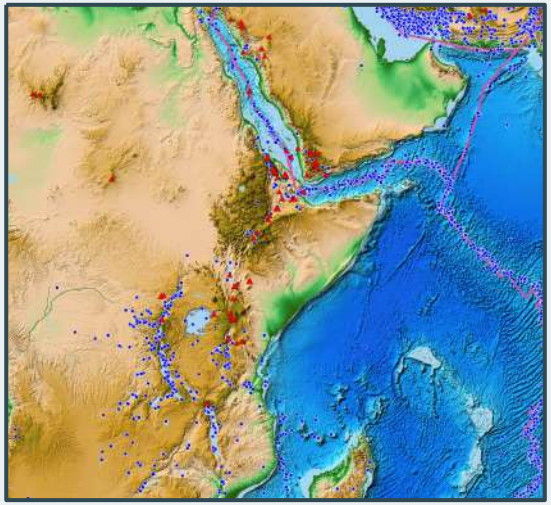
Slide B

Navigate

With your class

Earthquakes and volcanoes in East Africa did not appear to be along an established plate boundary.



What ideas could explain **where the forces come from** to cause earthquakes, volcanic eruption, and breaking in the Afar region?

Navigate

Turn and Talk

What data could we use to investigate the matter below Earth's surface to explain **where the forces might be coming from** to cause earthquakes, volcanic eruption, and breaking where there are no clear plate boundaries?

→ Be ready to share your ideas with the class.

Slide D

Read about Investigating Earth's Interior

With a partner

Read *How do scientists explore Earth's interior?* to answer some of our questions about how scientists figure out what lies beneath the surface of our planet.

Use the protocol at the top of the handout to guide your reading. DO NOT ANSWER ANY QUESTIONS.

Building Understanding: Seismic Waves

Patterns in the vibrations that travel through matter from an earthquake (**seismic waves**) help scientists make inferences about Earth's structure.

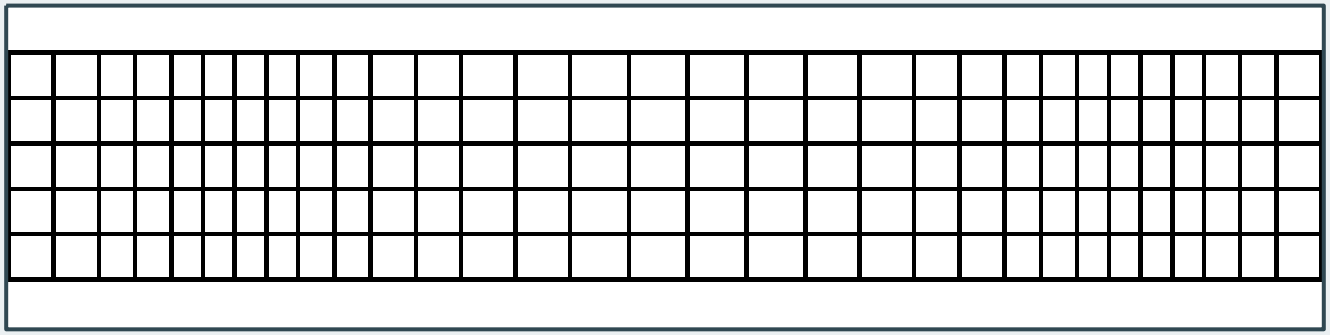
With your class

What evidence have we seen that vibrations can travel through solid matter?

Building Understanding: P-waves

With your class

- What do we know about P-waves from the reading that can help explain this animation?
- If lines in the animation represent bonds between particles, where are the particles, and how are they moving?
- What is actually traveling through the solid if it is not the particles themselves?



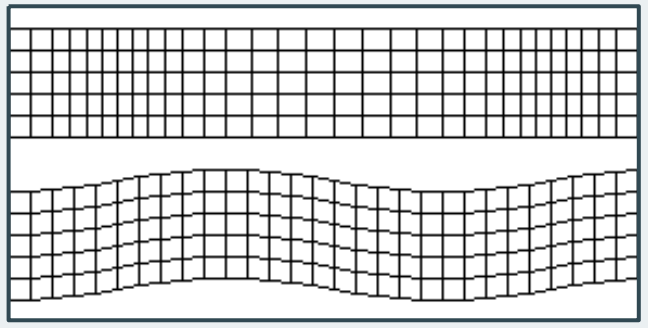
Building Understanding: S-waves

P-waves can travel *through any state of matter*.

