Report on EarthScope Synthesis Workshop:

# Synthesizing EarthScope Results to Develop a New Community Model for the 4-D Evolution of North America

Dates: November 18-20, 2016
Location: James Madison University

**Workshop participants**

| | | |
|---|---|---|
| Scott Burdick | University of Maryland | |
| Cynthia Ebinger | Tulane University | |
| Heather Ford | University of California, Riverside | |
| Atleigh Forden | EarthScope National Office | |
| John Hole | Virginia Polytechnic Institute | *convener* |
| Bernard Housen | Western Washington University | |
| Eugene Humphreys | University of Oregon | |
| Vadim Levin | Rutgers University | |
| Gary Pavlis | Indiana University | |
| Terry Pavlis | University of Texas, El Paso | *convener* |
| Ryan Porter | Northern Arizona University | |
| Sarah Roeske | University of California, Davis | |
| Adam Schultz | Oregon State University | |
| Basil Tikoff | University of Wisconsin | |
| Suzan van der Lee | Northwestern University | |
| Lara Wagner | Carnegie Institution for Science | *convener* |
| Laura Webb | University of Vermont | *convener* |
| Steven Whitmeyer | James Madison University | *convener, host* |
| Michael Williams | University of Massachusetts | *convener* |

**Workshop Goals**

1. Synthesize what we have learned about the evolution of the North American continent through time from pre-EarthScope through today
2. Identify major themes within the overall 4-D evolution of the continent, based on integration beyond the results of individual research projects
    a. Themes could be continental, regional, orogenic, temporal, etc.
3. Discuss the next steps, which could include a new community model for the 4-D evolution of North America
4. Discuss key themes that might be relevant to the public
5. Produce an executive summary with the results of the workshop
6. Ultimately produce a themed issue (probably in Geosphere) with synthesis papers derived from this and any follow-up solicitations

## Overview of Workshop

The 2.5 day workshop began on Day 1 with a discussion of the workshop goals and background on the state of knowledge regarding the 4-D evolution of North America prior to the EarthScope project. This was followed by short individual presentations by workshop participants on key topics from EarthScope research that are relevant to the 4-D evolution of the continent (Table 1). Day 1 concluded with a general discussion of common themes, research directions, and general insights gained from EarthScope, within the overall context of 4D Evolution of North America. The goal was to establish topics for discussion and further development in break-out groups. Table 2 is a summary of proposed themes for breakout discussions.

Day 2 involved a series of breakout sessions first discussing and redefining major themes and topics, and then beginning the process of developing themes into a suite of synthesis papers. These papers (listed in Table 3) will form the core group of manuscripts for a special issue of Geosphere. A proposal for the special issue will be submitted by the workshop conveners to Geosphere editors following the submission of this report. Based on preliminary discussions with Geosphere editors, we anticipate that the special issue will be approved.

Day 3 began with follow-up discussions and planning for completion of synthesis papers. Then, the main topic of discussion focused on 'Next Steps' for continuing and capitalizing on the momentum provided by EarthScope. One topic of discussion involved the potential development of a community model for the 4-D evolution of North America. The concept will be filled out and discussed in one synthesis paper to be included in the proposed Geosphere volume. In brief, we envision development of an open source multidimensional model of North American continental evolution. As a starting point, we picture a set of time slices such as those published by Whitmeyer and Karlstrom (2007), but each time slice would be a digital model in itself, incorporating data sets, hypotheses, simulations, models of structure, stratigraphy, geochronology, geomorphology, petrology, lithospheric and crustal dynamics, and high resolution geophysics and environmental sensing enabled by observational networks such as those built by EarthScope. These digital time slices will function as a platform for discussion and collaboration, through which they will undergo iterative development and improvement as new data and models are added. Workshop participants recommend development of a proof-of-concept pilot project focusing on a specific time slice or geographic region.

