

USArray

the first five years



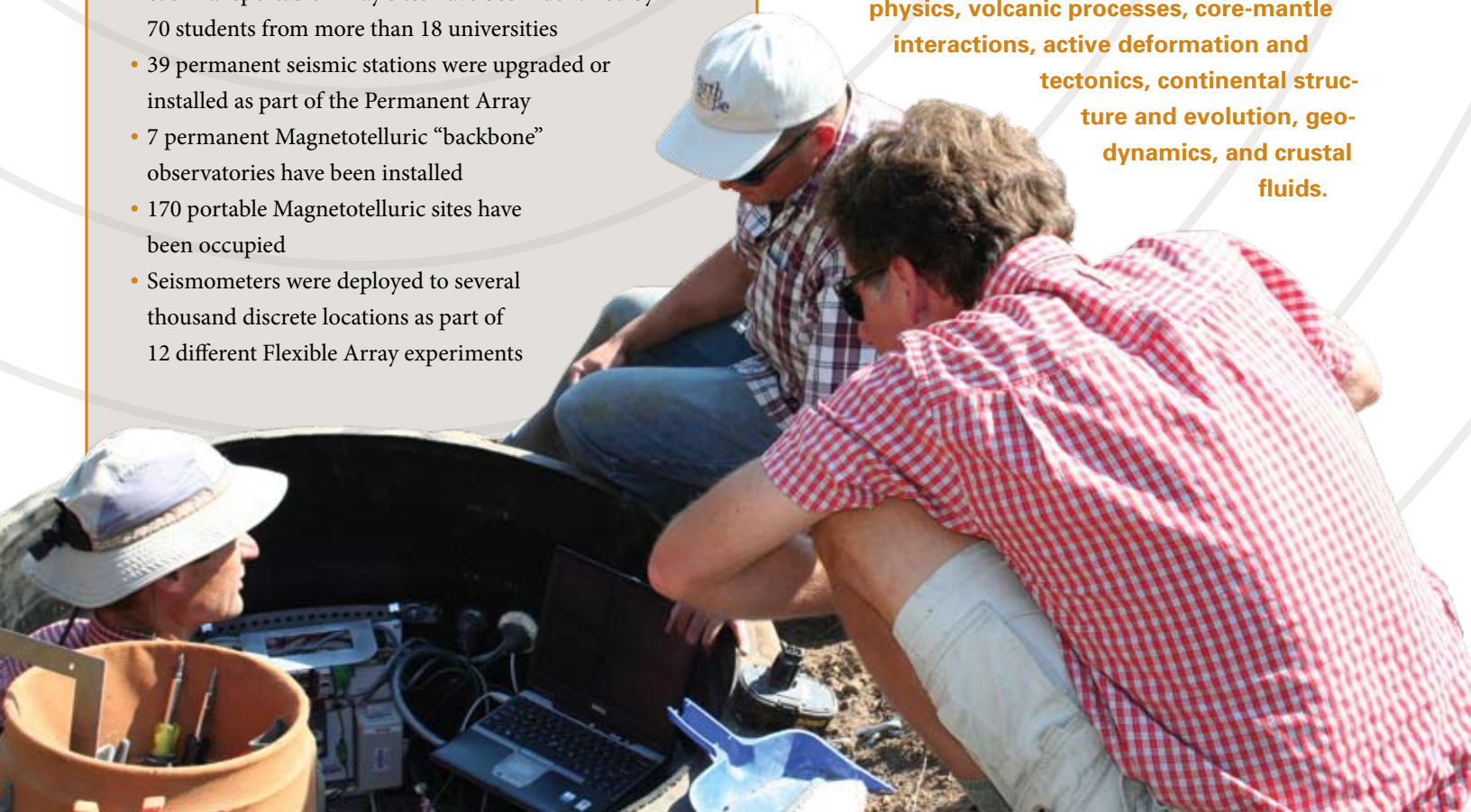
USArray

A Continental-Scale Seismic

By the Numbers (2003–2008)

- More than 600 Transportable Array sites have been occupied and more than 535 permits acquired
- Over 25 Transportable Array stations have been “adopted”
- In excess of 12 terabytes of EarthScope data have been collected and archived
- About 187,000 data requests have been filled since 2004
- 675 Transportable Array sites have been identified by 70 students from more than 18 universities
- 39 permanent seismic stations were upgraded or installed as part of the Permanent Array
- 7 permanent Magnetotelluric “backbone” observatories have been installed
- 170 portable Magnetotelluric sites have been occupied
- Seismometers were deployed to several thousand discrete locations as part of 12 different Flexible Array experiments

