Boise State University
ScholarWorks

2018 Graduate Student Showcase | Graduate Student Showcases

May 2018

Seismic Constraints on Geothermal Resources Beneath the Western and Central Snake River Plain

Thomas Harper
Boise State University

Lee Liberty
Boise State University

Dylan Mikesell
Boise State University

Mark Schmitz
Boise State University

Seismic Constraints on Geothermal Resources Beneath the Western and Central Snake River Plain

Abstract

Using geophysical data, we identify crustal sills that presumably produce the high heat flow expression within the central and western Snake River Plain (SRP) region of southern Idaho. We invert receiver function waveforms and analyze seismic velocity datasets from IRIS to identify anomalous velocity layers in the mid-crust that may relate to either partial melt or cooled sills. Gravity and magnetic data is used to further constrain the locations of these sills. We find the majority of identified sills to be located along the southern portions of the western SRP, which is coincident with locations of high geothermal gradient.

This scholarly poster is available at ScholarWorks: https://scholarworks.boisestate.edu/gss_2018/48

Seismic Constraints on Geothermal Resources Beneath the Western and Central Snake River Plain

Thomas Harper, Lee Liberty, Dylan Mikesell, Mark Schmitz

Boise State University

1) Abstract

Using geophysical data, we identify crustal sills from volcanic intrusions that presumably produce the high heat flow expression within the central and western Snake River Plain (SRP) region of southern Idaho. While the topographic, volcanic and thermal signature of the eastern and central SRP directly maps to the track of the Yellowstone hotspot, the origin of this expression beneath the western SRP remains enigmatic. We invert receiver function waveforms and analyze seismic velocity datasets from IRIS to identify anomalous velocity layers in the lower to middle crust that may relate to either partial melt or cooled sills. Gravity and magnetic data is used to further constrain the locations of these sills. We find the a large sill to be located along the southern portions of the western SRP, which is coincident with locations of high geothermal gradient. With these results, we hope to further constrain the evolution of the western SRP.

2) Study Area

- The low topography arcuate shaped Snake River Plain (SRP) stretches ~600 km through southern Idaho (Green outline in figure 1).
- The eastern SRP represents a thermal downwarp connected to the passage of the mantle-derived Yellowstone hotspot, with the hotpot track migrating northeast at 2.7 cm/year with respect to the North American plate (Gripp and Gordon, 2002).
- The western SRP trends northwest and has been interpreted as a structural graben filled with ~2km of lacustrine sediments from the Neogene Lake Idaho underlain by up to 2 km of volcanic rocks (Wood and Clemens, 2002) .
- Unlike the eastern SRP where thermal drivers are better understood, the western SRP's relationship between tectonics, volcanism, and the passage of the hotspot is poorly constrained. Here, we examine seismic data for anomalous crustal velocities related to mantle-derived volcanism.

