summer 2006

earthscope onSite newsletter

A publication for landowners and those interested in the EarthScope Project.

From The USArray Principal Investigator

Hundreds of earthquakes occur throughout the world every day. Most of these earthquakes are too small to be felt by people, but can be detected by seismometers. Using these data, scientists learn about the structure and dynamics of the Earth.

This issue of *onSite* focuses on the USArray Project, EarthScope's seismic and magnetotelluric component. Our science feature by Morgan Moschetti, a scientist at the University of Colorado, describes a new innovative technique using seismic "noise" to get a better picture of the geologic structure along the west coast of the U.S. We also report on the recently launched Magnetotellurics Project, an array of instruments that detect naturally occurring electric and magnetic fields. These data will help identify the thermal structure of the Earth. Our guest seismologist, Michael Wysession of Washington University in St. Louis, explains the basics of interpreting a seismogram. Updates on the progress of the Transportable Array, as well as our sister project, the Plate Boundary Observatory (PBO), are presented in this and every issue of *onSite*.

Starting with this issue, each *onSite* will alternate in focus between EarthScope's USArray and PBO Projects. The Fall newsletter will provide an update on the progress of PBO and will highlight this summer's installation of GPS units on remote Aleutian Island volcanoes. We value your continued interest in the EarthScope Project and hope you find this newsletter educational as well as informative. If there is a topic of special interest to you, please let us know by contacting one of the EarthScope *onSite* editors (USArray: dorr@iris.edu or PBO: barbour@unavco.org) or the EarthScope office.

David W. Simpson
USArray Principal Investigator

featured science:

Seismic Data Helps Scientists See Below the Earth's Surface

As the Transportable Array is deployed over the next decade, it provides an unparalleled means to study the geology of the U.S. through seismology. By knowing the speeds that seismic waves travel through rocks at different locations and depths, we can learn about geologic structures in the Earth. At the University of Colorado, we are using data from the Transportable Array to learn more about the structure of the western U.S.

In traditional seismology, the arrival times of earthquake seismic waves are observed at various seismometers. Seismologists can then determine the wave speeds of the rocks along the earthquake path. Unlike traditional seismology, our measurements make use of the ever-present seismic noise in the Earth caused by ocean waves, large storms, and cultural phenomena, such as traffic, to map subsurface features. Our ambient noise technique is not limited by the timing and location of discrete natural events and guarantees that we are able to collect data at all times without waiting for an earthquake.

By comparing long sequences of noise recordings between two seismometers, we generate signals similar to those from earthquakes. If we do this for every pair of Transportable Array seismometers, we obtain paths criss-crossing the western U.S. As the Transportable Array moves across the country, paths between seismometer pairs will be established in regions that experience few or no earthquakes and we will be able to identify smaller geologic structures not typically imaged by earthquake seismology. The figure below shows an example of the noise records (free of earthquakes) from two seismometers and their mathematical comparison (cross-correlation).

We use surface waves – seismic waves that propagate along the Earth's surface – to learn about the crust and upper mantle. These waves contain many different frequencies which travel at different speeds. Higher frequency waves are sensitive to near-surface structures, and lower frequency waves are sensitive to deeper structures.

For every station pair, we measure arrival times at different frequencies and create maps showing the speed of waves of a certain frequency. Monthly and cumulative results are posted on our project website (http://ciei.colorado.edu/~morganm). In general, slower speeds are associated with sediments and fractured rocks, and higher speeds are associated with crystalline rocks, such as granite. The maps from different frequencies tell us about features at different depths. Maps at 0.125 Hz provide information about rocks shallower than 10 km. The 0.0625 Hz maps provide information about rocks as deep as 20 km.