USArray is the seismic and magnetotelluric element of the national EarthScope program. Having established full facility operational status during the first five years of the program, data acquired by USArray sensors are already providing the anticipated foundation for integrated studies of continental lithosphere and deep earth structure over a wide range of scales. The scientific community is actively gaining new insights into earthquake physics, volcanic processes, core-mantle interactions, active deformation and tectonics, continental structure and evolution, geodynamics, and crustal fluids.



October 1, 2003 NSF awards contract to IRIS for USArray	April 2004 First Transportable Array shared stations come online	July 2005 100 th Transportable Array station deployed	September 30, 2006 All Permanent Array milestones accomplished	August 2007 400 th Transportable Array station installed in Newdale, ID	Late 2007 Adopt-a-Site program initiated
2003	2004	2005	2006	2007	2008

Observatory

USArray Components



■ **Transportable Array**

The Transportable Array is a network of 400 high-quality seismographs that are being placed in temporary sites across the United States from west to east in a regular grid pattern.

With station spacing of about

70 km, Transportable Array data are extremely useful for mapping the structure of Earth's interior. After a residence time of two years, each instrument is picked up and moved to the next carefully selected location on the eastern edge of the array. When completed, nearly 2000 locations will have been occupied during this program.



■ **Magnetotelluric Array**

The Magnetotelluric Array consists of seven permanent and 20 portable sensors that record naturally occurring electric and magnetic fields. These data are used to image Earth's interior and directly complement the seismic observations.



■ **Flexible Array**

As the Transportable Array moves across the country, a pool of more than 2000 portable seismometers is available to scientists for dispatching to targeted areas for very detailed studies of specific structures. Flexible Array instru-

ments remain in place for varying amounts of time, ranging from a day to as long as two years, depending on the type of seismometer being used for the project.



■ **Permanent Array**

USArray, in close collaboration with the US Geological Survey's Advanced National Seismic System, has contributed to the establishment of a permanent network of seismic stations across the United States with

uniform spacing of approximately 300 km. This combined set of permanent stations, often referred to as the "USArray Reference Network," provides baseline measurements for the Transportable Array and Flexible Array.

December 2009
Transportable Array
reaches the Gulf Coast

September 30, 2008
All permanent
Magnetotelluric
stations installed

January 2011
Transportable
Array crosses the
Mississippi

Late 2011
Flexible Array
instruments occupy
10,000th site

2013–2018
USArray heads
north to Alaska

2009

2010

2011

2012

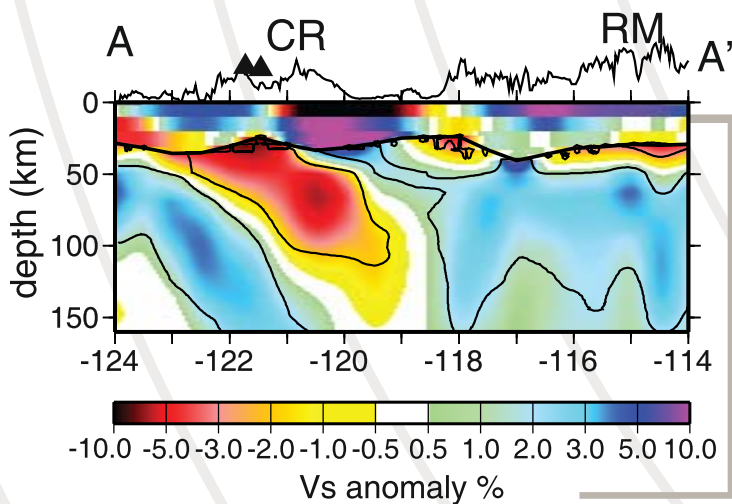
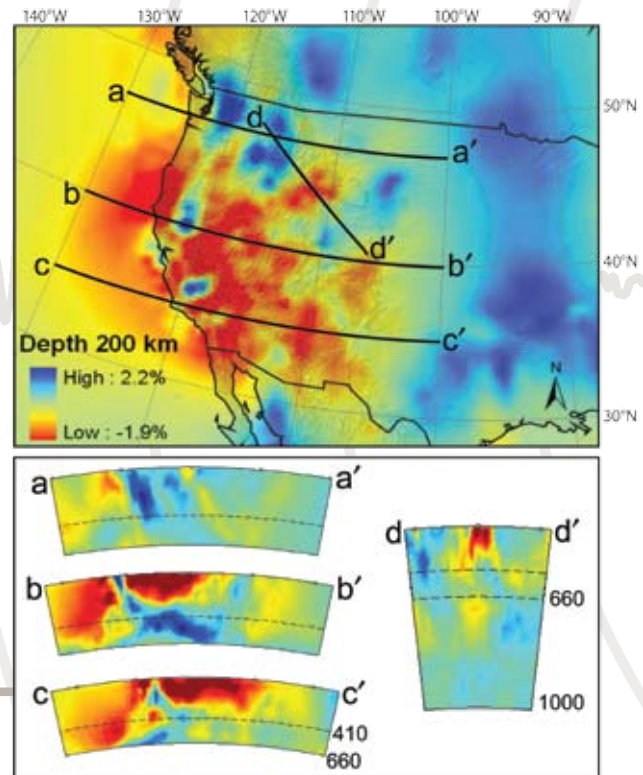
2013

