



The Nevada FlexArray experiment to study the geometry of continental normal faults successfully redeployed instruments in June. C. Riddle and IRIS summer intern L. Kant at work.

■ **Save these dates!** The 2012 **UNAVCO** Science Workshop will be February 28-March 1 at the Millennium Hotel in Boulder, Colorado. The **2012 IRIS Workshop** will be June 13-15 in Boise, Idaho.

■ The first deployment of Ocean Bottom Seismometers (OBS) from the joint EarthScope/GeoPRISMS **Cascadia Initiative** was completed in July. Visit <http://cascadia.uoregon.edu/CIET> for status and updates. Combined with new and updated land seismic and geodetic sites, the 4-year deployment of OBSs will provide unprecedented data across a subduction zone.

■ All **Transportable Array** stations installed since February 2011 have been equipped with atmospheric and infrasound sensors. Data are available from the **IRIS Data Management Center** with SEED channel codes BDO (barometer) and BDF (infrasound).

■ The **Superior Province Rifting EarthScope Experiment (SPREE)** team deployed 83 **FlexArray seismic stations** in Minnesota, Wisconsin, and Ontario to study the Midcontinent Rift and continental rifting in general.

■ **Plate Boundary Observatory** engineers installed meteorological

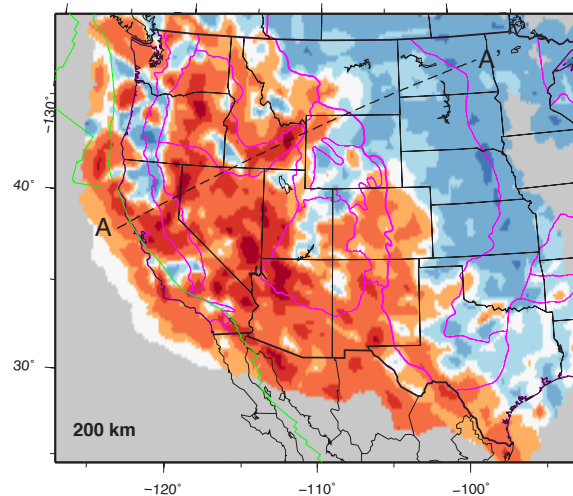
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## Seismic Tomography with USArray Data

In its July 2011 issue, *Popular Science* ranked EarthScope the “most epic” big science project because of its ambitious scope: Exploration of the deep geologic structure and evolution of an entire continent. A key EarthScope element is the Transportable Array (TA) of 400 seismic stations, on its way to populating over 1600 sites across the US. Each station stays at a site for about 2 years before moving eastwards. Since its start on the West Coast in 2004, the TA has already occupied over 1200 sites and has reached the westernmost of the Great Lakes; in 2013 it will arrive in Washington DC. The high TA station density, data return rate, and data quality allow researchers to image the US mantle structure with unprecedented detail.

North America’s geologic diversity has made it a long-standing favorite target for 3D imaging of its deep structure. Global 3D Earth models from the 1980s documented a strong contrast between the weak, hot mantle beneath the tectonically active western US and the strong, solid mantle beneath the large, stable, cratonic part east of the Rocky Mountain front (RMf). This contrast, incidentally, is the reason why the Aug 23 M5.8 Virginia earthquake was felt at greater distances than we would expect for an equivalent earthquake occurring in the western US. Fine-scale lateral variations in deep structure have been resolved for selected, small areas covered by local seismic networks, such as southern California. Much of what we understand about how continents form and are sustained is based on global studies and a small number of high-resolution local studies. EarthScope’s USArray is bringing the imaging detail from local and regional studies to the broader continental scale, reinforcing as well as challenging our established understanding of continent formation and underlying mantle processes.

