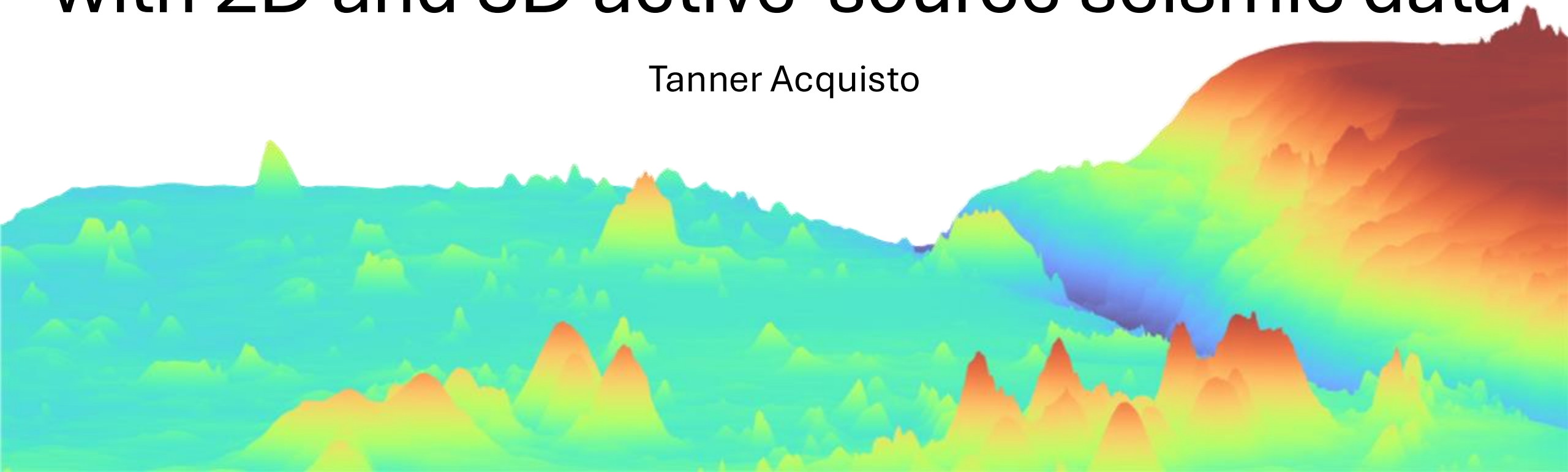
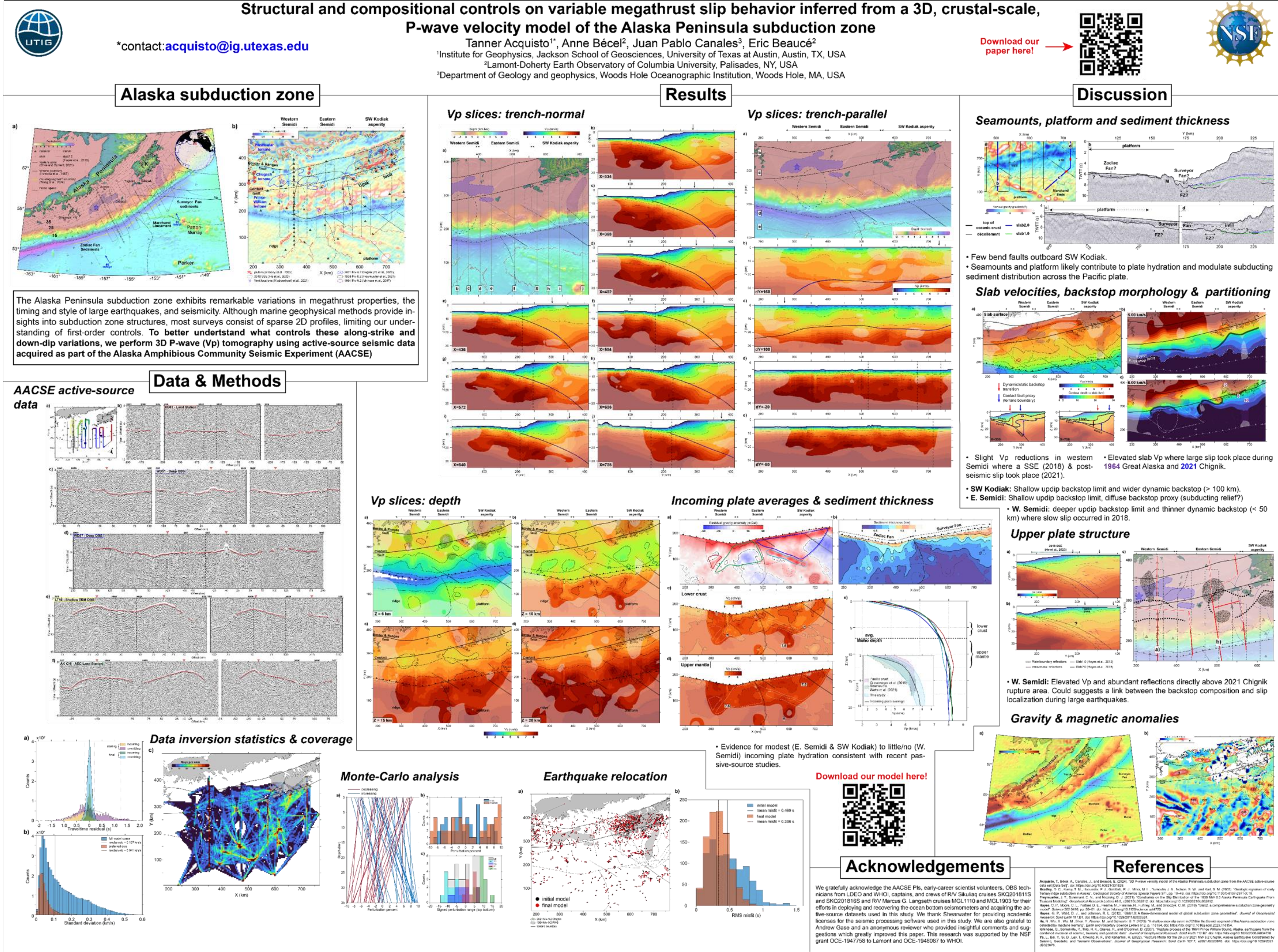
Crustal-scale imaging of subduction zones with 2D and 3D active-source seismic data

