Integrating lithospheric structure, mantle dynamics, and surface processes to investigate topographic and lithospheric evolution of the southeastern US continental margin

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Several of the science questions outlined in the GeoPRISMS RIE implementation are inextricably linked to the science targets outlined in the EarthScope Science Plan for 2010-2020. Four areas of fertile overlap between these two documents include:

- Characterizing the broad-scale lithospheric structure of the eastern US margin and how it relates to the syn- and post-rift continental evolution
- Understanding the role mantle dynamics plays in controlling passive margin development and surface topography
- Investigating the role that magma and volatiles played during continental breakup and post-rift evolution
- Understanding the feedbacks and interplay between surface processes and tectonics in the evolution of the continent.

The most effective way to probe the structure and dynamics of the crust and mantle over a region as broad as the proposed ENAM focus site is to analyze seismic array data in the context provided by geochemical, geomorphological, and geodynamical constraints. Our preliminary analysis of existing broadband seismic data as well as new data collected by the TEENA array (Test Experiment for Eastern North America; Benoit and Long, 2009) suggests three main findings. First, we observed extremely sharp variations in crustal thickness (on length scales of ~25 km or less) that correlate with Precambrian structures and domain boundaries, suggesting that inherited pre-rift structures may have influenced rifting (Benoit et al., in prep.). Second, we identified evidence for magmatic underplating beneath the Appalachian Piedmont and Coastal Plain based on an analysis of lithospheric structure from receiver functions and gravity data (Benoit et al., in prep). Third, we identified lateral variations in SKS splitting patterns between stations located in the Appalachians and those located closer to the coast, which suggests a transition in mantle flow direction and/or a transition in lithospheric anisotropy structure at the southeastern edge of the North American continent (Long et al., 2010).

Our own preliminary work (Long et al., 2010; Benoit et al., in prep) as well as the recent work of others (e.g., Abt et al., 2010) suggests that there are intriguing variations in both crust and mantle structure trending perpendicular to the present day margin. Unfortunately, the 75 km EarthScope Transportable Array station spacing that is planned for this region is too sparse to fully sample the small-scale variations in structure across domain boundaries. Thus the densification of the TA with Flexible Array-style experiment(s) trending perpendicular to the margin, in combination with constraints from geodynamical modeling and geomorphological analysis, is necessary to address the science questions related to the role that preexisting structures and mantle dynamics have played in rifting and evolution of the margin.

Variations in crustal and mantle structure can be linked to both surface processes (from geomorphological investigations) and mantle flow (from geodynamical models) to provide a vertically integrated picture of tectonic processes from the surface to the deep mantle. There is an ongoing interplay between erosion, topography, and lithology, and topographic change records a complex set of processes, including dynamic processes in the mantle and perhaps changes in the buoyancy structure of the crustal roots that underlie the mountains. It is not well understood how each of these factors contributes and better constraints on the history of topographic change and its relationship to the deep structure and dynamics are needed. Therefore, a collaborative interdisciplinary effort is required to constrain the nature of these relationships at the continents margin.

We suggest that a transect from the Virginia coastline westward past the Grenville Front in Kentucky (Figure 1) represents an ideal location for investigating these science questions. As a choice for the location of a margin-perpendicular transect, this region offers a number of advantages. The transect would sample a large number of physiographic provinces and domain boundaries, including those of the Appalachian Plateau, Appalachian Valley and Ridge, Blue Ridge Mountains, Pieldmont, and Coastal Plain. The region contains significant Proterozoic, Paleozoic, Mesozoic, and Cenozoic volcanic exposures and has exhibited recent seismic activity (the magnitude 5.8 earthquake in Mineral, VA, in August 2011, and subsequent aftershocks). The region is unique globally in that it preserves two overlapping large igneous provinces. The proposed transect exhibits relatively high, persistent topography and active surface processes. There is evidence for abrupt spatial variations in crustal and lithospheric structure in this region from the TEENA experiment (Benoit and Long, 2009). Finally, this choice of location offers the advantage that the Grenville Front is relatively close to the Atlantic coast compared to other locations along the margin, which makes the logistics of a linear seismic array that goes from the coast to the west of the front substantially easier.

References

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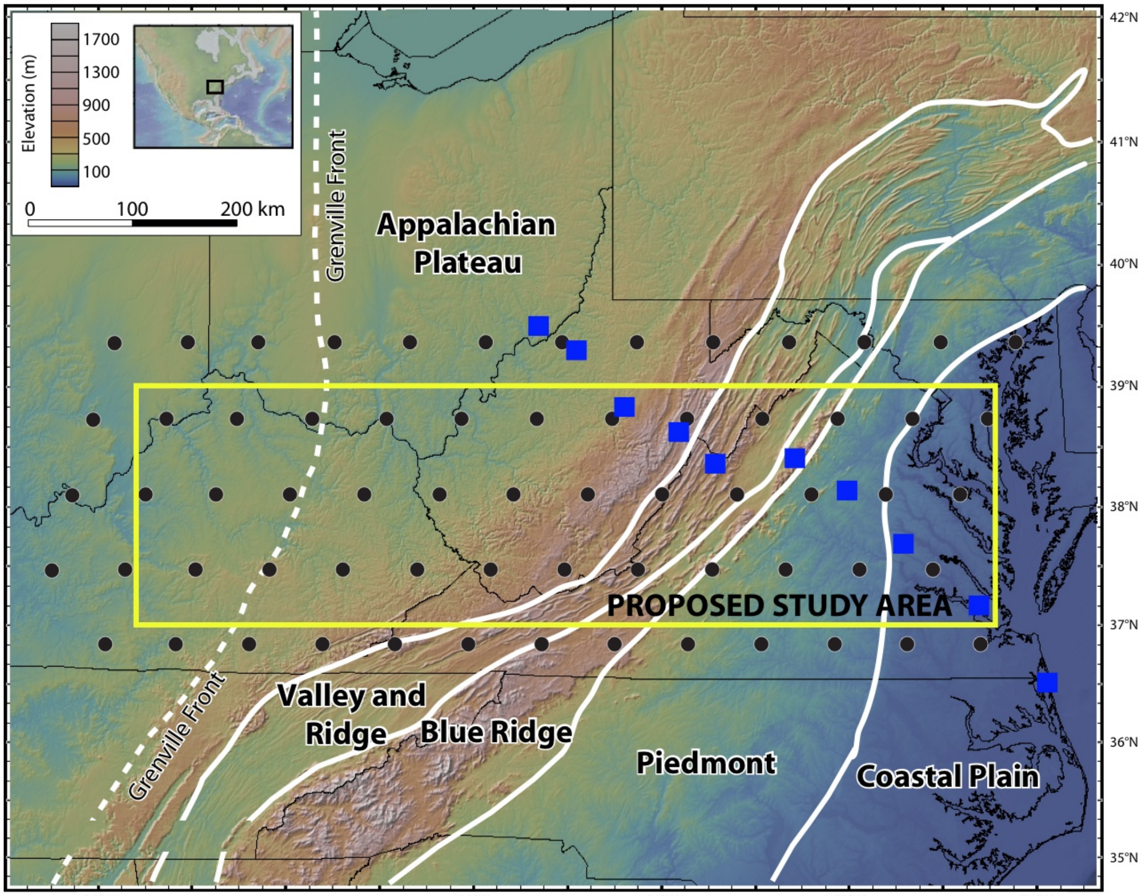

Figure 1. Map of proposed study area showing topography and physiographic provinces. Black circles show the nominal Transportable Array station locations in the region; blue squares show the locations of the TEENA experiment stations (Benoit and Long, 2009).