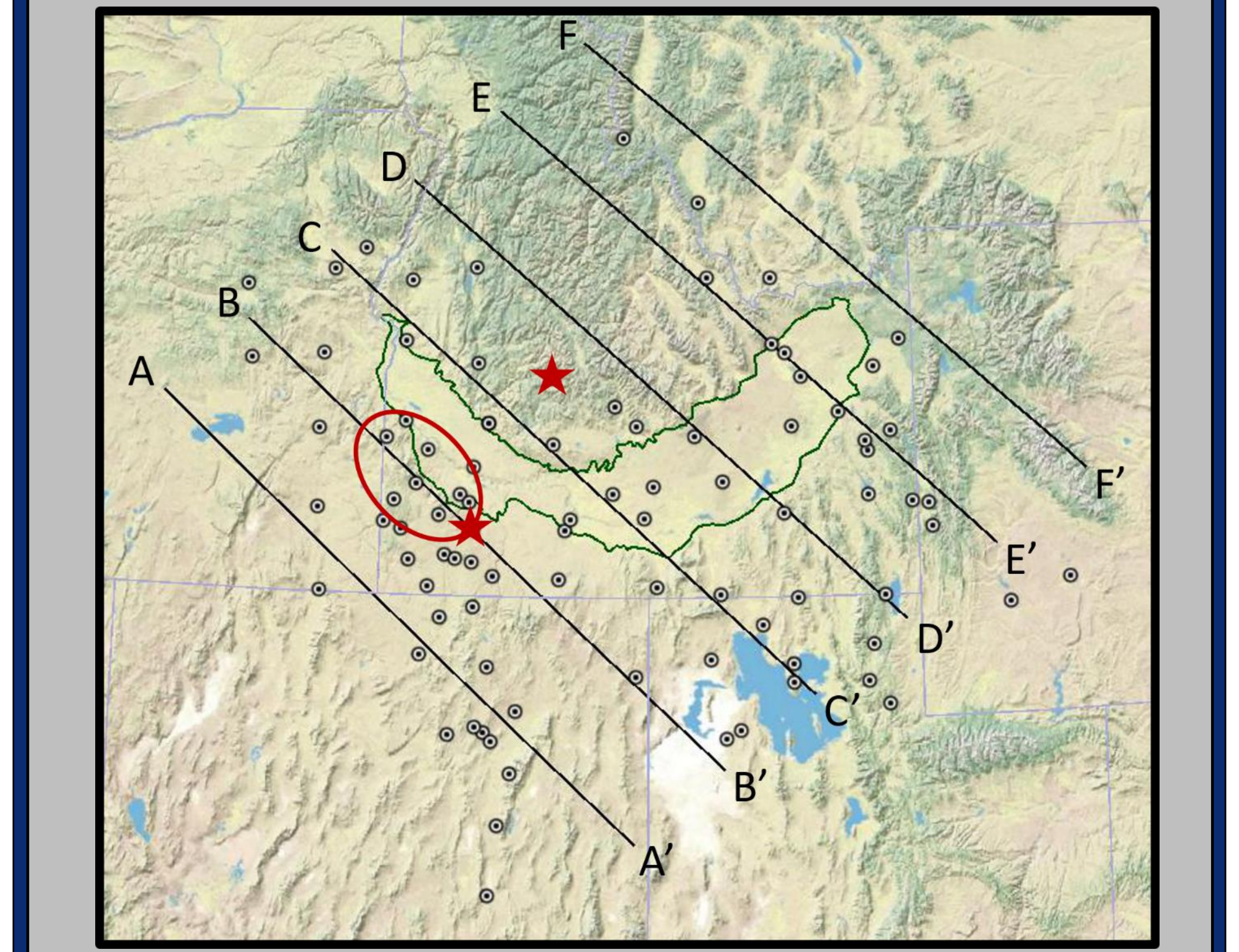


Fig. 1.) Map showing the SRP (green), receiver function station locations for the inversions (bullseyes), locations of stations TA.I12A and XC.ID008 (red stars), the locations of the cross sections, and the location of the low-velocity zone we interpreted from the receiver function inversions (red oval).

3) Previous Work

- Beneath the WSRP, more than 2 km of basalt underlie Neogene lake sediments (Wood and Clemens 2002). Active source seismic and drill hole data constrain the evolution of the upper crust.
- Magnetic intensity map (Fig. 2a) identify dike-filled lineations, fractures, and eruptive centers in the upper crust along the southern margin of the western SRP, exposing fault orientations (e.g., Glen and Ponce, 2002; UTEP PACES database).
- High Bouguer gravity values within the WSRP (Fig. 2b) extend mafic volcanic rocks from drill hole depths to the lower crust (Glen et al., 2016; Khatiwada and Keller, 2017; UTEP PACES database) and exhibit the replacement of the Idaho batholith by the addition of mafic volcanic rocks.
- Crustal thickness estimates derived from both active seismic, passive seismic and gravity data show MOHO depths ranging from 30-40 km in the region, consistent with our observations. No apparent crustal thinning is observed relative to the average regional MOHO depths.
- A geothermal play fairway analysis by Shervais et al. (2016) produced a heat flow map for southern Idaho (Fig. 2c). This map was constructed using measured thermal gradients, interpolated heat flow values, groundwater temperatures, the distribution of volcanic vents, measured temperatures of thermal waters, calculated ionic and multicomponent temperatures of thermal waters from springs and wells, and the distribution of high $^3He/^4He$ in thermal waters. The sources of these heat anomalies are interpreted to be partial melt, mafic sills, and radioactive decay of the Idaho Batholith.

