

Eastern North America Margin (ENAM) Opportunities Mini-Workshop Report

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1.0 Executive Summary

On May 20 & 21, a joint *EarthScope-GeoPRISMS* mini-workshop was held in Austin, TX to begin to address areas of common scientific ground in the study of Earth science in eastern North America (ENAM). Thirty scientists attended this 1.5 day meeting that included members from the *EarthScope* and *GeoPRISMS* communities, NSF and other federal agencies, and one graduate student. The transportable array of *EarthScope* arrives in the eastern United States in 2012-13, and *GeoPRISMS* has identified ENAM as a primary site for the investigation of rift initiation and evolution (RIE initiative). Collectively, *EarthScope* and *GeoPRISMS* research spans the shoreline and in doing so, provides an integrated framework for understanding the orogenic inheritance, rift-initiation, evolution, and structure of a mature continental margin. The associated broader impacts of natural hazards and assessment of the nation's natural resources, including traditional and alternative sources of energy in the most-densely-populated part of the country are fundamental to both programs. Therefore, the timing is perfect to organize both communities to identify the crucial science targets and to develop or modify the necessary strategies for science implementation.

The goal of this mini-workshop was to (1) plan for a larger science workshop to be held 27-29 October, (2) begin to focus the broader *EarthScope* and *GeoPRISMS* communities on the key science targets in ENAM, addressing the various challenges and synergistic opportunities in how *EarthScope* and *GeoPRISMS* science have been typically implemented, and (3) articulate pragmatic considerations linked to proposal submission dates, access to, staging, and deployment of instruments, and (4) consider longer-range facility potential.

Results from the meeting included: (1) review of the *EarthScope* and *GeoPRISMS* science plans, including an *EarthScope* workshop report from 2004 that was specifically targeted at ENAM; (2) determination of scientific and regional overlap between *GeoPRISMS* and *EarthScope*; (3) a better understanding of the research approaches used by *GeoPRISMS* and *EarthScope* that included an example of collaborative research in the Salton Trough; (4) an understanding of the timing of *EarthScope* operations on the east coast; and (5) development of a preliminary agenda for a full workshop planned in October, 2011 at Lehigh University. It was broadly concluded that a goal for the fall meeting should be to establish a clear research strategy where the largely P.I.- driven and non-site specific approach of *EarthScope* can inform the largely community-driven site-specific, integrated systems approach of *GeoPRISMS* and visa versa.

The *EarthScope* and *GeoPRISMS* communities need to be cognizant of rapidly approaching summer deadlines for proposal submissions and fall workshop preparation. Proposal pressure will play a key role in determining the importance of focused research site selection as well as

the important science targets. Furthermore, proposal pressure will play a role in determining the fate of the *EarthScope* instrument pool once the TA completes its scheduled deployment in 2015.

The October workshop will place an emphasis on groups of PIs that have collective interests in the key science targets and locations where that science can be accomplished. Taken together, these efforts will guide the larger community effort that has real resource and planning limitations/considerations. A consensus was reached that researchers should self-organize prior to the October workshop to discuss the science and implementation strategies for research on ENAM. Investigators should come to the October workshop with a clear vision for research focus and collaboration. Details on white paper submission are presented in the full report.

2.0 Introduction

On May 20 & 21, a joint *EarthScope-GeoPRISMS* mini-workshop was held in Austin, TX to begin to address areas of common scientific ground in the study of Earth science in eastern North America (ENAM). 30 scientists attended this 1.5 day meeting, including scientists from the *EarthScope* and *GeoPRISMS* communities, funding agencies, and other federal agencies, and one graduate student (See Appendix A). We report here on the results of this mini-workshop.