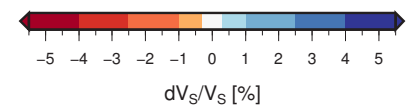
Regional tomographic images based on TA data recorded in the western US (see [online version](#)



for recent publications or visit [www.earthscope.org/highlights](http://www.earthscope.org/highlights)) show, for example, details of present and past subduction beneath the western margin and the extent of the Yellowstone plume at unprecedented resolution. Current TA tomography models are mainly derived from P waves. As the TA migrates east, we are folding in new S-wave data, which are more sensitive to structural, compositional and thermal variations than P waves. Figures 1 and 2 present a map view and cross section for preliminary results of a joint inversion of different types of S and surface waves, all sensitive to the same S-velocity structure. For a preliminary inversion, our model is remarkably consistent with previous, less detailed S-velocity models as well as with the above-mentioned P-velocity models. For example, the large high S-velocity region in Figure 1 illustrates the thickness of the strong lithosphere of the North-American craton. These high S velocities extend to the Colorado Plateau, which is surrounded on the west, south and east by low-velocity, deformable material. High S velocities are also imaged about 300 km landwards from the trench between the overriding North-American plate and the subducting Gorda and Juan de Fuca plates, two remaining Farallon plate fragments.

Figure 2 shows low velocities in the lower mantle beneath Yellowstone and high-velocity fragments of the subducted Farallon plate in the transition zone between 400 and 700 km deep.

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**Figure 1:** Map of S-velocity anomalies, relative to a constant reference S velocity at 200 km depth from a preliminary joint inversion of different types of S and surface waves, recorded at USArray and other North American seismic stations. The green lines approximate the tectonic plate boundaries. The thick purple line approximates the Rocky Mountain front (RMf). A-A': cross-section shown in Figure 2.

# EarthScope News

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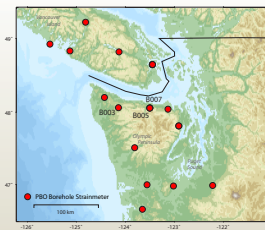


Continuous GPS station PJZX in Baja California with meteorological instrument (on top of solar panel).

instruments at four continuous GPS stations as part of the [El Mayor-Cucapah earthquake response](#). The project is a successful international collaboration between NSF-funded investigators and Mexican research institutions. Adding meteorological stations in this data-poor region greatly improves the ability to model water vapor fields, a critical variable in quantitative precipitation forecasts.

- The **PBO strainmeters** are recording the 2011 Cascadia Episodic Tremor and

Slip (ETS) event. A few months earlier than anticipated, the 2011 ETS may be underway. Visit [pbo.unavco.org/news/highlight/353](http://pbo.unavco.org/news/highlight/353) and the [PNSN](#) for more information.



Map of the PBO borehole strainmeter network near the Olympic Peninsula, Washington.

## Greetings From the New ESNO at Arizona State University!

We are excited, humbled, and honored to host the new EarthScope National Office (ESNO) at Arizona State University. We serve the broad and diverse community of EarthScope stakeholders, including EarthScope researchers, formal and informal educators in Earth science, and the general public.

Ramon Arrowsmith is serving as ESNO Director and chairman of the EarthScope Steering Committee. Steve Semken is the Deputy Director for Education and Outreach (E&O), Wendy Taylor is the E&O Coordinator, and Ed Garnero and Matt Fouch will be heavily involved as Principal Investigators.



The new ESNO@ASU. Back left to right: Matt Fouch, Steve Semken, Ed Garnero. Front: Ramon Arrowsmith and Wendy Taylor.

EarthScope enables the exploration of the structure and evolution of the Earth, with a primary focus on the North American continent by scientists accessing a range of seismological, geodetic, in situ fault zone sampling, magnetotelluric, geochronology, and high resolution topography observational resources. Going beyond narrow analyses of discipline-specific datasets, EarthScope science combines analyses and interpretations of diverse observational datasets with innovative experimental and theoretical exploration. These results produce transformative knowledge for studying Earth's structures and processes and in understanding hazards and guiding resource exploration.

