winter 2008

earth scope

onSite
newsletter

From the San Andreas Fault Observatory at Depth Principal Investigators

More than a century ago, the San Francisco Bay region was rocked by a great earthquake when the Earth ruptured along a section of the San Andreas Fault. Extending from near the Gulf of California northwestward to San Francisco Bay and then continuing off the coast of Northern California, the San Andreas Fault is the boundary between the Pacific Plate on the west and the North American Plate on the east. This complex fault system displays a range of behaviors over its 800-mile length with some sections having sudden large movements causing big earthquakes and other sections creeping slowly passed each other without being felt by humans.

In this issue of *onSite*, we highlight the San Andreas Fault Observatory at Depth (SAFOD), a 3-km (2-mile) deep hole drilled directly into the San Andreas Fault. This hole is providing the first opportunity to directly observe the conditions under which earthquakes occur. We report on the first-ever recovery of rocks from across an active plate boundary in the featured science article. The SAFOD Project Status presents an overview of the activities that are planned to learn more about this significant fault zone, from analyzing the rock and fluid samples obtained in 2007 to continuously monitoring the properties in and around the borehole starting in the summer of 2008. Also in this issue are updates on the progress of the Transportable Array and the Plate Boundary Observatory.

We value your continued interest in EarthScope. If there is a topic of special interest to you, please let us know by contacting one of the EarthScope *onSite* editors (EarthScope National Office: jbraunmiller@coas.oregonstate.edu, USArray: dorr@iris.edu or PBO: tallerday@unavco.org).

Mark Zoback, SAFOD Co-Principal Investigator

Stephen Hickman, SAFOD Co-Principal Investigator

William Ellsworth, SAFOD Co-Principal Investigator

featured science:

In-Situ Fault Zone Observations from SAFOD

The San Andreas Fault Observatory at Depth (SAFOD), a seismological observatory constructed directly within the San Andreas Fault Zone in central California, reached a major milestone in September 2007. More than 40 m (120 ft) of rock weighing nearly a ton were recovered from fault zones at depths where earthquakes originate. This is the first time that intact rock samples have been recovered from such depths across an active plate boundary!

A component of EarthScope, SAFOD was drilled into the San Andreas Fault Zone to study the physics of earthquake rupture and to determine the composition, physical properties and mechanical behavior of an active fault at depth. The drill site is located near Parkfield on a segment of the San Andreas Fault that lies between the "creeping" section of the fault and the section that produces magnitude 6 earthquakes every several decades (Figure 1). The main hole, drilled in 2004 and 2005, intersects the San Andreas Fault Zone at about 3 km (9850 ft or nearly 2 miles) depth and is 100 m (325 ft) above a cluster of small, repeating magnitude 2 earthquakes that marks the southwest limit of the creeping segment. Drilling resumed in 2007 to obtain additional information and samples from the active fault.

Exciting results from the 2004-2005 field season included identification of several distinct active fault traces within a ~250 m (825 ft) wide fault zone and detection of talc in rock cuttings brought to the surface. Talc is one of the weakest minerals known and could provide an answer as to why this section of the San Andreas Fault moves slowly and steadily, producing many small – rather than a few strong – earthquakes. Talc may be derived from serpentine, a rock found in oceanic crustal fragments and long considered a potentially important mineral in controlling the mechanical behavior of the San Andreas Fault in central California. It is also significant that elevated fluid pressures were NOT observed in the fault, because high fluid pressure is widely considered to be a mechanism for weakening faults.

During the summer of 2007, SAFOD recovered intact rock cores from two actively creeping sections of the San Andreas Fault that had deformed the steel casing which was cemented in the borehole in 2005. These cores showed that the deformed rock was highly localized and that the width of the fault gouge – a "powder" formed by rock that has been finely ground by intense shearing – is 1 and 3 m (3 ft and 10 ft) in the two fault segments. The gouge also contains abundant fragments of serpentine, providing the first direct evidence for its occurrence in the zone of active deformation (Figure 2).

