Upper Mantle Shear Wave Structure in the Southeastern United States from Rayleigh Wave Tomography

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Abstract: 237169

Goals

Model the upper mantle shear wave velocity structure in the area around the Suwannee suture and answer the following:

1.) What do mantle velocity structures tell us about the accretion of Suwannee?
2.) Do mantle velocity structures show signatures of Mesozoic rifting?

The Suwannee Suture

The Appalachians were formed over the course of several Paleozoic orogenies. During this process, The accretion of Peri-Gondwanan terranes onto Laurentia produced much of the Piedmont region. The Alleghanian orogeny, which resulted from the collision of Laurentia with Gondwana, was the final member of this sequence and culminated with the formation of Pangea. The Suwannee terrane (most of southern Georgia and Florida) is believed to have accreted to Laurentia sometime during the formation of Pangea (Hatcher, 2010).

Borehole data of stratigraphy and fossil evidence in Suwannee suggest that Suwannee has an African affiliation (e.g. Chowns and Williams 1983, Cramer 1971). More recent geochemical studies have suggested a South American affiliation (Heatherington and Mueller, 2003). Either way, Suwannee has been shown to have a Gondwanan origin.

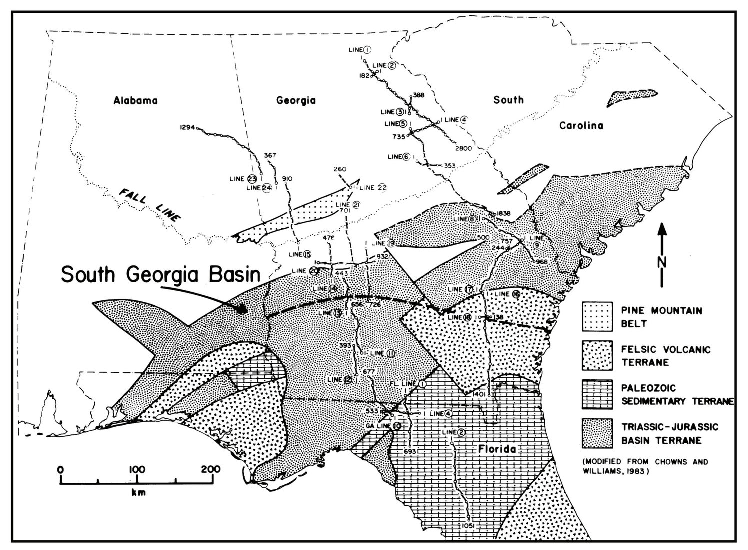


Figure 1. Taken from McBride and Nelson (1989). Map of rift basins and Basement Rock. The dashed line marks the southward extent of reflectors interpreted as the Suwannee suture.

Seismic reflection profiles by COCORP show a series of southward dipping crustal reflectors that are interpreted as the Suwannee suture (Nelson et al., 1985). Such reflectors may suggest a convergent margin where Laurentia is subducted beneath Suwannee (McBride and Nelson, 1989). Still, a lack of observed volcanism in Suwannee has been used as evidence for a more transpressional boundary at the Suwannee suture (Mueller et al., 2013).

This area has also been affected by continental rifting during the Mesozoic breakup of Pangea. Large rift basins with up to ~6km of sediment fill cross the area (McBride and Nelson, 1989), and a number of rift intrusions/ volcanics have been observed (e.g. Chowns and Williams,1983).