EarthScope and *GeoPRISMS* represent research communities of geologists, geophysicists, geochemists, and geodynamicists who study the processes that build continents, open ocean basins, erode, transport and deposit sediment, and the associated natural hazards of earthquakes, tsunamis, sea level rise, and landslides both on land and under water. *EarthScope* science is done primarily, but not exclusively on land and involves arrays of geodetic instruments and seismometers with the primary goals of measuring crustal deformation and imaging the lithospheric and sub-lithospheric foundation the United States, respectively. *GeoPRISMS* studies the formation of continental margins at sea and on land. The transportable array of *EarthScope* arrives in the eastern United States in 2012-13, and *GeoPRISMS* has identified ENAM as a primary site for the investigation of rift initiation and evolution (RIE initiative). Collectively, *EarthScope* and *GeoPRISMS* research spans the shoreline and in doing so, provides an integrated framework for understanding the orogenic inheritance, rift-initiation, evolution, and structure of a mature continental margin. The associated broader impacts of natural hazards and assessment of the nation's natural resources, including traditional and alternative sources of energy in the most-densely-populated part of the country are fundamental to both programs. Therefore, the timing is perfect to organize both communities to identify the crucial science targets and to develop or modify the necessary strategies for science implementation.

There are several excellent reasons why the *EarthScope* and *GeoPRISMS* communities might elect to collaborate on ENAM research. The eastern United States encompasses the Appalachian Mountains and the archetypal Atlantic passive margin, and as a result, is a source of formative thinking related to continental assembly, mountain building, continental rifting, and post-rift passive margin evolution. Key paradigms such as the Wilson cycle and eustasy are based on data and research in this geographic area. Furthermore, there are tremendous opportunities for collaborative research to raise awareness of the geological sciences, natural resources, energy and communications infrastructure, and natural hazards including earthquakes, tsunamis,

flooding, clathrate degassing, and sea level rise in the most densely populated part of the United States.

3.0 Mini-Workshop Goals.

The goals of this mini-workshop were to (1) plan for a larger science workshop to be held 27-29 October, (2) begin to focus the broader *EarthScope* and *GeoPRISMS* communities on the key science targets in ENAM, addressing the various challenges and synergistic opportunities in how *EarthScope* and *GeoPRISMS* science have been typically implemented, (3) articulate pragmatic considerations linked to proposal submission dates, access to, staging, and deployment of instruments, and (4) consider longer-range facility potential. The agenda for the mini-workshop can be found in Appendix A. This planning workshop was to set a clear vision and agenda for the October science workshop at Lehigh University. We provide that vision below as a workshop result.

4.0 Workshop Results.

4.1. EarthScope Science and Implementation Plan.

Early in the meeting, we reviewed the *EarthScope* and *GeoPRISMS* Science Plans with particular focus on their implication for the Eastern North American Margin (ENAM). The *EarthScope* science plan (<http://www.earthscope.org/ESSP>) and accompanying presentations of the 2009 science plan workshop articulate the key science targets for *EarthScope* research. Many of these science targets have direct relevance to ENAM, and presentations at the 2011 *EarthScope* National Meeting highlighted a range of scientific results from the study of these targets. More specific to ENAM was a 2004 *EarthScope* conference that focused on research frontiers and opportunities (<http://www.earthscope.org/workshops/archive>). Our effort here builds on these two community-driven documents.

The implementation of *EarthScope* science has community-driven and PI-driven components. The community component includes a transportable array (TA) of 400 portable, three-component broadband seismometers deployed on a uniform grid that is systematically covering the US. Each TA station includes the instrumentation necessary to continuously sense, record, and transmit ground motions from a wide range of seismic sources, including local and distant earthquakes, volcanic eruptions, and other natural and human-induced activities. The spacing of the TA allows for imaging of the sub-lithospheric mantle and major variations in lithospheric structure. The TA is entering eastern North America in 2012 and the last instruments will be extracted in 2015. Several hundred of these instruments are slated to go to Alaska after leaving the eastern US, but the fate of the others is not yet determined and requires timely community input to *EarthScope* and IRIS as to their next deployment. Possibilities range from remaining for a longer period of time in ENAM or becoming part of the flexible array (see below), which can also have an impact on continued focus on ENAM science and coordination with *GeoPRISMS*. The planning workshop identified monitoring of known zones of seismicity as well as better imaging of the base of the lithosphere as good criteria for advocating longer deployment of instruments in ENAM.