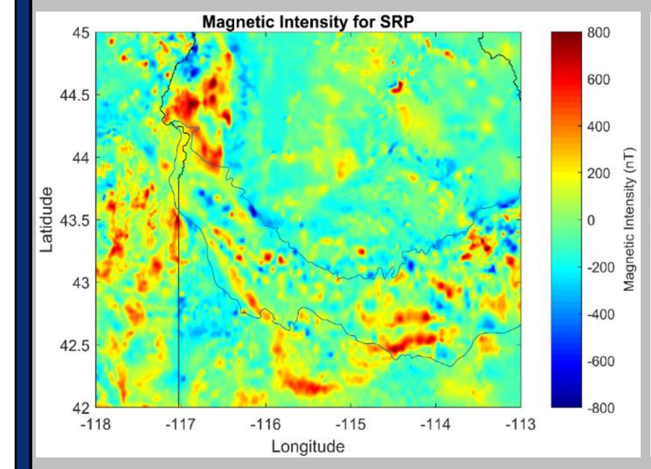


Fig. 2a.) Magnetic intensity to help identify dike-filled lineations, fractures and eruptive centers in the upper crust.

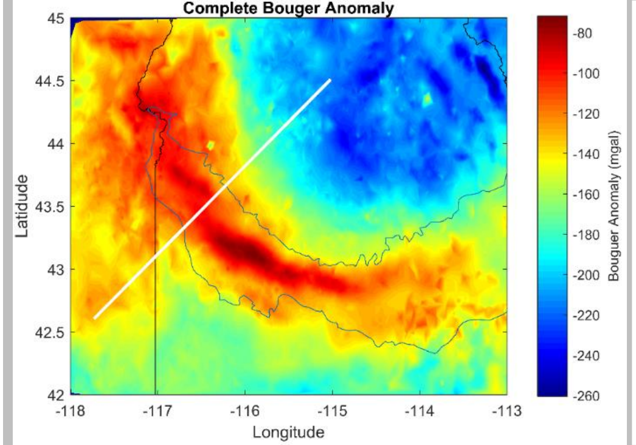


Fig. 2b.) Bouguer gravity to help identify mafic volcanic rocks in the crust.

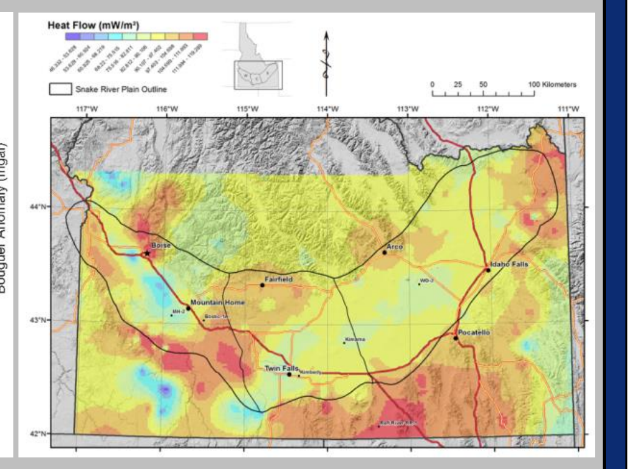


Fig. 2e.) Interpolated heat flow of southern Idaho from Shervais et al. (2015)

4) Methods

- The receiver function is the seismic waveform from the propagation within the crust and upper mantle. This waveform is obtained by deconvolving the horizontal component with the vertical component of motion to achieve a combination of P-S converted waves (Ammon, 1991).

