Combining EarthScope data with petrology and geochemistry to explore the Mid-Continent Rift's evolution

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A central theme of EarthScope is to better understand the evolution of continental lithosphere and its relation to upper mantle processes. One major target is the Mid-Continent Rift System (MCRS), the 2000-km long trace of a massive igneous event that nearly split North America 1.1 Ga. The MCRS offers a frozen snapshot of aspects of continental rifting and rift failure. The rift started, evolved, and terminated via a complex and not-yet-understood interplay of mantle dynamics, magmatism, and extension. Details of the processes surrounding melt formation and the associated depletion of the lithospheric mantle, and re-thickening of the extended crust remain poorly constrained. A major advance will come from EarthScope studies that focus on joint interpretation of existing gravity and magnetic constraints with newly acquired seismic (USArray) and magnetotelluric data to develop integrated three-dimensional present-day images of the seismic velocity, density, magnetic, and electrical structure of the rift system and surroundings. The next step, using these images to develop and test models of MCRS evolution, involves integrating the geophysical data with petrological and geochemical studies to probe the magmatic processes that led to the initiation and evolution of the rift system with particular focus on the impact of these processes on the continental lithosphere. Three broad questions remain: 1) Can the volume of magmas preserved in the MCRS be explained by extensional processes in the absence of a plume thermo-chemical anomaly? 2) Do the geochemical characteristics of MCRS magmas require the presence of mantle plume throughout the development of the rift? 3) What was the impact of the MCRS formation on the regional lithospheric structure? A key to understanding the driving mechanisms of lithospheric modification during the Mid Continental Rifting episode is creating a geodynamic framework built upon joint interpretation of geophysical and geochemical evidence of asthenospheric and lithospheric processes that have impacted lithospheric structure. The vast magmatic record preserved within the MCRS allows for the exploration of the geochemical characteristics (major elements, trace elements, Sr-Nd-Pb-Hf isotopes) of Keweenaw flood basalts and associated alkaline rocks to probe the lithospheric and sub-lithospheric source of rift magmatism. Geophysical data can constrain the volume and distribution of magmatic rocks and seismic velocity, density, and electrical structure within and below the rift. Combining geophysical and geochemical observations with geodynamical modeling will aide in also constraining the mechanism and timing of rifting and associated magmatic activity. Conducting these studies in close collaboration with the ongoing geophysical programs will benefit both types of studies and yield a more integrated view of the complex rift evolution process.

The MCRS is an unparalleled natural laboratory for students to explore plate tectonic processes, which often seem remote and hard to relate to in the Midwest. The photo shows MSU undergraduate students examining an outcrop of Keweenaw flood basalt (Mamainse Point). Data collected in this region has a direct impact on undergraduate education by enriching field experience and connecting students with their environment.