The figure on page 3 shows a comparison of maps at two frequencies for October 2004 and February 2006. During this time, more stations were installed, extending the region over which we obtain results. The maps show the low velocity sediment

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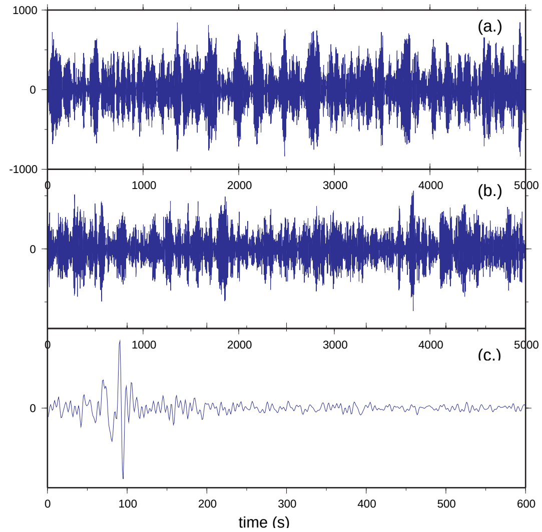


A comparison of noise recordings at Transportable Array stations (a.) 109C and (b.) Y12C that results in (c.), a pulse of energy whose travel time between stations can be measured.

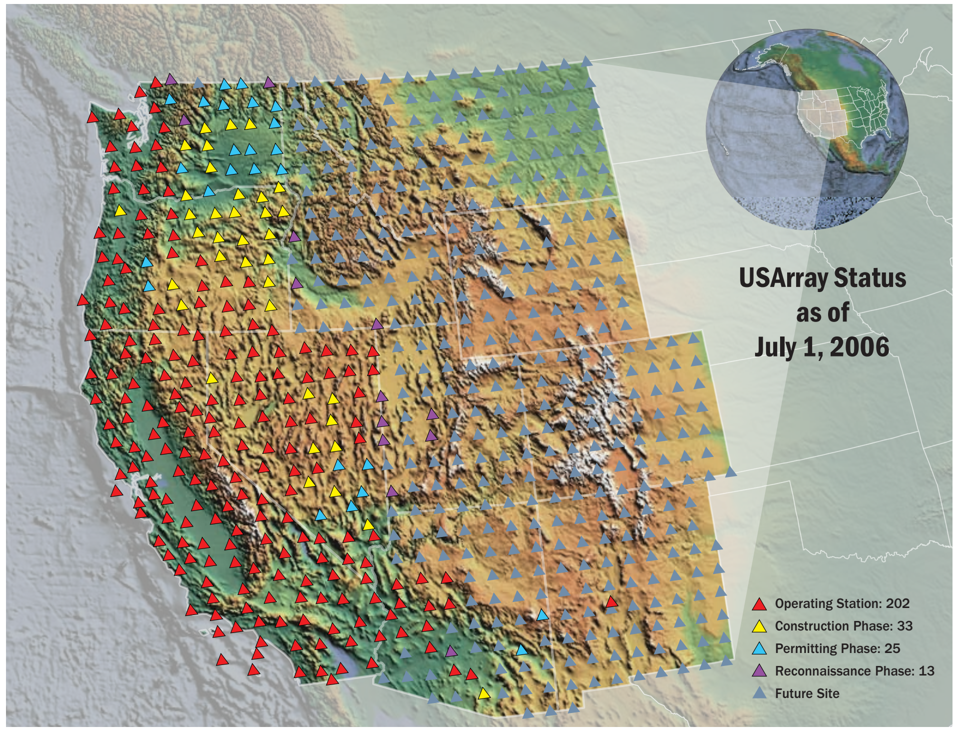
project status:
USArray

Where is the Transportable Array?

Installation of the Transportable Array continues to make excellent progress. Sixty-seven new stations were added in the last four months and over half of the initial 400 stations are now operational. As of July 1, 2006, there were 202 stations operating in California, Oregon, Washington, Nevada, and Arizona with more stations becoming operational every week.

Field crews are currently focusing their efforts in Washington and Nevada with one construction crew and one installation crew active in both states. In the next few weeks, the last station in Oregon will be built. The few remaining stations in Nevada will be constructed and installed in the near future. In Washington, USArray staff is conducting reconnaissance to find suitable sites along the border with Canada. Reconnaissance is also being conducted in Idaho, Montana, and Utah.