Data and Methods

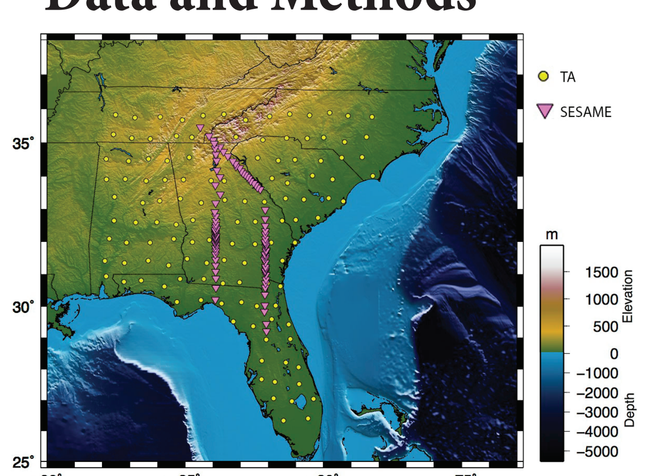


Figure 2. Map of study area and stations.

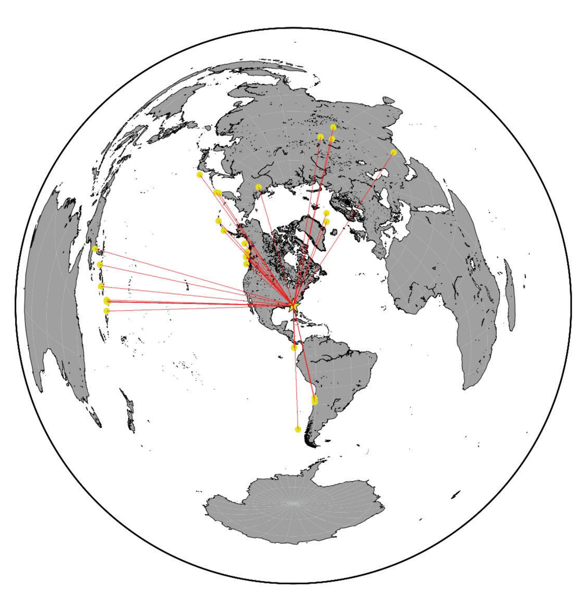
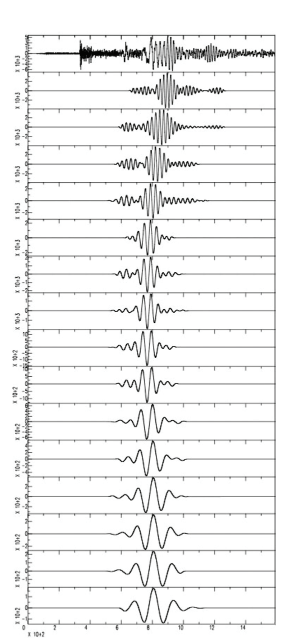


Figure 3. (Above) Arrival map for the 32 events used in this analysis.
Figure 4. (Below) Example Rayleigh wave arrival on vertical component seismograms. Top window is unfiltered. Following windows are filtered for periods ranging from 22.2 s to 143 s. Note that we later only used periods as low as 33 s because of a lack of clear arrivals.



Data for this study was collected from a total of 213 broadband seismic stations affiliated with the Southeastern Margin of the Appalachian Experiment (SESAME) and local Earthscope Transportable Array (TA) stations. A total of 32 events (spanning May 2012-May 2013) were analyzed for Rayleigh wave arrivals. Azimuthal coverage was relatively well distributed, though we lacked an abundance of arrivals from the southwest and southeast.

We utilize a two-step inversion for modeling shear velocities:

1.) Inversion for phase velocity
- Uses the two-plane wave of Forsyth and Li (2005) and the finite frequency kernels of Yang and Forsyth (2006).
- Models an incoming wavefield as a function of the interference of two incoming waves.
- Initial phase velocities for each period are calculated from IASP91 (Kennet and Engdahl, 1991).

2.) Inversion for shear velocity
- Uses best fitting phase velocity maps for each period observed (33 s-143 s).
- Uses a starting velocity model from Kennet and Engdahl (1991) that is adjusted with crustal thicknesses from Crust1.0 (Laske et al. 2013), Parker et al. (2013), and Wagner et al. (2012).
- Uses varying depth sensisitivy of Rayleigh waves to fit shear velocity model to observed phase velocities.

