Geologists recover rocks yielding unprecedented insights into San Andreas Fault

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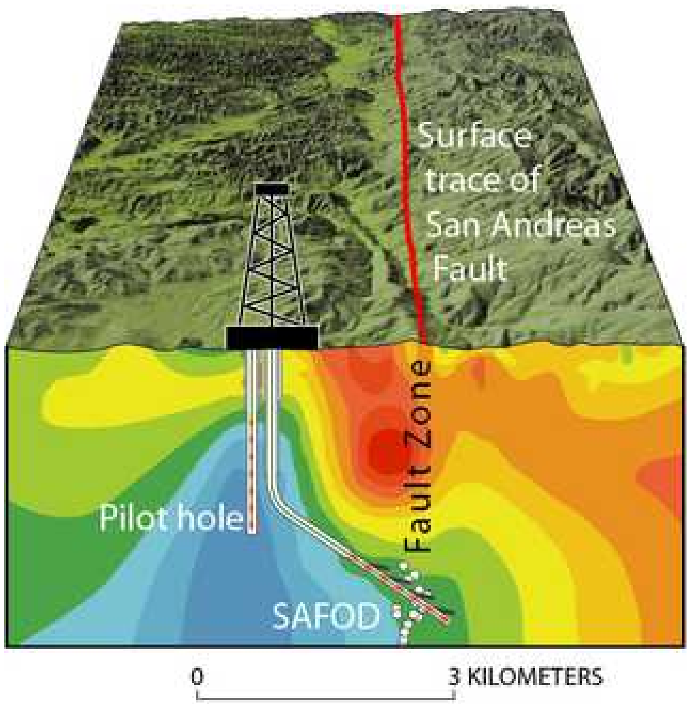

For the first time, geologists have extracted intact rock samples from 2 miles beneath the surface of the San Andreas Fault, the infamous rupture that runs 800 miles along the length of California.

Never before have scientists had available for study rock samples from deep inside one of the actively moving tectonic plate-bounding faults responsible for the world's most damaging earthquakes. Now, with this newly recovered material, scientists hope to answer long-standing questions about the fault's composition and properties.

Altogether, the geologists retrieved 135 feet of 4-inch diameter rock cores weighing roughly 1 ton. They were brought to the surface through a research borehole drilled more than 2.5 miles into the Earth. The last of the cores was brought to the surface in the predawn hours of Sept. 7.

Scientists seeking to understand how the great faults bounding Earth's vast tectonic plates evolve and generate earthquakes have always had to infer the processes through indirect means. Up until now, they could only work with samples of ancient faults exposed at the Earth's surface after millions of years of erosion and uplift, together with computer simulations and laboratory experiments approximating what they think might be happening at the depths at which earthquakes occur.

"Now we can hold the San Andreas Fault in our hands," said Mark Zoback, the Benjamin M. Page Professor in Earth Sciences at Stanford. "We know what it's made of. We can study how it works."

Zoback is one of three co-principal investigators of the San Andreas Fault Observatory at Depth (SAFOD) project, which is establishing the world's first underground earthquake observatory. William Ellsworth and Steve Hickman, geophysicists with the U.S. Geological Survey (USGS) in Menlo Park, Calif., are the other co-principal investigators.

SAFOD, which first broke ground in 2004, is a major research component of EarthScope, a National Science Foundation-funded program being carried out in collaboration with the USGS and NASA to investigate the forces that shape the North American continent and the physical processes controlling earthquakes and volcanic eruptions.

"This is tremendously exciting. Obtaining cores from the actively slipping San Andreas Fault is truly unprecedented and will allow truly transformative research and discoveries," said Kaye Shedlock, EarthScope program director at the National Science Foundation.

In the next phase of the experiment, the science team will install an array of seismic instruments in the 2.5-mile-long borehole that runs from the Pacific plate on the west side of the fault into the North American plate on the east. By placing sensors next to a zone that has been the source of many small temblors, scientists will be able to observe the earthquake generation process with unprecedented acuity. They hope to keep the observatory operating for the next 10 to 20 years.

