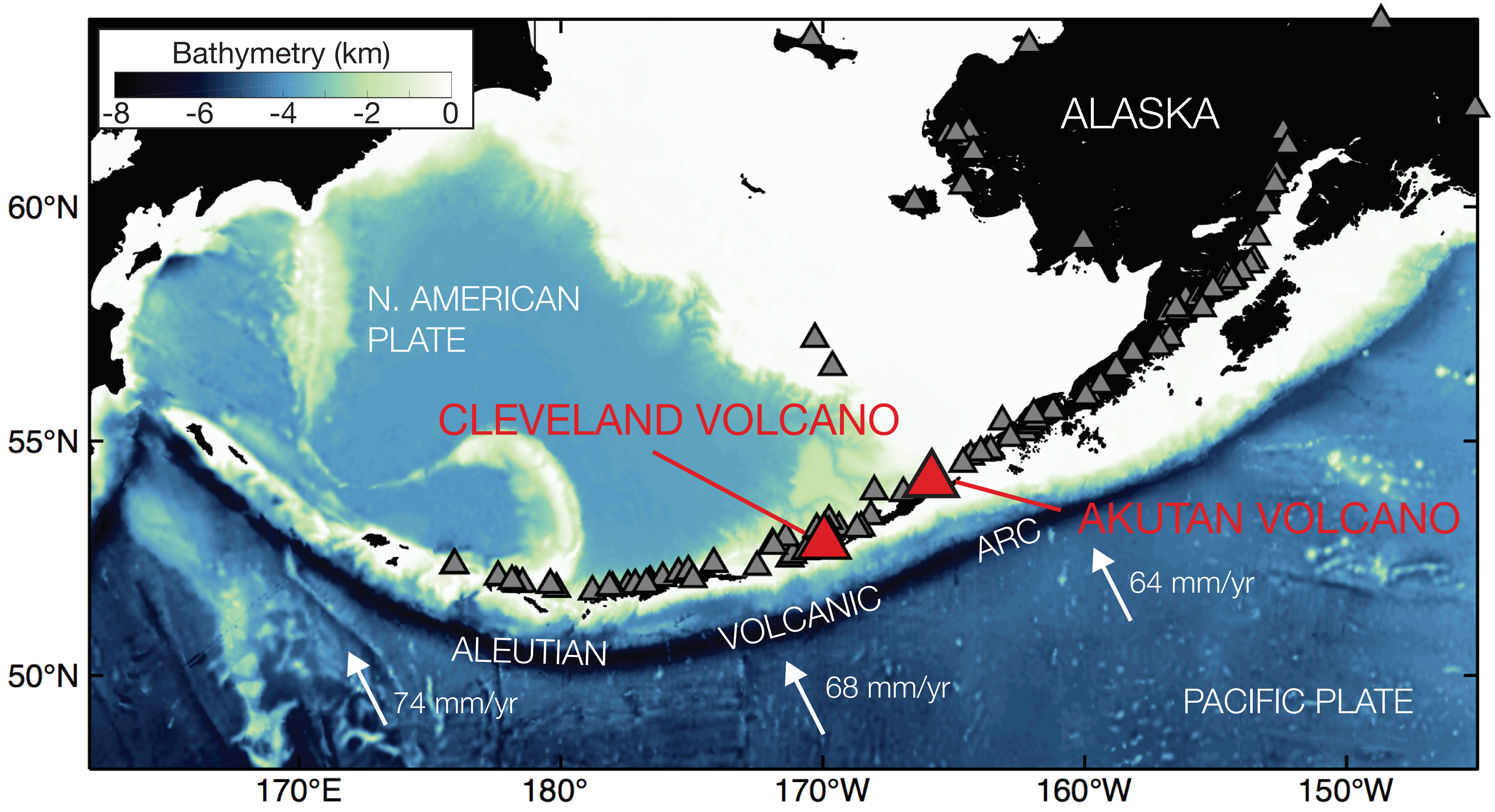
Imaging Trans-Crustal Magmatic Systems with Receiver Functions

A Path Towards Linking Tectonic and Eruptive Processes



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Lara S. Wagner, Diana C. Roman

SAGE/GAGE, 10 October, 2019

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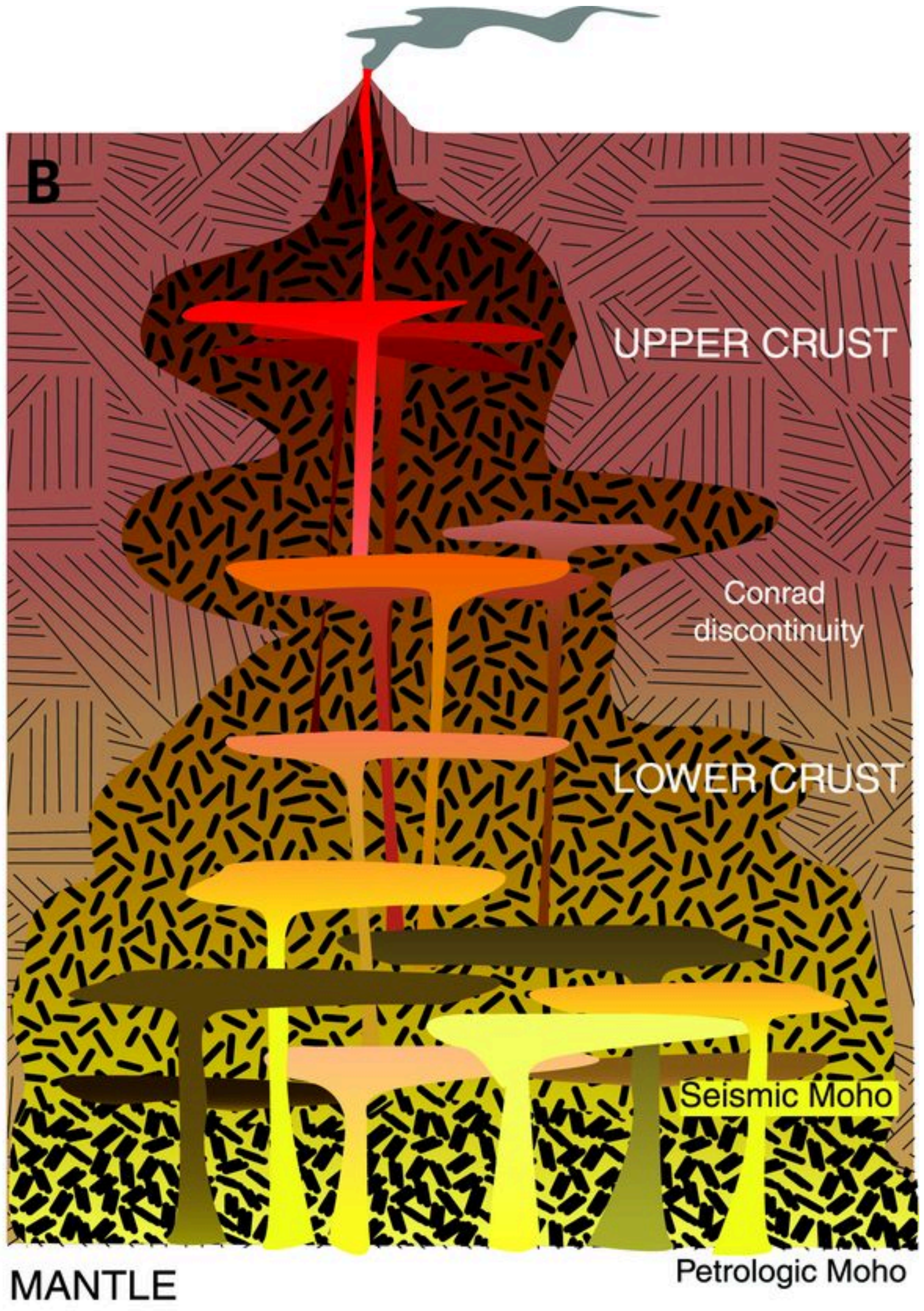
What is the crustal magmatic architecture beneath individual volcanoes?

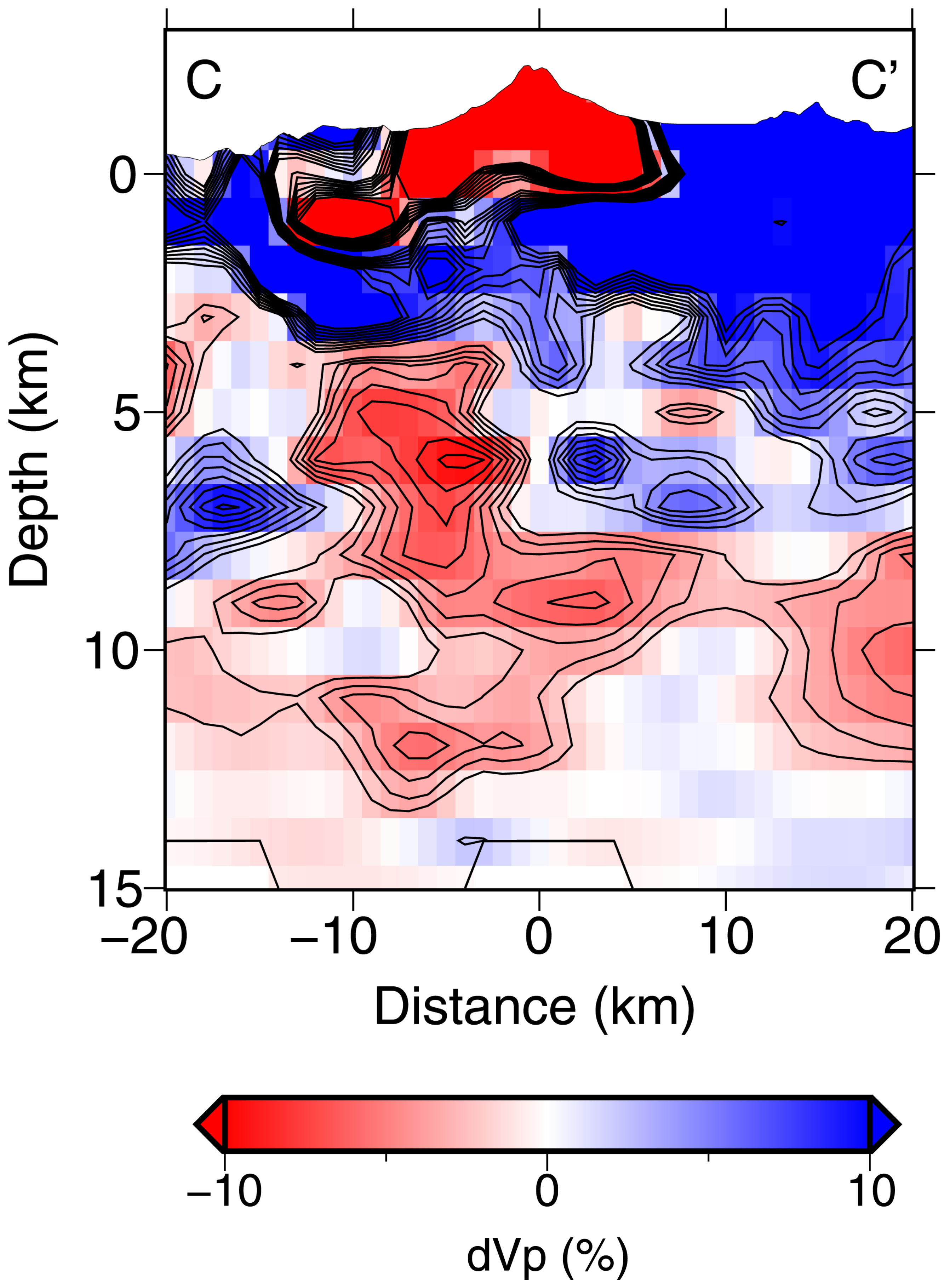


Cashman et al., 2017

What is the crustal magmatic architecture beneath individual volcanoes?

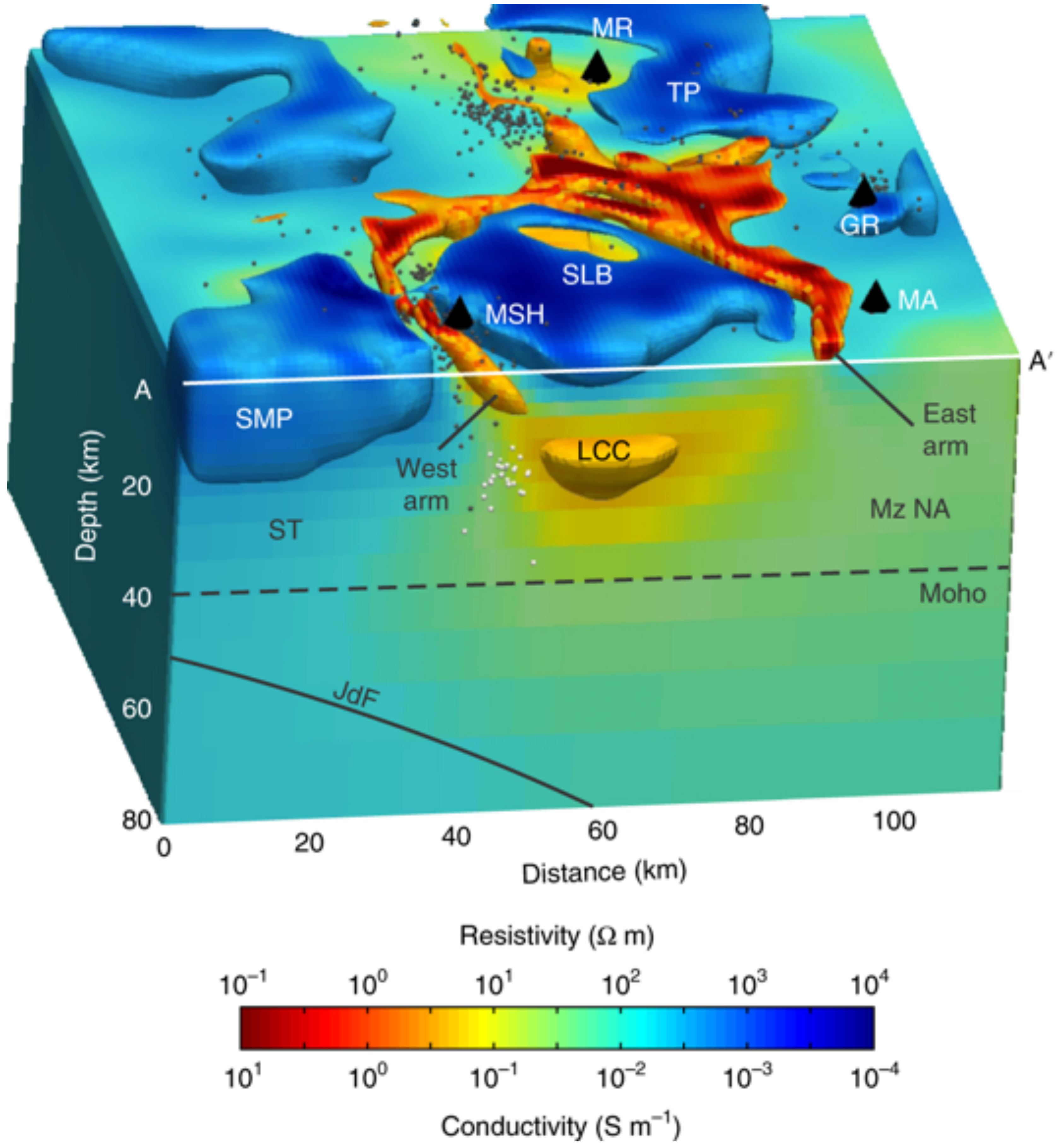
Examples from iMUSH

Active Source Seismic Imaging



Kiser et al., 2018

Resistivity



Bedrosian et al., 2018

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Examples from iMUSH

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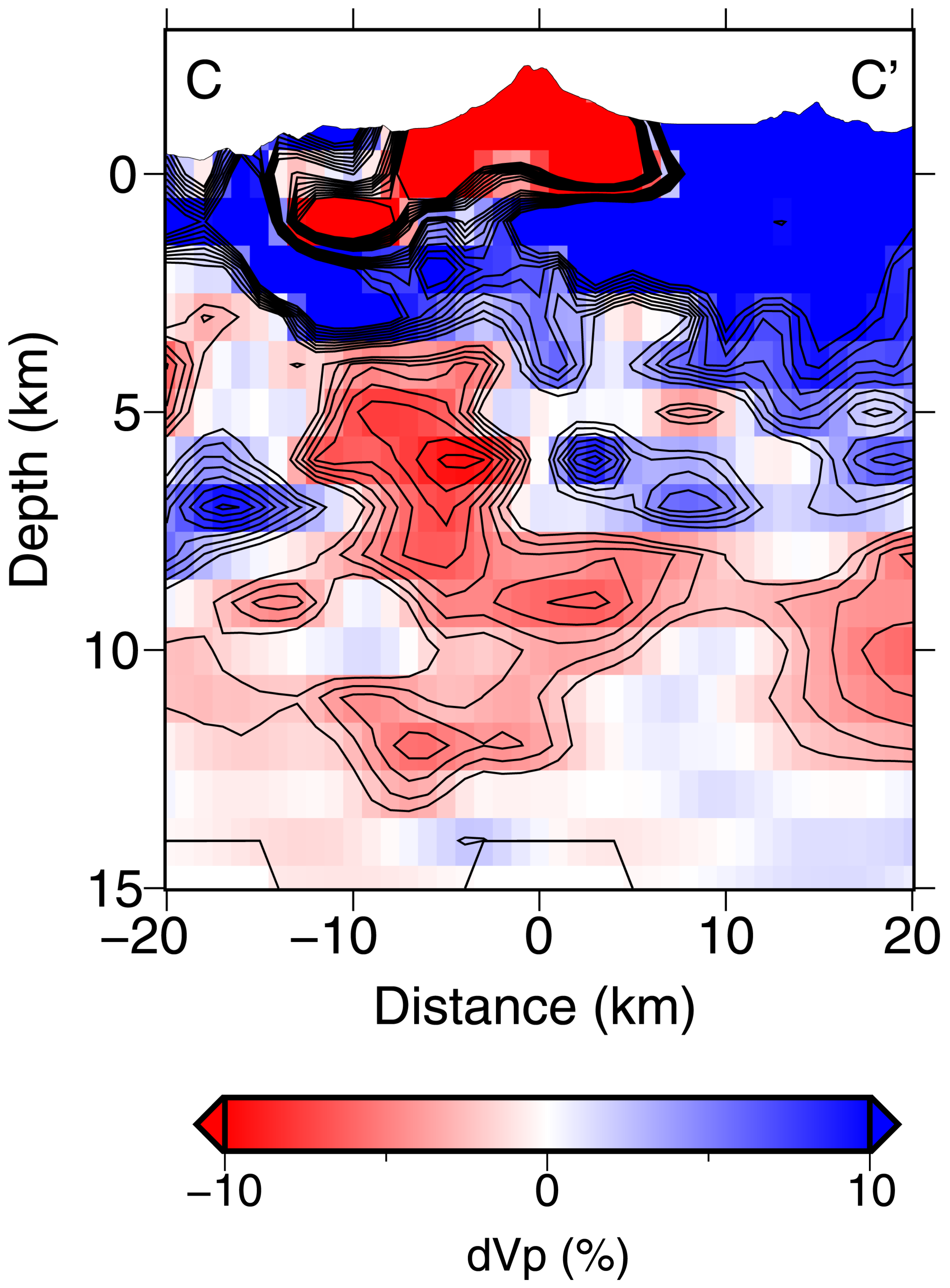

