How Many More After Northridge?

A continuing surge of destructive quakes in Los Angeles presents a greater cumulative hazard there than the Big One, and researchers wonder if the worst is yet to come

The earthquake that struck the San Fernando Valley east of Los Angeles last week wasn't the fabled Big One, but residents of Northridge and vicinity might have wished it was. The moderate, magnitude 6.6 earthquake, generated by a modest-sized fault that broke directly beneath the LA suburb, left 51 dead, 4000 injured, tens of thousands of households without water and electricity, and $15 billion or more in damage—greater losses than researchers expect for that area from a magnitude 8+ earthquake on the San Andreas fault, 50 kilometers away. The damage produced by a great San Andreas earthquake would, of course, be more widespread, but what the San Fernando Valley experienced could soon become all too familiar in other parts of the Los Angeles basin, too.

That's the grim implication of a report on earthquake hazards in Southern California that was being prepared by the Working Group on Southern California Earthquake Probabilities even as last week's quake struck. The Northridge quake dramatically illustrated one of the working group's main conclusions: that faults rupturing far from the San Andreas but right beneath the feet of Angelenos represent a threat to the city comparable to that of the traditional focus of earthquake anxiety, the San Andreas. As last week's toll showed, proximity makes all the difference in earthquakes. In Los Angeles, "the most intense shaking will come from earthquakes beneath" the city, says seismologist Thomas Heaton of the U.S. Geological Survey (USGS) in Pasadena. And the threat looms larger because Northridge may be only the latest and largest sign that a new surge in seismic activity is under way within the fault-riddled Los Angeles basin.

What researchers still don't know, because of the geologic complexity of the basin and the mysterious driving force behind the recent activity, is just how often to expect Northridge-sized earthquakes—and whether still larger events might be in store for the Los Angeles region, population 12 million. "This is not the largest earthquake you could imagine beneath the city," says Heaton. "There is some feeling they could go well up in the magnitude 7 range." If so, Los Angeles may have to get used to a new definition of the Big One: a smaller but much closer quake that would rank as the United States' biggest disaster ever.

SPECIAL REPORT

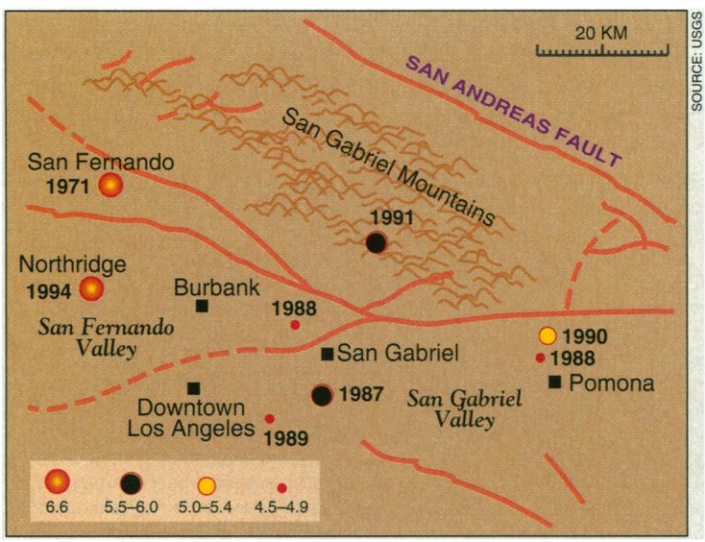
A news report on the recent outcry over early radiation experiments begins on page 470. The News & Comment and Research News sections are combined into a single News section for this issue.

Not that the San Andreas isn't still a threatening presence for Angelenos. That fault—where the Pacific plate slips past the North American plate, carrying with it a sliver of western California—could certainly give Los Angeles a good, long shaking. And its wandering course through California is ultimately to blame for last week's quake and for the complex geology that makes future risk so hard to assess. If the San Andreas cut straight through California and the two plates ran exactly parallel to each other, no other faults would be needed to take up the motion. Los Angeles would be safer, and seismologists' lives simpler. But instead of taking a straight shot toward the northwest, the San Andreas jogs to the west as it passes Los Angeles. Crust sliding northwestward on the west side of the San Andreas encounters this "Big Bend" and is squeezed. As a result, the Los Angeles region is being shortened by perhaps 10 to 15 millimeters per year from the ocean to the San Andreas as the crust is forced around the Big Bend.