Last December, researchers from around the world came to view the SAFOD cores and to submit requests to obtain samples for scientific study. The researchers will conduct a wide range of laboratory investigations on the samples to try to answer fundamental questions about the composition, structure and frictional properties of the San Andreas Fault at depth. The ultimate objective is to better understand the processes controlling

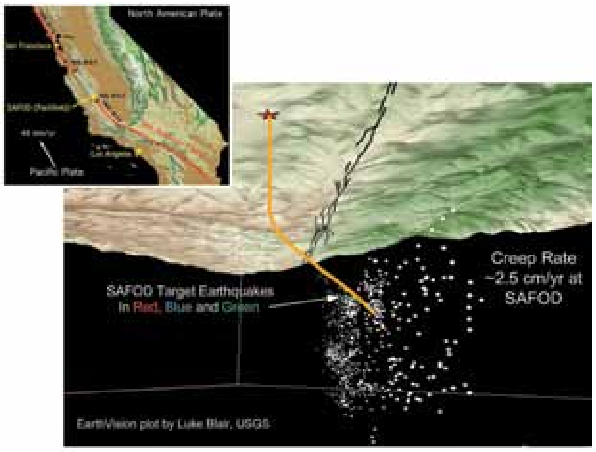


Figure 1: The location of the San Andreas Fault Observatory at Depth from a depth of 3 km (9850 ft), looking to the northwest and up toward the Earth's surface. The observatory is 1.8 km (~1 mile) southwest of the surface trace of the fault, which is shown in black draped over the topography. After drilling vertically, the borehole was deviated through the fault. Earthquake locations (dots) were determined by Cliff Thurber and Haijiang Zhang (University of Wisconsin) and Steve Roecker (Rensselaer Polytechnic Institute) using data from the Parkfield Area Seismic Observatory as well as the U.S. Geological Survey and University of California at Berkeley seismographic networks. Inset: A map view showing the location of SAFOD near the town of Parkfield, in central California.

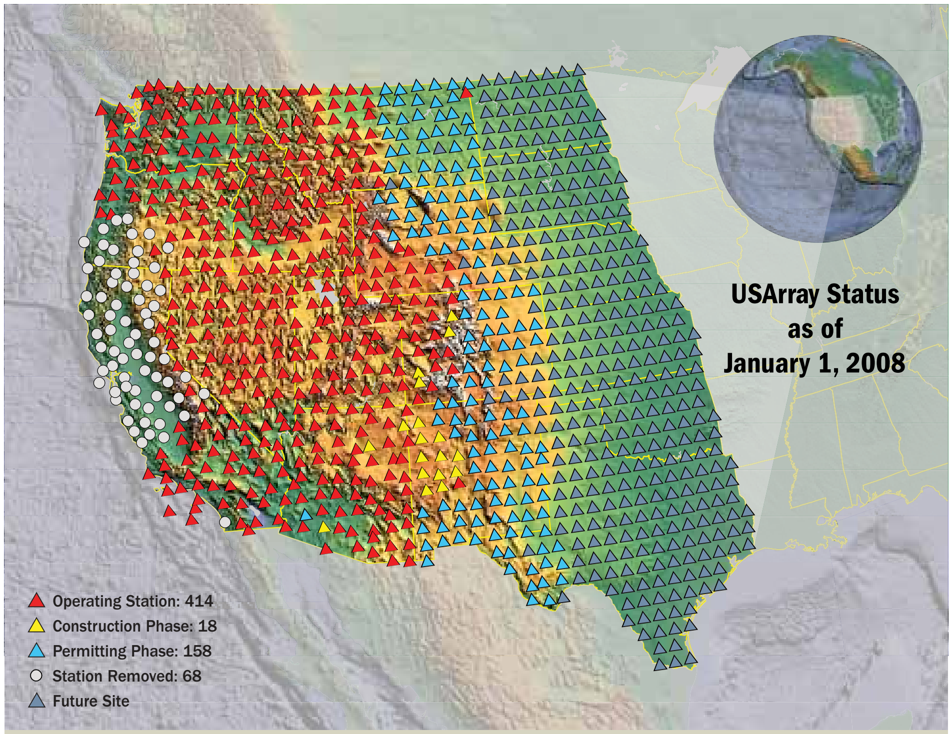
(continued on page 3)

project status: USArray

Where is the Transportable Array?

Following the achievement of establishing one of the world's largest real-time networks of 400 earthquake recording stations in early August 2007, the Transportable Array began its much anticipated multi-year "roll" toward the East Coast. By the end of 2007, 50 stations were removed from California and Oregon, and the seismometers and other reusable equipment are now being re-installed at sites on the eastern edge of the array. During the months of October, November and December, 43 new stations began operating in Montana, Wyoming, and Colorado. The construction and installation crews slowly moved south during this time as winter snows make these activities difficult and treacherous. These crews are now working primarily in New Mexico where site verification was previously conducted.