Results

2D Phase Velocity Maps

- Zone of low phase velocities for low to intermediate periods south of the Suwannee suture and in the Appalachians.
- Regionally low velocities appearing between 91 s and 100 s.

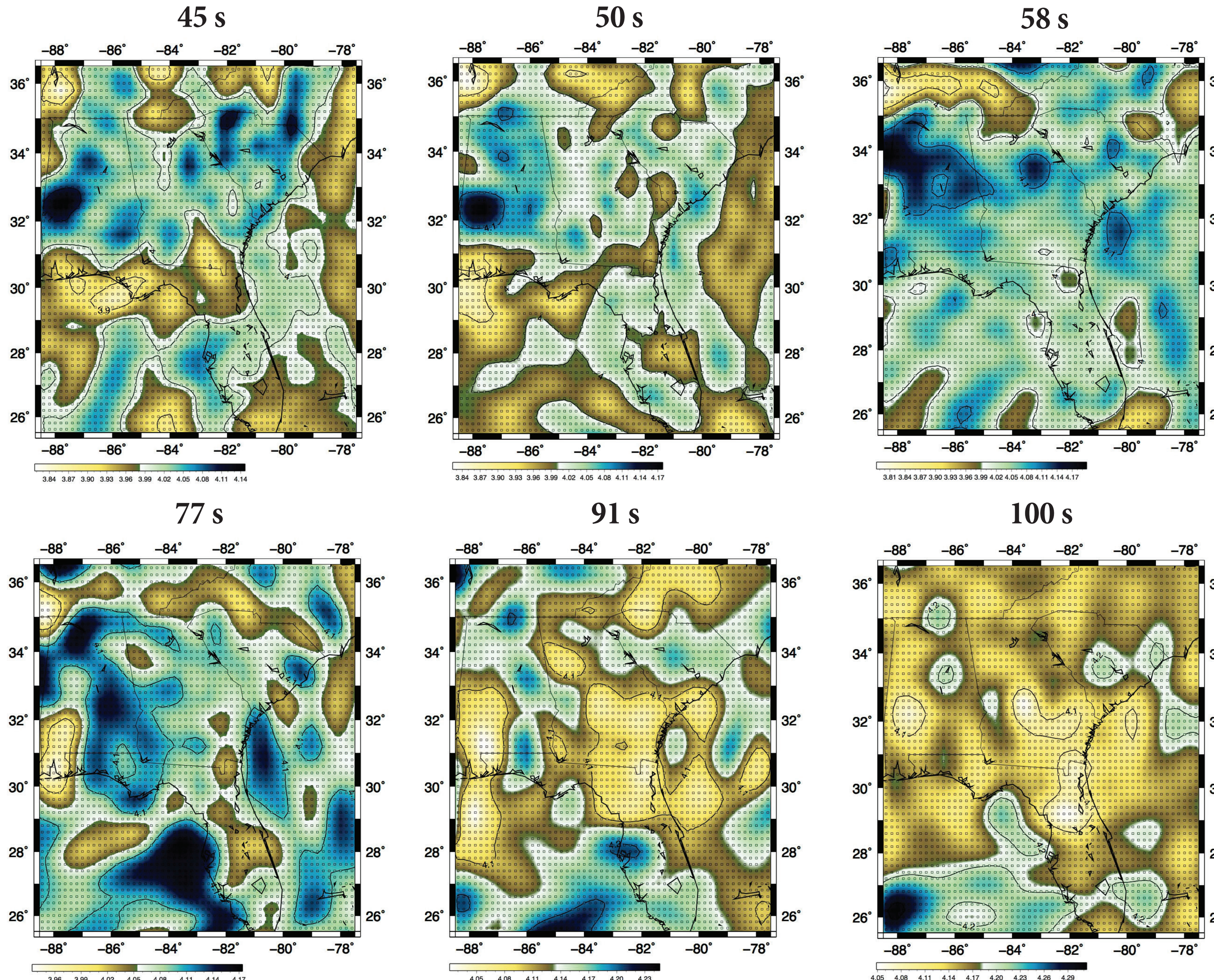


Figure 5. 2D maps of phase velocity for selected periods. Colors indicate absolute phase velocity (km/s). Blues and yellows are associated with high and low velocities, respectively.