Tanner Acquisto



T53C-3223

- Friday afternoon, 13h40-17h30.
- 3D crustal-scale Vp model of Alaska subduction zone.
- Reveals structural and compositional changes in both plates that could help explain different megathrust behaviors.
- Recently published in JGR: Solid Earth (Acquisto et al., 2024)
- Model available for download on the MGDS.



T13C-337

- Monday afternoon, 13h40-17h30
- Constraints on water content of the Cocos plate outboard the Middle America Trench, Mexico.
  - Most of the water is stored in the upper crust, whereas the lower crust and mantle are relatively dry.
- Joint inversion of OBS & MCS data produces a sharper, crustal-scale image.

Water content of the Young, Incoming Cocos Plate outboard of the Guerrero Gap and Neighboring Segments at the Middle America Trench offshore Mexico

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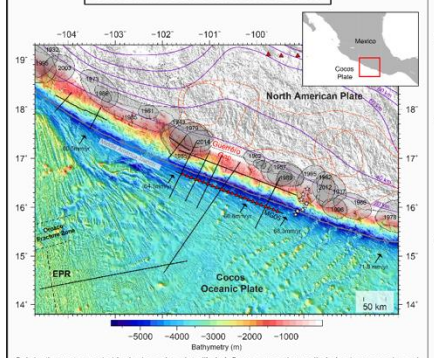
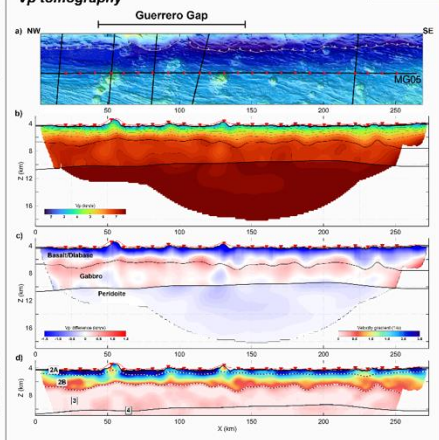
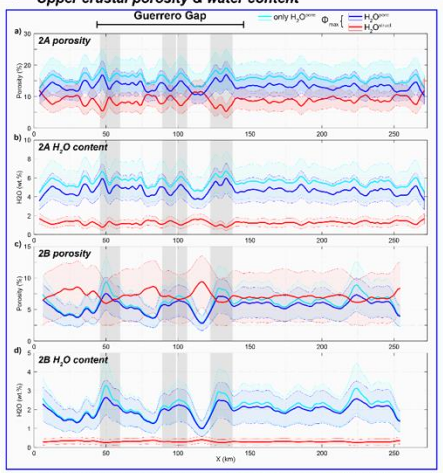
Mexico subduction zone