There are several factors that affect how we construct and install Transportable Array stations. A major consideration is weather. Because monitoring stations are preferred in quiet, remote locations away from primary and secondary roads, very wet or snowy conditions can make access difficult. Generally, the teams work in northern areas in the late spring through the early fall and then move to southern regions for the winter months. Construction requires the use of a small backhoe, a small cement mixer, a 6-foot long piece of 42-inch diameter drainage pipe, and an assortment of other equipment. Materials for dozens of stations are sent in advance to a storage depot where the construction and installation teams access the equipment as needed. The trucks can haul materials for multiple sites, so a 3-person construction team using three vehicles, one trailer, and one backhoe can construct four sites in five days before returning to the storage depot. ■



REAL-TIME STATION STATUS: To view a map of current Transportable Array stations, visit http://www.earthscope.org and click on 'Current Status'.

To view seismograms recorded at a USArray station, go to http://usarray.seis.sc.edu/ and enter the station code. You can also enter a zip code to view the recordings from the USArray station closest to that area.

TRANSPORTABLE ARRAY COORDINATING OFFICE: usarray@iris.edu 1-800-504-0357

On The Move...

Following the success of last summer's pilot program in Oregon, a workshop was held in May to prepare a group of interns to identify potential sites for future Transportable Array stations. Twelve students with interests in the Earth sciences from Boise State University, the University of Idaho-Moscow, Montana Tech, and the University of Utah and their faculty sponsors participated in the 4-day program on the University of Utah campus. At the end of the workshop, each of the seven 2-person teams was assigned about 15 sites for which to recommend a specific location for an earthquake monitoring station. During the 10-week program, more than 100 sites in Utah, Idaho, and western Montana will be identified. Installation of these stations over the next 12-15 months will complete the first 400-station footprint of the Transportable Array.

The workshop included an overview of the EarthScope and USArray Projects and

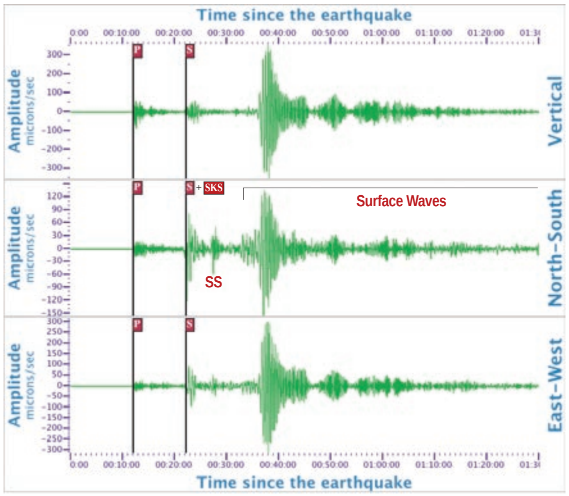
(continued on page 4)

ask a seismologist:

How Do I Read a Seismogram?

Seismograms are records of motions that travel as seismic waves within the Earth. All seismic waves are variations of two types: P and S. Interpreting these waves teaches us much about the Earth.

Pick up a stick. Now close your eyes and start bending the stick. At some point the stick is going to break. How do you know when the stick breaks if you can't see it? First, you hear the stick break. What you just experienced is a P wave. When earthquakes occur, they cause compressional waves, or P waves, that behave just like the sound of the breaking stick. The snap pushes on the air, which pushes the next bit of air, and so on, all the way to your eardrum. Second, you feel the stick break. This is an S wave. Unlike P waves, S waves travel in a direction that is perpendicular to the motion at any point. You cannot hear the S waves because they only propagate through rigid materials – not in air or water. In the figure above, you can see the P and S waves labeled on the seismograms that recorded the Earth's motions in all directions (vertical, or up and down; north-south; and east-west) at a given location.