While frozen ground hampers the digging of holes for new vaults in many areas, operation of stations typically continues undisturbed. Occasionally, large accumulations of snow, long periods without sun, or vendor-imposed changes to the communications systems necessitate a site visit by a service crew. Just like the U.S. Postal Service motto from years ago, "neither rain, nor sleet, nor dark of night will keep the post office from their appointed rounds...," the dedicated EarthScope staff find creative ways to reach remote sites to keep stations recording and transmitting data that will give us a better understanding of our planet. ■



REAL-TIME STATION STATUS: To view a map of current Transportable Array stations, visit http://www.earthscope.org and click on 'EarthScope Information System (EIS)'.

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

The EarthScope crew, arriving by snocat, makes a service call at Transportable Array station G12A near Yellow Pine, Idaho.

project status: SAFOD

Successful coring activities during the summer of 2007 recovered rock samples from the San Andreas Fault Zone at depths where earthquakes originate. Since then, nearly 800 requests for samples have been received from approximately 100 scientists in the U.S. and abroad. These requests are currently being evaluated by the National Science Foundation. Through a wide variety of laboratory analyses on these unprecedented core samples, scientists seek answers to many fundamental questions about the origin, evolution and behavior of the San Andreas Fault that have arisen over the past several decades of earthquake research.

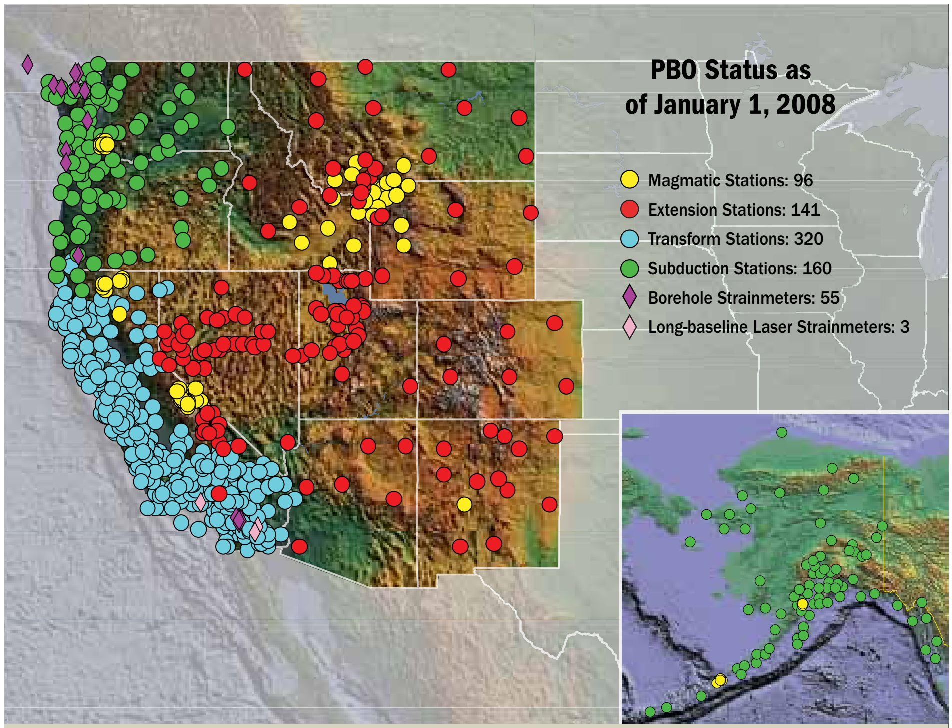
At the same time, plans are being finalized for the seismological observatory that will be deployed directly in the San Andreas Fault Zone at 3 km (9850 ft) depth. For the first time, instruments will be installed at depth to monitor at close range the initiation, propagation and termination of ruptures associated with magnitude ~2 earthquakes that occur quite regularly on the fault in the area. The SAFOD observatory will consist of an array of conventional seismometers capable of detecting small earthquakes, less sensitive accelerometers to record strong shaking from nearby earthquakes, tiltmeters to monitor both seismic and aseismic movement, and an extremely precise pressure transducer to determine if fluctuations in fault zone pore pressure precede, accompany or follow the local small earthquake events. Installation of this observatory is planned for the summer of 2008. ■

project status:
Plate Boundary Observatory

UNAVCO is building and operating the Plate Boundary Observatory (PBO) as part of the NSF-funded EarthScope program which is collecting data on the interactions between the Pacific and North American plates in the form of 3-D motions and earthquake data. When completed in October 2008, the PBO will comprise the largest integrated geodetic and seismic network in the United States, and the second largest in the world. Data from the PBO network will facilitate research into plate boundary deformation with unprecedented scope and detail.