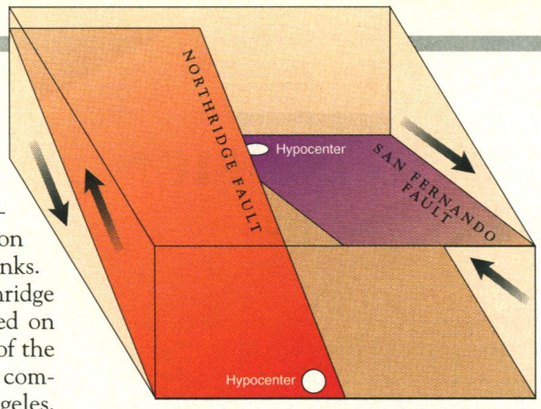
The stresses of making the turn around the Big Bend have riddled the Los Angeles region with fractures: About 100 major active faults have been identified so far. Most are so-called thrust faults, inclined fractures created by compression. During earthquakes, the wedge of crust above the thrust fault shoves abruptly over the lower wedge. The motion shortens the crust and reshapes it, narrowing valleys and pushing up mountains. In 1971, for example, the San Fernando quake—centered 25 kilometers northeast of Northridge—pushed up the San Gabriel Mountains by 2 meters.

That quake, and the 1987 Whittier Narrows quake 30 kilometers east of downtown Los Angeles, which also took place on a thrust fault, were the first in a series of warning shots that drove home the danger of the faults beneath Los Angeles. Then came a surge of smaller thrust earthquakes along the northern Los Angeles basin beginning in 1987: A progression of magnitude 4 and 5 quakes swept across the San Gabriel Valley, east of the San Fernando Valley, and into the San Gabriel Mountains beyond. According to studies by seismologist Lucile Jones of the USGS in Pasadena and her colleagues, the valley had been comparatively quiet before that (*Science*, 3 January 1992, p. 30). She and others think that the volley of quakes was part of a multi-year increase in seismic activity, perhaps triggered by some change in the overall pattern of deformation.

The San Gabriel area fell quiet in 1992 and 1993, but if anybody's attention was drifting back to the San Andreas, last week's quake recaptured it. The 25-kilometer patch of fault that broke upward from 14 kilometers beneath Northridge generated what seismologist Thomas Hanks of the USGS in Menlo Park calls "hellish ground motions"—some of the strongest



A prelude or just a flurry? The Northridge earthquake has broadened the surge of recent moderate quakes that began in 1987, but it hasn't revealed whether an even larger one is on the way. Even a continuation of the recent activity could be disastrous.



SOURCE: USGS

Quite a pair. The thrusting of one crustal wedge over another during the Northridge quake mimics that of the adjacent 1971 San Fernando rupture; the two may be connected.

shaking ever recorded in the Los Angeles basin. It was so strong, particularly in the vertical direction, because Northridge was right on the chunk of crust being shoved upward. "There really is something special to being right on top of a thrust earthquake," says Hanks. The Big One wouldn't shake Northridge nearly as hard, especially if it occurred on what is now the most suspect section of the San Andreas: its southern segments, a comforting 100 kilometers from Los Angeles. (The 3 million residents of San Bernardino and Riverside, who live astride the southern San Andreas fault system, might not find that prospect so comforting, however.)

But while the Northridge earthquake has bolstered seismologists' conviction that homegrown quakes pose a major threat to Los Angeles, it isn't helping them judge the size of the threat. Says David Schwartz of the USGS in Menlo Park, "It's just not as easy as it first looked" when he and his colleagues on the Southern California working group first sat down in late 1992.

One of the group's primary goals was to look beyond the risks posed by the San Andreas and make the first official evaluation of seismic hazard from the myriad small faults webbing the Los Angeles basin and other parts of Southern California. To gauge the hazard, they divided the region into 65 zones. For each one, the group combined geologic evidence of fault motion over periods as long as millennia—as recorded, for example, in ground ruptures—with geodetic measurements of how the crust is deforming today. By comparing this geologic evidence with the historical record of quake frequency, the researchers hoped to get a consistent picture of how each zone had behaved in the past, which could then be extrapolated into the future.