Kiser et al., 2018

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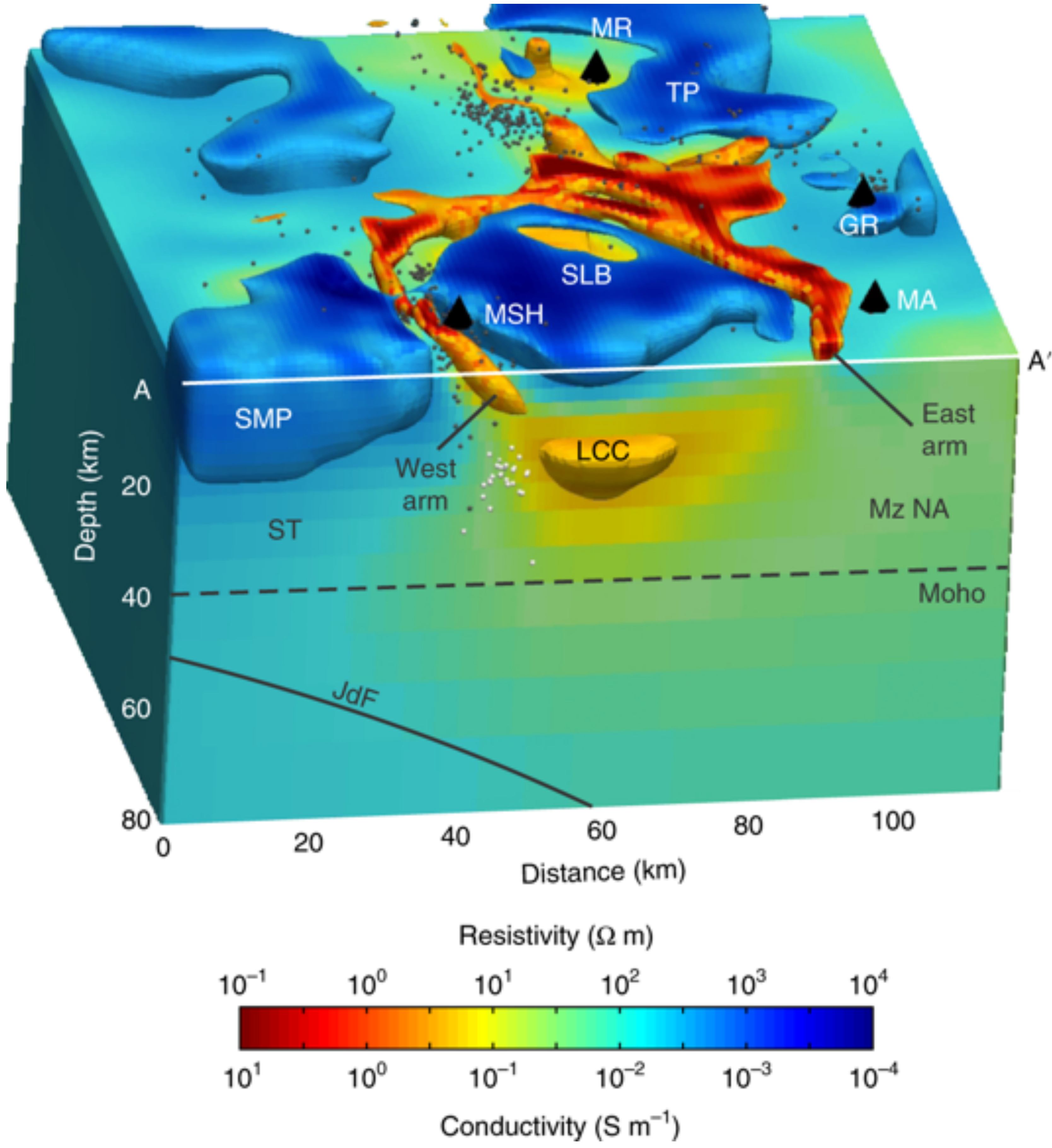
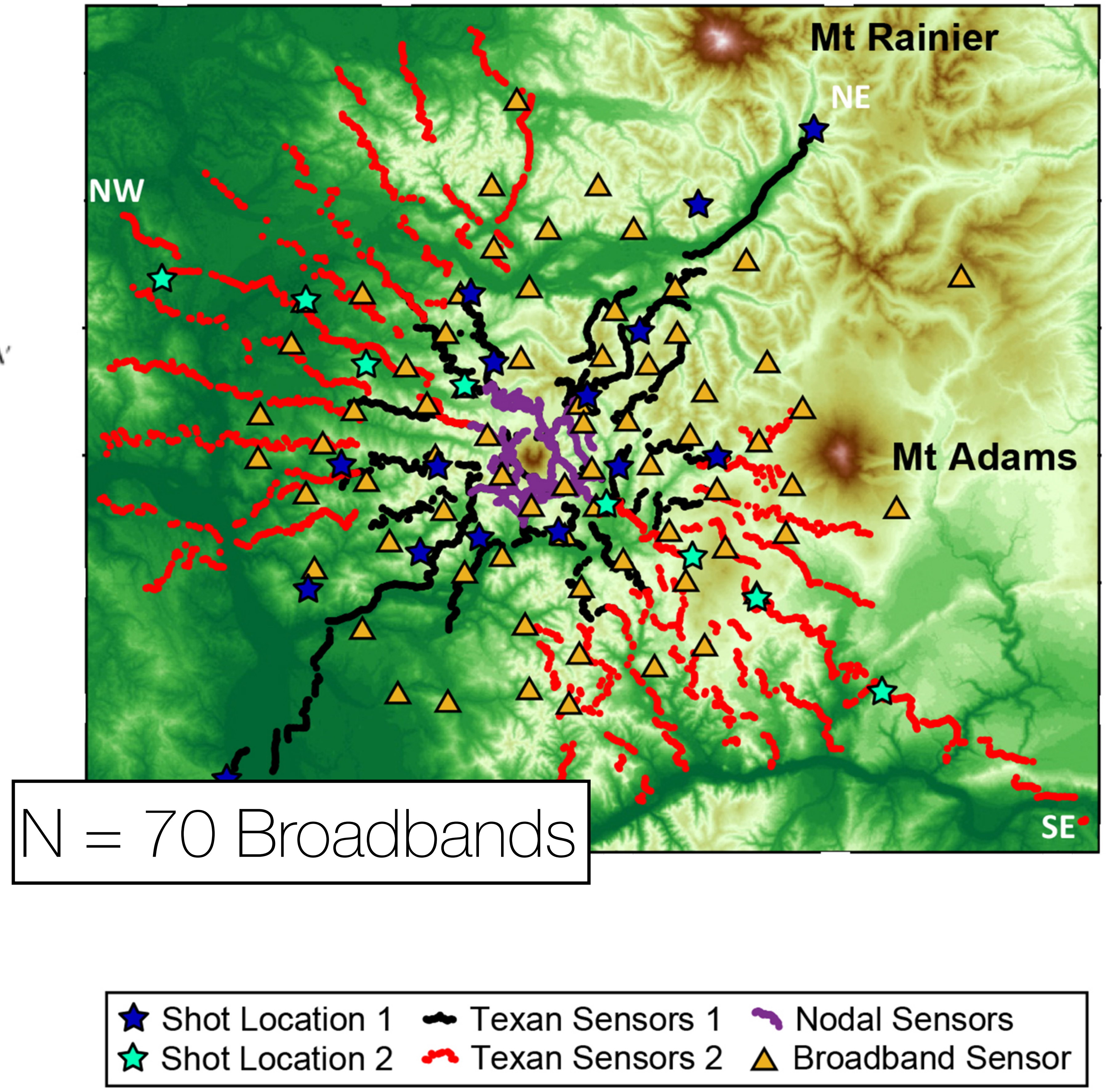
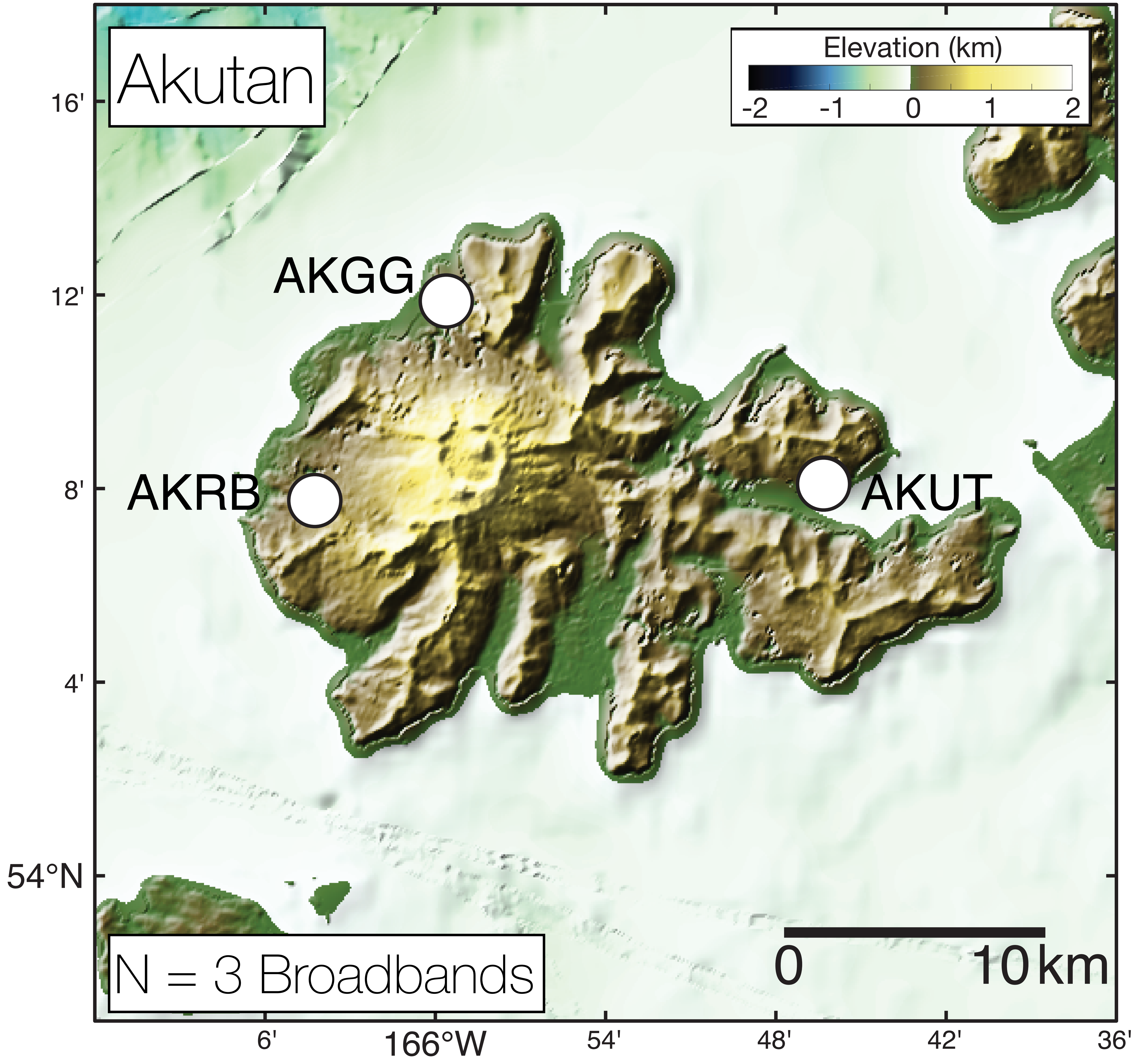


Bedrosian et al., 2018

Seismic Array



What can we do with fewer resources?



Janiszewski et al., 2013

Receiver function techniques can image deep crustal magmatic structure with only a few broadband instruments.

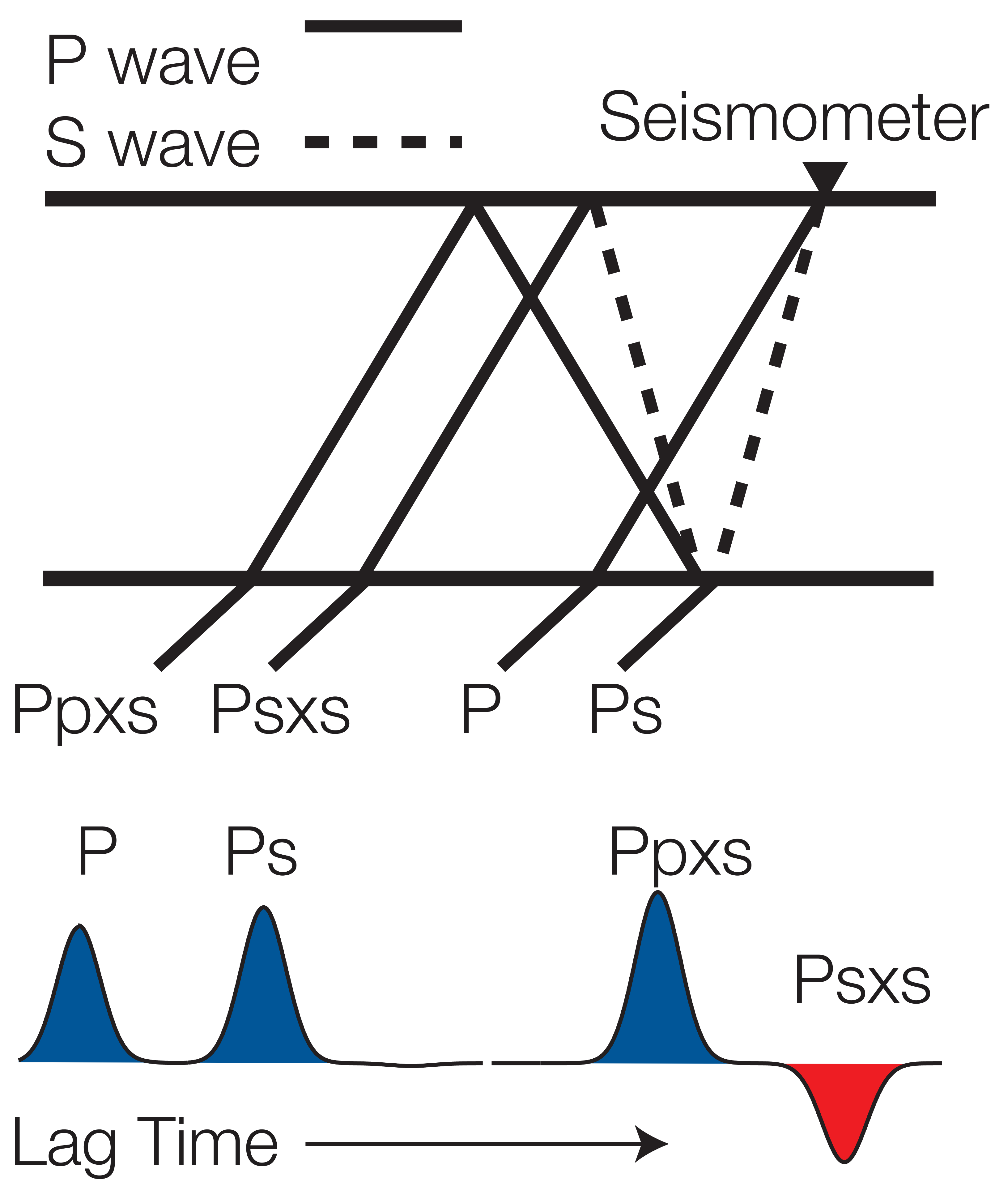
Comparable to a monitoring network.

Receiver Functions

Receiver functions are sensitive to **abrupt seismic velocity boundaries**.