The expertise, enthusiasm, and findings of the EarthScope community also constitute an increasingly rich resource for enhancing Earth

science education in formal (K-12, college, university) and informal (parks, museums, media) settings. The education and outreach program of the ESNO is committed to facilitate dissemination of EarthScope science to educators and to the public.

Our role as the ESNO is to best serve you – we welcome your ideas, comments, and help to best accomplish this. EarthScope success comes from our communal efforts to produce and share knowledge. Please email [earthscope@asu.edu](mailto:earthscope@asu.edu) with your comments, questions, and concerns.

As an entire community, we owe the ESNO office from Oregon State University a tremendous debt of gratitude. This includes Anne Trehu, Bob Lillie, Jochen Braunmiller, Charlotte Goddard, and Chris LeBoeuf. Thank you for your leadership and service! ■

## Highlights from the 2011 EarthScope National Meeting

The 2011 EarthScope National Meeting brought 325 graduate students, post-docs and scientists to Austin, Texas to discuss the latest EarthScope research. PDFs of talks and abstracts are at [www.earthscope.org/meetings/national\\_meeting\\_11](http://www.earthscope.org/meetings/national_meeting_11). Many presentations were updates to articles that have appeared in previous issues of inSights.

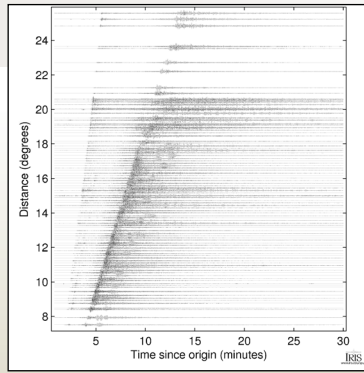
Sessions covered the breadth of EarthScope research. "Reconstructing a Continent" highlighted the exciting imaging capabilities enabled by USArray and the importance of integrated geoscience synthesis. "Processes at Active Plate Boundaries" presentations included updates on slow-slip and tremor events, fault mechanics from SAFOD observations, and deformation processes as measured by the PBO. "Key Targets for the Future" explored EarthScope science opportunities in the mid-continent, the eastern US passive margin and Alaska as the Transportable Array is marching east and eventually to Alaska.

One of the unexpected results from EarthScope is that the Earth science community's "noise" in GPS data is a signal that provides information on the temporal variability of soil moisture at the site – data that are of great use to the meteorological and agricultural communities. This was discussed in the [Fall 2010 issue of inSights](#). For an update on PBO-H<sub>2</sub>O, [click here](#). Similarly, USArray gets the shakes from signals traveling through the atmosphere as well as through the solid Earth, and can be used to study hurricanes and tornados in addition to earthquakes and Earth structure. Using USArray to study infrasound sources

was featured in the [Winter 2009 newsletter](#); [click here](#) for more on USArray infrasound.

A session on EarthScope's broader impacts featured the use of EarthScope data for K-12 education and the development of earthquake early warning and rapid response systems. Lunchtime "EarthScope Café" presentations gave an overview of key EarthScope science fields and techniques for their study. The meeting closed with presentations on key targets for future EarthScope research and an open moderated discussion of the community's role in planning EarthScope's future. ■

- Two strong earthquakes shook the central and eastern US on August 23, 2011. A magnitude M=5.8 earthquake that occurred in Virginia at 1:51 PM local time was felt as far north as Montreal, as far west as Indianapolis and Detroit, and caused damage in Washington, DC. About 12 hours earlier, a M=5.3 earthquake rattled the Colorado-New Mexico border region. This earthquake was the strongest this region has experienced since 1973. Visit the USGS website for information on these unusual events in [Virginia](#) and [Colorado](#). USArray ground motion visualizations show how the signal propagated across the **Transportable Array**



