Harbingers of the Coalinga Earthquake

An encircling pattern of earthquakes preceded the damaging shock near Coalinga, suggesting how some earthquakes might be anticipated

Another California earthquake sneaked up on geophysicists last May. The moderate shock that heavily damaged the town of Coalinga gave no warning that it was about to strike, but seismologists can now see that for 8 years clusters of smaller earthquakes were marking the edges of the eventual rupture. This first recognition of the classic doughnut pattern of precursory seismicity in California may aid in forecasting only a small portion of future earthquakes but offers reassurance that the search for earthquake precursors in California will not go unrewarded.

The magnitude 6.5 Coalinga earthquake on 2 May had no foreshocks in the usual sense. Jerry Eaton of the U.S. Geological Survey in Menlo Park, California, will report at next month's American Geophysical Union meeting that he can exclude the possibility of any seismic activity larger than magnitude 1.5 immediately before the main shock. Among thrust earthquakes in California like Coalinga's, during which a block of crust is thrust over an underlying block, only one has been preceded by a foreshock.

The Coalinga main shock may have lacked foreshocks immediately before it, but the increasing crustal stress that triggered it had peppered the general area with smaller shocks in earlier years. These earthquakes of magnitude 4 and 5 made the Coast Ranges between the Great Valley and the San Andreas fault one of the most seismically active areas in California. What that meant was not clear. Roughly east-west compression of the crust was clearly squeezing the Coast Ranges upward the way a rug on a slippery floor folds into a series of ridges. Equally clearly, the folds had not broken into the long faults that could produce large earthquakes. All this was curious but not provocative enough to spend precious resources expanding the monitoring network.

Chinese seismologists might have reacted differently to the seismic hot spot in the Coast Ranges. Lacking a single, long fault like the San Andreas on which to focus their prediction efforts, the Chinese must look for other signs of where to concentrate their monitoring networks. One of a variety of apparent clues has been unusual geographic patterns of seismicity, especially a pattern of high activity encircling a core of seismic quiescence where the main shock would be expected to strike. Called a Mogi doughnut by Americans, after Kiyoo Mogi of Tokyo University who first drew attention to the phenomenon, such a pattern of magnitude 5 earthquakes served as a basis for the prediction of the magnitude 7.2 Songpan earthquake of 1976 8 months in advance.

In 1975, the Mogi doughnut of magnitude 4 and 5 earthquakes began to encircle the eventual site of the Coalinga shock, the fourth and final cluster of activity striking the northeastern edge of the eventual aftershock zone in October 1982. Through it all, the future aftershock zone remained relatively quiet. Its northwest half had actually been devoid of events larger than magnitude 3.0 since 1930, according to Gregory Beroza and his colleagues at the University of California at Santa Cruz. In hindsight, that appears ominous, but, ignorant of the large fault now known to be buried beneath Anticline Ridge, seismologists presumed that a larger earthquake could not follow.

One way to visualize the behavior of the crust as the doughnut formed is to follow the concentration of stress in an asperity, a strong section of fault that resists increasing stresses better than surrounding rock (*Science*, 2 November 1979, p. 542). In the case of Coalinga, the asperity would have been at the hole in the doughnut. As compressive stresses squeezed the Coast Ranges harder and harder, weaker patches of crust surrounding the asperity failed, producing the encircling clusters of moderate earthquakes and their aftershocks. The failure of each patch passed the stress to the asperity, concentrating it there until even the asperity had to fail. That produced a shock 30 times more energetic than any of those that formed the doughnut.

Without too much trouble, one can see another doughtnut, as yet not filled by a large earthquake, that is formed by the 1974, 1975, 1982, and 1983 clusters. But seismologists caution that there is much they do not know about doughnuts. The existence of a doughnut depends on the magnitudes included in a seismicity map. Which magnitudes are important? How often do doughnuts form without a subsequent damaging earthquake?

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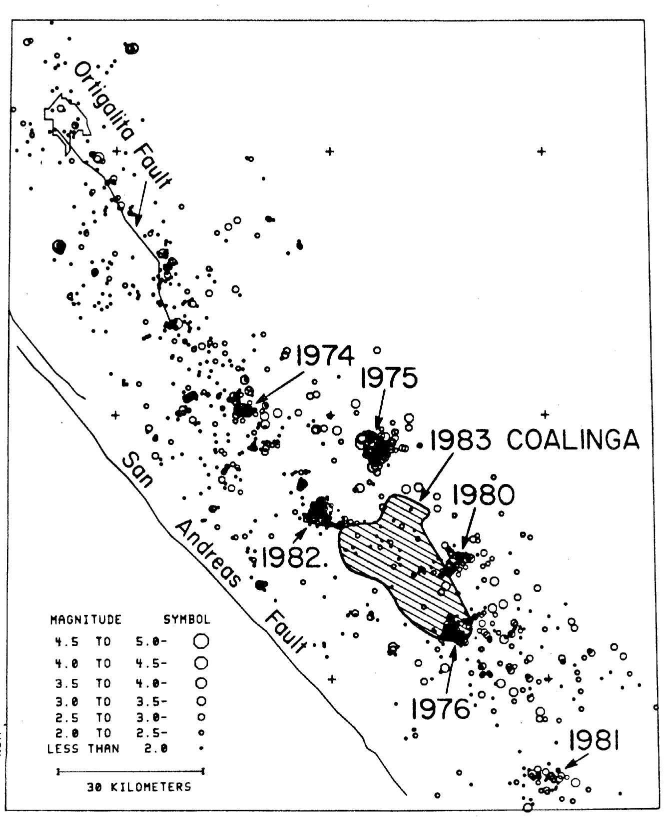

J. P. Eaton

Coalinga's doughnut

This seismicity map of the Coalinga area of the central Coast Ranges (midway between San Francisco and Los Angeles) includes the earthquakes recorded from January 1982 through April 1983. The seismicity associated with the nearby San Andreas fault has been removed to emphasize the clusters of activity that encircled the eventual site of the May 1983 Coalinga earthquake. The hatched area is the aftershock zone of that event. The dated clusters of activity are moderate earthquakes and their aftershocks or earthquake swarms. Coalinga is just outside the aftershock zone to the southwest.