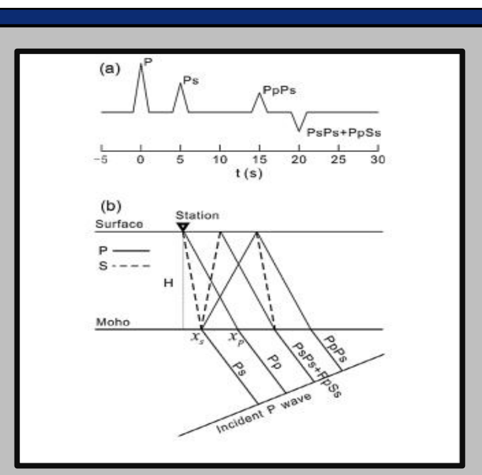


Figure 3. Simplified receiver function diagram for a single layer crust. Source: http://eqseis.geosc.psu.edu/

- Although receiver functions are very useful for determining MOHO depth, it is also extremely useful for finding strong velocity anomalies and velocity inversions in the crust that typical cost prohibitive refraction surveys would not be able to resolve.
- The inversion technique used in this project is the Metropolis algorithm, which is based on the work by Jansson (2008). This method is considered a Markov Chain Monte Carlo method, which is a sequence of random models that depend only on the previous model.
- Parameters for the inversion include depth to layers and P-wave velocity of the layers. Vp/Vs ratio and density are assumed constant.
- Velocities are assigned to a grid based on raypaths to construct a 3-D velocity model.