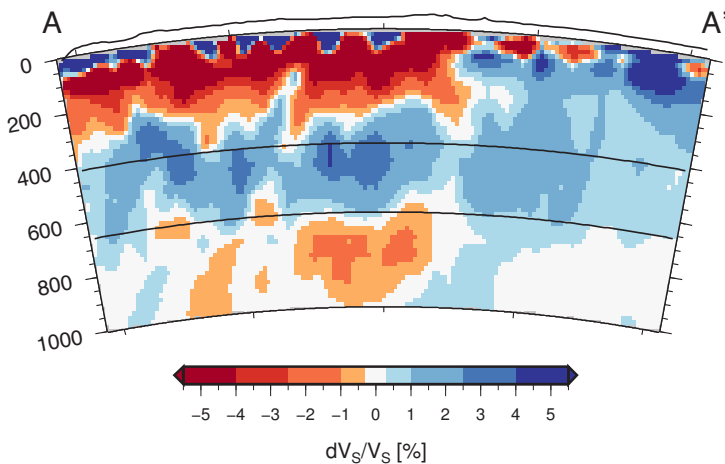
([Virginia](#) and [Colorado](#)) and the event plot suite shows TA seismogram record sections ([Virginia](#) and [Colorado](#)). IRIS and UNAVCO both authored outreach materials for the Virginia earthquake; IRIS released a [Teachable Moment Presentation](#) and UNAVCO released an [Event Response Highlight](#).

- Failure analysis for the **SAFOD observatory** was completed at a SAFOD Failure Analysis sub-committee meeting held at UNAVCO on March 1-3, 2011. The complete report is available at [www.earthscope.org/observatories/safod\\_report\\_Apr11](http://www.earthscope.org/observatories/safod_report_Apr11).

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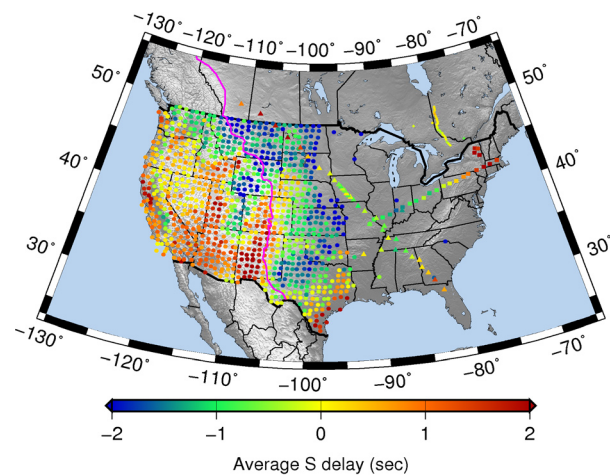
## Seismic Tomography with USArray Data

Heterogeneity and complex fine structure were expected in the mantle beneath the mobile western US. Now that the TA is sampling structures east of the RMf in the stable, cratonic part of the US, will we find smaller heterogeneity and less structural complexity? Figure 3 shows average delays of teleseismic S waves for each TA site and stations of select, preceding seismic deployments. The delays east of the RMf have the same range as delays from sites in the western US, implying that the mantle beneath the eastern US is at least as heterogeneous as that west of the Rocky Mountains. Exciting science targets are abundant east of the RMf. Their study will likely lead to significant improvements in understanding continental formation and longevity (“[Key Targets for the Future](#)” was also an EarthScope National Meeting session).



**Figure 2:** SW to NE cross section through a preliminary S-velocity model. The location of section A-A' is indicated on Figure 1 and is roughly centered on the Yellowstone hotspot.

For example, the new S-wave data from USArray provide dramatically improved resolving power compared to a continent-scale study in the 1990s that found (1) low seismic velocities in the mantle transition zone beneath the Paleozoic eastern margin and (2) trailing fragments of the Farallon plate beneath the Cenozoic western US. A follow-up study with pre-USArray data suggested these features could be connected through a deep-mantle water cycle, which is possibly working to initiate the subduction of oceanic lithosphere beneath the Atlantic seaboard. New TA data from the eastern margin will have the resolving power to test this hypothetical relation between a deep-mantle water cycle and the sustained triggering of subduction zones through time.