Maps from 3D Shear Velocity Model

- Show velocity anomalies for subcrustal depths.
- Low shear velocity anomalies are present along northern Florida (in Suwannee mantle lithosphere).
- Low velocity anomaly beneath the southern Appalachians as well.
- Regional low velocity anomalies starting at around 145km depth.
  - Intrepeted as the lithosphere-asthenosphere boundary (LAB). Doesn't appear to vary across the Suwannee suture.

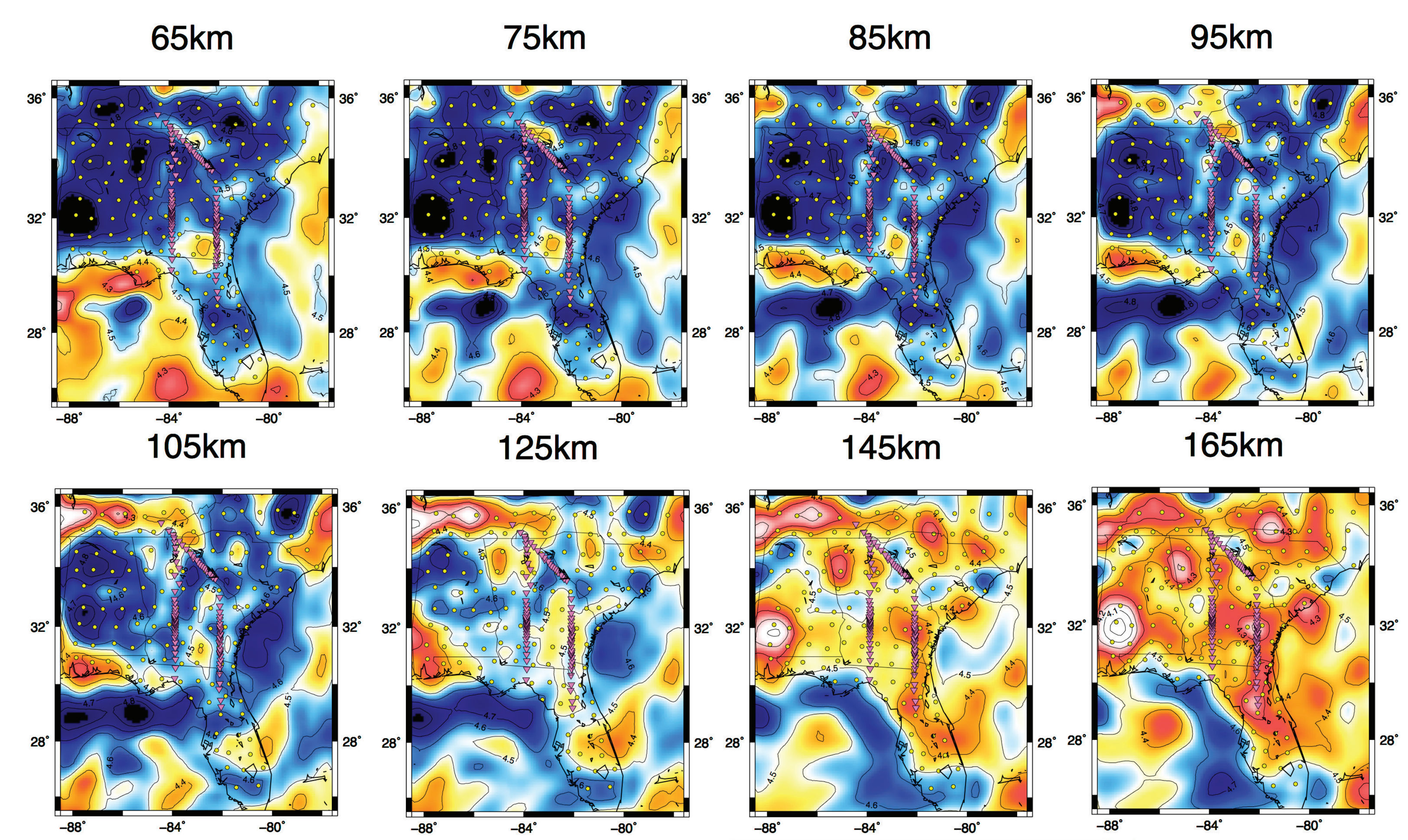


Figure 6. Maps of shear velocity anomalies for depths ranging from 65km to 165km.