5) Observations and Results

USArray Tomograms

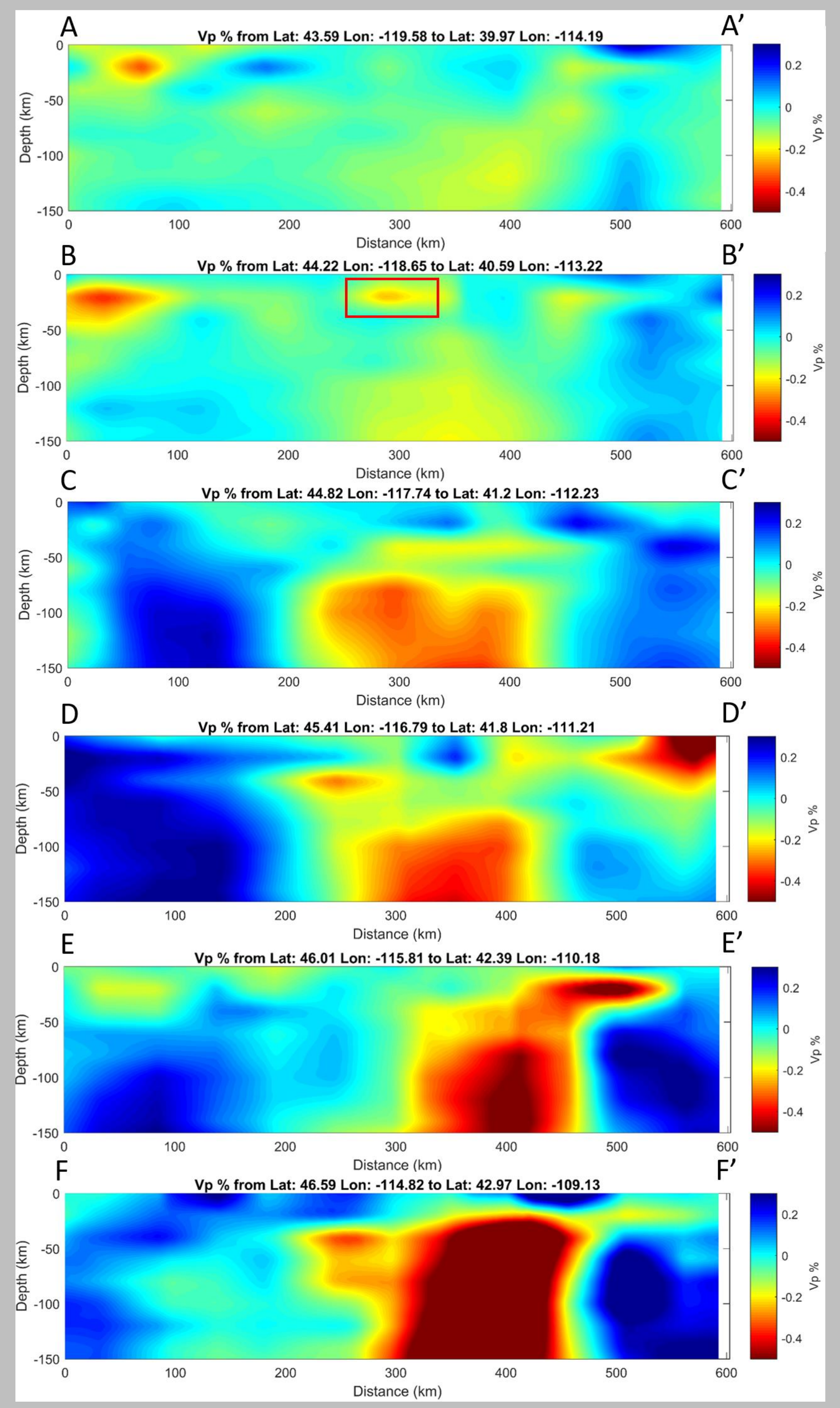


Fig. 4.) USArray tomograms along cross-sections derived from seismic velocity perturbation data (Porritt et al., 2014). The tomograms show seismic velocity differences from the standard IASP91 velocity model. In cross section B, we observe crustal low velocity zones (red box) that are coincident with high heat flow areas where the depth is not well constrained. Anomalously low p-wave velocities in the lithosphere constrain plume width and geometry.

