Parkfield Keeps Secrets After A Long-Awaited Quake

Last week's moderate-to-strong earthquake in central California has justified seismologists' belief that Parkfield (population 37) was the place to wait for a sizable quake they could study. "It's right in the very middle of our network," says seismologist Malcolm Johnston of the U.S. Geological Survey (USGS) in Menlo Park, California, about the densest fault-monitoring system in the world. It cost more than $10 million over 20 years. "We got great stuff," says Johnston.

But they didn't get it entirely right. When seismologists began the Parkfield Earthquake Prediction Experiment in the 1980s, they expected to capture the next magnitude 6 in unprecedented detail within a few years. Instead, they had to wait 2 decades, a delay that casts additional doubt on models of predictable seismic behavior. And far from providing practical experience in the nascent science of short-term earthquake prediction, Parkfield 2004 seems to have given no warning that would lend hope to the field of short-term quake forecasting. All in all, Parkfield has driven home the point that even one of the world's best behaved fault segments can be pretty cantankerous.

Twenty years ago, the 25-kilometer section of the San Andreas fault that runs under the town of Parkfield seemed like a model seismic citizen. Earthquakes of about magnitude 6, noted two USGS seismologists, had ruptured the same Parkfield segment of the San Andreas in 1857, 1881, 1901, 1922, 1934, and 1966. The average of 22 years between recurrences seemed reliable enough (after rationalizing 1934's "early" arrival), so the next quake in the series should arrive in 1988, give or take 5 years. The National Earthquake Prediction Evaluation Council, a federal committee advising the USGS director, had concurred with that long-term forecast.

But the accuracy of that "give-or-take" forecast had long ago come into question. Now, 16 years after the forecast's most probable date, official quake forecasts say the likelihood of the next Parkfield quake occurring in 2004 was just 5% to 10%. The delay only reinforces the idea that "earthquake recurrence is less regular than had been hoped," says seismologist William Ellsworth of the USGS in Menlo Park. "There are real practical limits to the type of forecast we made at Parkfield."

The limits of quake forecasting became clearer still when seismologists looked at the magnitude-6.0 event on 28 September, which caused little damage to the sparsely populated region 75 kilometers inland from the coast. Seismologist Ross Stein of USGS Menlo Park recalls a number of 1980s ideas about quakes that would have favored predictability. They included the idea that quakes could recur with some regularity; that the more time a fault had to build up strain, the larger the eventual quake would be; and that the same fault segment would rupture in the same "characteristic" quake—the same magnitude and same section of fault—each time.

Of these and other optimistic quake ideas, "the only one still alive at Parkfield is the characteristic earthquake," says Stein. The quake's timing certainly wasn't regular. And to judge by the amount of fault strain accumulated in the intervening 38 years, Parkfield 2004 should have released 20 times the energy that it did and have been a magnitude 6.7.

Even the characteristic aspect does not hold up in detail, Stein notes. The same 25 kilometers of fault broke as in 1966 and 1934, producing a similar-magnitude quake. But in 2004 the rupture started at the southeast end of the segment and ran northwestward, the opposite direction from those that struck in '34 and '66. Parkfield earthquakes—once considered among the most regular of quakes—"are certainly not peas in a pod," observes Menlo Park's Johnston.

Unfortunately for the prediction experiment at Parkfield, the individuality of quakes there extended to geophysical activity before the main shock, activity that seismologists once hoped could be used to predict the main event. The 1966 Parkfield main shock was preceded by a number of possible and even certain precursors. They included a flurry of microearthquakes 2 to 3 months before, cracks in the ground along the fault at least 11 days prior, and a magnitude-5.1 foreshock 17 minutes ahead of the main shock. A magnitude-5 foreshock preceded the 1934 Parkfield quake by 17 minutes as well.

Nothing obvious heralded the 2004 Parkfield quake. "At the moment, nothing has jumped off the screen,"
The sweet smell of success greeted Richard Axel and Linda Buck this week as the two U.S. neuroscientists were awarded the 2004 Nobel Prize in physiology or medicine for their pioneering work on the sense of smell.

The pair first worked together as professor and postdoc in Axel’s lab at Columbia University in New York City and have since worked independently to answer fundamental questions about how the brain notices odors wafting through the air. Both are now investigators of the Howard Hughes Medical Institute. Their work has enticed researchers from other fields to study olfaction. “They’re magnificent scientists who made a key discovery that opened a big area of research,” says Solomon Snyder, a neuroscientist at Johns Hopkins University in Baltimore.

That discovery, reported in a landmark 1991 paper in Cell, was the first description of olfactory receptors, the proteins responsible for turning a smell into something the brain can understand. The receptors are embedded on the surfaces of neurons at the back of the nasal cavity. When the receptors bind to odorant molecules sucked into the nose, they trigger a biochemical cascade that ultimately generates a nerve impulse that transmits information to the brain. The paper described a family of about 1000 genes that encode olfactory receptors in rats. The receptor proteins belong to a large class of proteins already familiar to researchers for the variety of roles they play in cell signaling.

Some previous work had suggested that olfactory receptors belonged to this class—G protein–coupled receptors—but the sheer number of olfactory receptors was far greater than anyone had expected, says Columbia’s Stuart Firestein, who was not involved in the research. The human visual system, he points out, is able to distinguish myriad colors using only three types of receptors—ones tuned to blue, green, and red. (Subsequent research has revealed that humans have fewer working olfactory receptor genes than rodents—only about 350.) “The work was clearly a breakthrough,” says Peter Mombaerts of Rockefeller University in New York City, who joined Axel’s lab as a postdoc after reading the 1991 paper and went on to start his own olfactory research laboratory.

Identifying the receptors paved the way to understanding how information about smell is organized in the brain. Independently, Axel and Buck, who is now at the Fred Hutchinson Cancer Research Center in Seattle, Washington, determined that each olfactory receptor neuron expresses one—and only one—olfactory receptor protein. This provided an essential clue to understanding how the brain distinguishes smells. Each odor activates a unique combination of olfactory neurons, allowing the brain to distinguish, say, a good apple from a rotten one.

Axel, 58, and Buck, 57, are both known among colleagues as extremely thorough scientists. “Richard will never publish anything unless it’s a really important step forward,” says Snyder. The same goes for Buck, who becomes only the sixth woman to win the physiology or medicine Nobel in its 103-year history.

Although the duo’s work has answered important questions about the sense of smell, it has also posed additional puzzles. Researchers have just begun to make inroads, for example, toward understanding how an olfactory neuron chooses which receptor gene to express (Science, 19 December 2003, p. 2088). The layered mysteries of the olfactory system are part of the draw for Buck. “It’s a wonderful, never-ending puzzle,” she says. “I can’t think of anything else I’d rather be working on.”

—RICHARD A. KERR

2004 NOBEL PRIZES

Axel, Buck Share Award for Deciphering How the Nose Knows

Smells like Stockholm. Richard Axel (left) and Linda Buck share the 2004 Nobel Prize in physiology or medicine for their research on olfaction.