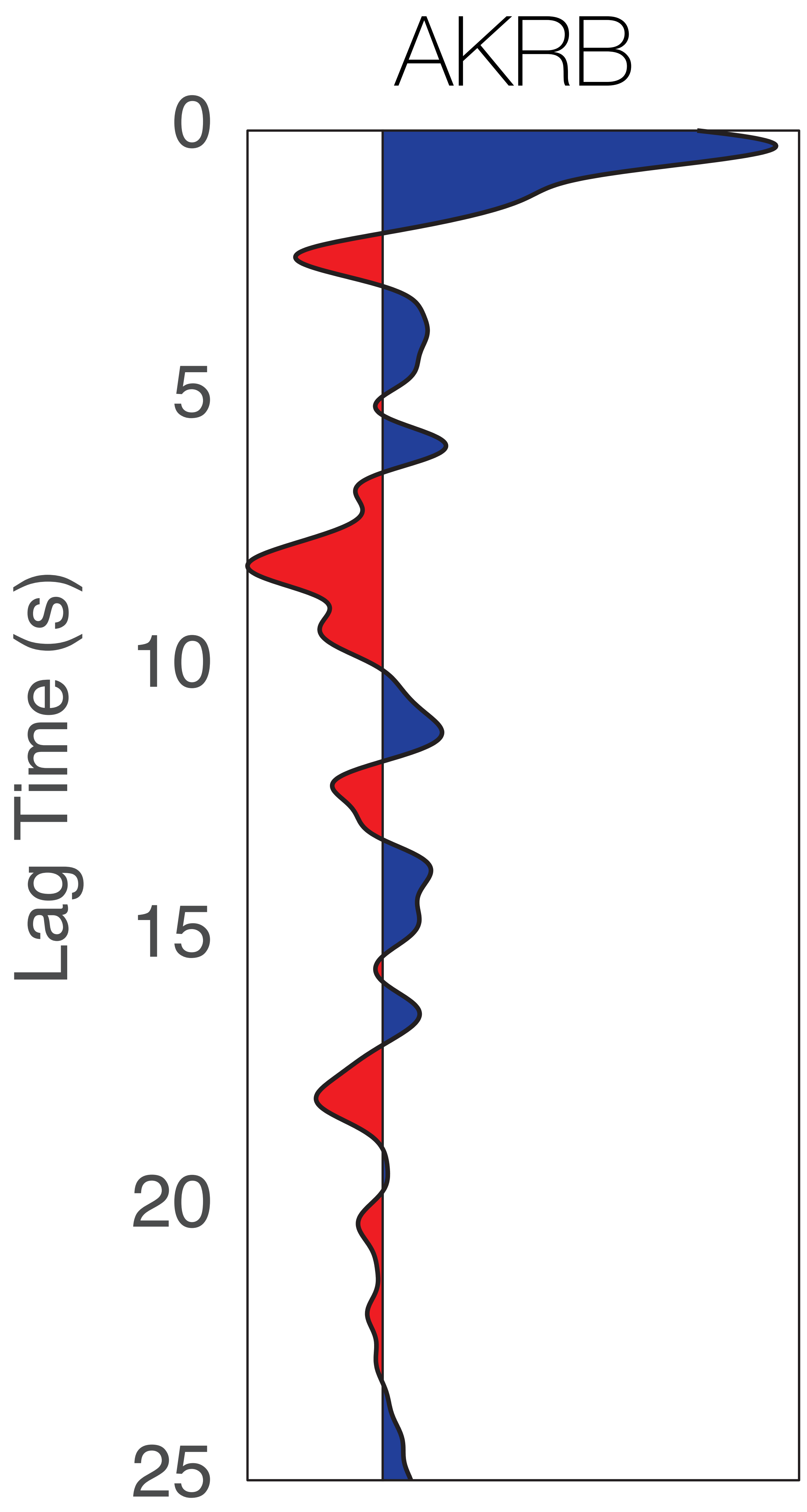
Traditionally used to image the Moho, Lithosphere-Asthenosphere Boundary, Transition Zone.

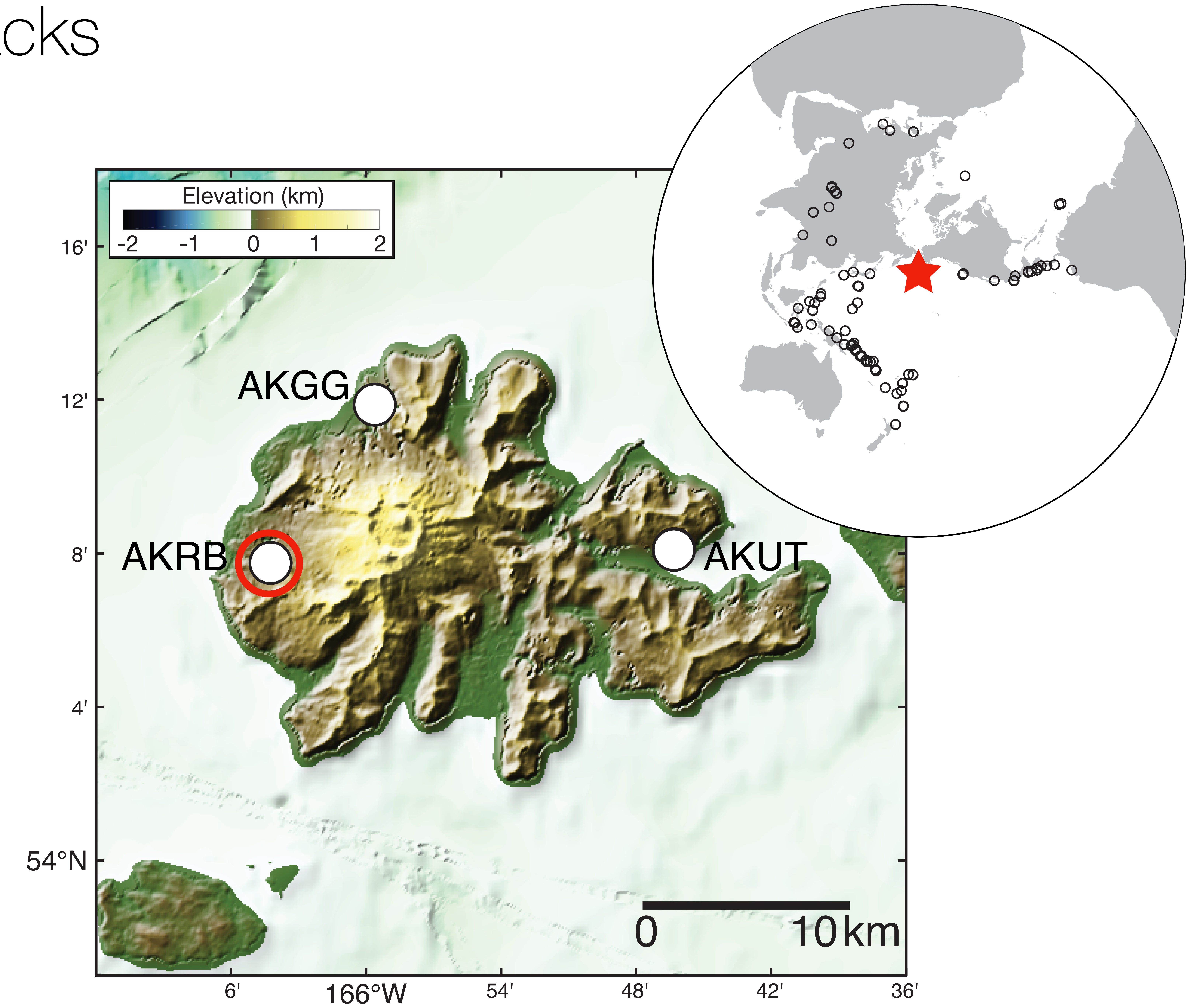
Trade off between velocity and thickness of layer.



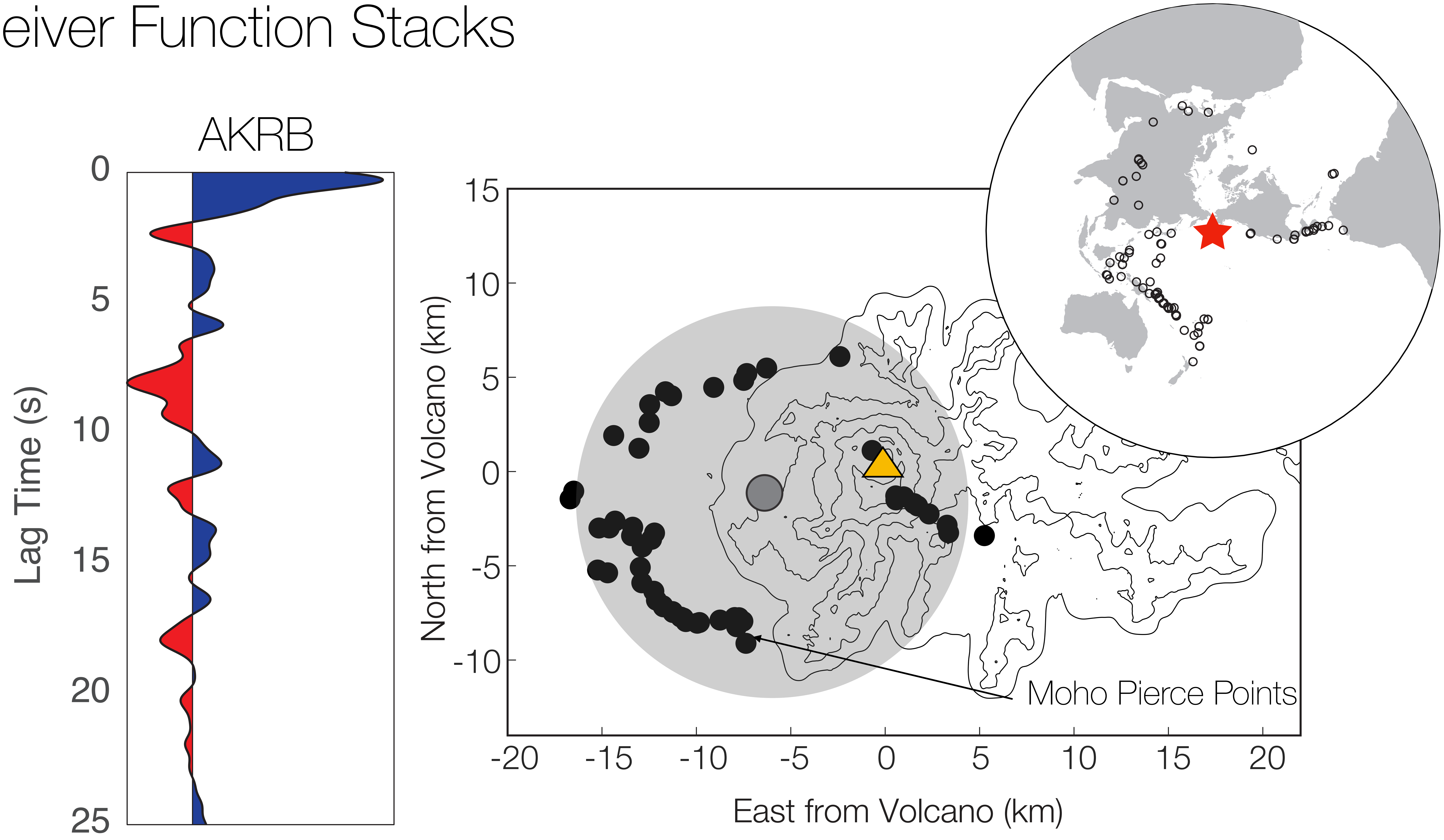
Arrival times relate to depth and velocity to boundaries