Discussions on Day-3 also included plans (and potential topics) for broader community outreach on the theme of 4-D Evolution of North America. Ideas included a synthesis article for Scientific American, a Groundwork article for GSA Today, and opportunities for blog or radio posts on selected topics. The final discussion centered on (1) opportunities for follow-up workshops, including the possibility of a workshop at the next EarthScope National Meeting and (2) an evaluation and discussion of the current format for synthesis workshops, with suggestions for future format(s). One common theme that ran through this discussion and earlier discussions was that EarthScope syntheses should

underscore the success of EarthScope as an exploratory science project. This theme as well as the inherently collaborative necessity of the project needs to be emphasized in outreach activities as a successful approach to science efforts. It was also noted that our attempts to include concurrent WebEx participants did not fit well within the in-person workshop structure. If WebEx participation is desired, it is suggested that this be in the form of a separate stand-alone event.

**Table 1: Presentations by Participants**

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| Laura Webb | "Perspectives on the 4D Evolution of Continents and Continental Margins" |
| Bernie Housen | "Paleomagnetic framework for North American paleogeography, with an illustration of issues for the Jurassic" |
| Adam Schultz | "Beyond Stare-and-Compare: Synthesizing consistent views of Continent and Eastern North America from Magnetotelluric data in Light of Seismic Results" |
| Ryan Porter | "Crustal Imaging with EarthScope Data: How do Orogens Behave Post Orogeny" |
| Scott Burdick | "Constraints on past subduction from transdimensional body wave tomography" – slab fragments beneath the US |
| Heather Ford | "The effects of seismic anisotropy on receiver function analysis" |
| John Hole | "Salton Trough and implications for continental rifting & passive margins" |
| Basil Tikoff | "ID-OR, the Western Idaho Shear Zone, northern Rockies" |
| Gene Humphreys | "Farallon slab left under the northern Rocky Mts" |
| Gary Pavlis | "The importance of 3D visualization for 4D North America" |
| Sarah Roeske | "The challenge of determining when and how crustal/lithosphere features formed in the northern Cordillera (aka Geologist eagerly awaiting EarthScope results!)" - Alaska |
| Suzan van der Lee | "SPREE project; continental-scale joint inversions" |
| Vadim Levin | "A report on a continent-scale passive-seismic transect from Hudson Bay to Bay of Fundy that crossed ~3Ga of tectonic history (from Archean Superior to Paleozoic rifted Fundy)" |
| Lara Wagner | "Not so stable after all" - foundering lithosphere in the eastern US |
| Terry Pavlis | "Questioning the deep slab…" |
| Cindy Ebinger | "NE US study of steep crustal density contrasts and their correlation with intraplate seismicity" |

**Table 2: Proposed Themes for Breakout Discussions**

- Heterogeneity at all scales in the mantle and lithosphere
    - Red-ite and blue-ite
    - What can the transition zone tell us?
    - Mountainless roots come in here and also below…
- The Moho:
    - Moho geometry; Moho through time
    - The active west and the inactive east
    - Distinction between crust and mantle… how do we grow crust…
    - Accretion??
    - Mantle images where do structures exist….
- Tectonic environment
    - Collision, extension, etc…
    - Long-term signature of different tectonic environments
    - How does an actively created environment evolve into a geologic record?
- Inheritance
    - Case studies, examples…
    - Places where inheritance matters and places it doesn't.
- New discoveries… places where predictions have not proven to be the case…
    - The value of explorative science - The "huh, what's that?" moment
    - Finding something under Kansas
- Metastability
    - Waiting 1 b.y. to pull the trigger
    - Cumulates
    - Eclogite
- Long term evolution of North America integrated vertically (crust – mantle)
    - Regional or orogenic examples?
    - Different time scales for crustal evolution through time vs lithospheric evolution through time
    - Polarity reversals in Earthscope images and in the geologic record…
    - Mountainless roots… (e.g. Illinois Basin OINK)
    - Preservation of mantle structure
    - Long term evolution of crustal and mantle density
- Fluids in the Earth (Inheritance)
    - Slab hydration/ dehydration; CO2 etc.
    - Metamorphism
- The concept of the Wilson cycle
    - Is it still valid? How has EarthScope changed the model?
- Dirty secrets: What you need to know about other disciplinary data sets and models… (Specific case studies?)
- Synthesize EarthScope in a way that the public can understand – post-Geosphere derivative papers?