Cross Sections

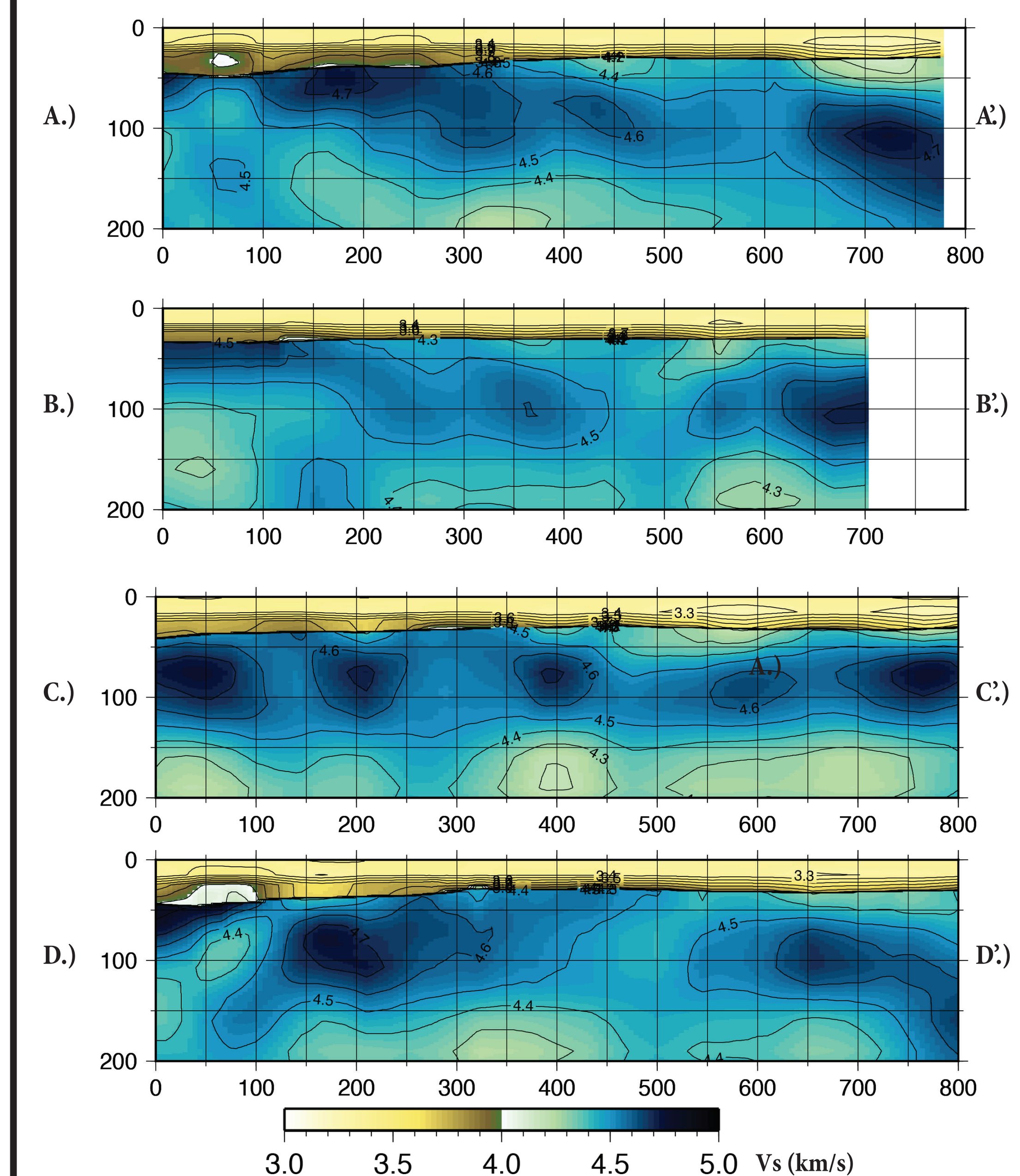


Figure 7. Cross sections of absolute shear velocity.

Cross sections represent absolute shear wave velocity with colors and contours. Depths and distances are in km. Warmer colors represent lower velocities and cooler colors represent higher velocities. The gray line demarcates where we defined the base of the crust in our starting model.

Note that the dipping features in sections A and D occur in the Gulf of Mexico, where we lack stations. It has not yet been determined whether this is a real structure.

Section B is along the zone of low %dVs seen in shear velocity maps. It appears that this zone of low velocities ends to the east, where high velocities (associated with mantle lithosphere) reappear.

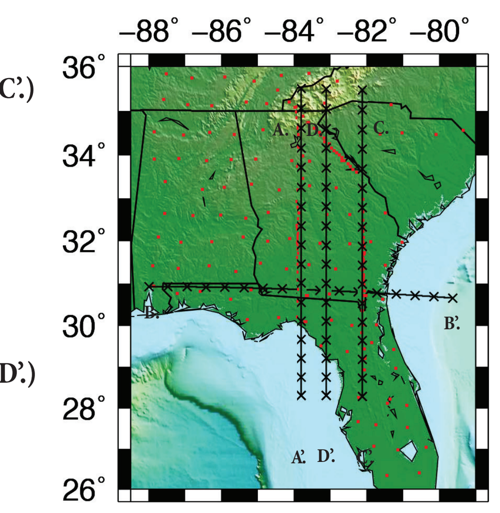


Figure 8. Map of stations (red dots) and cross section lines. X-marks are spaced in 50km increments.

Discussion

The LAB appears to occur at a roughly between 125 and 165 km for much of Georgia and into Florida. We do not observe a major change in LAB depth across the suture zone, and low velocity anomalies in southern Georgia appear to occur within the mantle lithosphere.