Receiver Function Stacks

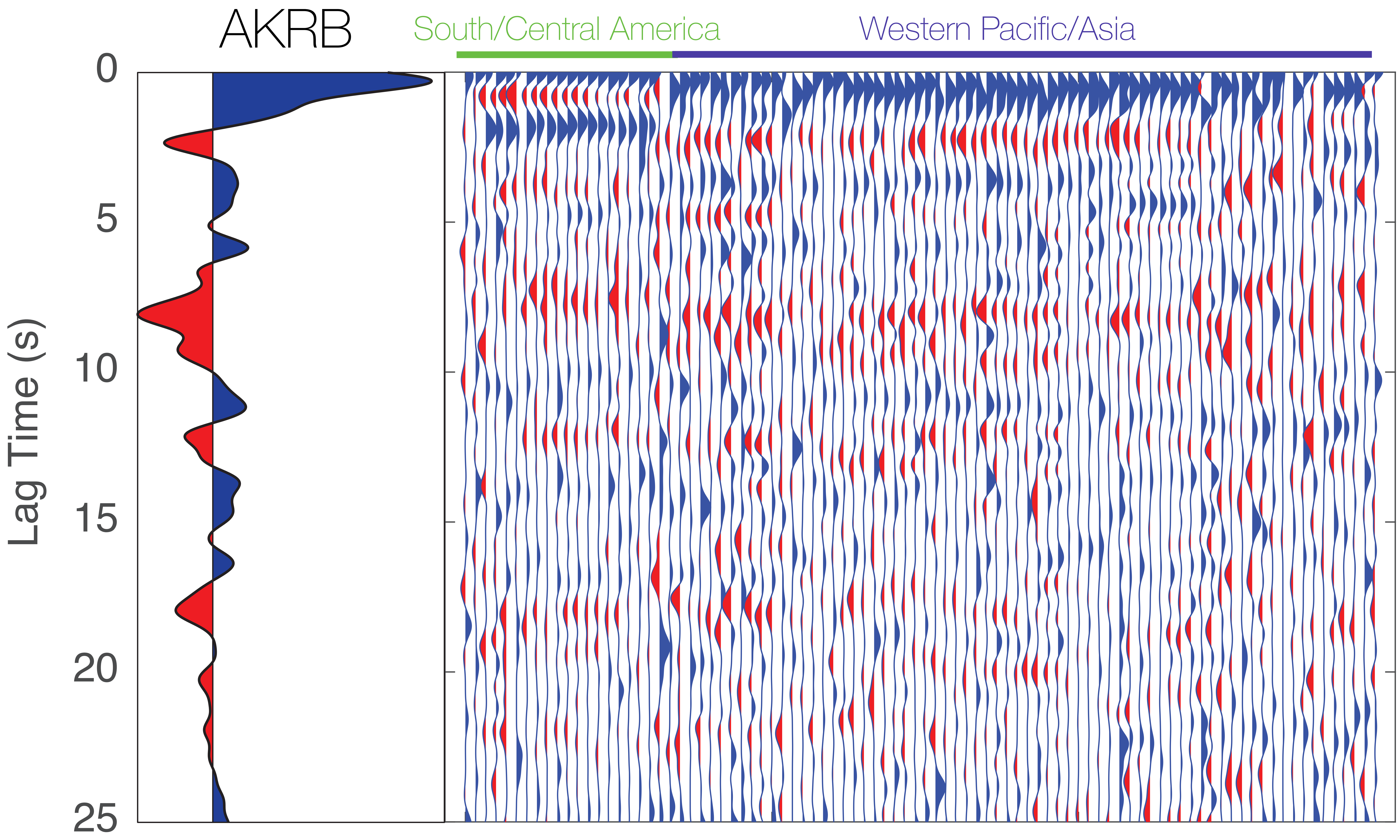




Receiver Function Stacks



Individual Earthquake Receiver Functions



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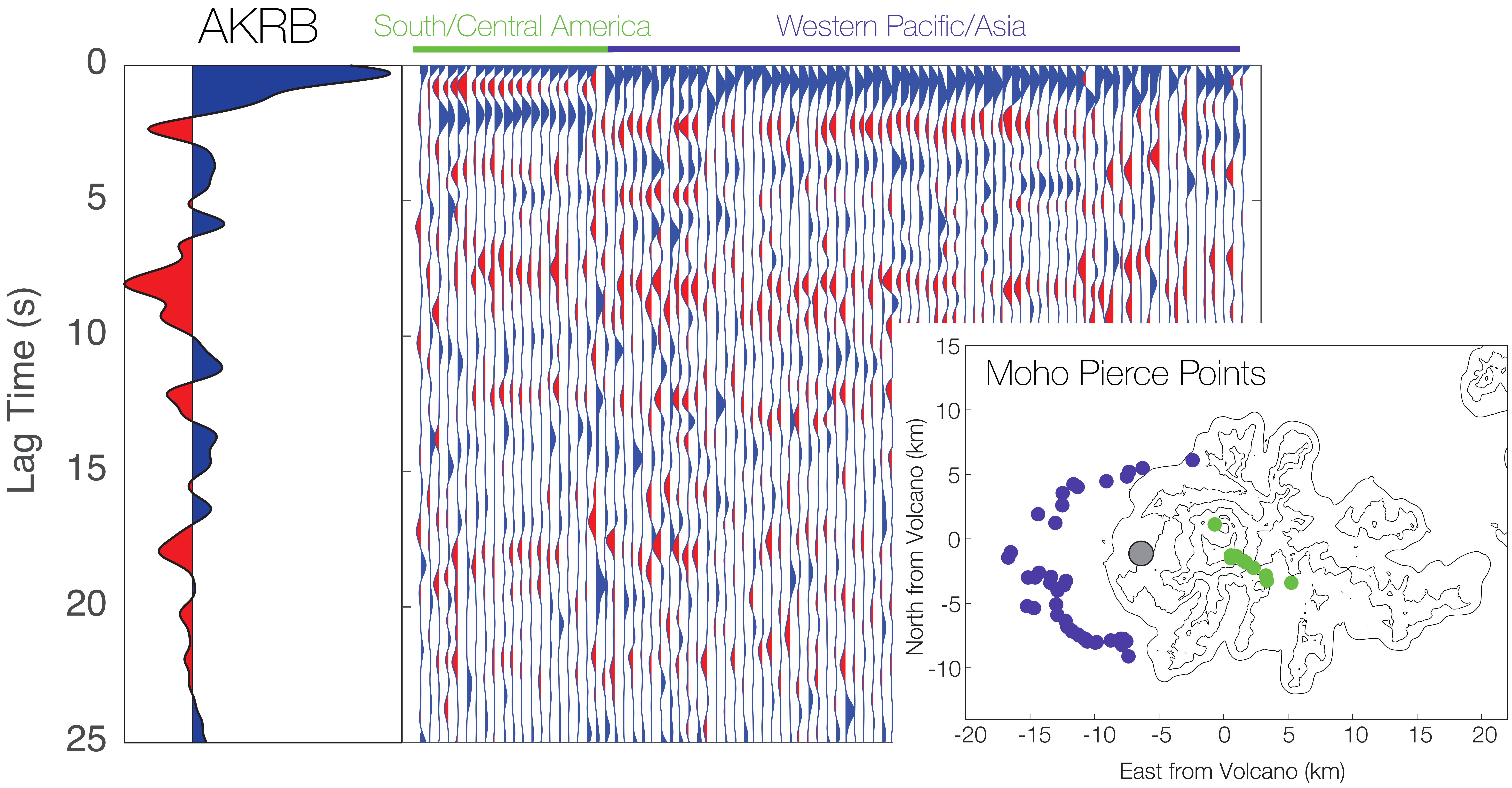
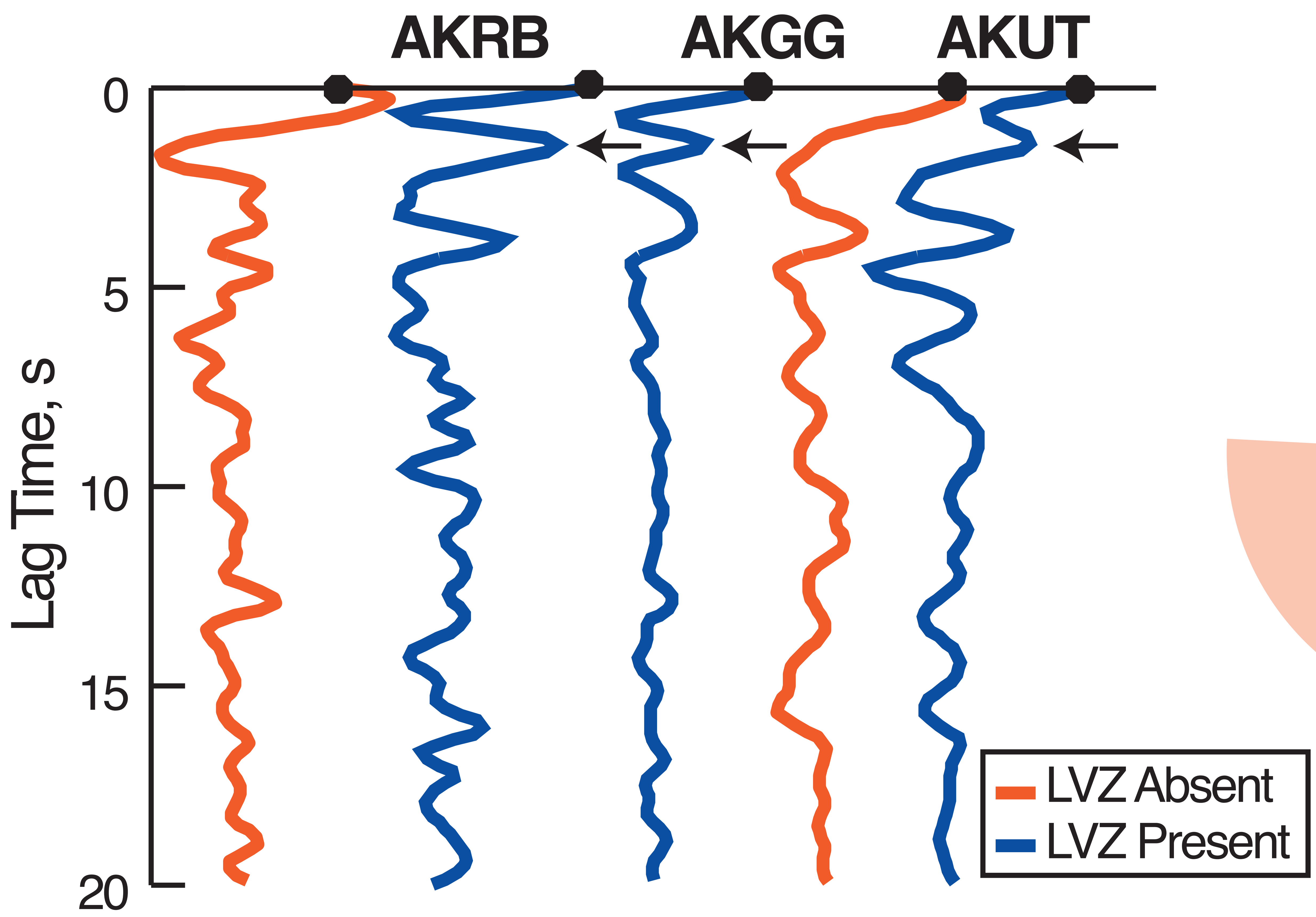
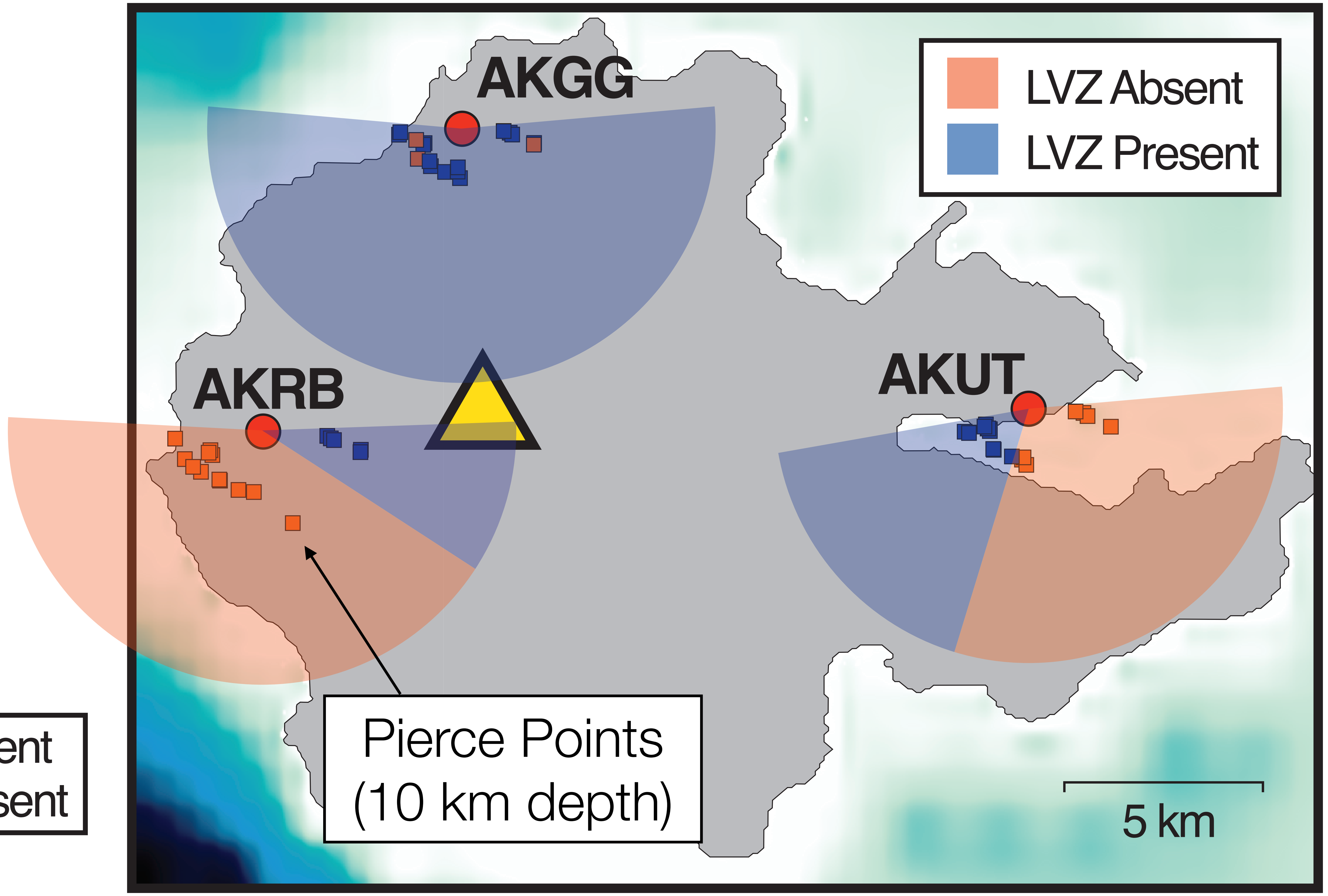


Akutan Volcano

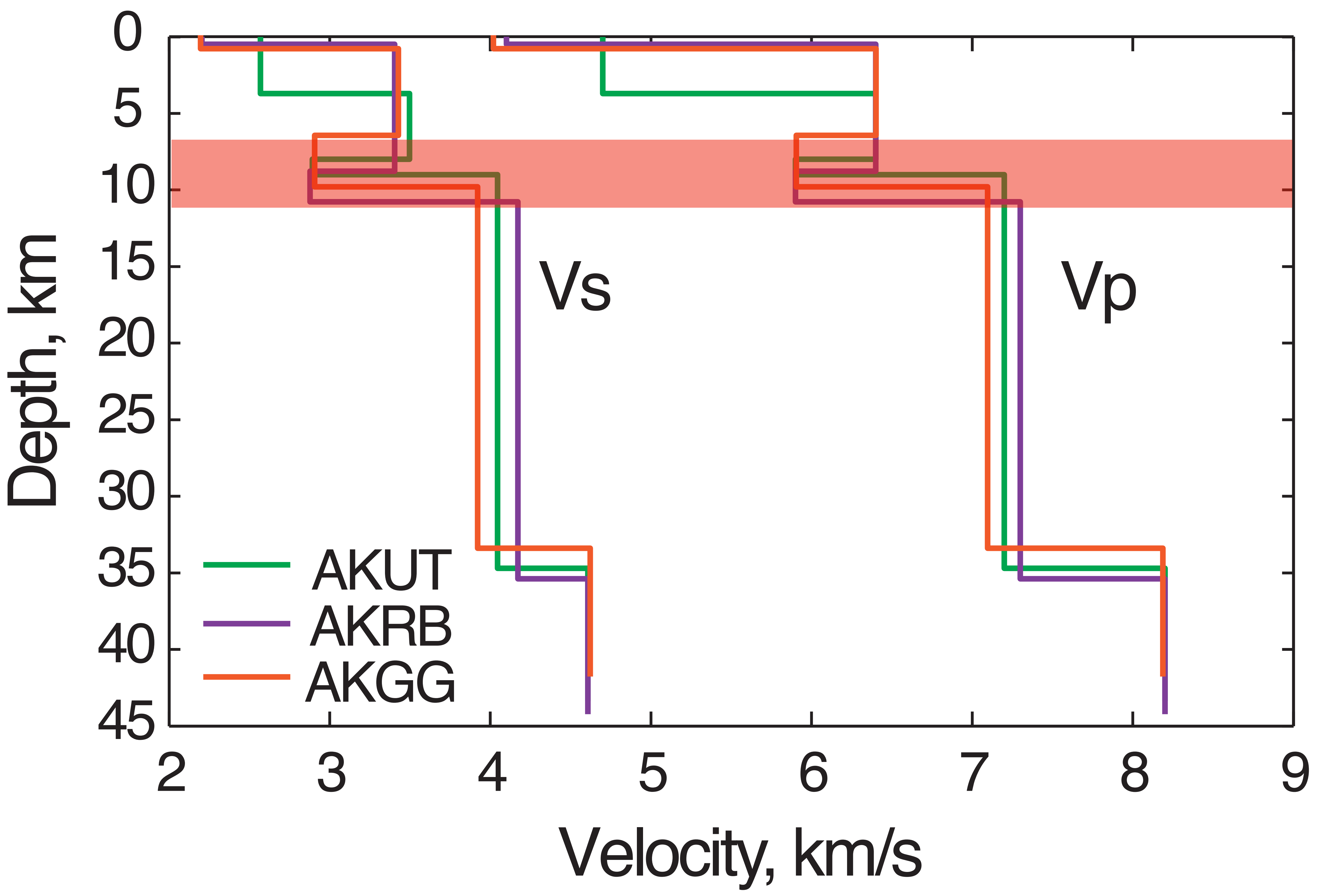


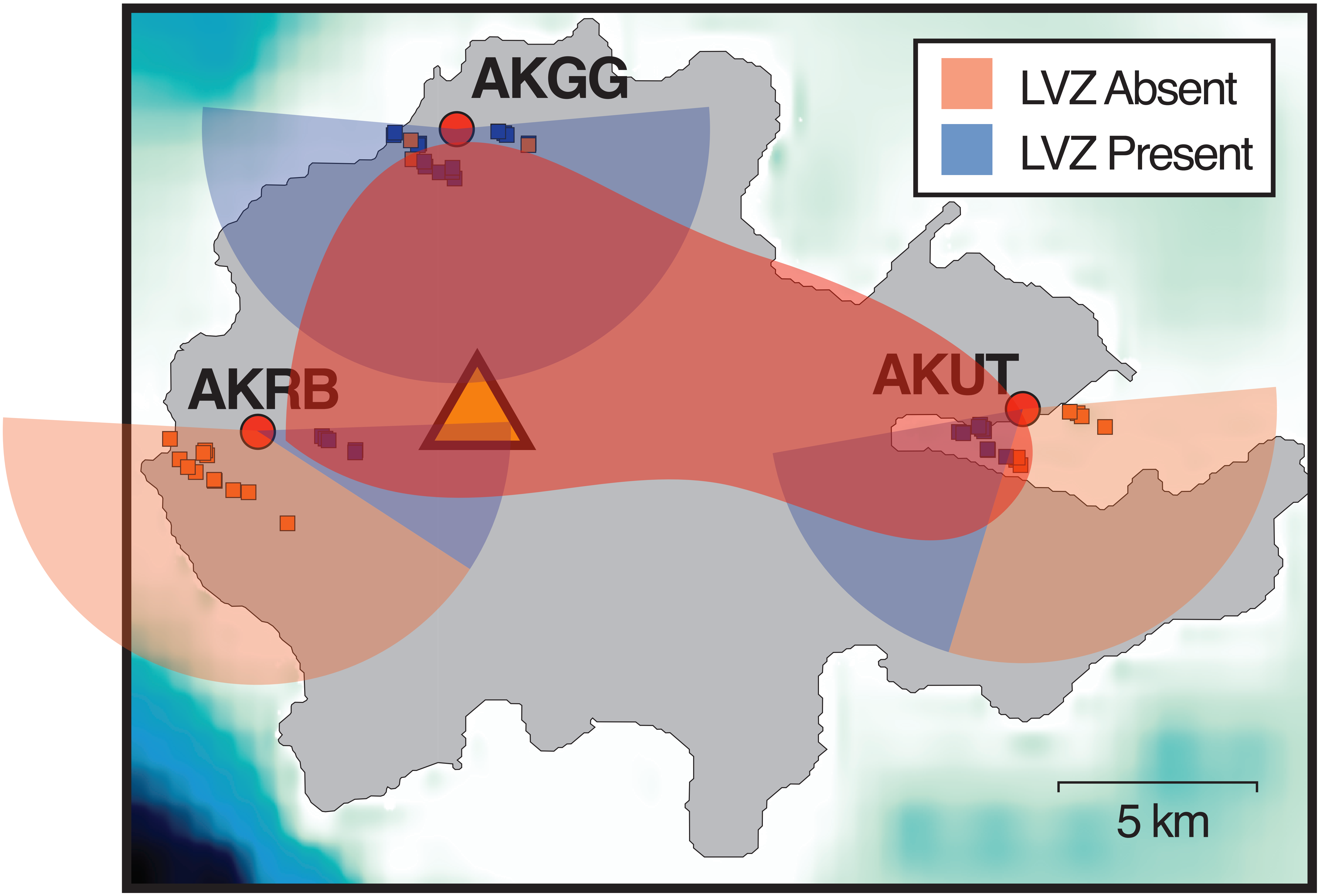


Janiszewski et al., 2013

Akutan Volcano

Mid-crustal magmatic region (7 - 11 km), widespread under island.