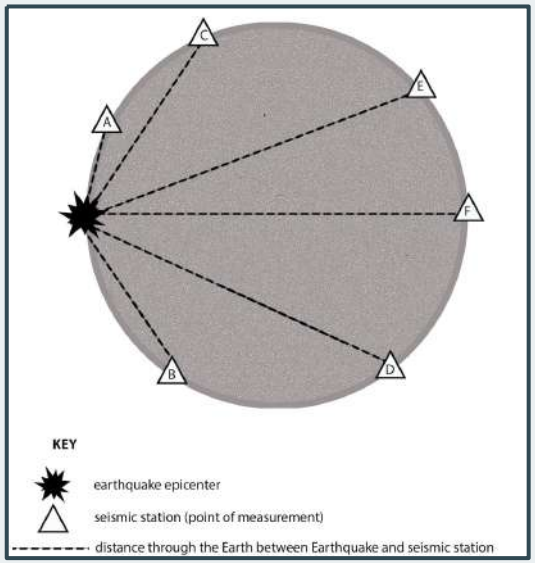
S-waves are back-and-forth waves that only travel *through solids*.

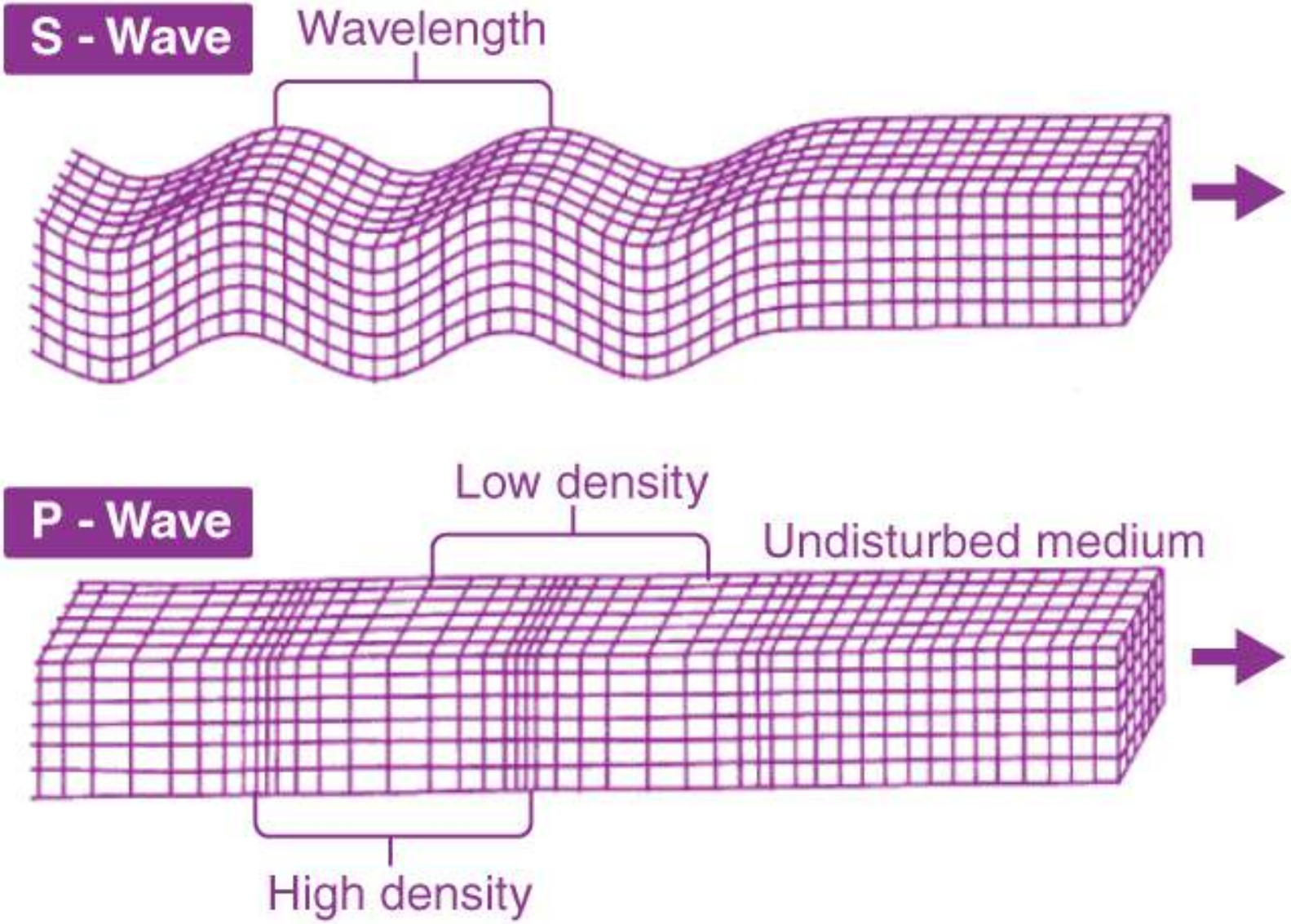
With your class

Which type of wave should reach the seismic measurement stations first?