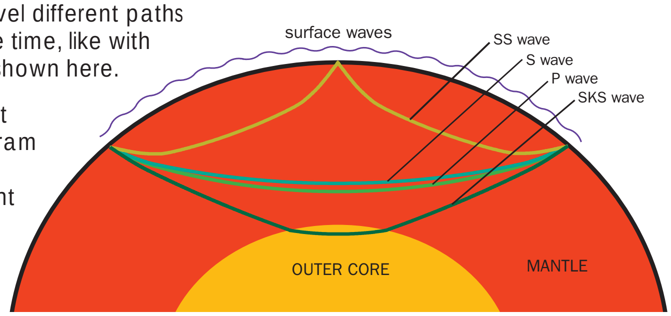


Seismograms from the magnitude 8 earthquake in the Tonga Islands on May 3, 2006, as recorded by Transportable Array station H04A in Detroit Lake, Oregon. The data are displayed by the Rapid Earthquake Viewer (http://rev.seis.sc.edu/).

The paths that the P and S waves take through the Earth are shown in the figure below. There are many other waves that are recorded in the seismograms because the P and S waves break up into many different paths as they travel through the Earth. As you can see, some waves *reflect* off of the surface, like the SS wave. This is like an echo off of a canyon wall. Some waves pass through the Earth's core, like the SKS wave, bending as they pass between layers. The waves with the largest heights, or amplitudes, and which are the most spread out in time, are the rumbling *surface waves*. Sometimes waves travel different paths but arrive at the same time, like with the S and SKS waves shown here.

All of the different wiggles on a seismogram represent waves that have traveled different paths through the Earth. Each path is given a name composed of a series of letters that characterize how the wave traveled. The individual waves are very useful to geoscientists because they sample different regions of our planet. This allows us to learn more about the Earth's deep structure in regions where we will never be able to drill because the temperatures and pressures are too great. It is the Earth's structure that holds the key to extremely important unanswered questions about what our planet is made of, how it changes and evolves over time, and what the mechanisms are by which the continents move about the surface as part of the system of Plate Tectonics. By interpreting the many different P and S waves from many seismograms such as the ones shown here, we will have a much better idea of the geology of North America from the crust to the core. ■

By Michael Wysession, Department of Earth & Planetary Sciences, Washington University, St. Louis, Missouri.



The paths of the P, S. SKS, SS, and surface waves through the Earth.

featured science:

Seismic Data Helps Scientists See Below the Earth's Surface

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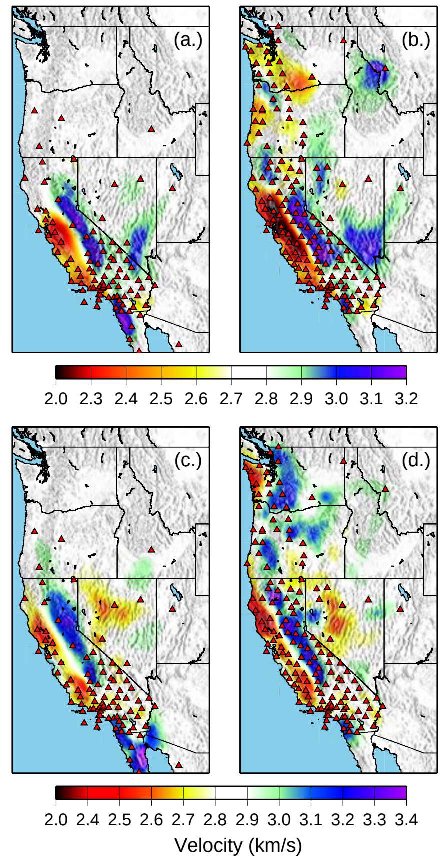