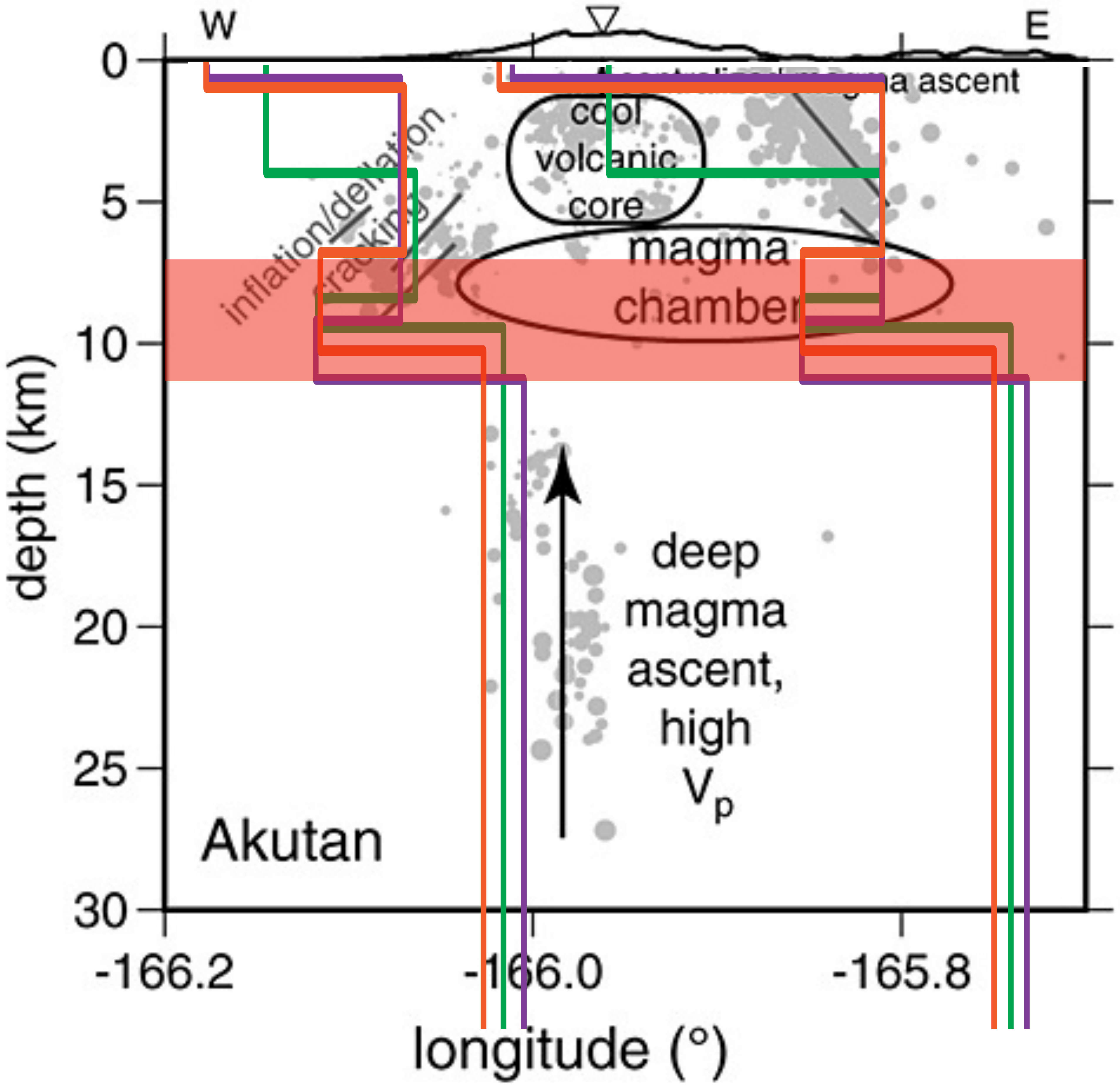




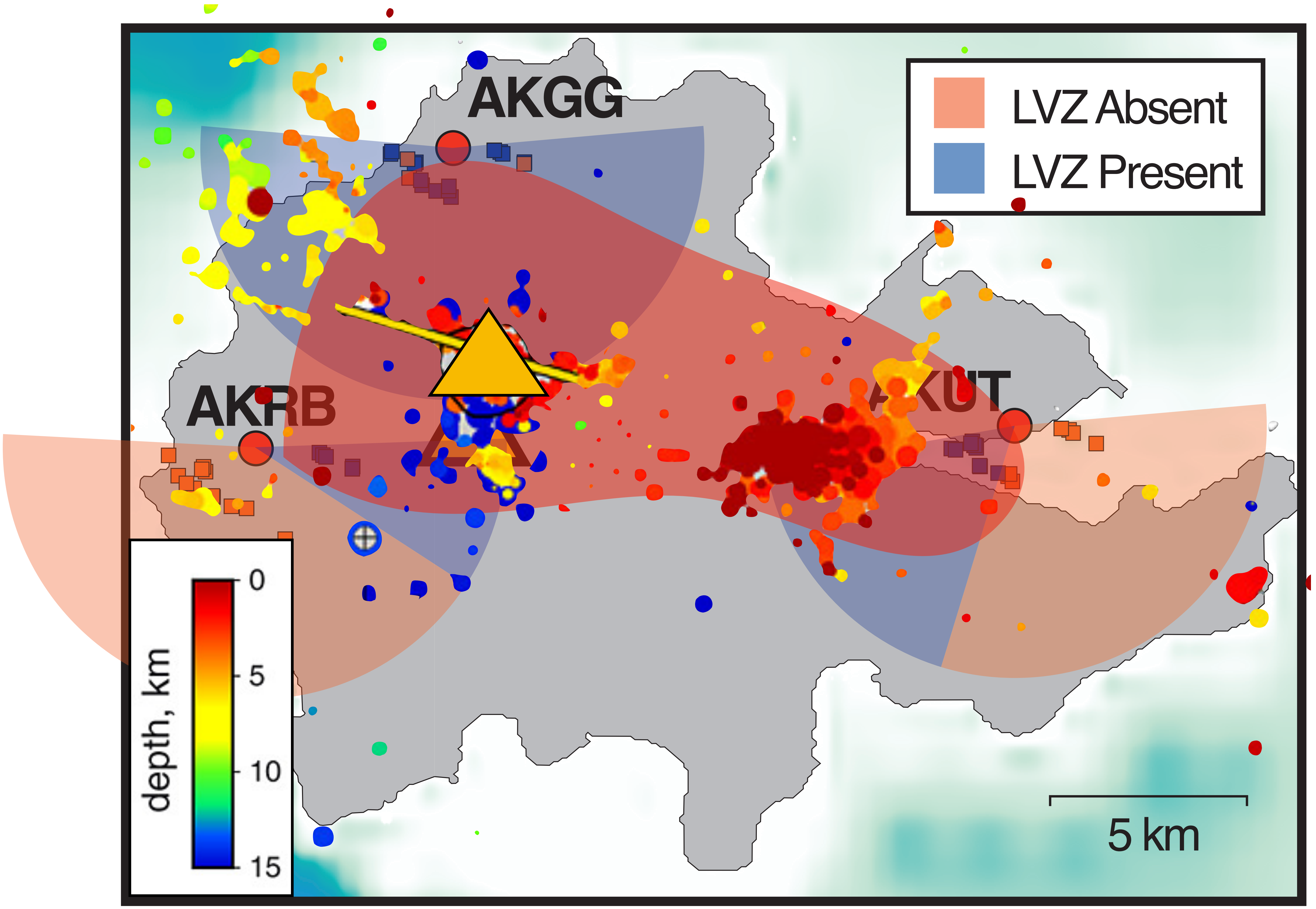
Janiszewski et al., 2013

Comparison with Seismicity

Similar depth and spatial extent as shallow seismicity related to inflation.

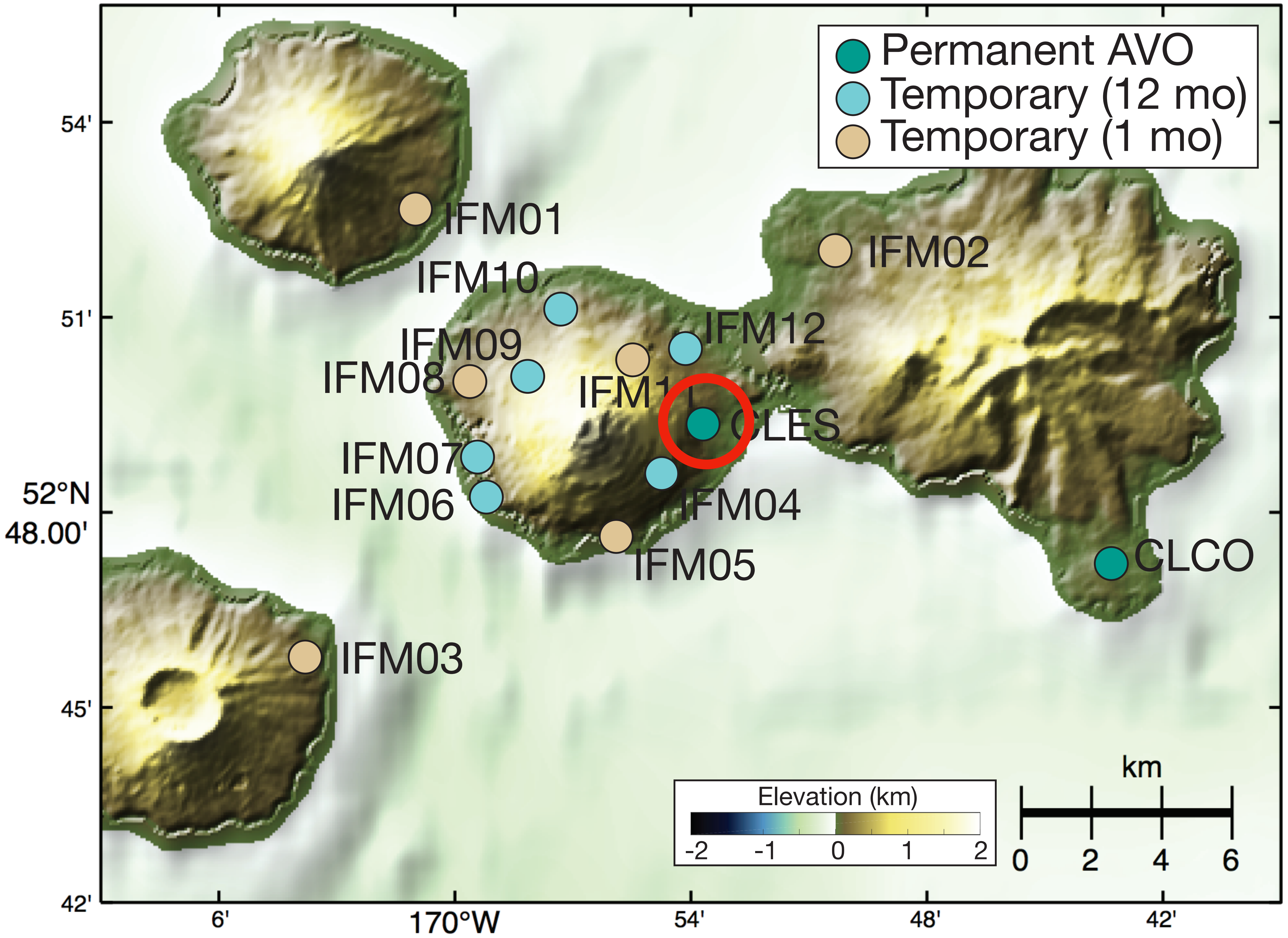


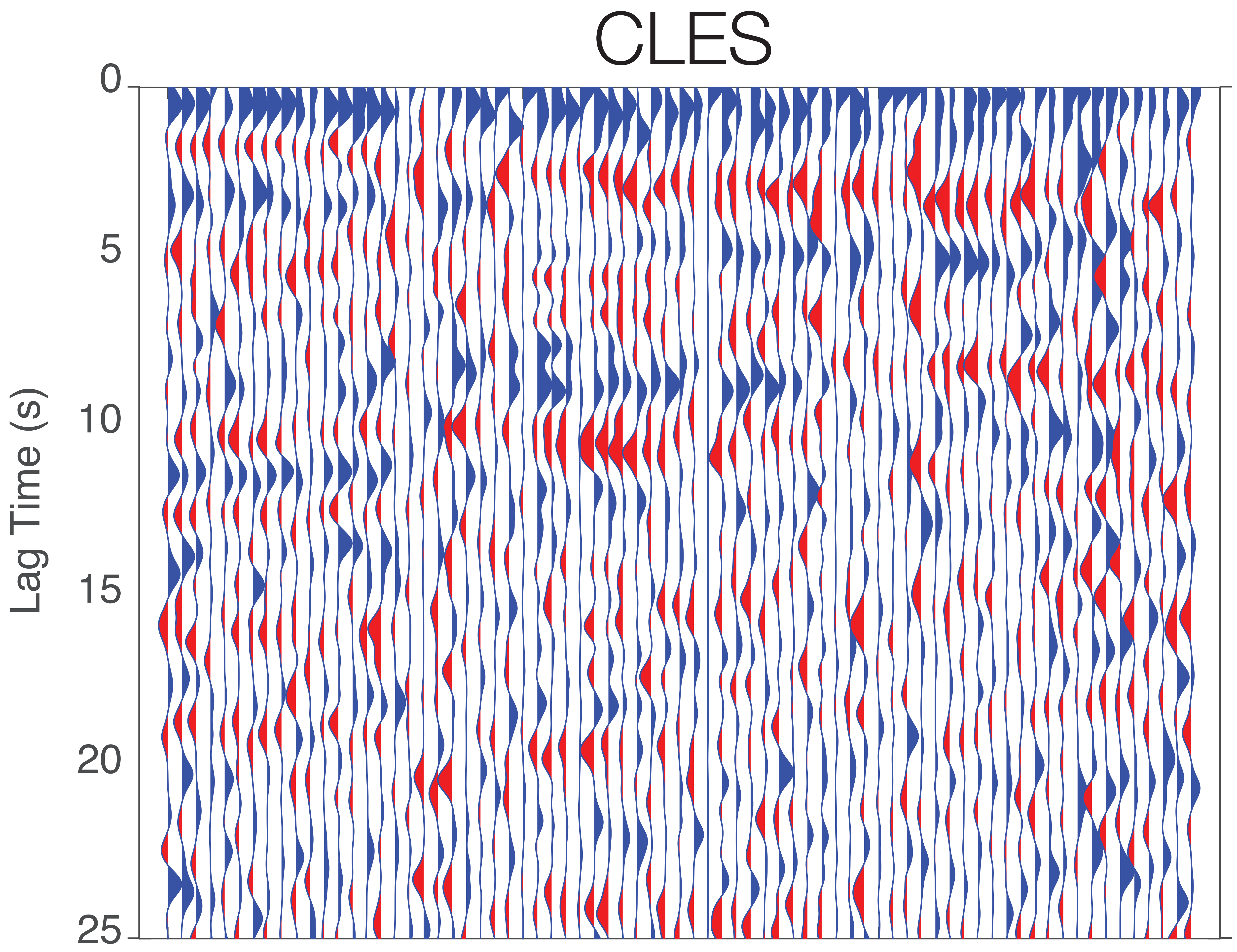
Syracuse et al., 2015



Janiszewski et al., 2013

Cleveland Volcano

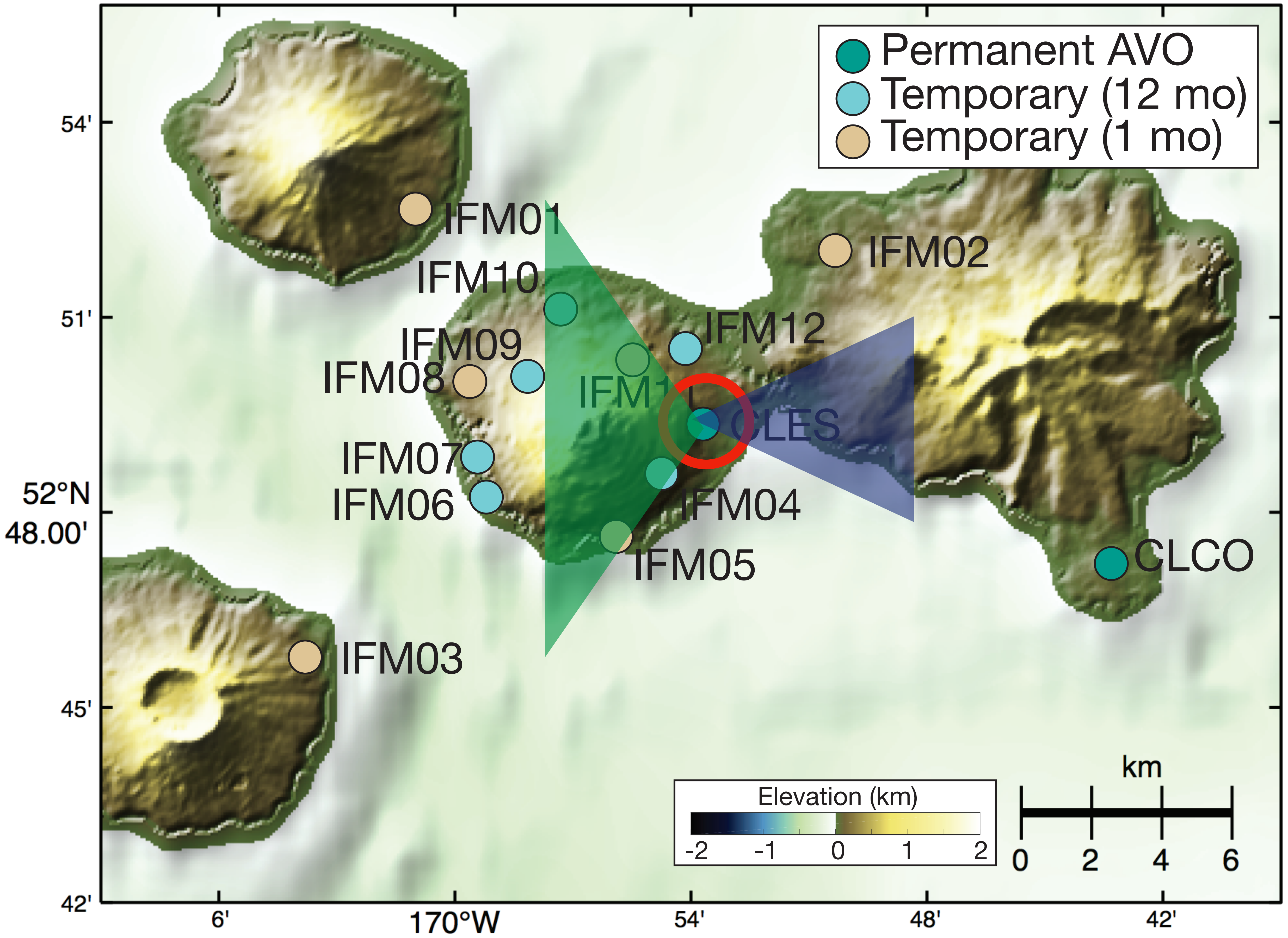


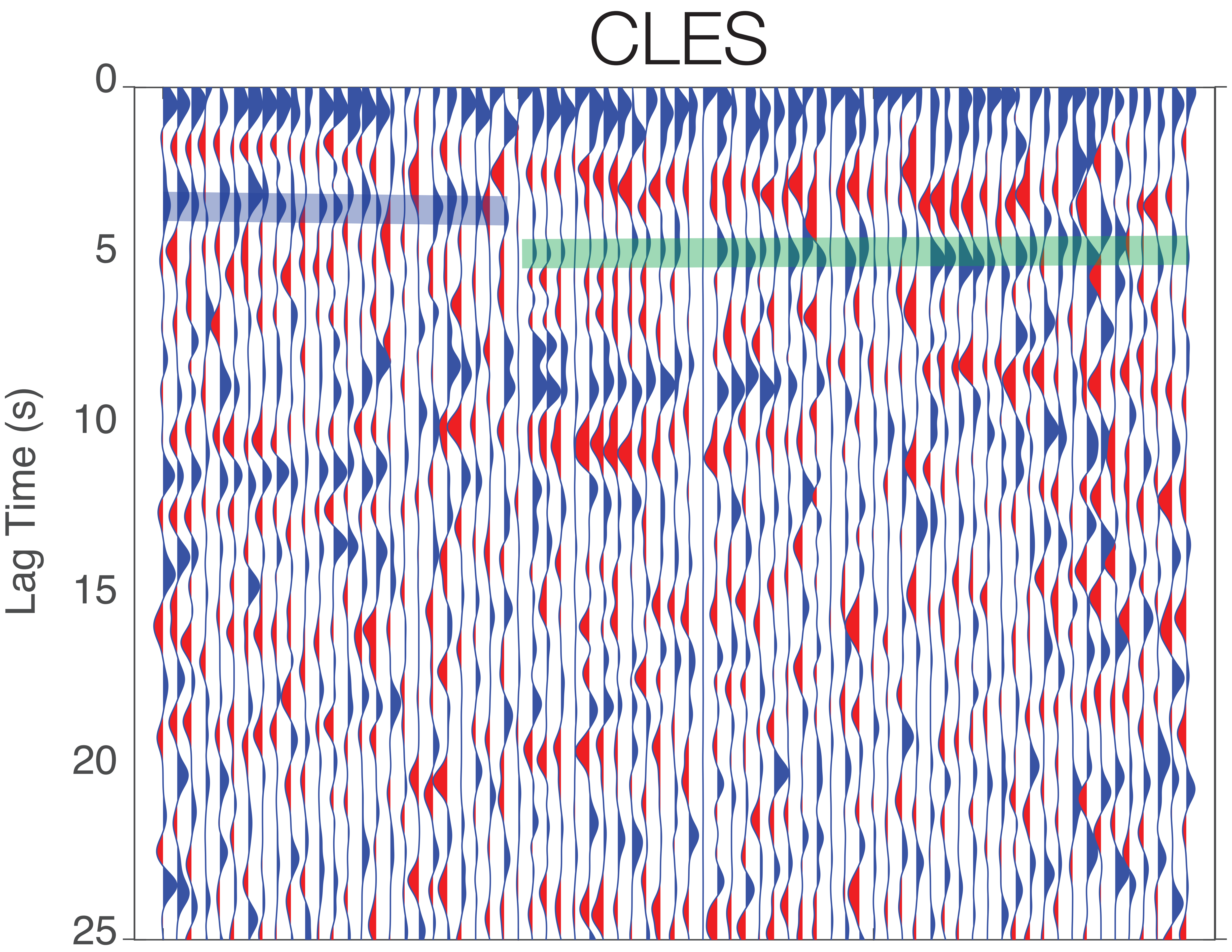


Janiszewski et al., in prep

Do we see a low velocity zone underneath Cleveland, and does it have a similar relationship to seismicity as Akutan?