Inversions of Receiver Functions

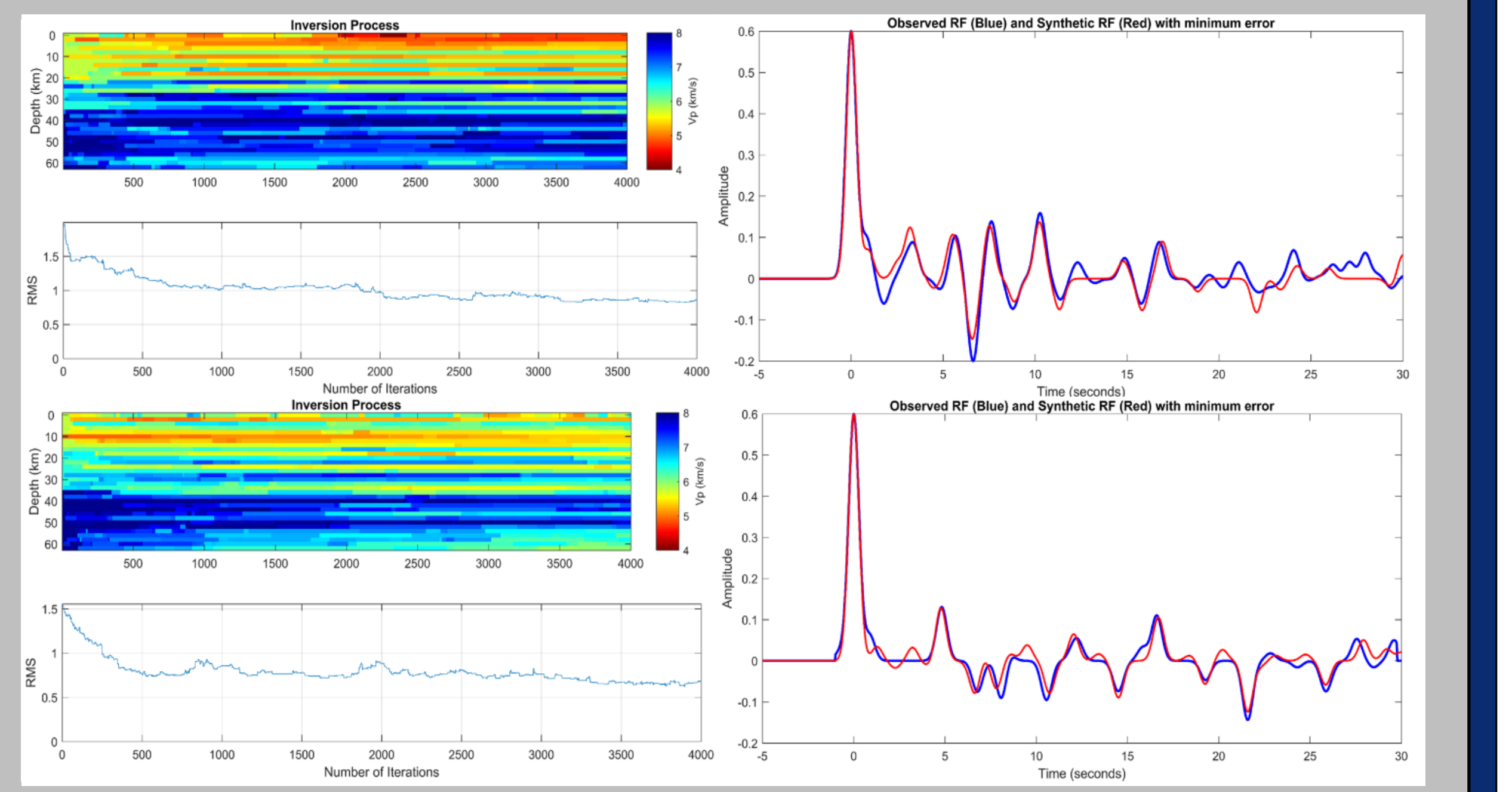


Fig. 5) Examples of the inversion process shown at stations TA.I12A (top) and XC.ID008 (bottom). Station TA.12A lies in the Idaho batholith and displays a gradual increase in velocity to the MOHO. Station XC.ID008 lies on the margin of the western SRP. A velocity inversion is featured here at 7-15 km depth.

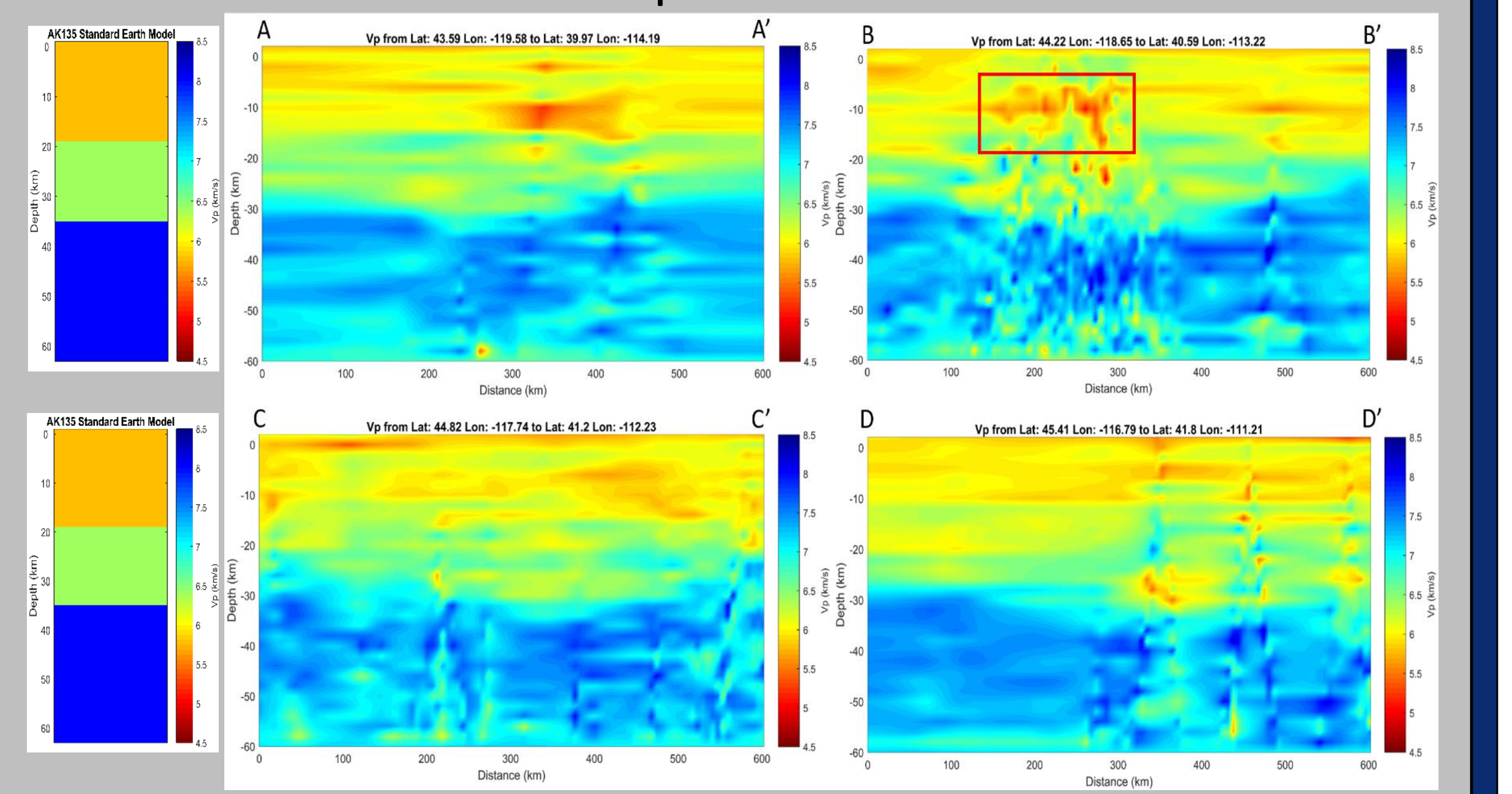
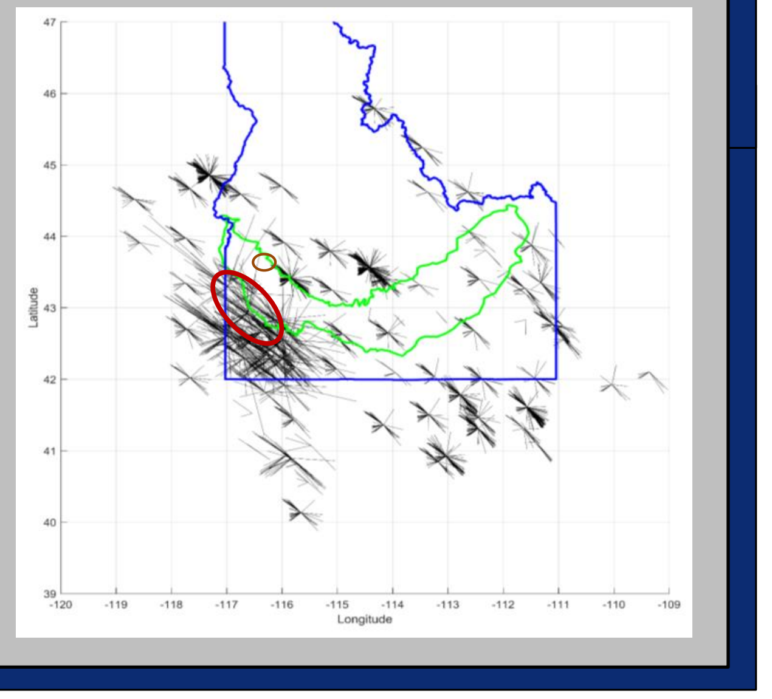