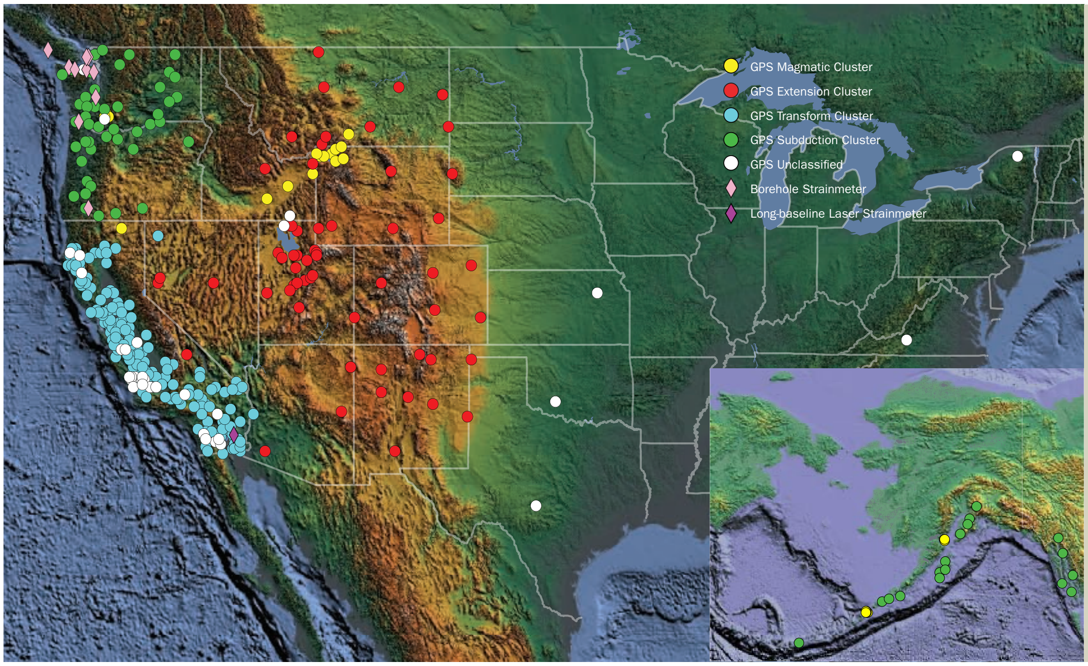
Top: The 0.125 Hz surface wave (0-10 km depth) velocity maps from (a.) October 2004 and (b.) February 2006. Bottom: The 0.0625 Hz surface wave (0-20 km depth) velocity maps from (c.) October 2004 and (d.) February 2006.

in the Great Valley of California, the low velocity sedimentary rocks of the Olympic Peninsula in Washington, and the high velocity root of the Sierra Nevada Mountains. The Cascades are visible only as a high velocity feature at the lower frequency (which samples a greater depth). As the Transportable Array expands across the country, ambient noise measurements will be an indispensable tool for learning about geologic structures of the U.S. and improving information on seismic hazard. ■

By Morgan Moschetti, Center for Imaging of the Earth's Interior, Department of Physics, University of Colorado at Boulder.

project status:

Plate Boundary Observatory



PBO Status as of July 1, 2006:

Magmatic stations: 39

Transform stations: 199

Subduction stations: 79

Extension stations: 64

Borehole strainmeters: 18

Long-baseline laser strainmeters: 1

PBO REGIONAL OFFICES:

Alaska 907-346-1522

Pacific Northwest 509-933-3221

Basin and Range 801-466-4634

Northern California 510-215-8100

Southern California 951-779-6400

As the EarthScope project nears the end of its third year, the Plate Boundary Observatory (PBO) network continues to unfold. As more stations are installed and more data are acquired, the 3-dimensional velocity field of the western U.S. and Alaska comes into clearer focus.

