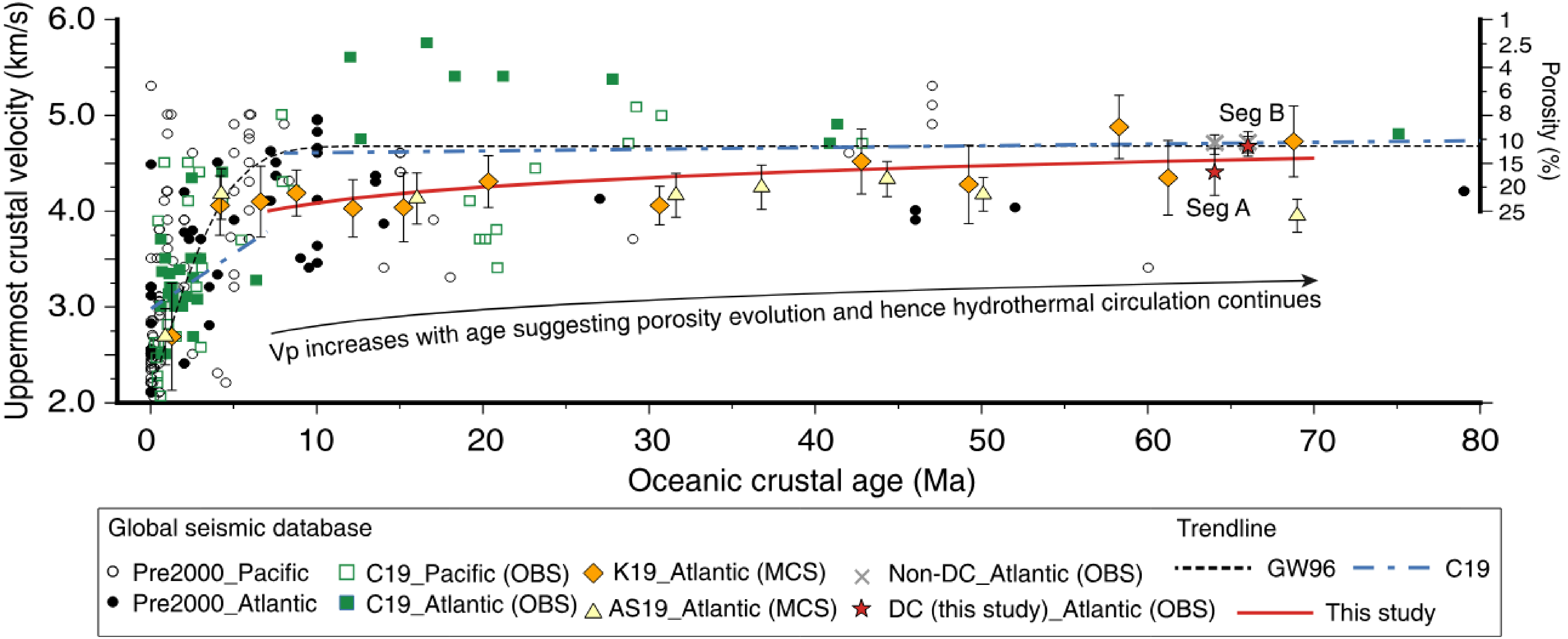


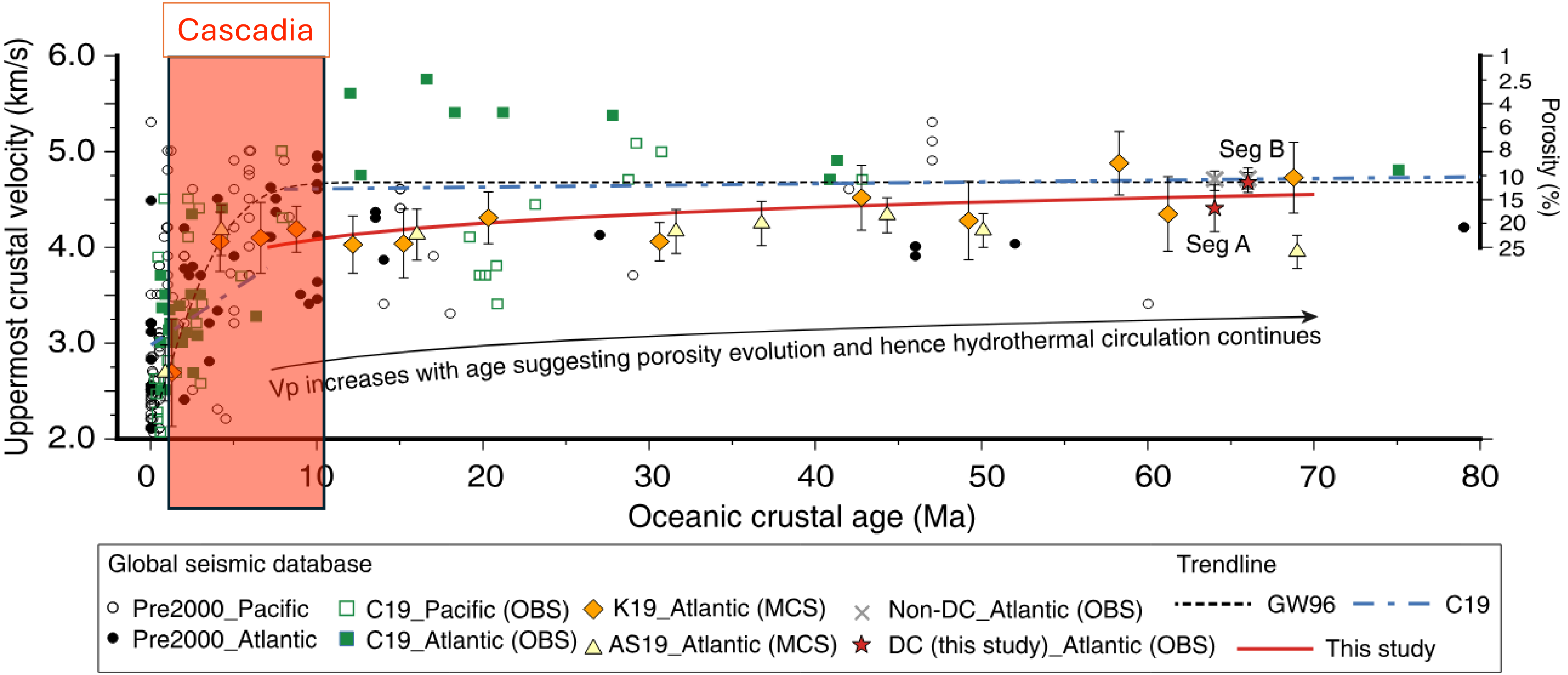
Li et al., 2024

Improved estimates of velocities through DC-tomography and FWI could increase expected water content of uppermost oceanic crust



Li et al., 2024

Improved estimates of velocities through DC-tomography and FWI could further increase expected water content of uppermost oceanic crust