Fig. 6) After all of 6847 events were inverted, P-wave velocity tomograms were constructed. Shown here are cross sections A, B, C, and D. In cross section B, we observe a low velocity zone at 5-15 km depth along the southwest margin of the western SRP. The area of this zone is featured in figure 1. Vertical exaggeration = 6.3.

Fig. 7) A map view of the receiver function rays as they travel through the upper 60 km of the Earth. The red oval represents the low velocity zone in cross section B-B', green represents the outline of the SRP, brown circle represents the location of future Boise station, and blue is the outline of Idaho.



6) Conclusions/Future Work

- Inverting receiver functions show a low velocity zone at 5-15 km depth beneath the southwest margin of the western SRP.
- Magnetic field data point to dikes along the southern margin of the western SRP. This pattern of dikes does not appear along the northern margin of the western SRP.
- This low velocity zone is inferred as a partially melted mafic sill that is the source for the intrusive dikes and high heat flow observed at the near surface.
- Faults and sills are sparse beneath the northern margin of the western SRP. This suggests low heat flow related to volcanism in the area (Wood and Clemens, 2002).
- New analysis from Boise seismometer will be incorporated into final model.
- Quantify seismic velocities to partial melt and temperature.

7) References

Ask Thomas Harper for page of references

8) Acknowledgements.

We gratefully acknowledge support from the Geological Society of America for the graduate student research grant.