As of July 1, 2006, there were 383 GPS stations and 18 strainmeter stations installed. From these stations, the Boulder data archive has received over 113 gigabytes of data. The data are recorded every fifteen seconds from each instrument, assembled into 24-hour data files and processed to determine the relative movement of each station in the network. By tracking the day-to-day status of each station, we can monitor the movements of fault systems, like the San Andreas, and volcanoes, such as Mt. St. Helens, down to the millimeter level (about the width of a dime). PBO instruments have captured several significant geological events including the September 2004 magnitude 6 earthquake in Parkfield, California; the 2004 earthquake and tsunami in Asia; recent volcanic activity at Mt. St. Helens in Washington and St. Augustine in the Alaskan Aleutian Islands; and the May 2006 magnitude 7.9 earthquake in Tonga. All GPS data products can be found on the web at http://pboweb.unavco.org/?pageid=88, and strainmeter data and data products at http://pboweb.unavco.org/?pageid=89.

The PBO project is on schedule and on budget. Now that the Alaska installation season has arrived (mid-June to late September), field engineers from all regions will take turns to complete a very full schedule of activities. We will be working in all areas of Alaska, including the Aleutians, to install up to 40 GPS stations and to conduct reconnaissance at 35 sites. Look for the next issue of EarthScope *onSite* to read more about recent PBO events and activities that have taken place in some of the most remote areas of Alaska and the western U.S.

For more information on the PBO Project, please visit the PBO website at http://pboweb.unavco.org/. ■

On The Move... (continued from page 2)

presentations on how an earthquake monitoring station is constructed, how the sensors detect and record ground motions, and the criteria for a high-quality seismic station. Other topics included a discussion of the telemetry options for near real-time data transmission, siting considerations on public and private lands, and information on preparing a site reconnaissance report to document their findings. The students learned how to use geographical information system (GIS) software, as well as aerial photographs and topographic maps. Each team also received a backpack with a laptop computer, a hand-held global positioning system (GPS) unit, a cell phone, and a digital camera to help them do the required reconnaissance work.

Students, faculty sponsors, and workshop instructors spent a day in the Wasatch Mountains learning to evaluate field sites. The workshop also included time for the teams to begin work in their assigned areas, as well as to take an informative tour of the University of Utah Seismograph Stations facility. By the end of the workshop, these enthusiastic interns were eager to get started! ■

Participants in the 2006 Transportable Array Siting Workshop.

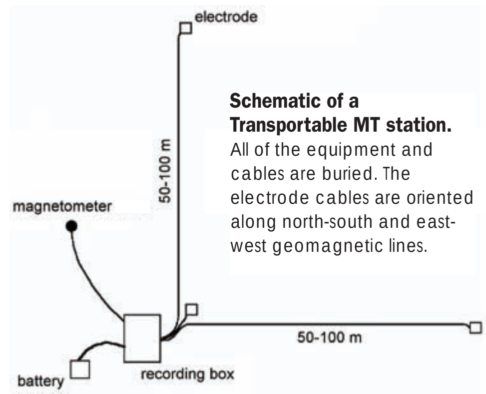
project status:

Magnetotelluric Experiment Begins

EarthScope recently began installing a network of magnetotelluric (MT) sensors across the U.S. These sensors record naturally occurring electric and magnetic fields at the surface of the Earth caused by currents flowing in the ionosphere and also deep within the Earth. From these data, inferences can be made about electrical conductivity. Because conductivity increases systematically with temperature and with the presence of fluids, MT measurements help identify the thermal structure of the Earth as well as areas of active melting. EarthScope scientists will integrate MT images with other geophysical and geological data to address unresolved issues about the Earth's structure, evolution and dynamics.

The MT network has two components. The Backbone component consists of seven permanent MT stations installed across the U.S. as a reference network. The Transportable component is a mobile array of 20 MT systems that will each be deployed for a period of about one month in regions of identified interest with a spacing of approximately 70 km (~43 miles).

An MT station is passive with no associated noise or motion, and consists of a magnetometer, four electrodes and a data recording unit that are buried in shallow holes. The four electrodes are placed along two lines in a cross or "L" shape, oriented along north-south and east-west directions, and connected by a thin cable to the magnetometer and data recording unit which are usually at the intersection of the two lines. The electrodes are saturated with a common salt solution to improve conductivity with the ground. Data from Backbone stations will be transmitted electronically to the IRIS Data Management Center while data from Transportable MT stations will be recorded on site and retrieved when the equipment is recovered.