As of January 2008, UNAVCO has completed 750 of the 875 planned GPS stations, 55 of the planned 103 borehole strainmeters and seismometers, three of five long baseline laser strainmeters, and 12 of the 28 planned borehole tiltmeter stations. The project has also collected airborne LiDAR imagery of active faults in southern and northern California. The combined network has provided 750 gigabytes of raw data to date, approximately half of which is GPS data from the PBO Network.

Researchers use these data to understand the physical processes, crustal properties, and tectonic environment that give rise to earthquakes and to determine how tectonic plates interact. All PBO data products are immediately freely available and can be accessed from the PBO web page at http://pboweb.unavco.org. Recent scientific highlights from the network include capture of regularly occurring Episodic Tremor and Slip (ETS) events best observed on GPS and strainmeters in a region from southern Puget Sound to central Vancouver Island and measuring accelerated uplift and magmatic intrusion of the Yellowstone Caldera. ■



PBO REGIONAL OFFICES: Alaska 907-346-1523; Pacific Northwest 509-933-3221; Basin and Range 801-466-4634; Northern California 510-215-8100; Southern California 951-779-6400

In December 2007, EarthScope PBO Siting Outreach Specialist, Jayme Margolin, had two student volunteers from Eddyville Charter School act as two different tectonic plates and show their peers three different movements that can occur at plate boundaries. Ultimately, the students acted out subduction to relate to the local geology off the Oregon Coast.

(continued from front)

featured science: In-Situ Fault Zone Observations from SAFOD

earthquake generation within an active plate-boundary fault and to provide a stronger scientific basis for the prediction and mitigation of earthquake hazards.

For more information, please visit http://www.icdp-online.de/contenido/icdp/front_content.php?idcat=712 and http://www.earthscope.org. ■

By: Mark Zoback, Department of Geophysics, Stanford University; Stephen Hickman, Earthquake Hazards Program, U.S. Geological Survey; and William Ellsworth, Earthquake Hazards Program, U.S. Geological Survey.

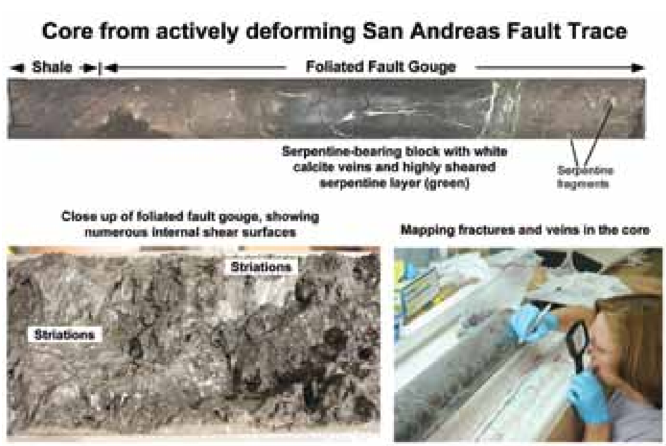


Figure 2: Serpentinite, fault gouge, veins, and faults are present in one of the core samples that was obtained from the San Andreas Fault Zone. Professor Judith Chester, from Texas A&M University, is seen documenting deformation structures in the core.

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SAFOD Core passing through a geophysical core scanner.

A Note from the EarthScope National Office

The return address on this newsletter has changed. The EarthScope National Office (ESNO) was established in July 2007 to coordinate planning activities for the EarthScope science community and to assist the EarthScope facilities with their education and outreach mission. It is currently located at Oregon State University and will move to another university in 2010.

EarthScope is funded by the National Science Foundation and conducted in partnership with the US Geological Survey and NASA. EarthScope is being constructed, operated, and maintained as a collaborative effort with UNAVCO Inc., the Incorporated Research Institutions for Seismology, and Stanford University, with contributions from several other national and international organizations. This material is based upon work supported by the National Science Foundation under Grants No. EAR-0323310, EAR-0323309, EAR-0323700, EAR-0323938, EAR-0323311, and EAR-0323704. Any opinions, finding, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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