Instead, the two kinds of evidence disagree. The 150-year historical record includes too few earthquakes to account for the rate of deformation implied by the much longer geologic record, says Keiiti Aki of the University of Southern California, who is a working group member. Based on the geologic record, Southern California should experience magnitude 6.5 quakes every 6 years—twice the historical frequency. For magnitude 7's, the geologic record predicts an event every 10 years, three times the historical frequency.

The most benign explanation for the puzzle, says Aki, is that much of the strain away from the San Andreas—such as the compression of the Los Angeles region—may be relieved without earthquakes. Whereas most strain on the San Andreas itself is known to be released in earthquakes, notes Schwartz, no one is so sure about other faults, such as the thrust faults beneath Los Angeles. They might slip slowly and thus aseismically, he says. But Schwartz's guess is that there, too, much or most of the slip takes place in earthquakes.

That would leave seismologists with less comforting alternative explanations. One is that Southern California's relative quiescence over the past 150 years was an anomalous lull. Schwartz notes that the San Francisco Bay area was far more seismically active in the 19th century, before the great earthquake there in 1906, than it was after. And things began picking up again there about 30 years ago. With that much variability in northern California, says Schwartz, perhaps Southern California's past will prove to be misleading, and the recent surge in activity will be only a taste of what is to come.

But there may be a still more disturbing explanation of the conflict between geologic and historical forecasts, says David Jackson of the University of California, Los Angeles, chair of the working group. Jackson argues that the scarcity of earthquakes in the historical record implies that some fault rupturing takes place in events too rare to show up in the historical record—great, magnitude-8 earthquakes—or to be recognized in the largely unexplored geologic record off the San Andreas. For example, the thrust faults responsible for the San Fernando, Northridge, and smaller quakes along the north flank of the Los Angeles basin might sometimes break all at once instead of separately. If so, last week was just a wakeup call for a really big one lurking in Los Angeles' future.

The working group isn't ready to commit itself to such a grim scenario. It delayed its report for months as it tussled with these options, but it finally gave up, says Aki. When the report appears this spring, it will simply lay out the alternatives. With the Northridge earthquake fresh in their memories, Angelenos should find it interesting reading.

–Richard A. Kerr

FRENCH AIDS SCANDAL

Letters Provoke Unintended Response

PARIS—When nearly 100 researchers wrote last week to President François Mitterrand, asking him to pardon the four doctors convicted for their role in France's HIV-contaminated blood scandal, they could not have anticipated the angry public reaction their letter touched off. Two of the convicted physicians, Jean-Pierre Allain and Michel Garretta—both formerly of the National Center for Blood Transfusion—are currently in prison, and from the tenor of French press coverage, much of the public wants them to stay there.

"Justice has been done," remarked Simone Veil, France's minister of health and social affairs. "Those voices that are expressing themselves today should have expressed themselves earlier." The Stéphane and Laurent Association, founded by the father of two hemophiliac children who died of AIDS, used the occasion to launch its own petition calling for a much wider prosecution of doctors, politicians, and drug manufacturers involved in the affair.

But French immunologist Jean-Claude Gluckmann, who drafted the letter together with fellow HIV researcher Françoise Barré-Sinoussi, says researchers were not given a chance to make their views known during the trial and subsequent appeal (*Science*, 30 October 1992, p. 735 and 23 July 1993, p. 422). "The court did not allow expert scientific testimony about the decisions that were made," he told *Science*. For example, Gluckmann says, the physicians were accused of giving contaminated clotting factors to already seropositive hemophiliacs, but the court refused to hear evidence suggesting that this was not harmful because the data had come from experiments with macaques and not humans. As a result of such rulings, the scientists argue in their letter, the four doctors were victims of "trial by the media, where sensationalism dominated to the detriment of accuracy, and passionate debate took the place of objective facts."

Similar claims are made in a second letter sent to Mitterrand last week, signed by 32 Nobel laureates and six other well-known scientists, asking a pardon for Allain alone. This campaign was organized by Cambridge University molecular biologist Max Perutz, a Nobel laureate in chemistry, and based on a detailed review of evidence presented in the case by hematologist Robin Carrell, Allain's department head at Cambridge and one of his staunchest defenders. "From the evidence Carrell showed me, I became convinced that Allain is innocent," Perutz told *Science*.

–Michael Balter

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