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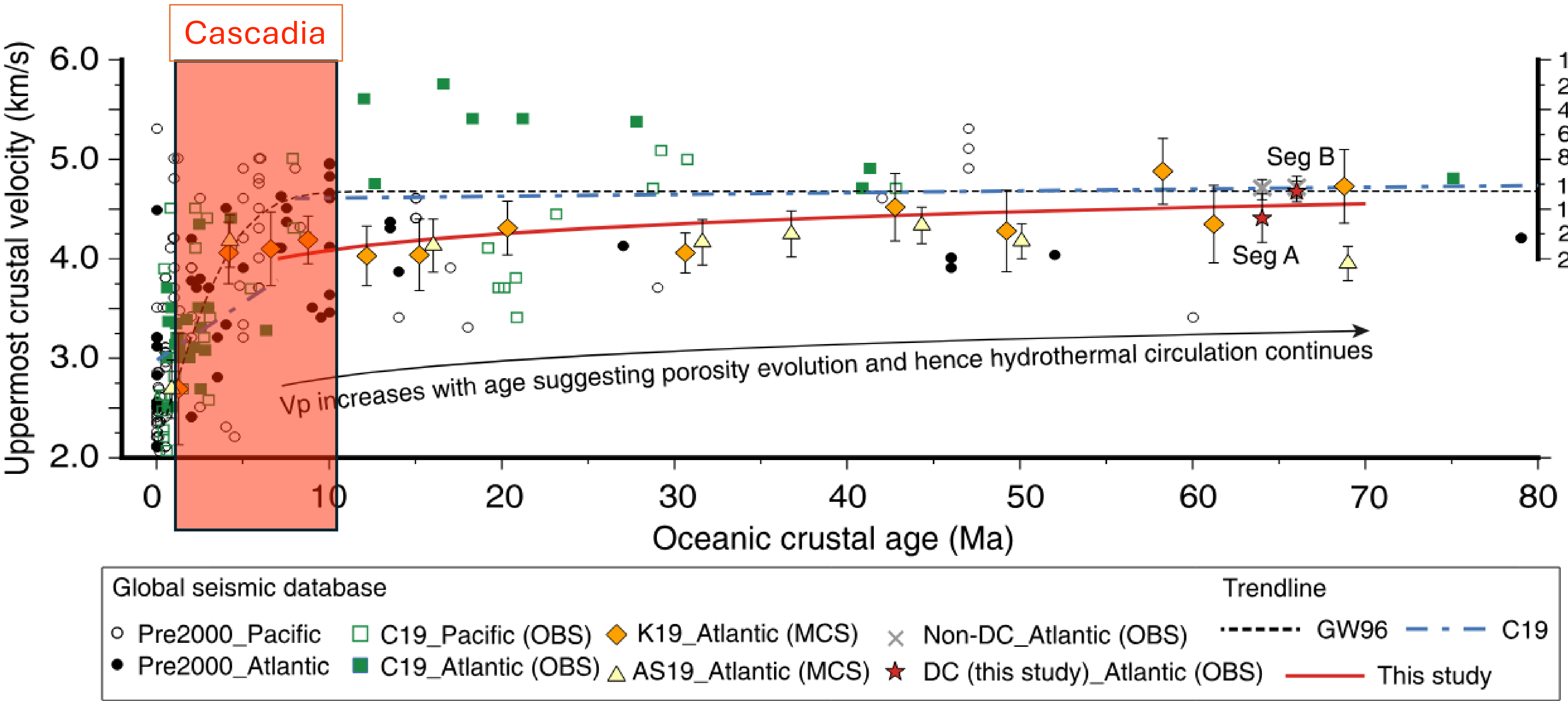
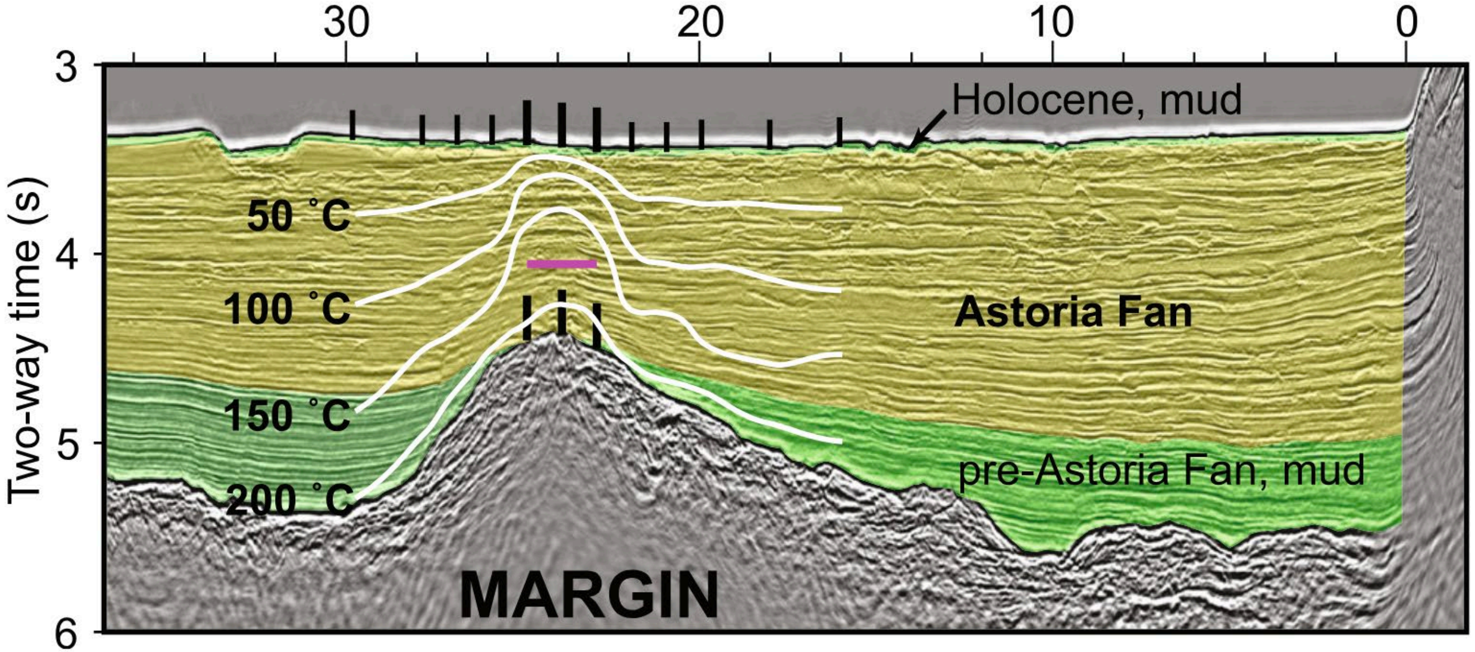