The Science and Discoveries of USArray

High-Resolution Tomography

Numerous studies are exploiting all facets of the rapidly increasing USArray data set and are resulting in much more refined pictures of crustal and upper mantle structure beneath western North America. By combining the thousands of seismic wave readings from the Transportable Array with observations from seismic stations around the globe, high-resolution images of the structure under western North America have been produced. Additional tomography methodologies that combine data from the Transportable and Flexible Arrays, as well as data from existing regional networks, have also produced more high-resolution images of the earth's interior.

*Burdick, S., et al. 2008. Upper mantle heterogeneity beneath North America from travel time tomography with global and USArray Transportable Array data. *Seismological Research Letters* 79(3):384–392.*



Ambient Noise Tomography

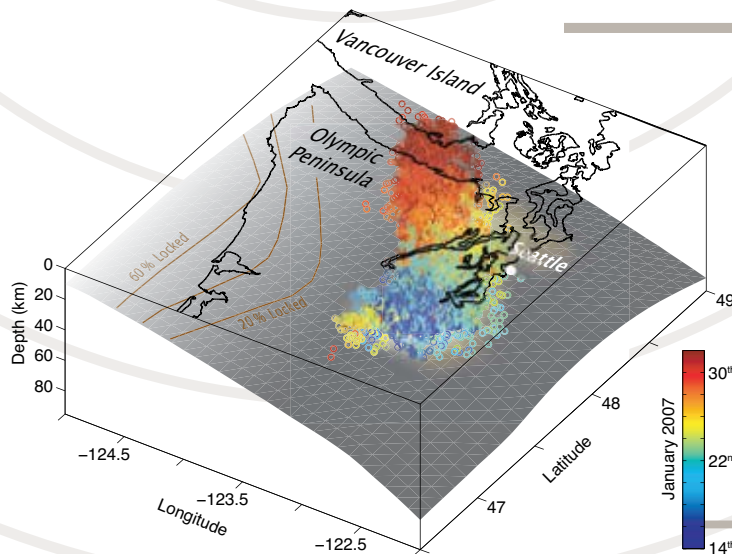
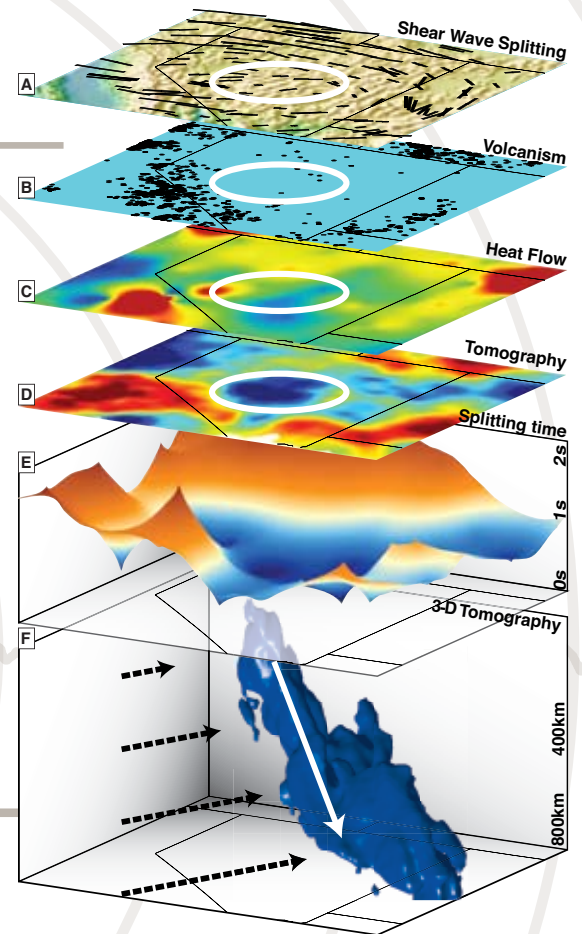
A recent innovation in seismic imaging reveals information about Earth structure without the occurrence of earthquakes. This technique, ambient noise tomography (ANT), is based on using long time series of noise that is present at all seismic stations. Application of ANT to data from ambitious new deployments of seismic arrays, such as USArray, has led to the development of large-scale seismic models of the earth's crust and uppermost mantle at high resolution. In addition, new methods of data analysis and interpretation of ambient noise data that exploit the array nature of the Transportable Array are currently under development and have the potential to provide more reliable information about crustal and uppermost mantle anisotropy.