The sharp lateral velocity gradient within Suwannee mantle lithosphere may be caused by factors that include thermal gradients, patial melt, water content, and chemical composition (Fischer et al., 2010). Consistently low heat flow across this area (Blackwell et al. 1991) may suggest that a locally high thermal gradient and/or partial melt are unlikely. Compositional variations could account for reduced velocities if there is a zone of more fertile rock within the mantle lithosphere (Fischer et al. 2010). Still, it is debated how much of a difference in velocity fertility/depletion can cause. Some estimate this could account for a ~2.5% change (Lee, 2003) but others argue for little effect (Schutt and Lesher, 2006). Hydrous phases within the mantle lithosphere could also reduce velocities (Karato and Jung, 1998). While rifting may potentially allow for the emplacement of fertile rock in the mantle lithoshere (Drury et al. 2001, Storey 1995), the debateable significance of fertility on seismic velocities (Schutt and Lesher, 2006) may indicate that water content (and consequently subduction) is more important here.

Conclusions

- LAB depth is fairly consistent across the Suwannee suture zone.
- A observed zone of low shear velocity anomalies in southern Georgia may be related to subduction processes, though a rift-related cause cannot be entirely ruled out.
- Another zone of low velocities has been observed beneath the southeastern extent of the Appalachians, but more analysis is needed before this feature is characterized.

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