EarthScope PI-driven science in the ENAM would largely take advantage of the flexible array (FA) that allows for focused observation and study of key geophysical locales and are available through proposals approved by the NSF. These instruments can be used to augment the permanent instruments, extend investigations into Canada and Mexico, and respond to volcanic and/or tectonic opportunities. FA instruments can be spaced more tightly than, and in complement with, the TA in order to image the crust, Moho, and higher-detail features in the mantle lithosphere. There are obvious advantages to planning FA deployment to spatially and temporally correspond to the TA.

In addition to the TA and FA, there is an opportunity to take advantage of other *EarthScope*-aligned facilities and other initiatives such as PBO GPS receivers and borehole strainmeters, LiDAR, and InSAR in the last five years of the operations and maintenance of *EarthScope*. These instruments might be used in novel ways in ENAM research targets, including active seismicity, buoyancy (in the mantle as well as from ice and water loading) induced surface displacements, and surface processes.

4.2 GeoPRISMS Science and Implementation Plan

GeoPRISMS has a science and implementation plan (<http://www.GeoPRISMS.org/science-plan.html>) that identifies rift initiation and evolution (RIE) as one of its initiatives. The implementation plan identifies ENAM as one of two RIE primary sites where the processes of continental rifting and transition to a passive margin will be studied. At ENAM, *GeoPRISMS* asks the following questions:

- A. How was deformation distributed throughout the lithosphere on the Atlantic margins, and how was it influenced by magmatism and pre-existing structural and compositional heterogeneity?
- B. How does rift structure and magmatism vary within and between segments along the ENAM?
- C. How do mantle dynamics influence syn- and post-rift evolution of the margin?
- D. What processes accompanied the transition from late-stage rifting to mature seafloor spreading? How has the margin been influenced by post-rift tectonics?
- E. What controls the large scale form of the passive margin?
- F. What are the magnitudes, mechanisms and timescales of elemental fluxes between the Earth, oceans and atmospheres along a passive margin during and after rifting?
- G. Is post-rift passive margin morphology self-regulating?
- H. What are the scales and frequency of submarine landslides, and what preconditions and triggers landslides?

GeoPRISMS espouses a practice of identifying sites where focused experiments can unite a broad cross-section of collaborators to develop a multi-disciplinary, systems-approach understanding of continental margins. ENAM is identified as one primary ‘site’. However, it is recognized that the community may achieve the most science with limited resources by focusing expensive data acquisition efforts within particular regions along the margin (e.g., “research corridors”). It is hoped that the development of a more focused implementation plan for the ENAM will occur at the October meeting at Lehigh University. Therefore *GeoPRISMS* science

has a correspondingly large community-based decision making component to insure that PI-driven projects are tractable. *GeoPRISMS* complements its ‘site-based’ approach with the recognition of certain themes that are not tied to specific locations (i.e., thematic studies), but which should be justified in terms of research questions posed at the primary sites.

4.3 Benefits to voluntary alignment of *EarthScope* and *GeoPRISMS* science and implementation.

At the workshop, we recognized there is tremendous common scientific ground between *EarthScope* and *GeoPRISMS*. We developed a matrix of *EarthScope* and *GeoPRISMS* science targets (Table 1). All eight *EarthScope* scientific targets are reflected in one or more of the 4 scientific questions that are posed by *GeoPRISMS*.

Table 1. Alignment of *EarthScope* and *GeoPRISMS* science objectives.

RIE questions -> EarthScope targets V	Continental Rift Initiation	Evolution of rifting processes	Control of architecture of rifted margins	Mechanisms and consequences of fluid and volatile exchanges with earth, oceans, atmosphere	Cross the shoreline?
Imaging crust and lithosphere	X	X	X		Y
Active deformation of the continent	X	X			Y
Continental evolution	X	X	X		Y
Deep earth structure and dynamics	X				Y
EQs, faults, and rheology of the lithosphere	X	X	X		Y
Magma and volatiles in the crust and lithosphere				X	Y
Topography and tectonics		X	X	X	Y
Connections to Hydrosphere, cryosphere, atmosphere				X	Y