**Table 3: Proposed Papers – Geosphere Special Issue**

Introductory papers

1) TITLE: The value of exploratory science: The role of EarthScope in deciphering the 4D evolution of North America
   Authors: M. Williams, S. Whitmeyer, T. Pavlis, L. Webb, L. Wagner, J. Hole

Temporal overviews

2) TITLE: Implications of Earthscope for the Cenozoic tectonic evolution of western North America
   Authors: G. Pavlis, A. Schultz, M. Wells?, R. Allen?, T. Pavlis, S. Burdick, B. Tikoff, J. Stock, T. Plank, T. Atwater?, B. Housen
3) TITLE: Implications of Earthscope for Mesozoic orogenies in the western US
   Authors: T. Pavlis, B. Tikoff, K. Sigloch?, E. Humphreys, G Pavlis, A. Schultz, J. Hole, B. Housen
4) Precambrian synthesis with ES data
   Authors: M. Williams, S. Whitmeyer, K. Karlstrom, D. Holm?, K. Chamberlain?
5) Paleozoic synthesis with ES data
   Authors: R. Wintsch?, L. Webb

Processes through time

6) TITLE: Characteristic signatures in type of tectonics processes get preserved in the geophysical signal through time (inheritance dominates the lithosphere)
   Authors: S. Burdick, H. Ford, B. Housen, J. Hole
7) TITLE: Time since last event rather than nature of last event dominates the geophysical record – in particular the mantle lithosphere
   Authors: R. Porter, S. van der Lee, S. Burdick, S. Whitmeyer, H. Gilbert?
8) TITLE: To what extent do driving forces contribute to the tectonic signal in the lithosphere compared to inherited features? (i.e., what controls deformation?)
   Authors: J. Hole, E. Humphreys, R. Porter, H. Ford, S. Roeske, J. van Wijk? and/or C. Currie?

Others

9) TITLE: Dynamics and the Wilson Cycle: The EarthScope vision
   Authors: M. Williams, V. Levin, L. Webb, S. van der Lee, E. Humphreys, B. Tikoff, C. Ebinger, T. Becker?
10) Comparison study considering stability vs instability vs relative stability within parts of North America—synthesis of eastern US EarthScope data
    Authors: L. Wagner, etc.

Regional / Project studies

11) TITLE: Pre-EarthScope Alaska – setting the stage for exploring the role of inherited crustal heterogeneity in a complexly deforming plate boundary zone
    Authors: S. Roeske, R. Saltus
12) Southern Appalachians
    Authors: L. Wagner, etc.

**Notes from Atleigh Forden:**

Importance of exploratory science

- There is a mantle signature for a lot of things we see at the crust
- Some geologic features that we see do not seem to relate directly to known plate tectonic processes – surprises
- What we see at the surface doesn't always equate to what we see at depth
- Tectonism at non plate tectonic settings; Earth is dynamic in non-plate boundary settings
- Plates continue to mature and evolve even when there are nowhere near traditional plate boundary settings (addresses intra-plate seismicity, etc.)
- There is a lot going on in places we previously thought were "stable", how plate interiors continue to develop through time
- Increased resolution shows how complex the Earth system is (esp. the 3rd and 4th dimensions)
- Scientific American article: Plate Tectonics was a 2D idea – EarthScope pushed this into 4D (Basil will take the lead)
- "Exploratory Science" as the observation stage of the scientific method; rethinking the scientific method (a more holistic approach)
- Modern technological advances require observation as the first phase of the scientific methods
- A Groundwork article for GSA Today?
- Outreach products need a short timeframe as well (mid. January)
- 4D Module for IRIS kiosk?; though server will be terminated at end of ES project

Thoughts on workshops:

- Freeform approach that resulted from a less defined agenda
- Regional vs. continental scale themes for workshops – there is a need for both approaches; this shows that the continental scale can work
- The multidisciplinary participant mix was effective (geophysics and geologists); we had a large number of applicants
- The WebEx approach to including the outside community didn't work; need a conference speaker phone; need specialized hardware
- Need an individual to manage the Teleconference process
- 9 external WebEx participants; but not very involved (our perception)
- Is there really a value-added to the WebEx contributions? The workshop format doesn't work well with WebEx
- Face-to-face contact is an important component of workshops
- The papers wouldn't have been written/outlined without us in the room