**Figure 3:** Station averages of teleseismic S delay times corrected for predicted crustal structure. The USArray TA stations can be viewed as two subsets, the TAW west of the RMf (purple line), and TAE east of the RMf. The three lines of triangles, squares, and small diamonds in the east and mid-continent represent independent seismic experiments (FLED, MOMA/ABBA, and Abitibi). The mean delay of each of the four sets of stations is subtracted from each set.

Other science questions are targeted using another key component of USArray: the Flexible Array (FA). The FA is used by Principal Investigators at universities to, for example, locally increase resolving power with dense seismic deployments with smaller aperture than a TA swath. FA experiments have been initiated or proposed for a variety of enigmatic continental features east of the Mississippi: Study targets range from the most active seismic zone in the central US (the New Madrid Seismic Zone) to the region with the largest Bouguer gravity anomaly in the US but curiously stable geology ([www.earth.northwestern.edu/spree](http://www.earth.northwestern.edu/spree)), and cover the transition from Proterozoic (Laurentia) to Paleozoic North America and the effect of Mesozoic rifting on the Paleozoic margin ([www.geo.brown.edu/geophysics/SESAME/Site/SESAME.html](http://www.geo.brown.edu/geophysics/SESAME/Site/SESAME.html)). Other targets include shallow sedimentary basins, such as the Illinois ([www.isgs.uiuc.edu/education/Train-EarthS.shtml](http://www.isgs.uiuc.edu/education/Train-EarthS.shtml)) and Michigan basins, which mysteriously appeared in the middle of a stable continent, and the aforementioned deep, possibly wet upwelling from the transition zone that might be on its way to wreak geologic havoc through triggering the subduction of Mesozoic Atlantic lithosphere.

With the new wealth of data, EarthScope researchers are busy testing hypotheses about how North America came to be the diverse continent that we thought we knew. ■

By Suzan van der Lee and Xiaoting Lou, Northwestern University.

See [online version](#) for references.

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## Student Poster Contest at the 2011 EarthScope National Meeting

The next generation of EarthScope researchers was well represented at the 2011 EarthScope National Meeting in Austin, Texas. Sixty-six student poster presentations – an increase of 50% compared to the 2009 meeting in Boise, Idaho – entered the student poster contest. A panel of 25 EarthScope scientists volunteered to view posters, lead informal discussions with each student about their poster, and select contest winners. The contest culminated in the award presentation held during a plenary session.

The high-quality posters made selecting winners a difficult task. First place went to Brett Carpenter from The Pennsylvania State University (advisor Chris Marone) for his poster “Mechanical behavior of the active San Andreas Fault: Insights from laboratory experiments on intact core.” Teira Solis from the University of Texas at El Paso (advisor Bridget Smith-Konter) was awarded second prize for “Investigating stress drop variations of major San Andreas Fault earthquakes over the last 1000 years,” and Melissa McMullen from Purdue University (advisor Hersh Gilbert) got third prize for her poster on “Coupling, detaching and sinking: How stages of Farallon subduction influenced topography of the 410-km discontinuity beneath North America.” A special award for the best face-to-face discussions went to Jacob Walter from the University of California at Santa Cruz (advisor Susan Schwartz) for “A shallow, offshore tremor and slow slip event at the Nicoya Peninsula,

Costa Rica.” EarthScope is grateful to Exxon/Mobil for sponsoring the poster judging and providing funds for gift certificates presented to



Winners of the student poster competition at the 2011 EarthScope National Meeting (left to right): Brett Carpenter, Jacob Walter, Melissa McMullen, and Teira Solis.

the students. In addition to posters, several graduate students gave keynotes and oral presentations highlighting the strong role of students in EarthScope research. ■