Actualist, CC BY-SA 3.0, via Wikimedia Commons

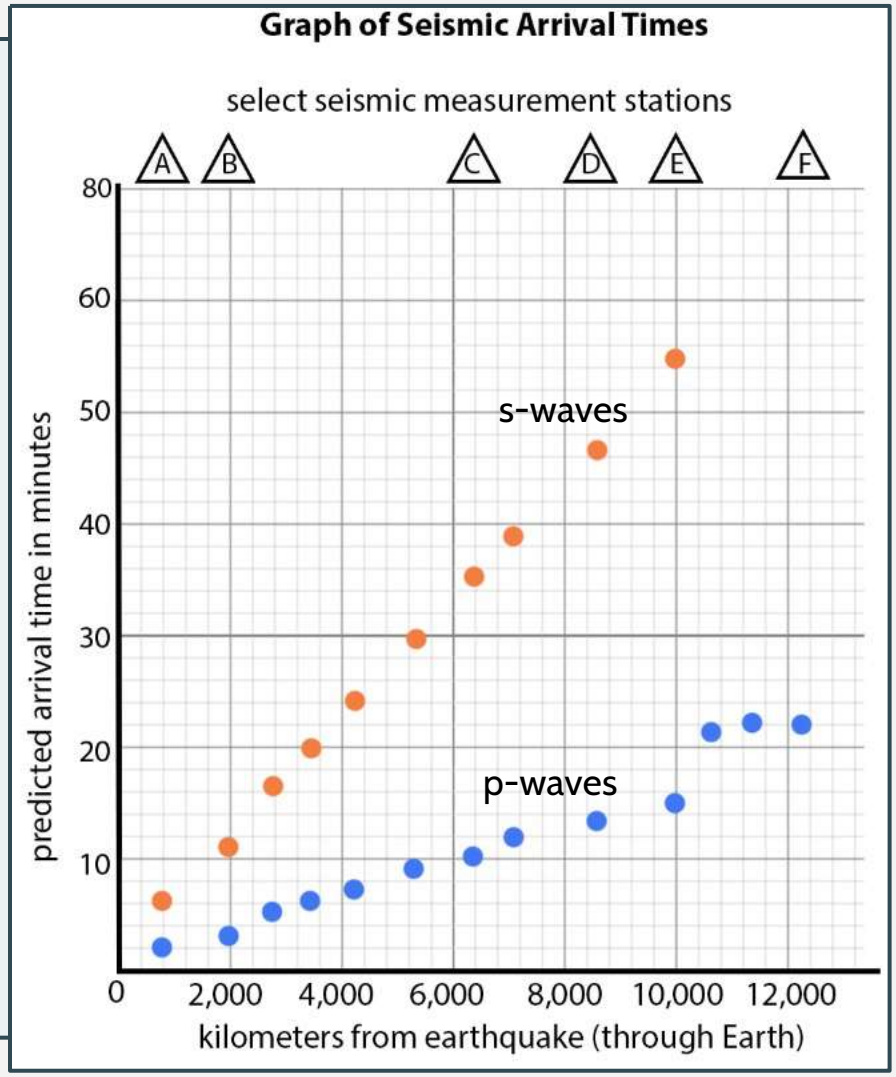



S - Wave
Wavelength
P - Wave
Low density
Undisturbed medium
High density

Building Understanding: Seismic Anomalies

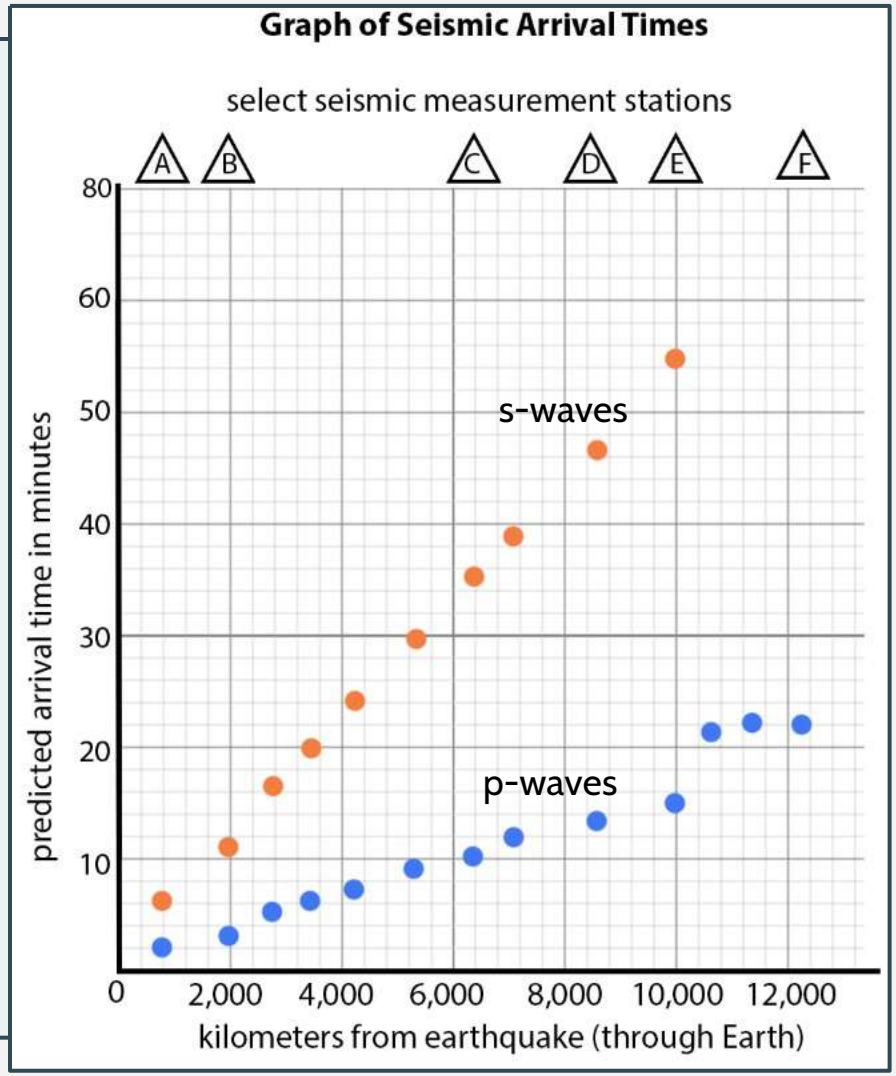
With your class

- What patterns can you *identify* on the graph?
- What does each of the patterns that you identified *mean*?



Building Understanding: Seismic Anomalies

- Where do the data appear to be different from what we would expect (an *anomaly*)?
- What could we do to test whether the data matches what we expect?