The workshop participants recognized that there are numerous ways in which the *EarthScope* and *GeoPRISMS* communities could interact. First, a project spatially co-located with a *GeoPRISMS* primary site may utilize some of the *EarthScope* facility. There are two examples of this approach that have been successful in the western United States (i.e., Salton Trough and Cascadia). Second, a more ambitious idea is for both communities to voluntarily coordinate

efforts in both the science target and site. In the *GeoPRISMS* parlance, this is the concept of a research corridor; for *EarthScope*, it is the concept of a geoswath (Tikoff, 2006). In either case research in ENAM offers a unique opportunity to coordinate efforts such that the coastline is straddled with instruments and key, long-standing questions regarding the orogenic legacy, rift initiation, the role of voluminous magmatism, continental to oceanic lithosphere transition, development of a passive margin, late-stage active seismicity and surficial processes can be addressed. Furthermore, alignment of the two communities goes a long way in making credible arguments for continued infrastructure, such as the FA, in observing ENAM geologic, seismic, surficial, or geodynamic processes that require longer-term commitments than those currently envisioned by the *EarthScope* implementation plan.

4.4 Important considerations for ENAM science.

At the workshop we had a spirited discussion as to some of the site characteristics and other considerations that should be taken into account to achieve *EarthScope* goals, *GeoPRISMS* goals, and potential synergy in their respective science:

- (1) Little to no salt in slope-shelf basin stratigraphy to allow for seismic wave penetration.
- (2) Exposure of rift intrusive and volcanic rocks on shore and seismic identification of seaward-dipping reflectors with large magnetic signature (including the ECMA – East Coast Magnetic Anomaly) in the subsurface.
- (3) Exposure of onshore rift basins and basin stratigraphy
- (4) A seismic array oriented generally orthogonal to the orogen and the margin that captures the transition from the craton to oceanic lithosphere. This should be aligned in a region where the orogen is particularly well-exposed geologically. Ideally, this region would also allow for allied studies where:
 - there is exposure of the temporal record of lithospheric modification since the assembly of the continent (rift initiation and rift-to-drift)
 - there are complementary areas with different records of lithospheric modification
 - a strategy of two adjacent corridors for comparative rift initiation can be pursued.
- (5) Presence of a known zone of seismic activity, as well as an aseismic zone containing deformed geomorphic markers or anomalous river incision.
- (6) Presence of active surface processes on the shelf-slope break (i.e. slumping, landslides)
- (7) Access to a well-studied conjugate margin on the opposite side of the Atlantic Ocean.
- (8) Ability to link onshore erosion and sediment transport to offshore deposition and stratigraphy to explore dynamic feedbacks or coupling between lithospheric and surface processes.

(9) Potential to leverage science and data acquisition with industry and/or community partners (BOEMRE, USGS, etc).

(10) Potential to perform a comparative analysis with the Canadian scientific community that is particularly pertinent in addressing the first-order observation of the lack of CAMP (Central Atlantic Magmatic Province) magmatism during rifting north of Nova Scotia.

Constructive debate ensued over different possible strawman strategies to pursue the research interests of *EarthScope* and *GeoPRISMS* along the ENAM. We discussed some of the advantages and disadvantages of different locations for ‘research corridors’. Some proposed multiple transects across the northern and southern parts of the margin which would capture changes in the style of orogenesis along the Appalachians and possible corresponding consequences for inheritance on rifting. Others emphasized the advantages of a geoswath / research corridor spanning the Appalachians and mid-Atlantic margin that can extend a recently funded mid-continent *EarthScope* project dedicated to understanding the transition from the Ozark Plateau, to Illinois Basin, to the Grenville front. Alternative strategies such as selecting research corridors or a spread of study areas along the ENAM that encompass magma-rich and magma-poor end-members were discussed.

In summary, it was broadly felt that a goal for the fall meeting should be to establish a clear research strategy where the largely P.I.-interest driven and non-site specific approach of *Earthscope* can inform the more community-driven site-specific, integrated systems approach of *GeoPRISMS* and visa versa. It was noted that a ‘research corridor’ approach might represent the best way for *GeoPRISMS* to achieve the most results with limited funds.

4.5 Planning and implementation considerations.

The *EarthScope* and *GeoPRISMS* communities need to be cognizant of rapidly approaching summer deadlines for proposal submissions and fall workshop preparation. Proposal pressure will play a key role in determining the importance of focused research site selection as well as the important science targets. Furthermore, proposal pressure will begin the process of determining the fate of the *EarthScope* instrument pool once the TA completes its scheduled deployment in 2015.