Schematic of a Transportable MT station. All of the equipment and cables are buried. The electrode cables are oriented along north-south and east-west geomagnetic lines.

For more information about the MT project, please visit http://www.emscope.org.

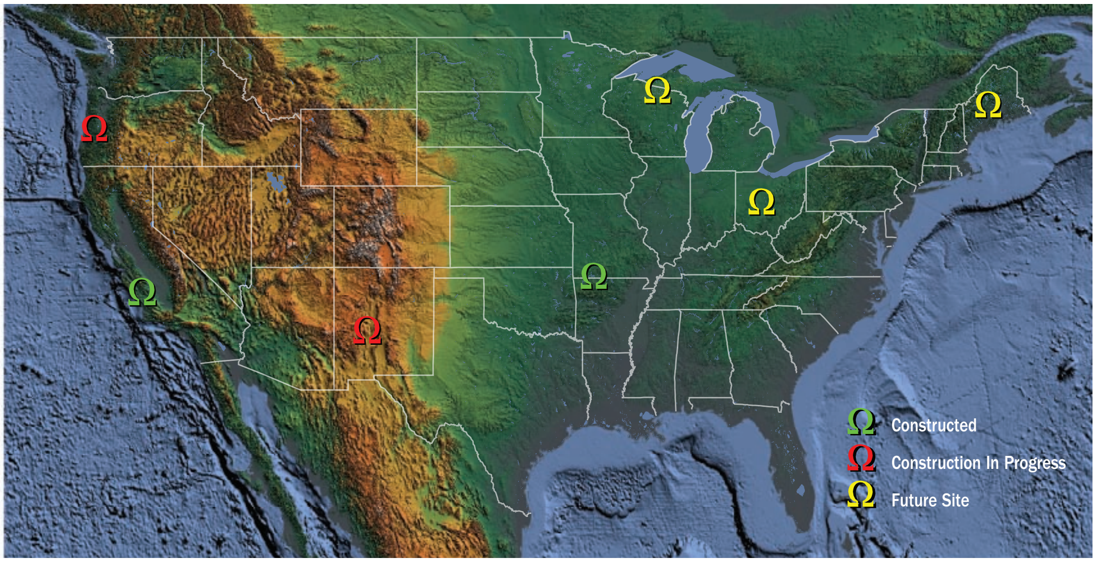
If you are interested in hosting a Transportable MT station, please contact us at usarray@iris.edu or 1-800-504-0357.

In May, the first Backbone MT station was installed near Parkfield, California. It is located near the long-established Carr Hill site where scientists have obtained 18 years of electric field data from telephone cables. A second Backbone MT station was installed in June near Braden, Missouri, with assistance from Missouri State University. Near-term plans include the installation of a third Backbone station near Socorro, New Mexico, with assistance from the New Mexico Institute of Technology.

An electrode ready to be buried.

To determine if seismic Transportable Array and Transportable MT stations could share the same site, three temporary MT stations were installed near Albany, Oregon. Each MT station was installed at a different distance from the seismic Transportable Array station to evaluate the potential for interference between these different instruments. The test was completed in June and demonstrated that there was no interaction between the seismic and MT sensors and recording systems. The site will be converted to a Backbone MT site in co-operation with Oregon State University.

In Oregon, a pilot project using 20 Transportable MT systems throughout the state will begin soon. The purpose of this trial is to gain field and cost experience with siting and permitting activities and with the installation, operation, maintenance, and demobilization of mobile MT sites. ■



Burying the cable connecting the data recording unit (foreground) to an electrode.

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Transportable Array station L09A on the Oregon-Nevada state line near McDermitt, Nevada. This station, which came online in late April, was the 100th new operating station.

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Revealing Earth's Secrets