The Overdue Quake

Unusual activity along the San Andreas hints at a long-expected tremor

By RICHARD MONASTERSKY

By rights, California earthquake scientists should be feeling mighty contrite these days.

As their first and, to date, only foray into official quake prediction, researchers at the U.S. Geological Survey issued a forecast in 1985 for the tiny town of Parkfield, Calif., located on the San Andreas fault halfway between San Francisco and Los Angeles. According to the prediction, a magnitude 6.0 earthquake would rattle Parkfield sometime before 1993.

At estimated odds of 20 to 1, it was as sure a bet as seismologists had ever seen.

The USGS and the state of California decided to spend $1 million each to wire the Parkfield area in hopes of detecting precursors of the predicted tremor. But the San Andreas stood everybody up: 1993 rolled by without the expected quake. With each subsequent New Year's Day, the hopes of researchers deflated as they struggled to keep their instruments running and to maintain funding for their experiments. Even today, the calendar continues to turn, and the Parkfield earthquake still has not struck.

Yet despite the fabulously wrong prediction, despite the millions of dollars and years of precious research time spent waiting, and despite the humiliation and loss of public trust, Parkfield researchers are displaying renewed excitement. The source of their inspiration is the San Andreas fault, which has started showing intriguing signs of activity.

Last year, it became obvious that measurements of the ground were picking up unusual stirrings at Parkfield. What's more, four medium-sized earthquakes had struck the San Andreas fault near the town, two of them within the critical zone thought to be the nucleation site for the next big quake.

Scientists are divided on how to interpret the recent changes. Some wonder whether they are catching signs of the fault preparing for a major shock—one of the key goals of the Parkfield experiment. "If we get the earthquake now, it will be really interesting, because everybody will wonder whether it had anything to do with these changes that we're seeing," says Evelyn Roeloffs, a geophysicist with the USGS in Vancouver, Wash., who managed the Parkfield prediction experiment from 1990 to 1991.

Parkfield is an agricultural hamlet consisting of a cafe, a school, a fire station, and a few other buildings, situated on a critical part of the San Andreas fault. To the north is the so-called creeping section of the fault, which rarely produces large earthquakes. There, land to the west of the fault slides by land to the east without much fanfare. South of Parkfield, however, the fault is locked, meaning that land to the west is stuck fast against land to the east. The two sides remain glued together until enough stress builds up to rip them violently apart in a major tremor.

John K. Nakata/Sight & Sound Productions

Researchers can gauge the warping of the land near the San Andreas fault by timing how long laser beams take to bounce off a nearby mountain and return.

Sitting at the junction of the creeping and locked sections, the Parkfield region had demonstrated unique behavior. Nowhere else on Earth have scientists found a place where quakes happen so regularly, with so much similarity from one major shock to the next.

Magnitude 5.5 or 6.0 earthquakes have rocked Parkfield six times in the historical record—in 1857, 1881, 1901, 1922, 1934, and 1966. Except for the shock in 1934, the quakes have come about every 22 years.

Moreover, seismic recordings of the events in 1934 and 1966 indicate that the quakes started in almost exactly the same location, beneath a landmark called Middle Mountain. Geophysicists believe that these two quakes and perhaps all other Parkfield quakes ruptured the same section of the San Andreas fault, with nearly identical characteristics each time. The records show another curious similarity. In both 1934 and 1966, a magnitude 5.0 foreshock preceded the main shock by 17 minutes.

Putting all the evidence together, William H. Bakun and Allan G. Lindh of the USGS in Menlo Park hypothesized in 1985 that Parkfield generated carbon-copy tremors, called characteristic earthquakes, every 22 years. The next one would come by 1988, plus or minus 5 years, they predicted.

The USGS, the state of California, and various universities have 20 networks of instruments around the Parkfield area to monitor the fault's vital signs. Seismometers pick up earthquakes down to magnitude 1.0. Lasers shoot across a valley to monitor warping of the broad area. Creepmeters, 30-meter-long wires strung across the fault, measure the movement of the land immediately adjacent to the fault. Chemical sensors track radon and hydrogen concentrations in groundwater. Large antennas pick up electromagnetic emanations from deep rock.

Last year, a group of Australian researchers reported something different in the data coming from three strain-sensing instruments they had installed near Parkfield. The instruments lie in boreholes and are designed to sense forces within the crust that gently deform the originally circular holes.

From 1986, when the instruments were installed, until 1993, the warping of the holes proceeded smoothly. Then, the instruments showed a marked change in the straining of the ground, says Michael Gladwin of the Commonwealth Scientific Industrial Research Organisation in Brisbane, Australia.

In the Sept. 1, 1996 GEOPHYSICAL RESEARCH LETTERS, Ross L. Gwyther, Gladwin, and their colleagues suggested that the anomalous behavior reflected deep-seated movement along that section of the San Andreas. They noted the four earthquakes of magnitude 4.0 or greater that had emanated from the fault between late 1992 and the end of 1994.

Since then, other groups have reported further changes in the signals coming from Parkfield. The creepmeters have picked up an increase in the quiet slippage of land on either side. Laser measurements have detected a boost in the rate of distortion of the valley containing the San Andreas, says John Langbein, the USGS scientist leading the Parkfield experiment.