The *EarthScope* proposal solicitation is available from http://www.EarthScope.org/about_us/revised_solicitation_0311. The upcoming proposal submission deadline is 16 July, 2011. This deadline is very important for research that requires FA data to be co-timed with the TA.

The *GeoPRISMS* proposal solicitation is available from <http://www.GeoPRISMS.org/research.html>. The upcoming proposal submission deadline is 01 July, 2011.

4.6 Other Meeting Insights.

- (1) Any input to modifying the TA removal plan would have to be provided to IRIS by mid-December, 2011.
- (2) An issue that was discussed in some detail is that to study crustal-scale problems, many of which are of interest to GeoPRISMS, it will be necessary to use the FA to increase the spatial resolution of the imaging.
- (3) There was broad recognition that *EarthScope*'s scientific interests do not stop at the shoreline and that *GeoPRISMS* interests also cross the shoreline.
- (4) The USGS research program examining the Extended Continental Shelf (ECS) means that there will be a series of research programs carried out (seismic and bathymetry) across the eastern U.S. margin in 2012 and 2013.
- (5) The BOEMRE is also pursuing analyses along the margin.

5.0 Planning the October Science meeting at Lehigh University

The mini-workshop attendees devoted considerable efforts to planning for the October science meeting at Lehigh University. The science workshop goal is to provide a forum where the advantages of research coordination, focused study sites, and facility leveraging can be transformed into a scale of scientific inquiry and discovery that would not be possible by either community working unilaterally. Because *EarthScope* and *GeoPRISMS* communities have traditionally worked in different ways, the meeting will be structured to accommodate both groups. We encourage attendees that have collective interests in the key science targets to carefully consider the best locations where that science can be accomplished (guided by section 4.4 above). Taken together, these efforts will guide the larger community effort that has real resource and planning limitations/considerations.

- (1) There was a consensus that researchers should self-organize prior to the meeting to discuss the science and implementation strategies for research on ENAM. Investigators should come to the October workshop with clear proposals of research focus and collaboration.
- (2) We will request white papers prior to the meeting, which will summarize these strategies.
- (3) An outcome of the meeting will be a strategy that represents the consensus of workshop participants for research efforts at ENAM.
- (4) White papers should adhere to the following criteria.
 - (a) 2-page maximum length
 - (b) If possible, research strategies should be cast in the context of the stated goals of both programs (e.g., see the *EarthScope-GeoPRISMS* science intersection matrix above)
 - (c) A clear statement that identifies the geographic scope, if any, of the research strategies..
 - (d) Clearly state how *EarthScope-GeoPRISMS* coordination would enhance scientific impact.
- (5) The science workshop planning committee will plan to select a number of these white papers for brief presentations during the meeting.

(6) A tentative agenda developed for the October meeting is in Appendix C

6.0 References

Tikoff, B. van der Pluum, Hibbard, J., Keller, G. R., Mock D., Selverstone, J., and Walker, D., 2006, An integrated geologic framework for EarthScope's USArray: EOS, 87, 221-232.

7.0 Appendices.

7.1 Appendix A. Workshop Agenda.

A Mini-Workshop following the 2011 EarthScope National Meeting *Hyatt Lost Pines Resort, Bastrop, TX; May 20-21, 2011*

Friday, May 20

Session 1: GeoPRISMS & EarthScope: what are they and how can they interact?