*Yang, Y., et al. 2008. Structure of the crust and uppermost mantle beneath the western United States revealed by ambient noise and earthquake tomography. *Journal of Geophysical Research*, 113, B12310, doi:10.1029/2008JB005833.*

Lithospheric Drips

Regional mantle downwellings, referred to as lithospheric drips, are widely inferred to exist, based on surface expressions. However, direct observations of such downwellings have proved elusive, due to their small size and transient nature. Analyses of new seismic data recorded by the USArray Transportable Array and other regional broadband seismic stations combined with other non-seismic data provide clear evidence for a large lithospheric drip beneath the Great Basin in the western United States. Such analyses are revealing the importance of lithospheric drips in the framework of global tectonics.

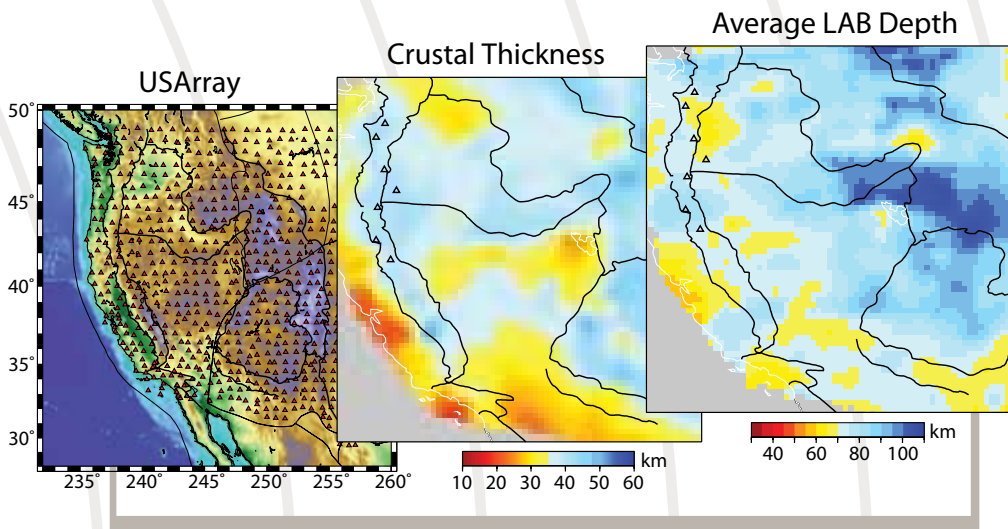
Image courtesy of J.D. West and M.J. Fouch, Arizona State University.



Episodic Tremor and Slip

There is significant earthquake hazard resulting from fault slip associated with subduction of an oceanic plate beneath the region straddling the US-Canadian border. This plate collision is accompanied by intervals of surprisingly regular seismic tremor and slow fault slip that are not generally felt by the local population. Existence of this phenomenon was discovered prior to deployment of EarthScope instruments. However, the combined information from USArray and Plate Boundary Observatory data sets have provided critical new constraints that have greatly improved our understanding of this complex phenomenon. The new picture of the fault zone provided by data analyses suggests that the probable region of strong ground motion during future earthquakes extends significantly further inland than had been thought, closer to the large population centers of Cascadia.