Cleveland Volcano

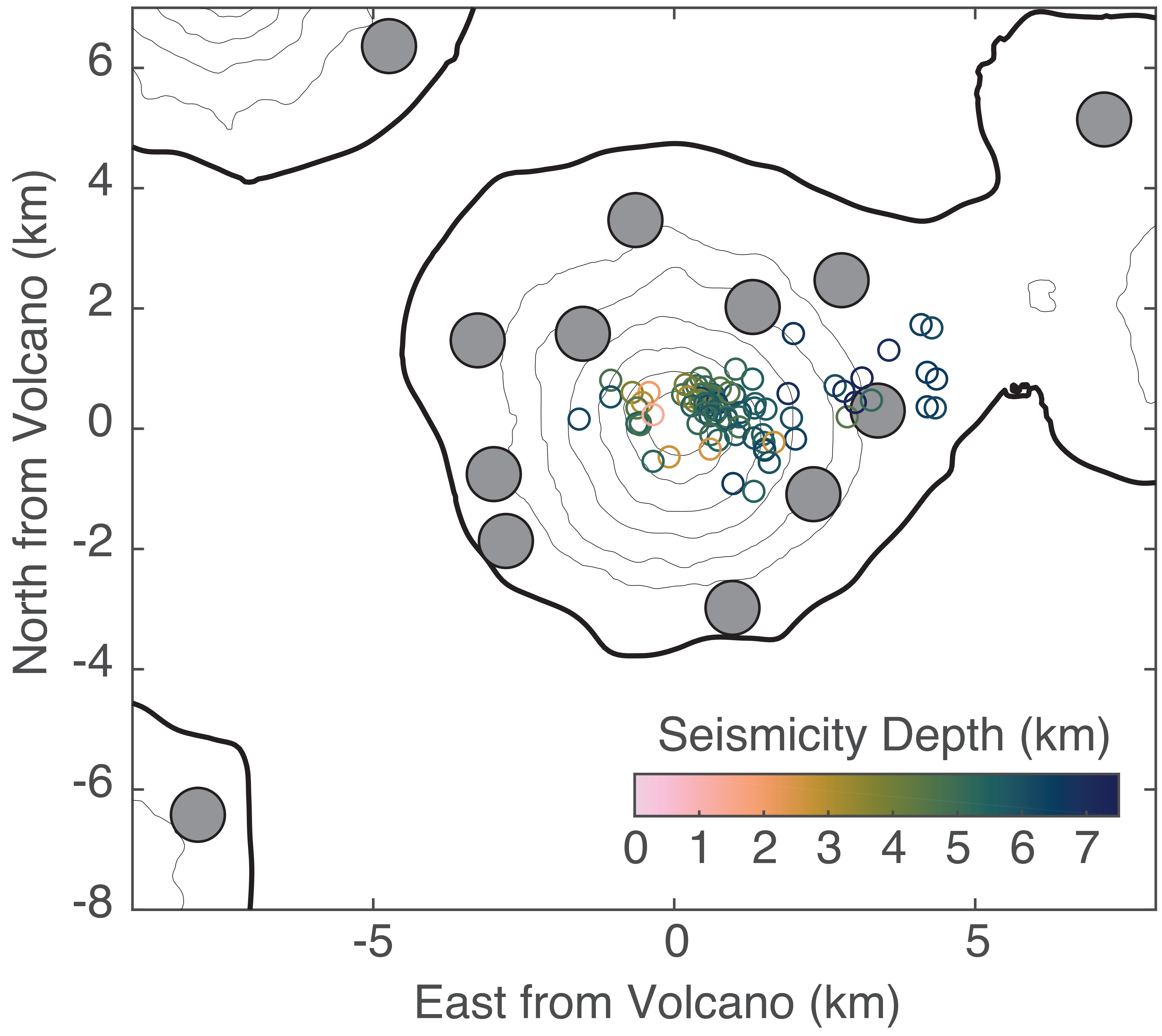




Janiszewski et al., in prep

We do see local variation in the receiver function data, but no distinct additional arrival. What structures causes this?

Evidence for shallow magma storage at Cleveland



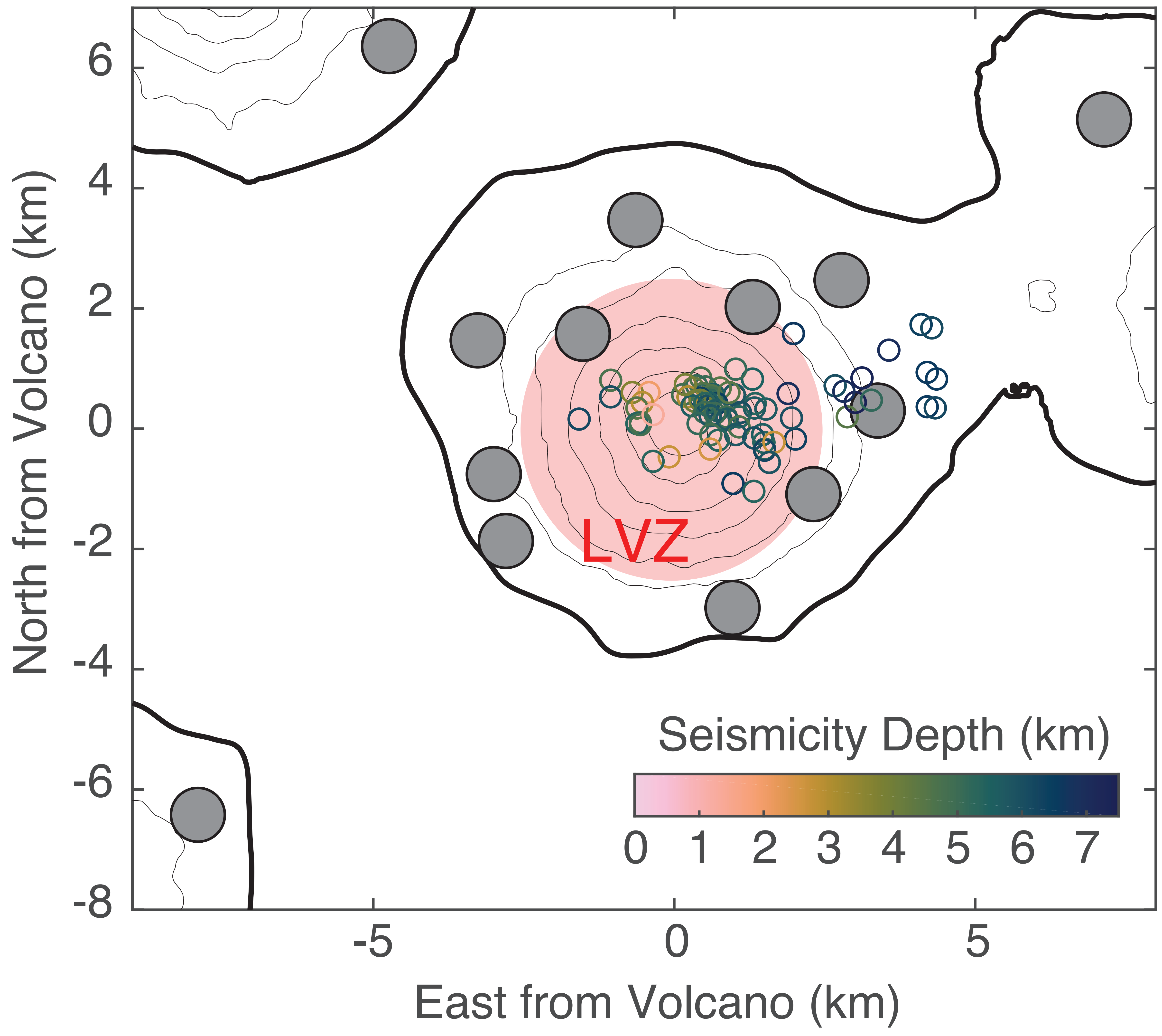
Seismicity < 7 km depth.

Magma/fluid transport at these depths.

Melt inclusions suggest storage at < 5 km

Can this shallow storage region explain the receiver functions, or are we seeing something new?

Modeling depth constraints from receiver functions



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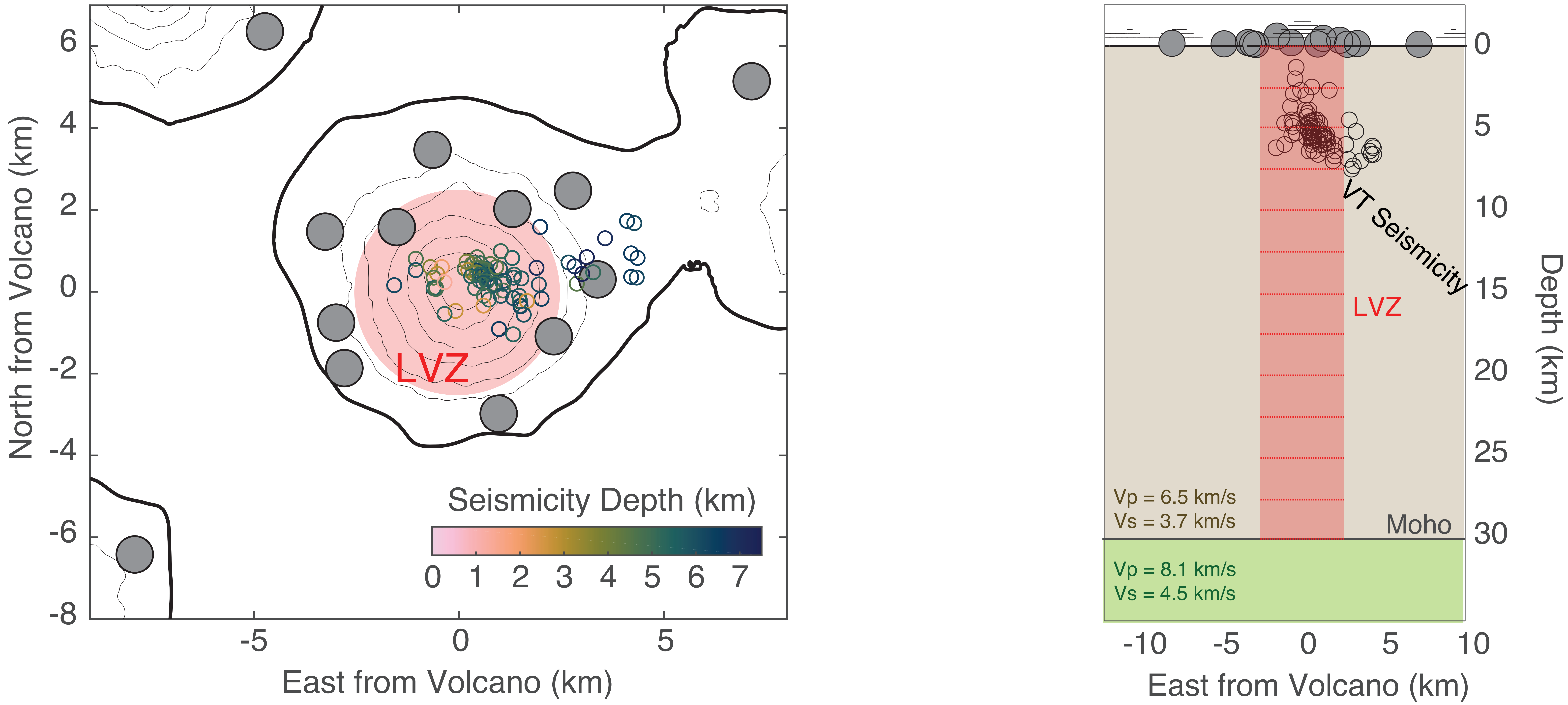
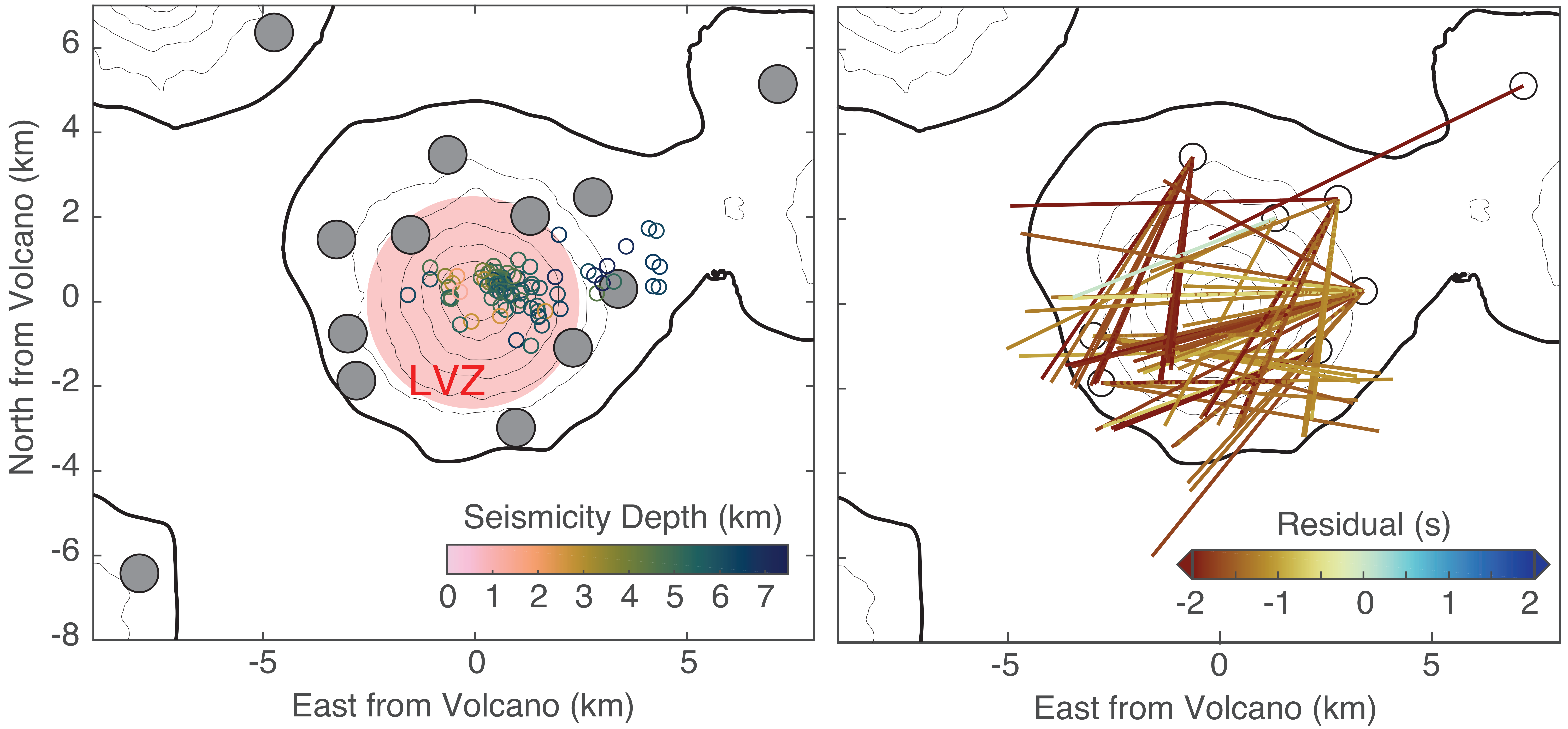