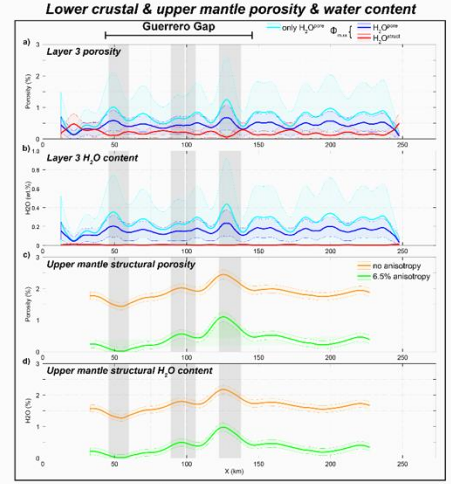


Subducting water carried in the incoming plate likely influences megthrust slip behavior once released downdip, particularly slow and aseismic slip. Offshore Mexico, fluids released at a range of depths might help explain why the Guerrero Gap has not ruptured in a large (Mw > 7) earthquake for some time compared to adjacent areas that regularly host large earthquakes. However, to date, the hydration state of the incoming plate remains unknown. **Here we use multichannel seismic (MCS) and ocean-bottom seismometer data to constrain the structural and pore water content of the incoming oceanic crust and upper mantle outboard the Guerrero Gap and adjacent areas just before subduction.**

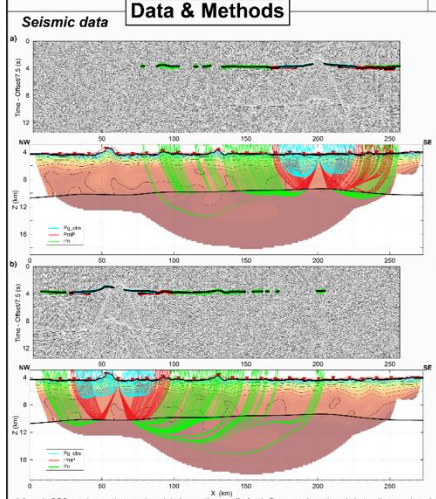
Results

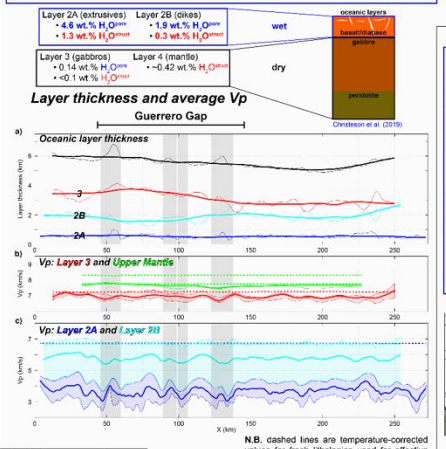






Data & Methods





N.B. dashed lines are temperature-corrected values for fresh lithologies used for effective medium modeling.

Discussion

Main takeaways:

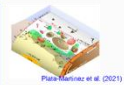
- Layer 2 is hydrated (more H_2O^{pore} than H_2O^{struct}), lower crust and mantle are dry.
- Petrologic models assume larger quantities of H_2O^{struct} and typically do not consider H_2O^{pore}.

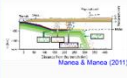
Northwestern segment (Guerrero):

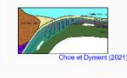
- ~30% more water is subducting there.
  - Higher H_2O^{pore} could help explain shallow aseismic slip.
  - Higher H_2O^{struct} could help explain slow slip downdip.
- Constraints on overriding plate structure, properties, and deformation are still needed!

Southeastern segment:

- Upper crust is still hydrated, slightly lesser extent.
- Could smoother basement topography and slightly thicker sediments contribute to plate locking?







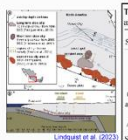
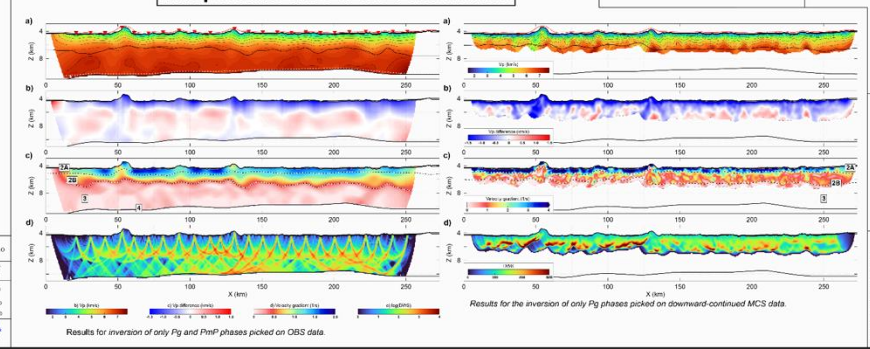