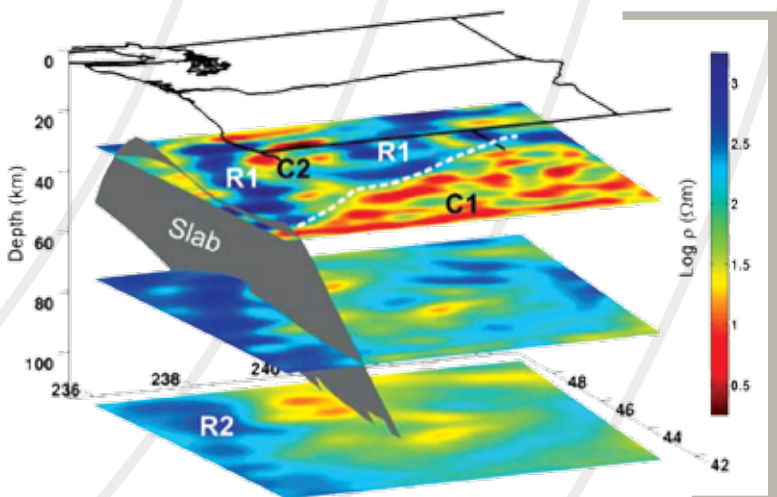
Image courtesy of K. Creager, University of Washington



Probing the Lithosphere-Asthenosphere Boundary

Transportable Array data provide a means for probing boundaries within the earth beneath USArray seismic stations. Key boundaries include the Mohorovicic discontinuity, which marks the transition between the crust and mantle, and the lithosphere-asthenosphere boundary, which marks the depth extent of continental structures. The resultant seismically determined boundary-depth maps can be combined with results from mineral physics and geochemistry to better understand the tectonic development and evolution of North America.

Images courtesy of A. Levander, Rice University; Meghan Miller, University of Southern California; and F. Niu, Rice University.



3D Conductivity

Mantle conductivity models generated from magnetotelluric data complement the seismic tomography images of the structure beneath North America. In some cases, conductivity observations provide constraints that are difficult to obtain from seismic data. For example, conductivity is particularly sensitive to the water content of the mantle. Joint interpretation of conductivity, velocity, and attenuation is beginning to provide better constraints on composition and physiochemical state than analysis of any one property alone. There is significant anticipation of further development of joint electrical and seismic interpretation of mantle observations.

Image courtesy of G. Egbert, Oregon State University, and P. Patro, National Geophysical Research Institute, India.



People Make it Happen

USArray's success over the first five years of the experiment is the result of the efforts of a large group of talented and enthusiastic people: the professionals who manage the program; the students, university professors, and regional network providers who contribute to siting efforts; the landowners who permit stations to be installed on their property; the backhoe operators and electrical engineers who construct the stations and install the equipment; the contracting officers and purchasing agents who facilitate equipment acquisition; the data quality analysts and software developers who ensure data accessibility; the scientists from around the world who develop techniques to analyze the large volumes of data and provide new insights into how the earth works; and many, many others.

USArray A Facility



A Partnership with NSF



Through the EarthScope program, the National Science Foundation has supported 150 researchers and many times this number of students to conduct cutting-edge earth science research. These NSF-funded projects have performed innovative experiments, developed new data analysis strategies, and explored numerous facets of the data. As a result of this research, entire sessions at major scientific meetings have been devoted to the discussion of results emerging from EarthScope. At the December 2008 meeting of the American Geophysical Union, 611 scientists contributed to 175 presentations describing results from EarthScope data.