Goal: Reduce misfit in Ps lag times from the Moho

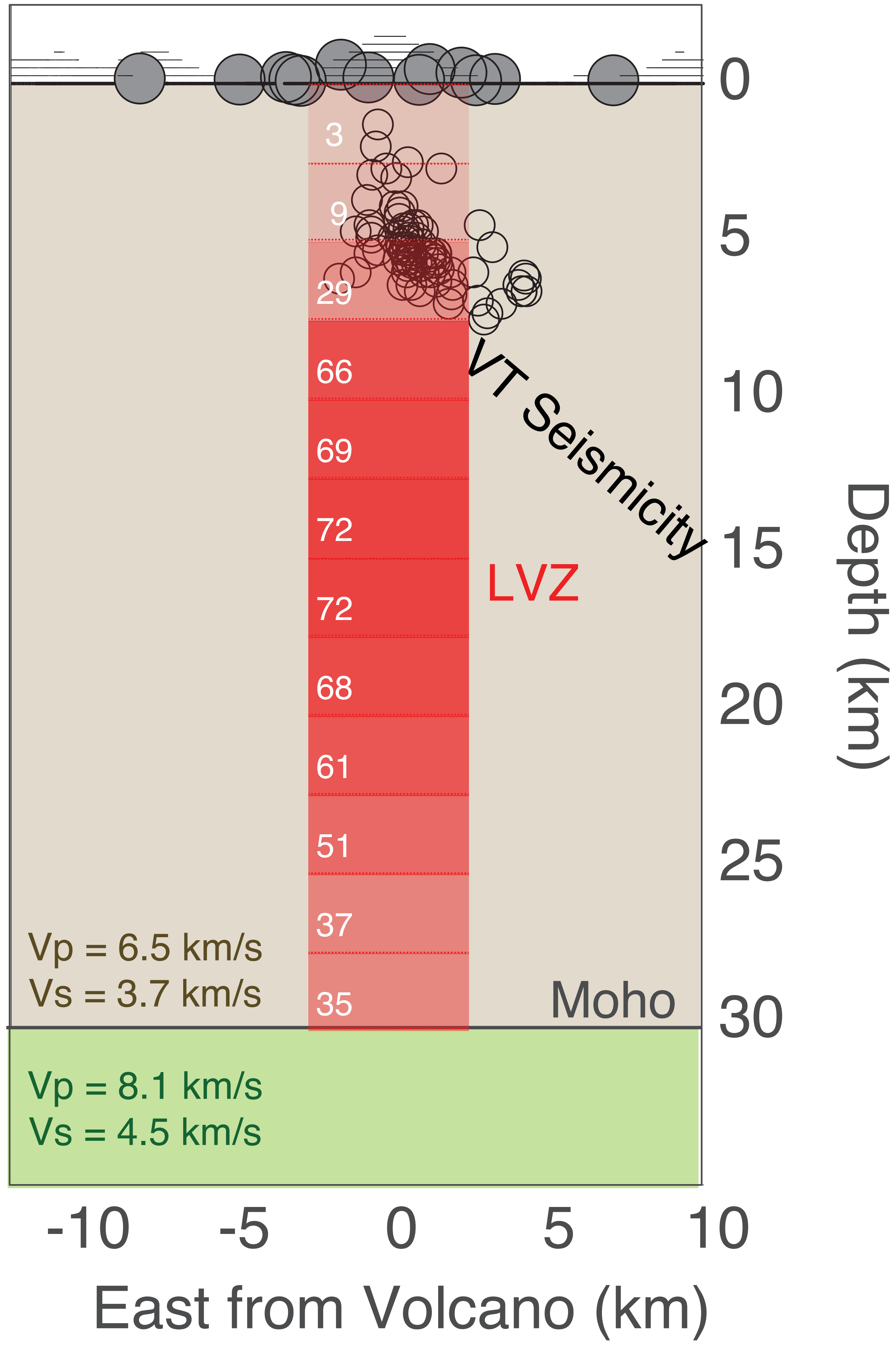


Depth Resolution

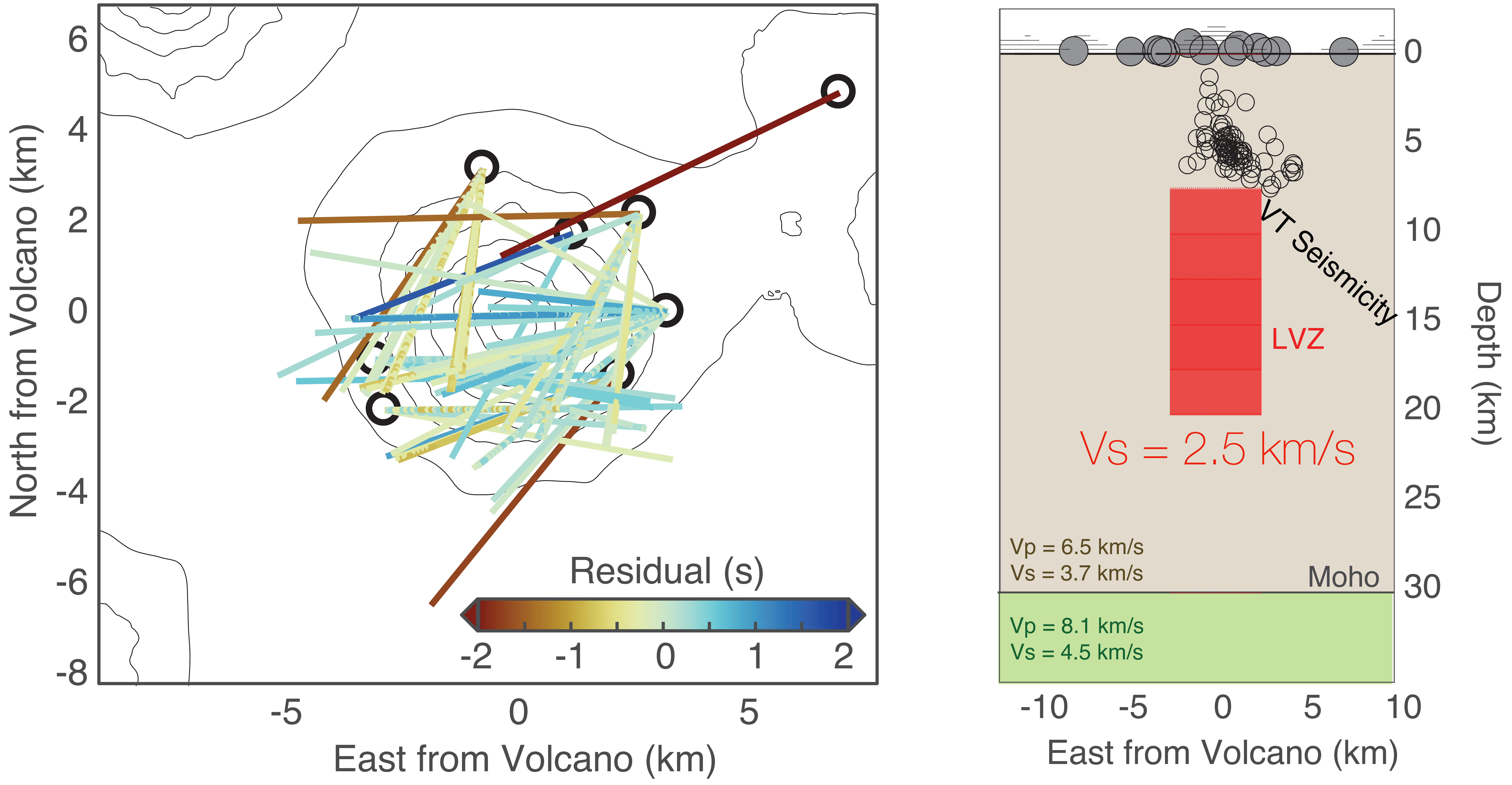
Few ray paths traverse the shallow crust.

These ray paths are not sensitive to shallow crustal structure directly beneath the edifice.

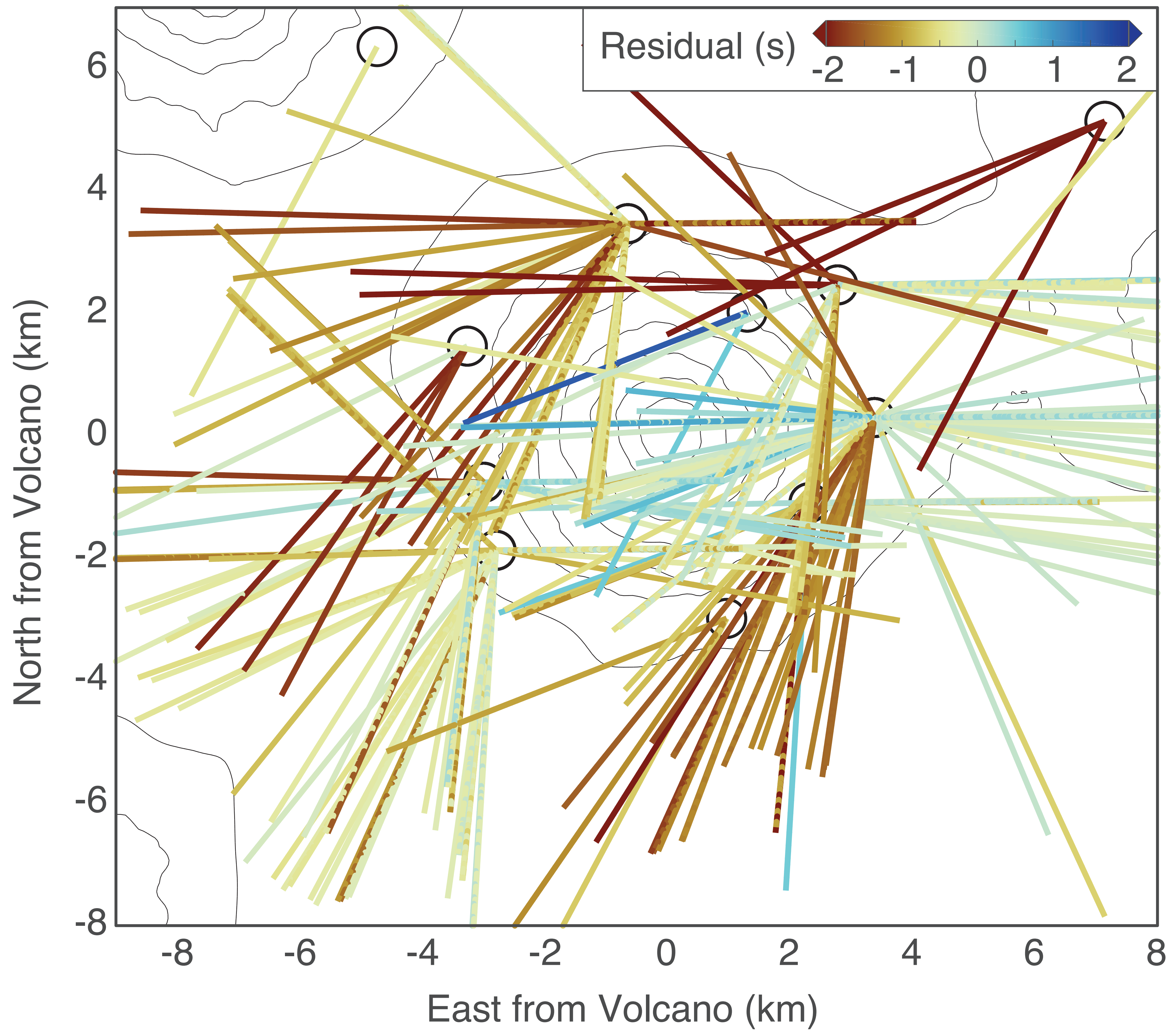
Simplest model for our observations of slow ray paths crossing this central column is an LVZ in the mid crust.



Mid-Crustal Magma Storage



Complex Magmatic Geometries

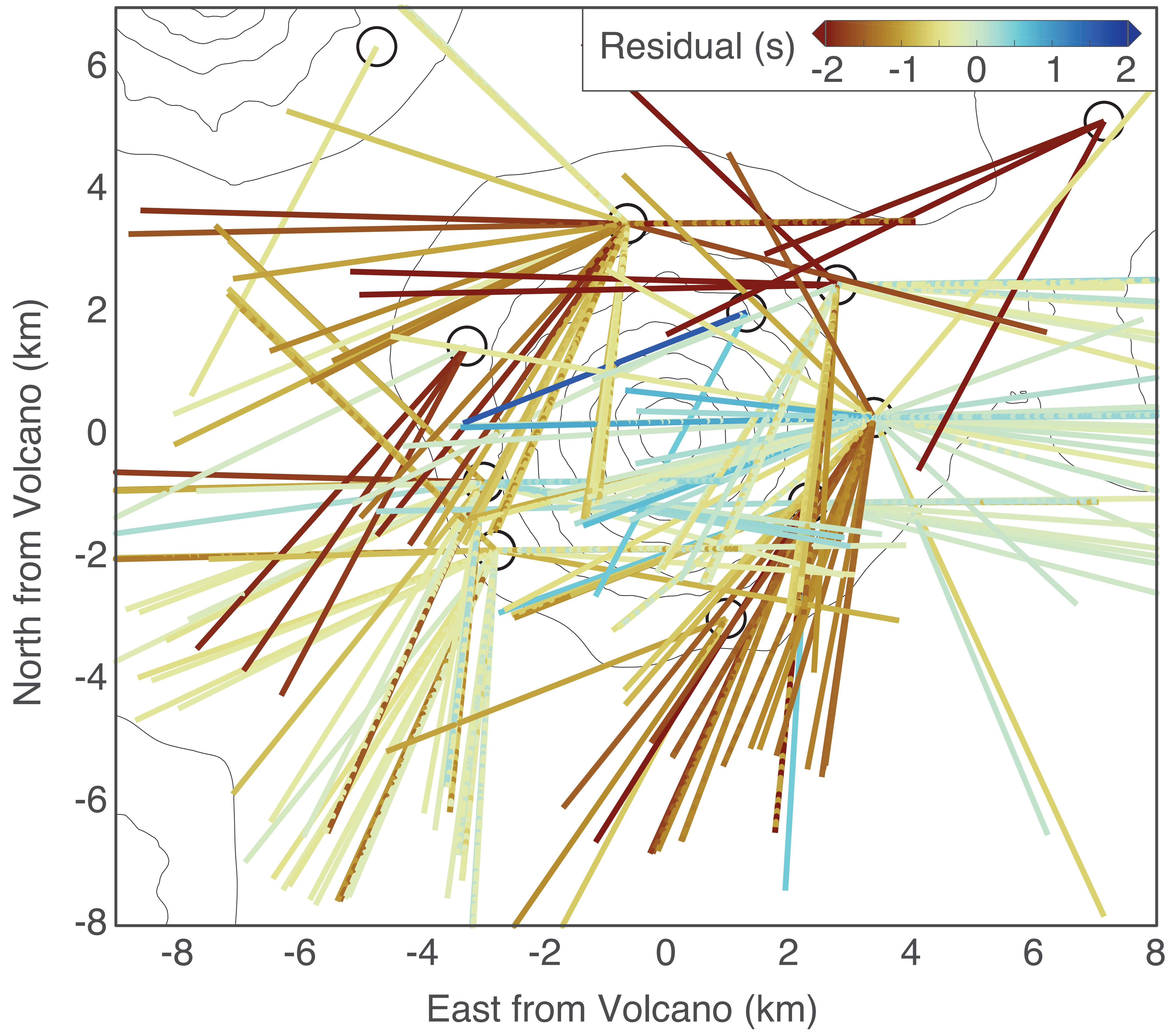


Under the main edifice, receiver functions point to a relatively thick LVZ indicating a region of melt/fluids in the mid-crust.

This doesn't explain all observations beneath Cleveland volcano.

Suggests a more complex 3-D geometry of velocity anomalies - potential for more detailed analysis.

Main Takeaways



Receiver function techniques are useful for determining basic mid- to deep-crustal magmatic architecture with only a few seismic instruments (monitoring scale).

Unlike at Akutan, slow velocities wider depth range and likely extend much deeper than seismicity.

Evidence that we can discriminate between different “types” of magmatic architecture - sharp sill vs. gradual.

Useful for characterizing a difficult to constrain piece of the volcanic system with few instruments. Complements typical volcanology techniques.

Potentially useful in planning future dense deployments around volcanoes.

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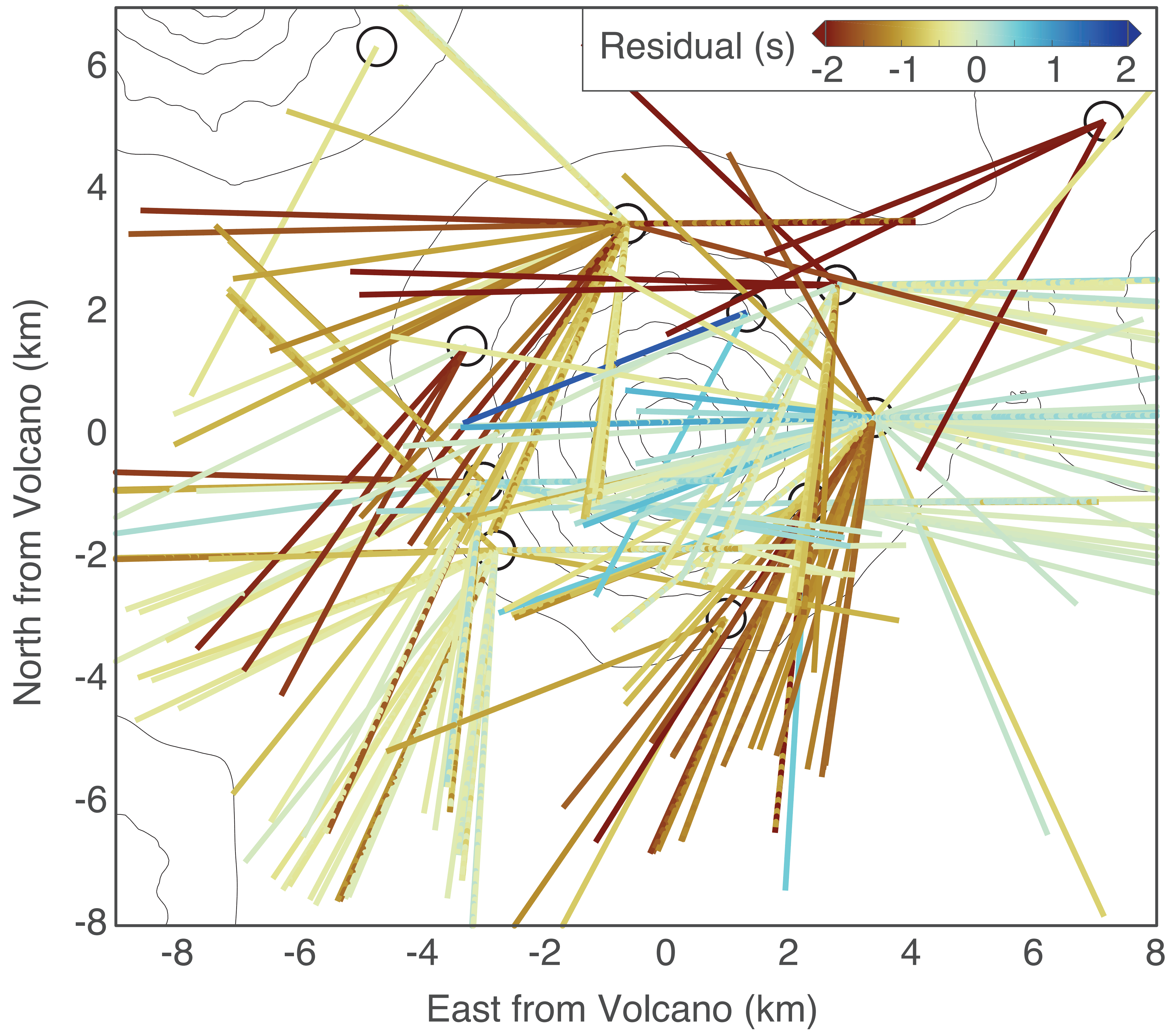

