It is now well established that in active orogens topography is both a reflection and throttle of the tectonic processes that deform and uplift rocks (e.g. Zeitler et al., 2001; Willett et al., 2006). At all stages of orogeny there are feedbacks between tectonic and surficial processes but the two are most fully coupled when mean elevation, relief, and slope grow to the point that surface process rates can balance the flux of rock fed into the orogen. Long after tectonic processes are extinguished, surface processes continue to erode rocks and mountains possessing a crustal root enter into a long period of topographic decay as the root is consumed by an isostatic response to that erosion. Despite the fact that most continental land mass is composed of decaying orogens, there are correspondingly few studies that explore surficial, isostatic, and/or epeirogenic coupling in this setting. Process rates may be generally slow in the decaying orogen, but they may also be unsteady, responding to changes in global climate (Zhang et al., 2001), or to epeirogenic processes rooted in crustal, lithospheric, or sub-lithospheric processes. An Earthscope investigation of unsteadiness in long-term landscape evolution stands to illuminate both of these possibilities in an integrated geophysical, geological, and geomorphologic context.

The Appalachian Mountains in the eastern United States are an old orogen whose crustal root was grown and modified during a long period of Paleozoic collisional tectonics, and then thinned by erosion and stretching associated with the opening of the Atlantic Ocean. Evolution of the Appalachian mountain landscape has engendered influential tectonic (Williams, 1978; Boyer and Elliott, 1982; Rodgers, 1987; Faill, 1997a, b; 1998; Hatcher et al., 2007) and geomorphic (Davis, 1889; 1899; Hack, 1960) paradigms and continues to shape thinking as new data and analytical techniques are able to increasingly quantify processes and rates (Pazzaglia and Brandon, 1996) and paradigms and continues to shape thinking as new data and analytical techniques are able to increasingly quantify processes and rates (Pazzaglia and Brandon, 1996; Granger et al., 1997; 2001; Reusser et al., 2005, 2006). The Appalachians are one of the few decay-phase orogens where a wealth of erosional data has already been assembled from thermochronometric (e.g. Hulver et al., 1997), river incision (e.g. Mills, 2000), and most recently cosmogenic (e.g. Matmon et al., 2003) methods.

These and supporting geologic and geophysical data make the Appalachians an excellent case study in long term erosion, persistence of mountainous topography, and coupling between surface and tectonic/isostatic/epeirogenic processes in an ancient, decaying orogen. For the Appalachians, there are six key observables that must be reconciled to explain its post-orogenic evolution and all six of these lend themselves well to an Earthscope investigation. First is that the metamorphic core of the range currently lies at the lowest mean elevation, and much of it is below sea level, covered by a coastal plain. What is commonly referred to as “the Appalachians” are really what is left of the former Appalachian foreland, now topographically inverted. Second, a long-term record of unroofing exists in the form of siliciclastic sediments in Atlantic margin shelf-slope basins. These sediments argue for unsteady exhumation driven by epeirogeny, climate, or both (Pazzaglia and Brandon, 1996) although there is some ambiguity regarding the precise provenance of the basin material. The most recent pulse of sediment delivered to the shelf-slope basins arrived in the middle Miocene and high sediment rates persist through the Quaternary. Third, the longitudinal profiles of Atlantic slope rivers increase in gradient towards
the Atlantic, forming a line of seemingly anomalous rapids (Fall Zone) near the coast. Fourth, the divide between Atlantic slope and Ohio drainages is not a static feature; rather, it has a long-term history of unsteady translation westward. Fifth, Appalachian topography is locally rugged, with lofty, steep mountains and deep, narrow canyons. The presence of mountainous topography in a foreland that has experienced kilometers of erosion over 180 m.y. is enigmatic. Lastly, the wealth of thermochronologic, river incision, and emerging cosmogenic data that are increasingly quantifying Appalachian erosion rates show little regional variation both in space and time, despite variable tectonic histories, rock-type, and relief.

An Earthscope long-term landscape evolution investigation to identify the epeirogenic processes and quantify the erosional response / feedbacks would involve the collection of geomorphic and geophysical data to augment existing data sets. Among these are (1) comprehensive coverage of thermochronologic cooling data including detrital AHe data, (2) basin-wide cosmogenic erosion rates, (3) river incision rates supported by cosmogenic and OSL geochronology, (4) crustal thickness (depth to moho), (5) lithospheric structure, and (6) dynamic responses to far field plate stresses and slab-induced sub-lithospheric mantle flow.

**Figure caption**

History of post-orogenic erosion in the Appalachians illustrating unsteadiness and possible epeirogenic and geomorphic processes driving that unsteadiness. (a) Cross-section oriented orthogonal to the New Jersey continental shelf showing the accumulation of siliclastic detritus eroded from the post-orogenic Appalachians and preserved in the Baltimore Canyon trough (BCT) (Pazzaglia and Brandon, 1996). (b) Detrital AHe data from New England, representative of an Appalachian-wide data set that argues for broad cooling of the rocks at the surface at 100 Ma. (Pazzaglia et al., unpublished) (c) Unsteadiness in post-orogenic Appalachian erosion reconstructed from (a) and expressed as the flux of eroded rock (left axis) and erosion rate (right axis) for a contributing basin equal to the modern Atlantic Slope watershed of 300,000 km² (Pazzaglia and Brandon, 1996). The shaded region under the curve amounts to 2 km equivalent of rock removed from the Appalachians which represents all of Cenozoic, and a small portion of the Cretaceous section shown in the transparent window in (a). Accounting for dissolution of ~10m/m.y. over the past 100 m.y., 1 km of rock has been dissolved, added to 2 km of rock by erosion, sums to 3 km of rock removed in 100 m.y. Thus, the BCT and thermochronologic data agree in the total amount of post-orogenic erosion; however, even the AHe data are insensitive to the nearly order of magnitude variation in erosion unsteadiness in the past 100 Ma. Unsteadiness may be linked to lithospheric processes like (d) margin flexure (Pazzaglia and Gardner, 2000, BR = Blue Ridge, AE = Allegheny Escarpment, CFA = Cape Fear Arch, NA = Norfolk Arch, SE = Salisbury Embayment), or (e) geomorphic unsteadiness in the westward migration of the continental divide (Harbor and Gunnell, 2007) driven by sub-lithospheric dynamic mantle flow (Forte et al., 2008).