Data for Research and Education

Quality-controlled data from all USArray components are freely available to the scientific community and the public through the IRIS Data Management Center in Seattle, Washington. The large USArray data holdings (exceeding 8 terabytes at the end of the first five years of the program) have encouraged new data processing approaches and new data analysis techniques. The open availability of USArray data has enhanced sharing of results among scientists, promoted deeper collaborations with the broader earth science community, and provided essential next-generation opportunities for student research.



in Motion



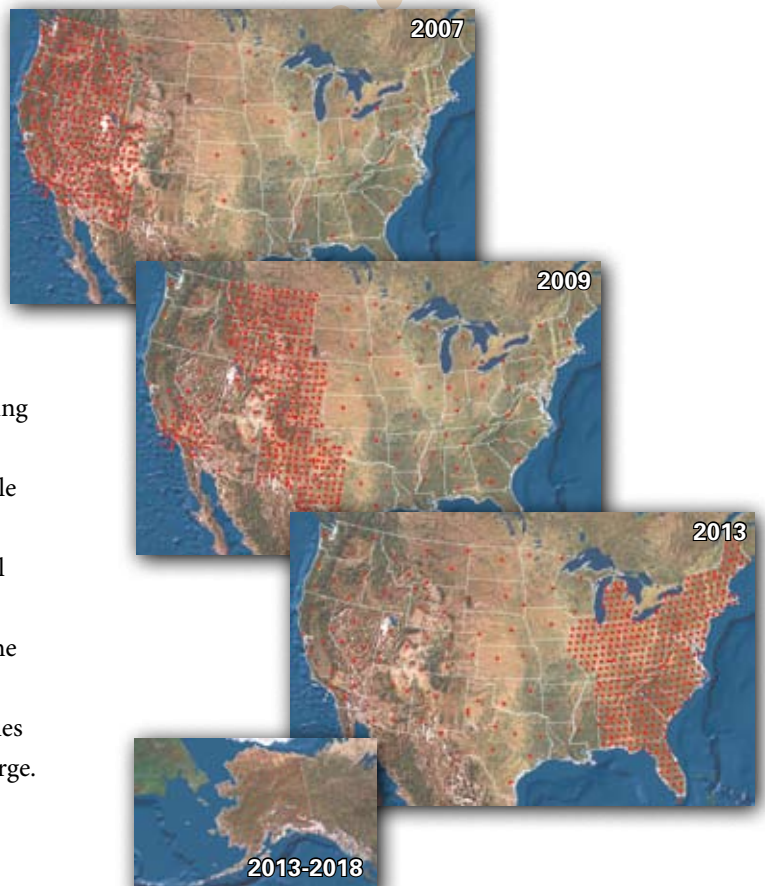
Staying Informed

Use of USArray data and knowledge of the program's discoveries go beyond the geoscience community. EarthScope's *onSite* newsletter informs station hosts, government agencies, educators, and others about EarthScope science and topics of general interest. The comprehensive USArray Web site (<http://www.iris.edu/USArray/>) contains information appealing to three main groups: researchers, the public and landowners, and educators. Brochures and other publications designed for broad audiences are also available in print and online.



Lots More Yet to Come

USArray is a unique observatory with its permanent and rolling components that work in tandem. In the first five years of the program, the most challenging component—the Transportable Array—occupied more than 600 sites in the western United States. The array is actively rolling eastward at full operational levels of approximately 18 installations and 18 removals each month. As Transportable Array stations occupy sites across the rest of the United States and data are acquired through more detailed Flexible Array experiments, numerous new discoveries about the structure and evolution of North America will emerge.



About earthscope

EarthScope is a set of integrated and distributed multipurpose geophysical instruments that provide observational data to significantly enhance our knowledge of the structure and evolution of the North American continent and the processes controlling earthquakes and volcanic eruptions. Three components being implemented in parallel define EarthScope:

- **USArray** is a dense network of permanent and portable seismographs and magnetotelluric sensors that are being installed across the continental United States to record earthquakes and naturally occurring variations in Earth's electric and magnetic fields.
- The **Plate Boundary Observatory** is a network of geodetic and strain instrumentation that is imaging fast and slow deformation in the lithosphere along the western United States and Alaska.
- The **San Andreas Fault Observatory at Depth** is a three-kilometer-deep hole drilled through the San Andreas Fault in an area between San Francisco and Los Angeles near Parkfield, California, that has ruptured seven times since 1857.



The EarthScope facilities were constructed under the National Science Foundation's Major Research Equipment and Facilities Construction account.



www.iris.edu/usarray



USArray is executed by the Incorporated Research Institutions for Seismology (IRIS) through cooperative agreements with the National Science Foundation. Community input is received via the IRIS Board of Directors, the USArray Advisory Committee, and the Transportable Array and Electromagnetic Working Groups.