Navigate: Earth's Layers

With a partner

Look at a model of how scientists believe Earth's interior is structured.

- What do you notice? What do you wonder?
- Which layers cause P-waves to slow down and S-waves to disappear? What is your evidence?

➔ Be ready to share your ideas on an exit ticket.

Test Our Ideas

With your class

Observe a simulation to test our ideas.

Be sure to select “shadow zone” under “waves shown” before pressing play (▶).

EarthScape Consortium

Turn and Talk

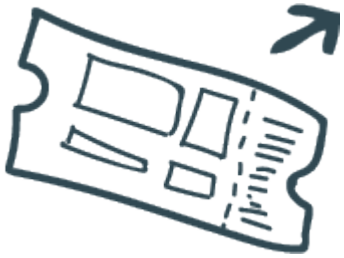
What do you notice about the P-waves and S-waves when they pass through Earth’s liquid core?

Simulation: Making Sense

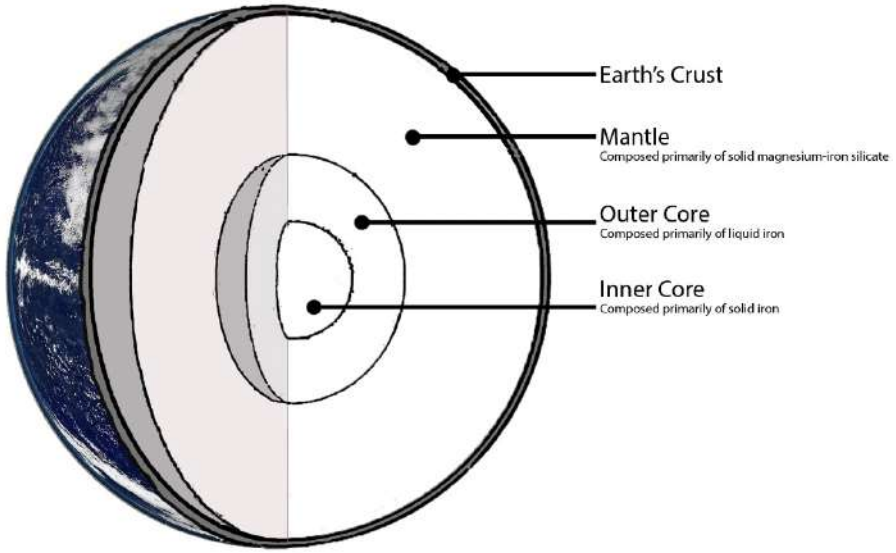
With your class

- Does the simulation support our model of what happens to the energy transferring in P-waves and S-waves when they pass through Earth's liquid outer core?
- What can we infer about where the energy transfers when S-waves arrive at Earth's liquid outer core?

Navigate: Earth's Layers



Exit Ticket



- Which layers cause P-waves to slow down?
- The speed of P-waves through liquid iron is ~9 km/s. Use this to support your claim with evidence and reasoning.

Use the SubMachine Tool

With your class

- What surface features did we observe in Afar that might be evidence for what is happening in the mantle?
- How do you think the mantle beneath where we live will compare? Why do you think that?

Use SubMachine to observe the Afar region and compare it to our region as a class. Record what the class observed in the first 2 rows of the data table provided.

Navigate and Add to Personal Glossary

With your partner

Record definitions for new words we encountered in this lesson in your Personal Glossary.

Return to the DQB

With your class

- How did observing seismic waves on a local scale help us understand more about the matter in Earth's mantle?
- What questions on the DQB might we be able to make progress on by changing from a global scale to a more local scale to investigate the mantle?

Use the SubMachine Tomography Tool

With a partner

Investigate at least 3 more locations.

- Use Google Maps or Google Earth to identify relevant surface features of the locations you selected.
- Use the provided list of coordinates to generate mantle cross section models.
- Complete questions 6 and 7 on the handout to prepare for class discussion.

Building Understanding

With your class

- What mantle patterns did you notice beneath:
  - volcanoes?
  - earthquakes?
  - mountains?
  - other surface features?
- What do these noticings tell us about the relationship between certain surface features and the matter in the mantle beneath them?