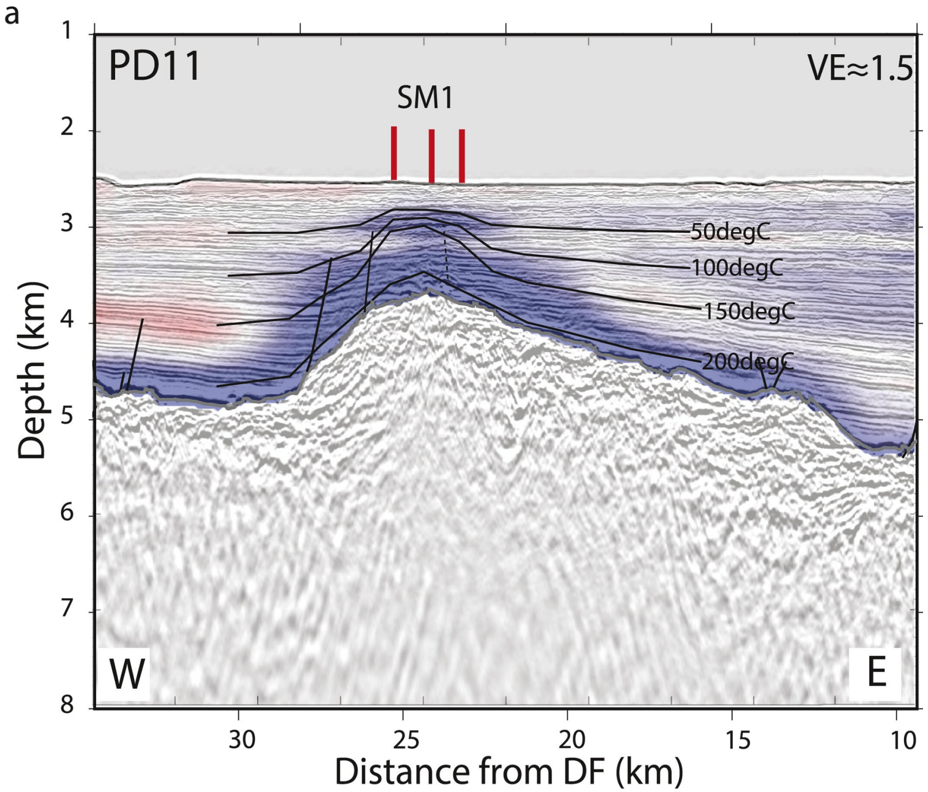
We know little knowledge of how rapid sedimentation influences this process

Li et al., 2024

Recent heat flow and P-wave velocity analyses suggest vigorous basement hydrothermal circulation that locally flows through into the sediment column due to overpressure