- 3:00-3:40 pm Introduction
- 3:00-3:10 *Overview, goals, and introduction (F. Pazzaglia)*
- 3:10-3:20 *NSF update, including EarthScope & Cascadia Initiative (G. Anderson)*
- 3:20-3:30 *GeoPRISMS update (J. Morgan)*
- 3:30-3:40 *USArray deployment update (R. Woodward)*
- 3:40-4:40 pm Program objectives, implementation strategies, examples
- 3:40-3:50 *GeoPRISMS objectives in ENAM (P. Flemings, D. Shillington)*
- 3:50-4:00 *EarthScope objectives in ENAM (F. Pazzaglia, B. Tikoff)*
- 4:00-4:10 *USGS update (Debbie Hutchinson, Peter Flemings)*
- 4:10-4:20 *Community experiments, research corridors (D. Shillington)*
- 4:20-4:30 *Salton Trough Example - EarthScope-GeoPRISMS collaboration (J. Hole)*
- 4:30-4:40 *USArray Science on the East Coast (L. Wagner)*
- 4:40-5:00 pm Coffee Break
- 5:00-6:30 pm Pop-up presentations and discussion
(3 minute presentations by workshop participants on important science for ENAM)
- 6:30-8:00 pm Dinner

Session 2: Identifying High Priority Science Problems

- 8:00-9:30 pm Break-out Sessions
- Two break-out groups will define important science problems that illuminate Rift Initiation and Evolution on the Eastern North American Margin. Both breakout groups will be given the same task of considering these problems in the context of*

- (1) *The geologic, geophysical, and geodynamic inheritance of the Grenville and Appalachian orogens,*
- (2) *The structural, magmatic, and geodynamic setting of rift initiation,*
- (3) *The rift-to-drift record preserved in syn- and post-rift sedimentary archives,*
- (4) *The processes that characterize the evolution to a mature passive margin, and*
- (5) *The active lithospheric and surficial processes that characterize the modern margin with an emphasis on possible feedbacks between surface and deep-Earth processes.*

Saturday May 21:

7:00-8:00 am Breakfast

Session 3: Focus on Joint EarthScope and GeoPRISMS Opportunities

8:00-10:30 am Break-out Summaries & Discussion

- (1) *Report from Bureau of Ocean Energy Management, Regulation and Enforcement on reprocessed 2D seismic lines for the Atlantic margin (BOEMRE; Paul Post).*
- (2) *Summarize high priority scientific problems and processes at the interface of EarthScope and GeoPRISMS on Eastern North America*
- (3) *Identify immediate research opportunities*
- (4) *Strategies to achieve these goals, e.g.,*
 - a. *Community-driven vs. PI-driven proposals*
 - b. *Research corridors*
 - c. *Joint EarthScope-GeoPRISMS opportunities*
 - d. *Other collaborations*

10:30-11:00 pm Coffee Break

Session 4: Science Themes and Approaches for Fall Workshop

11:00-12:15 pm Discussion

- (1) *Science themes for fall meeting*
- (2) *Key ongoing projects with potential tie-in to future ENAM science*
- (3) *Outline desired outcomes for fall workshop*
- (4) *How can we facilitate IRIS' long range plans?*

12:15 pm Lunch and Depart

Session 4 (convenors only)

1:30 pm-4:00 pm Synthesis

- (1) *Draft tentative agenda for fall meeting*
- (2) *Identify potential speakers*
- (3) *Discuss/plan grad symposium*
- (4) *Discuss who else should be involved: partner organizations, people*

7.2 Appendix B. List of Mini-Workshop participants.

First Name	Last Name	Email	Institution
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Appendix C. Tentative October Science Workshop Agenda.

Wednesday, 26 October.

- Pre-meeting graduate student symposium and field trip to Appalachian foreland.
- Evening ice breaker

Thursday, 27 October.

- Introduction
- Plenary session dedicated to geologic and tectonic history of ENAM
- Recent, relevant, *EarthScope* and *GeoPRISMS* (MARGINS) science projects.
- Emerging, hot topics relevant to ENAM
- Review and synthesis of EarthScope and GeoPRISMS science and implementation strategies
- Day 1 Breakouts.
- Evening BOEMRE mini-workshop
- Evening posters

Friday, 28 October

- Reports from Day 1 breakouts
- Breakout discussion
- Participant presentation of selected white papers
- Reports from aligned facilities and scientific/industry partners
- Day 2 breakout sessions dedicated to strategy development and possible selection of research corridors, most important science themes, recommendations on fate of TA instruments; other geodetic opportunities in ENAM.
- Evening posters

Saturday, 29 March

- Reports of Day 2 Breakouts
- Breakout discussion
- Decision making
- Closure
- Afternoon field trip to Newark basin.