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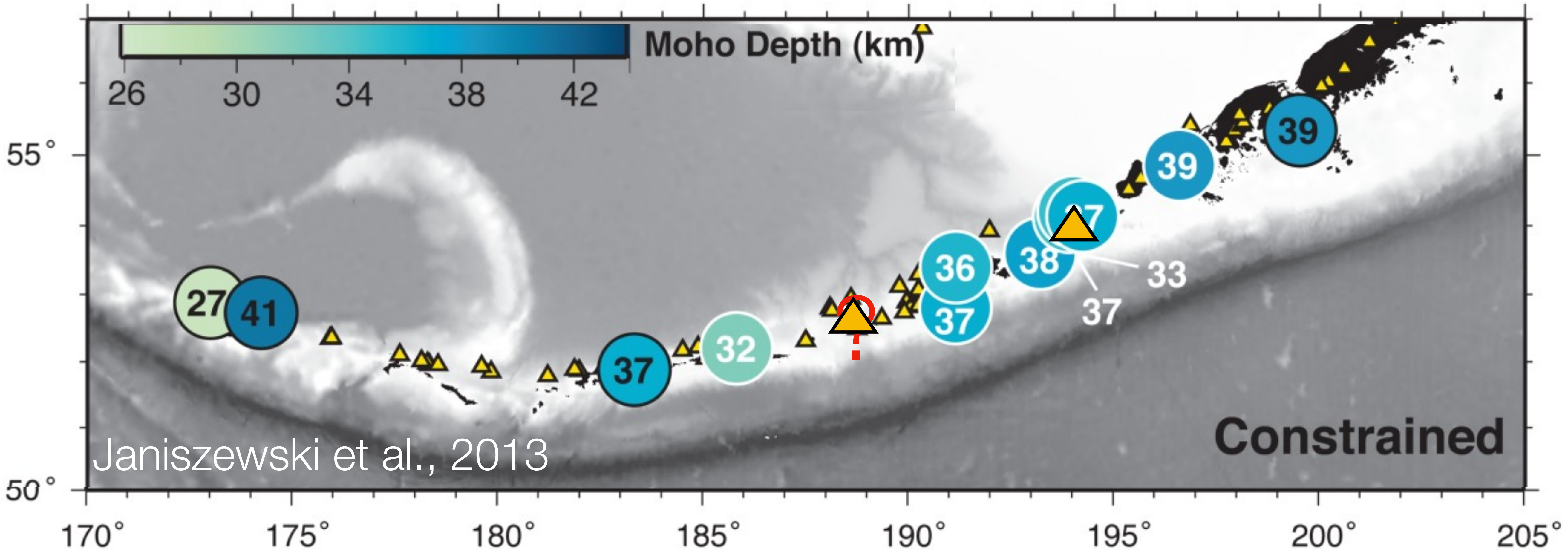
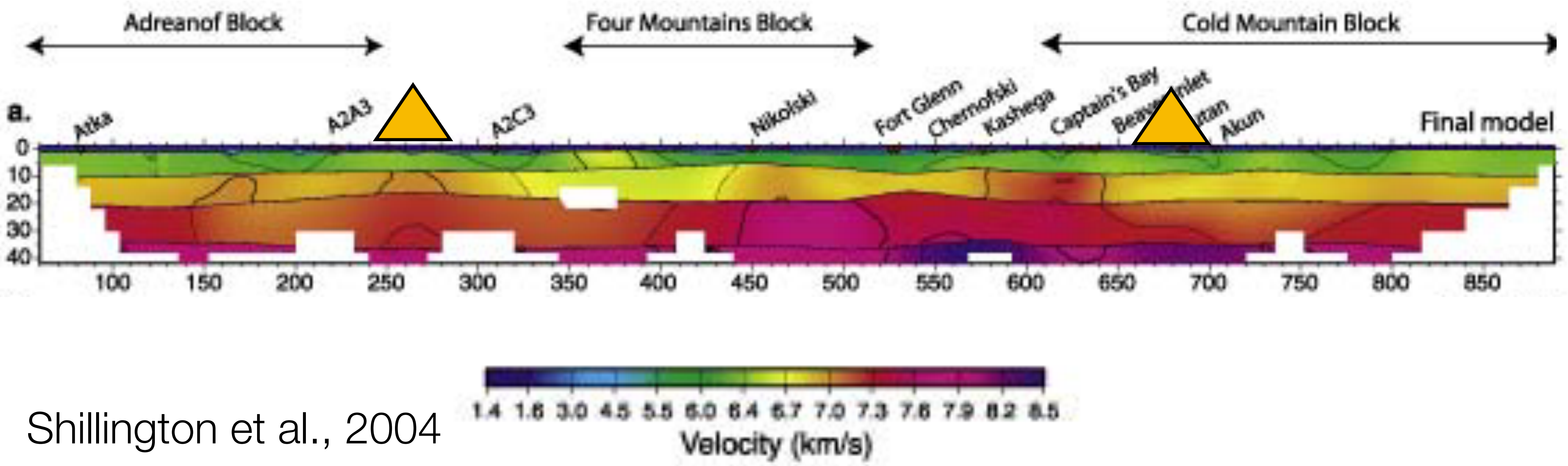
Why do two volcanoes part of the same arc have such different magmatic structure?

Crustal Thickness?



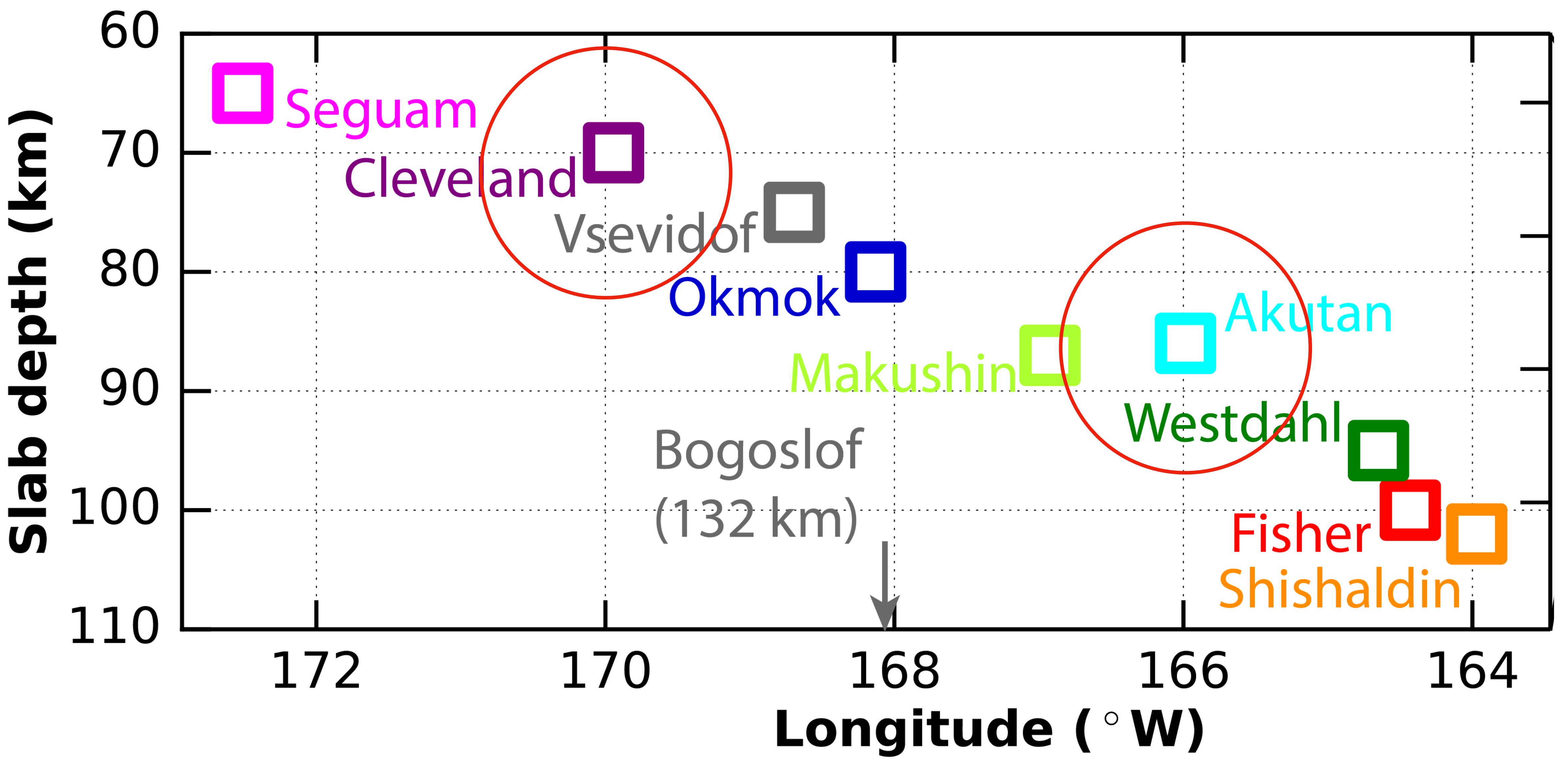
Janiszewski et al., 2013

Crustal Structure?



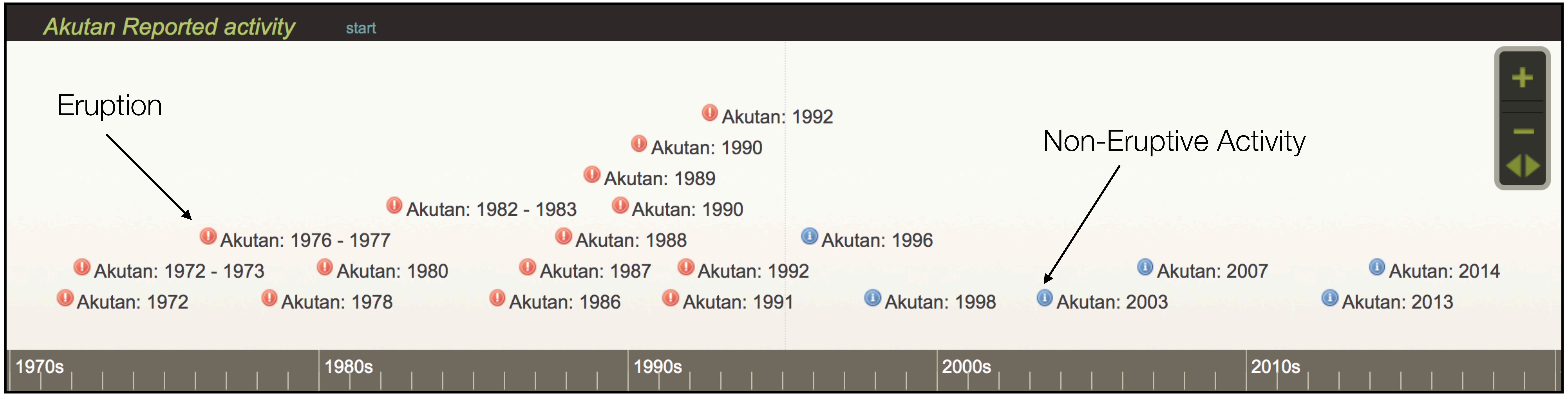
Shillington et al., 2004

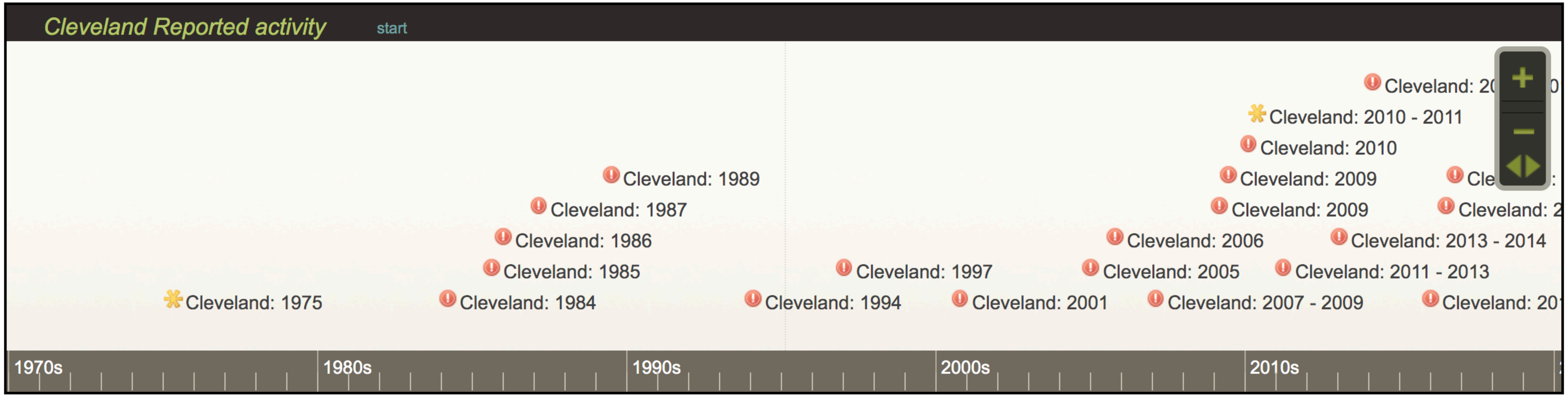
Slab Depth?



Rasmussen et al., in prep

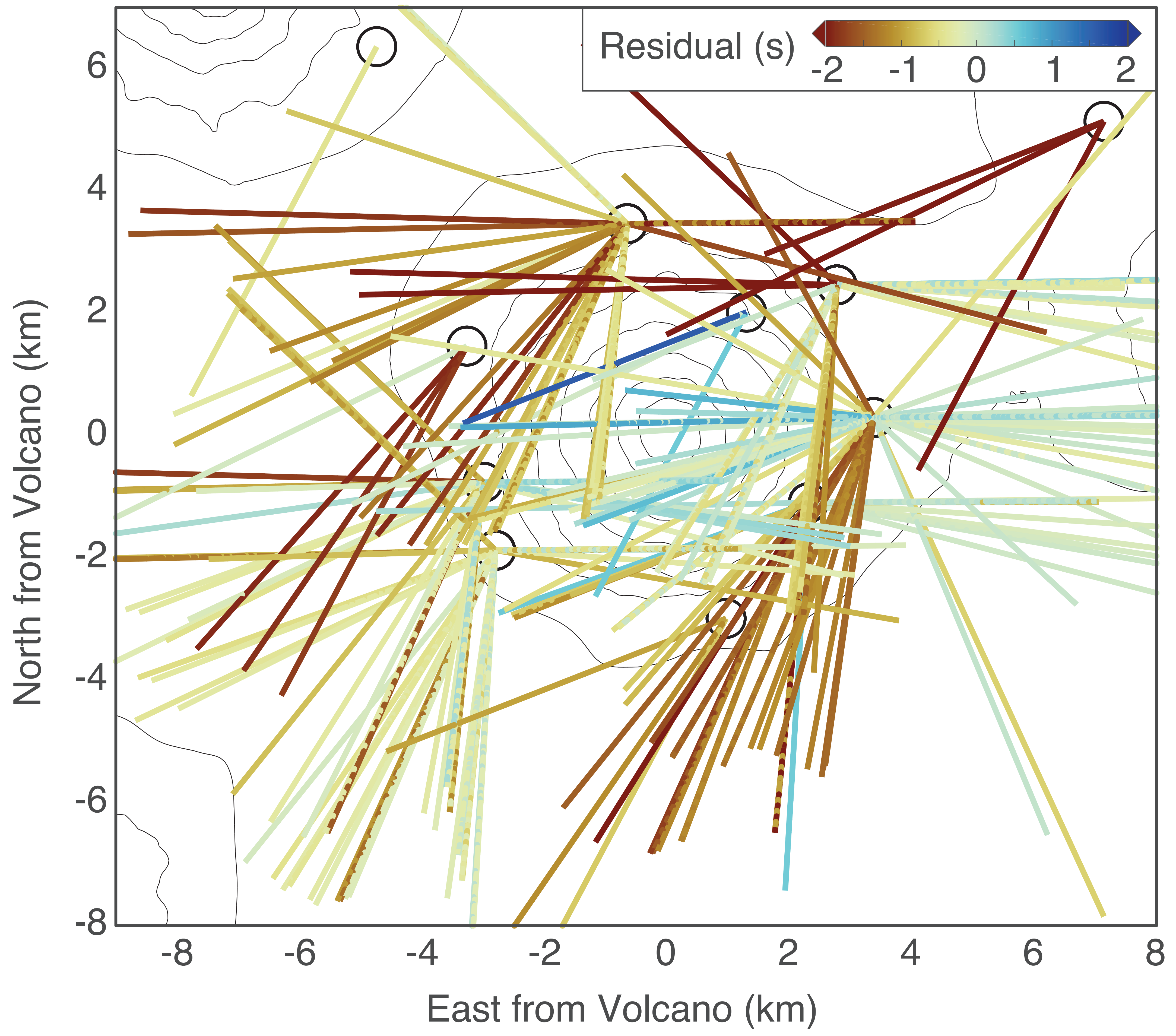
(How) Do differences in deep crustal magmatic structure influence variations in eruptions?





Alaska Volcano Observatory

Main Takeaways



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