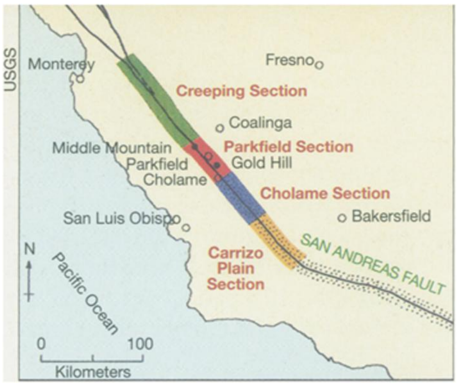
These changes could mean that the locked section of the fault is slowly starting to give way, says Gladwin. "Before failure, you will get an increased strain rate by reason of softening of the rock. These are the sorts of things you'd expect if you're trying to break something."

Computer simulations support that conclusion, according to William D. Stuart of the USGS in Menlo Park. At a meeting of the American Geophysical Union in May, Stuart described a computer model he uses to study the behavior of the San Andreas fault near Parkfield. In earlier versions of the model, Stuart represented the locked patch of fault as an oblong region that measures about 25 kilometers horizontally and 8 km vertically. Recently, he has split the locked region into two smaller sections separated by a weak zone that can creep.

As he simulated the period following a large earthquake, Stuart found the creep and strain rates decreasing. About halfway to the next model-generated quake, the locked patches started to give way around their edges, causing the land around the fault to deform faster. The kinds of signals seen recently along the San Andreas match this picture of a weakening fault becoming increasingly distorted.

Stuart remains cautious about predicting when the ground will give way in another large quake at Parkfield. "It seems to me from the data reported at the meeting that maybe we're in the last quarter of the cycle," he says.

This interpretation of recent activity could be all wet if other geophysicists are correct. Malcolm J.S. Johnston of the USGS in Menlo Park notes that the fault changed its behavior at about the same time that California experienced a shift in the weather. "This whole thing got really complicated because we went through a 7-year-long drought, which broke in 1993," says Johnston.



Caught in the middle: The Parkfield section (red) of California's San Andreas fault sits at the junction between the relatively quiet "creeping" section (green) to the north and several locked sections (blue, yellow) to the south, which produce large earthquakes.

As rains replenish groundwater, the pressure within subsurface rock increases from the weight of the water, he says. This could account for the additional straining of the rock near the fault. At the same time, the water could lubricate the uppermost part of the fault, allowing the surface rocks to slip faster than they had been. Such effects should have little influence on the deeper parts of the fault, where earthquakes are born.

"If it's rainfall, it's not of much interest. If it's tectonic [related to deeper movement of the fault], then it's really important," says Johnston. "I'm not sure how to resolve this."

Among the three sites his group monitors, Gladwin says, water has affected the measurements at one. Measurements at the other two sites were not contaminated by changes in weather, he contends. Therefore, those two sets of data are capturing tectonic changes, he argues.

Roeloffs, who studies water changes and earthquakes, leans toward Gladwin's interpretation. Weather-induced changes near the surface should wax and wane with the winter rainy season, but the strain measurements at Parkfield do not show this seasonal pattern.

Whatever the cause, the recent activity has certainly awakened researchers after an extended lull. "We've been looking for a long time. We sure would like to have something happen. When nothing happens, it's hard to maintain interest," says Johnston. "On the other hand, we have to be very careful that we don't jump on something that's hydrologically generated and claim it's tectonic and then fall on our faces in a few years when the next drought comes by."

In the end, only the San Andreas can settle this question. Even if tectonic forces are causing the current abnormalities, they will have little import in the search for precursory signals if the fault keeps quiet for many more years. In that case, researchers will have to maintain their vigil until their funding or their interest dries up. □

A predicted quake: What are the chances?

The Parkfield prediction failed more than 4 years ago, but that didn't stop two seismologists from unholstering statistical guns to shoot it down at a recent meeting.

David D. Jackson and Yan Y. Kagan of the University of California, Los Angeles chastised their peers for overlooking randomness when making the original prediction for Parkfield. That forecast, made in 1985, rested on the idea that earthquakes visit the town of Parkfield on a reasonably regular schedule, about every 22 years.

Jackson and Kagan contend that the apparent regularity of Parkfield quakes is probably just a fluke. They reached this conclusion after considering the broader picture of earthquakes throughout California.

The state's major faults can be broken into 30 segments about the same size as the Parkfield section of the San Andreas. Across Southern California, there is 0.8 quake per year with a magnitude between 5.5 and 6.5. If earthquakes occur randomly at this general rate, then about 9 of the 30 fault segments should have generated as many earthquakes as the Parkfield segment has since 1857, the date of the first recorded earthquake there.

"It would be a little unusual, but not at all impossible, that at random you would get this string of five [seemingly regular] earthquakes starting after 1857," says Jackson.

If the series of earthquakes at Parkfield is just a random sequence, then chances are slim that the expected quake will come anytime soon. Random quakes should hit only once a century there, they say.

This assessment stands in stark contrast to others, which place the chances of an earthquake at Parkfield much higher. According to the original prediction, the probability of a magnitude 6 earthquake at Parkfield now stands at 67 percent per year. In 1988, a California commission of seismologists made an estimate that today would give a 24 percent chance per year, says Jackson.

The two seismologists also warn against reading too much into a future Parkfield earthquake. Even if the quake comes next week, it will not verify the hypothesis of regular earthquakes at this site, says Jackson. To really test the idea, seismologists would have to wait for more than a century to see if the next several quakes follow the 22-year pattern. ***—R.M.***