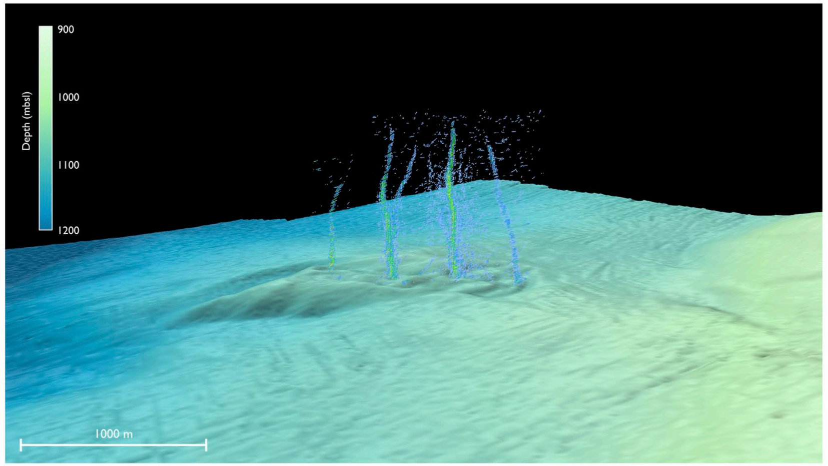


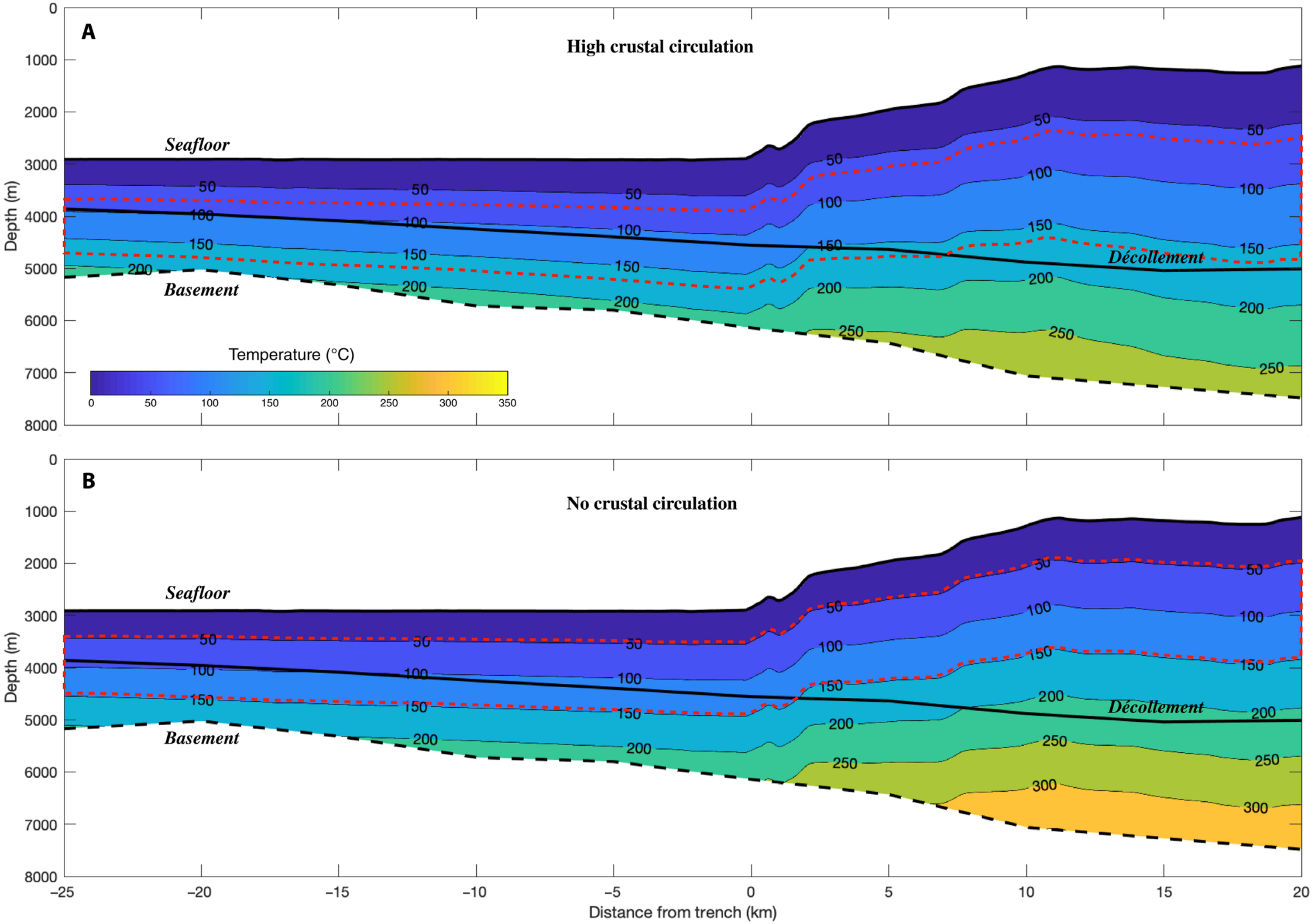
Norvell et al., 2023



Lee et al., 2024

Seep observations offshore Oregon suggest temperatures are warm enough for smectite (~150° C) and pumpellyite (200 ° C) dewatering along the shallow megathrust



