nehrp SeismicWaves
How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety
December 2007

Unearthing the Secrets of the San Andreas: A NEHRP-Related Success Story

Thoughts of standing atop an active fault can conjure primal fears and imaginings—of, for example, the ground falling open like a trapdoor and dropping like a rock into the deep, dark recesses of the earth. For centuries, native peoples living near present-day Seattle appear to have associated local faults with equally alarming imagery, passing down cautionary tales about a huge and dangerous serpent, *a'yahos*, that could arise in certain locations to shake the earth and cause landslides.[1]

Although scientists who study earthquakes now know that such images are inaccurate, faults have remained largely mysterious and unreachable. That is beginning to change, however, thanks to a scientific investigation under way on California's infamous San Andreas Fault. And in an eerie coincidence, a greenish mineral called serpentine (a name derived from the Latin word *serpentinus*, which means "resembling a serpent") is figuring prominently in this project.

The SAFOD Project

The San Andreas Fault Observatory at Depth (SAFOD) is a multiyear effort to build the world's first underground earthquake observatory. It is being funded by the National Science Foundation (NSF, a NEHRP agency) as part of its EarthScope program, which is investigating the forces shaping the North American continent and the processes controlling earthquakes and volcanic eruptions. EarthScope is a NEHRP-related activity.

The site of the observatory is midway between San Francisco and Los Angeles near the small town of Parkfield, California. The self-proclaimed "Earthquake Capital of the World," Parkfield has been the site of intense seismic monitoring since the mid-1980s. The town sits beside the San Andreas Fault, the boundary between two segments of the earth's crust (North American Plate and Pacific Plate) that extends for 800 miles down the length of California. Unlike sections of the San Andreas to the north and south of it, Parkfield is in a "creeping" segment of the fault, where the tectonic plates slide past one another in relatively slow, regular movements that generate only small earthquakes. It is the regularity with which these quakes occur that has made Parkfield so uniquely suited for surface monitoring and for SAFOD.

Led by scientists from Stanford University and the U.S. Geological Survey (USGS, a NEHRP agency), the SAFOD project team began drilling the main hole for the observatory in 2004. The team used directional-drilling technology developed by the oil industry to drill from the Pacific Plate through the fault to the North American Plate. The resulting hole, the first through the San Andreas, was completed in 2005 and extends for 2.5 miles down and to the east, ending about 2 miles below ground.

This past summer, the team completed another historic first by retrieving rock samples from deep within the fault. Drilling laterally into the San Andreas from several points

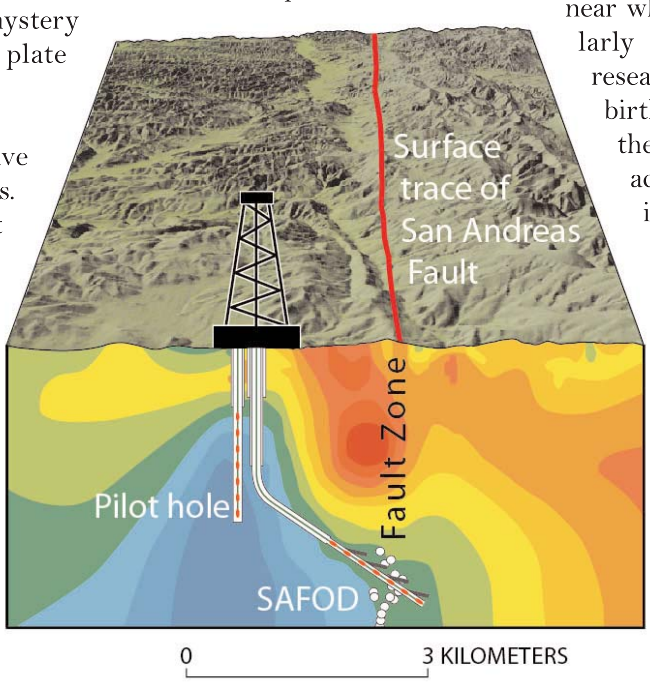
SAFOD drill rig, July 2004. Photo courtesy EarthScope-SAFOD.

[1] R. S. Ludwin et al., "Serpent Spirit-power Stories along the Seattle Fault," *Seismological Research Letters* 76, no. 4 (July/August 2005): 426–31.

along the downward sloping observatory hole, the researchers pulled out continuous cylinders or "cores" of earth. In total, 135 feet of 4-inch-diameter cores were brought up from areas more than 10,000 feet below ground where fault creeping continues to produce small earthquakes. Laboratory analysis of these samples will yield new information about the physical and chemical characteristics of the fault and about what enables this segment to creep. Until now, researchers could only speculate about such matters using computer and laboratory simulations and clues found at ground level.

"To an earthquake scientist, these cores are like the Apollo moon rocks," said Steve Hickman, a USGS geophysicist and one of the project leaders. "Scientists from around the world are anxious to get their hands on them in the hope that they can help solve the mystery of how this major, active plate boundary works."

Preliminary examinations have already produced some surprises. One was the width of the fault gouge, which is an area between the two sides of a fault containing rocks that have been cracked, deformed, polished, or ground into powder by the fault's shearing forces. Scientists had speculated that this area might be a few inches wide, but found gouge as wide as 8 feet in the cores. And intriguingly, the gouge contained fragments of serpentine, which has long been suspected of playing a role in fault creep. In the presence of high temperatures and water containing silica, serpentine can chemically alter to form talc, an extremely weak and slippery mineral. A USGS mineralogist detected talc in fault material excavated from the observatory hole in 2005.



Schematic cross section of the San Andreas Fault Zone at Parkfield, showing the SAFOD drill hole and a pilot hole drilled in 2002. Red dots in holes show sites of monitoring instruments; white dots represent area of persistent minor seismicity. Source: USGS Fact Sheet 049-02, http://pubs.usgs.gov/fs/2002/fs049-02/

With the core samples, scientists hope to learn whether these or other minerals allow the tectonic plates to slide past one another in the vicinity of Parkfield, while in other sections of the San Andreas the plates lock together, building up tremendous energy that periodically jolts the plates past one another in large, violent earthquakes. Eventually it is expected that hundreds or even thousands of scientists will request samples of the cores for study. A special NSF committee will evaluate these requests to ensure that this unique and limited resource is used as productively as possible.

Activating the Observatory

In 2008, the SAFOD team will install an array of seismic sensors—seismometers, accelerometers, tiltmeters, and a fluid pressure transducer—deep within the observatory hole near where small earthquakes have regularly originated. For the first time, researchers will be able to record the birthing process of earthquakes from the area where the quakes' energy accumulates. This will provide new information on the nature of the stresses that trigger earthquakes, the role of fluids in controlling faulting and quake recurrence, and the physics of earthquake initiation and rupture. Scientists hope to keep the observatory operating for the next 10 to 20 years.

Are there precursory phenomena that can be detected underground that reliably precede earthquakes? The observations and analyses made possible by the SAFOD observatory and core samples will help scientists to answer this question and to learn much more about whether and how earthquakes can be predicted.

Further information about the SAFOD project and photographs of the core samples are available on the EarthScope website at http://www.earthscope.org.