Prepare to Communicate Your Findings

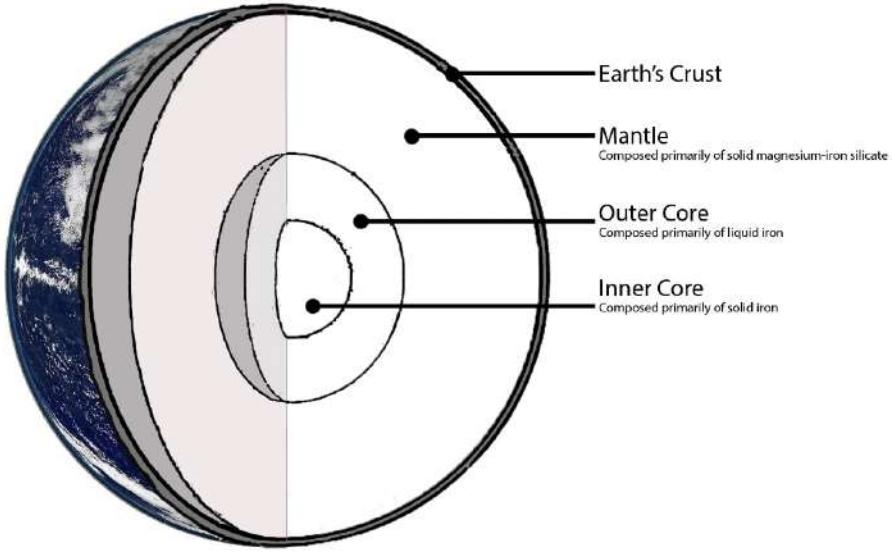
With your class

- What have we figured out that can help explain the plate motions we observed?
- How should we revise our *Earth's Interior Model* to reflect our new understandings about the mantle?

→ Be ready to share your ideas with the class.

Revise Model of Earth's Interior

On your own



Add labels, symbols, drawings, and/or annotations to your model of Earth's interior to reflect our new understandings about the mantle and its matter.

Navigate

With your class

- How does the scale of these mantle anomalies compare to the scale of the anomalies we used to figure out Earth's layers?
- Could these anomalies change over time?
- What DQB questions can we answer now?

Progress Tracker

On your own

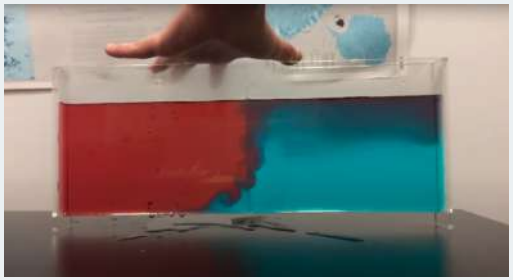
Update your Progress Tracker.

Lesson #	What did you figure out?	Which of these lenses did you use to figure this out?	How did using these lenses help you figure this out?
5		❑ Stability over time ❑ Change over time ❑ Thinking at/across different scales	

Navigate

Exit Ticket

We figured out that the temperature of solid rock in Earth's mantle is **heterogeneous**, and the rock can flow like a liquid.



UCAR

- What do we know about *how flowing matter of different temperatures interacts* that could explain how the mantle might change over time?

Additional Image Credits

SubMachine images created using the following data and platforms:

Hosseini, K., Sigloch, K., Tsekhmistrenko, M., Zaheri, A., Nissen-Meyer, T., & Heiner, I. (2020). Global mantle structure from multifrequency tomography using P, PP and P-diffracted waves. *Geophysical Journal International, (220)*1, 96–141. https://doi.org/10.1093/gji/ggz394

Hosseini, K., Matthews, K. J., Sigloch, K., Shephard, G. E., Domeier, M., & Tsekhmistrenko, M. (2018). SubMachine: Web-Based tools for exploring seismic tomography and other models of Earth's deep interior. *Geochemistry, Geophysics, Geosystems, (19)*5, 1464-1483. doi:10.1029/2018GC007431

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