Studying the San Andreas Fault is important because, as Zoback noted, "The really big earthquakes occur on plate boundaries like the San Andreas Fault." The SAFOD site, located about 23 miles northeast of Paso Robles near the tiny town of Parkfield, sits on a particularly active section of the fault that moves regularly. But it does not produce large earthquakes. Instead, it moves in modest increments by a process called creep, in which the two sides of the fault slide slowly past one another, accompanied by occasional small quakes, most of which are not even felt at the surface.

One of the big questions the researchers seek to answer is how, when most of the fault moves in violent, episodic upheavals, can there be a section where the same massive tectonic plates seem, by comparison, to gently tiptoe past each other with the delicate tread of little cat feet"

"There have been many theories about why the San Andreas Fault slides along so easily, none of which could be tested directly until now," Hickman said. Some posit the presence of especially slippery clays, called smectites. Others suggest there may be high water pressure along the fault plane lubricating the surface. Still others note the presence of a mineral called serpentine exposed in several places along the surface trace of the fault, which-if it existed at depth-could both weaken the fault and cause it to creep.

Zoback said the correlation between the occurrence of serpentine, a metamorphosed remnant of old oceanic crust, and the slippery nature of the fault motion in the area has been the subject of speculation for more than 40 years. However, it has never been demonstrated that serpentine actually occurs along the active San Andreas at depth, and the mechanism by which serpentine might limber up the fault was unknown.

Then, in 2005, when the SAFOD drill pierced the zone of active faulting using rotary drilling (which grinds up the rock into tiny fragments), mineralogist Diane Moore of the USGS detected talc in the rock cuttings brought up to the surface. This finding was published in the Aug. 16, 2007, issue of *Nature*.

"Talc is one of the slipperiest, weakest minerals ever studied," Hickman said.

Might the same mineral that helps keep a baby's bottom smooth also be smoothing the way for the huge tectonic plates" Chemically, it's possible, for when serpentine is subjected to high temperatures in the presence of water containing silica, it forms talc.

Serpentine might also control how faults behave in other ways. "Serpentine can dissolve in ground water as fault particles grind past each other and then crystallize in nearby open pore spaces, allowing the fault to creep even under very little pressure," Hickman said.

The SAFOD borehole cored into two active traces of the fault this summer, both contained within a broad fault "zone" about 700 feet wide. The deeper of the two active fault zones, designated 10830 for its distance in feet from the surface as measured along the curving borehole, yielded an 8-foot-long section of very fine-grained powder called fault gouge. Such gouge is common in fault zones and is produced by the grinding of rock against rock. "What is remarkable about this gouge is that it contains abundant fragments of serpentine that appear to have been swept up into the gouge from the adjacent solid rock," Hickman said. "The serpentine is floating around in the fault gouge like raisins in raisin pudding."

The only way to know what role serpentine, talc or other exotic minerals play in controlling the behavior of the San Andreas Fault is to study the SAFOD core samples in the laboratory.

"To an earthquake scientist, these cores are like the Apollo moon rocks," Hickman said. "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."

Will these new samples allow scientists to predict earthquakes" The short answer is no. But research on these samples could provide clues to answer the question of whether earthquakes are predictable. The observatory will allow scientists to begin to address whether there are precursory phenomena occurring within the fault zone.

The other fault zone, called 10480, contains 3 feet of fault gouge. It also produces small earthquakes at a location about 300 feet below the borehole. "Remarkably, we observe the same earthquake rupturing at the same spot on the fault year after year," Ellsworth said. This repeating earthquake, always about a magnitude 2, will be the focus of the observatory to be installed inside the fault in 2008.

Sensitive seismometers and tiltmeters to be installed in the SAFOD borehole directly above the spot that ruptures will observe for the first time the birthing process of an earthquake from the zone where the earthquake energy accumulates. Preliminary observations made in 2006 already have revealed the tiniest earthquakes ever observed-so small they have negative magnitudes.

In early December, a "sample party" will be held at the USGS office in Menlo Park, where the cores will be on display and scientists will offer their proposals to do research projects in a bid to be allowed to analyze part of the core.

Zoback said most of the initial testing will be nondestructive in order to preserve the samples for as long as possible. "But then, some of the material will be made available for testing that simulates earthquakes and fault slip in the lab," he said.

When not being examined, the core samples will be refrigerated and kept moist to prevent the cores and the fluid in them from being disturbed.

Source: Stanford University

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