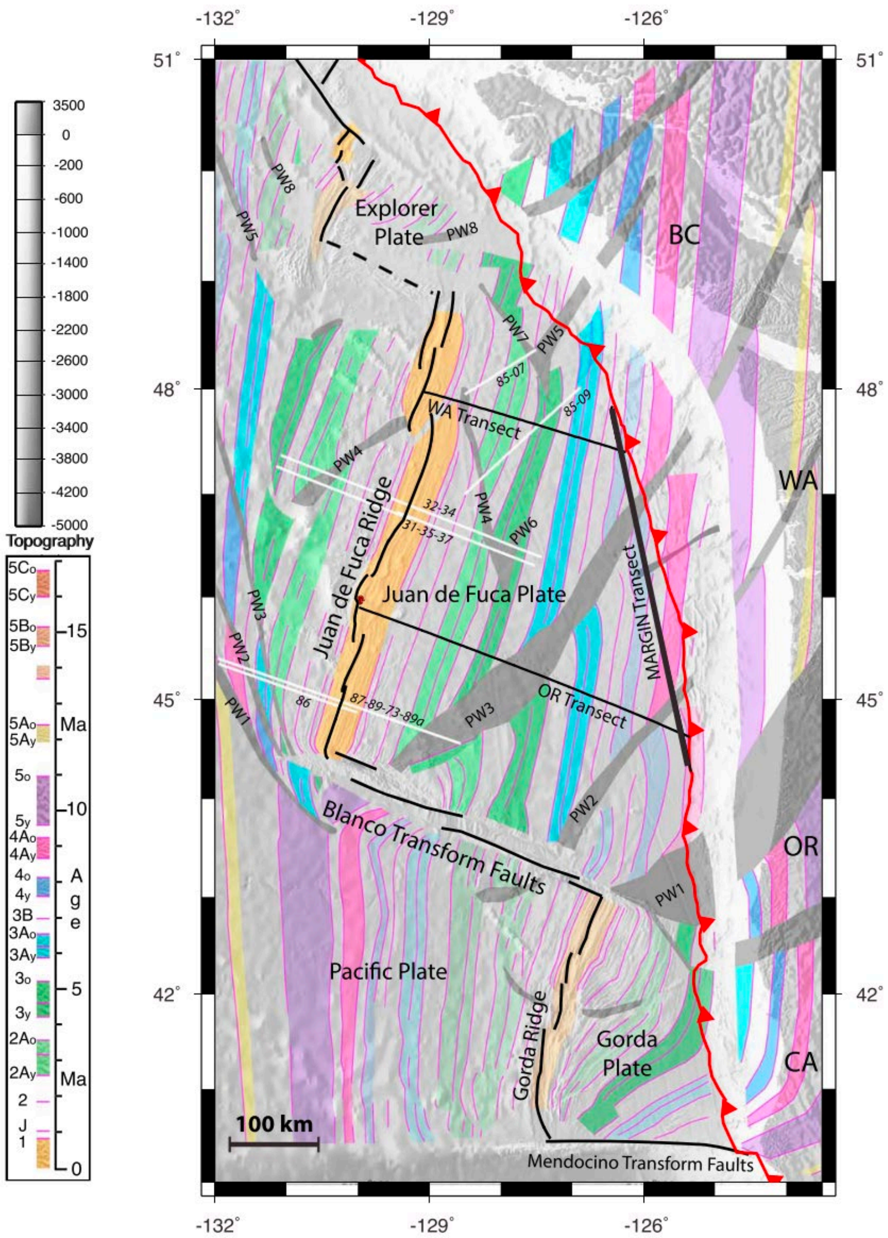


Implies hydraulic connection between basement and surface seeps

Philip et al., 2023

Large portions of the Cascadia margin have subduction of young oceanic crust (< 10 Ma), which likely has porous upper crust with active hydrothermal circulation

Offshore California, Southern Oregon, and Northern Vancouver Island in particular



Han et al. 2018

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   - Low-temperature dewatering reactions are likely occurring in JDF basement prior to subduction or within shallow forearc

DC tomography and FWI with CASIE2021 data should be examined for differences in upper crustal fluid reservoirs along the Cascadia margin