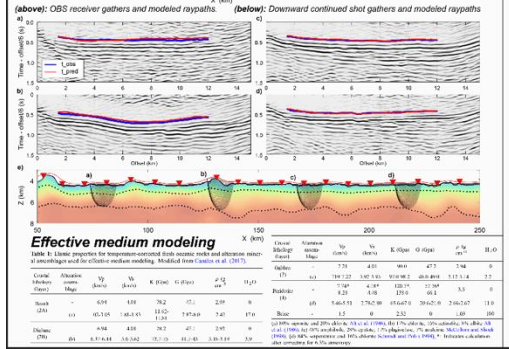
Table 2: Summary of outer rise water content estimates. Modified from Canales et al. (2017) and Acquisto et al. (2022)

Setting	Water content estimates (wt.% H_2O)							
	2A		2B		3		4	
	struct	pore	struct	pore	struct	pore	struct	pore
Global averages	2[a] 2-3[b] 1[c]	-	2[a] 0.5-2[b] 1-3[c]	-	0.2-0.7[c] 0.5-1.3[d]	-	-	-
Alaska[e]	-	3.9	-	-	-	-	1.8	-
Sumatra[e]	-	-	-	-	-	3.2	-	0.8,1.3
Nicaragua[f,g]	-	3–4.8	-	1.6	~1	0.6	-	3,0.9
Cascadia[h]	1.8	3.0	0.27	2.3	<0.01	0.07-0.15	<0.01-0.11	<0.02-0.04
Mexico (This study)	1.3	4.6	0.3	1.9	<0.01	0.14	1.85, 0.42[a]	<0.04-0.11

[a]Peacock (1990); [b]Ripple et al. (2004); [c]Carlson (2003); [d]Carlson and Miller (2003); [e]Acquisto et al. (2022); [f]Naif et al. (2015); [g]Van Avendonk et al. (2011); [h]Canales et al. (2017); ~6.5% anisotropy

Independent MCS & OBS inversions





Future Work

Tomographic inversion:

- Explore the tradeoff between velocity and Moho depth.
- Resolution tests
  - Checkerboards.
  - Vp uncertainty (Monte-Carlo)
- Tie with intersecting MCS/OBS profiles
  - Crustal anisotropy?
  - Quantify upper mantle anisotropy

Porosity and water content estimation:

- Explore different alteration mineral assemblages (Table 1).
- Compare to independent OBS and MCS results.
- Use full model instead of layer averages.
- Account for plate bending/faulting (macro-porosities)?

Acknowledgements/References

We thank the RV Marcus G. Langseth's Captain, crew, and techies. Acquisto, T., Bécel, A., Shuck, B. T., & Canales, J. (2022). Extension of strong upper mantle serpentinization to the trench in young subducting lithosphere. Journal of Geophysical Research: Solid Earth, 127(10), e2022JB024781. Canales, J. P., Carbotte, S. M., Nedimović, M. R., & Carton, H. (2017). Dry and hydrated fault crustal properties at the rupture area of the 2010 Maule earthquake and implications for subduction megathrust mechanics. Nature Geoscience, 10(11), 844-849. Carlson, R. L. (2003). How crustal thickness varies on the Earth. Geophysical Research Letters, 30(13). Christeson, G. L., Goff, J. A., & Reece, R. S. (2019). Synthesis of oceanic crustal structure from three-dimensional seismic data. Reviews of Geophysics, 57(2), 504-529. Canales, J. P., Gouveia, V. L., Jagoe, J. S., & Verdel, N. E. (2022). Wet sediments in warm subduction zones at depths of the updip limit of the seismogenic zone. Geochemistry, Geophysics, Geosystems, 23(11), e2022GC010687. P. C. L. Plata-Martinez, V. M. Cruz-Atienza, J. A. Canales, J. P. (2021). Seismic activity and slow slip events along the fault at the subduction zone interface beneath southern Mexico. Journal of Geophysical Research: Solid Earth, 126(5), e2020JB021190. Plata-Martinez, R., Ide, S., Shinohara, M., Garcia, E. S., Iglesias, A., Yamamoto, Y., Ito, A., Yamada, T., Kostoglodov, V., Husker, A., Arciniega-Ceballos, A., & Ito, Y. (2021). Shallow slow earthquakes to decipher future earthquakes in the Guerrero seismic gap. Scientific Reports, 11(1), 6874. Manea, V. C., & Manea, M. (2011). Flat-slab thermal structure and evolution beneath central Mexico. Pure and Applied Geophysics, 168, 1475-1487. Ruiz-Barrera, R., Ide, S., Shinohara, M., Garcia, E. S., Iglesias, A., Yamamoto, Y., Ito, A., Yamada, T., Kostoglodov, V., Husker, A., Arciniega-Ceballos, A., & Ito, Y. (2021). Shallow slow earthquakes to decipher future earthquakes in the Guerrero seismic gap. Scientific Reports, 11(1), 6874.

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