Earthquake Prediction and Control

There is as yet no reliable method for predicting exactly when and where earthquakes will occur. But qualitative predictions of where earthquakes may be expected are possible, and measurements, with strain gauges and other instruments, of motion in the earth's crust before and during earthquakes may eventually allow more detailed prediction, and possibly some warning, of these events. Preliminary experiments conducted in the Rangely oil field of western Colorado have indicated that under some circumstances earthquakes can be controlled, although it is not known whether the technique can be applied to major fault zones. But it seems certain that large earthquakes will occur repeatedly in Turkey, western South America, California, Japan, and other populated areas—regions which, according to plate tectonics, correspond to the boundaries of the large crustal plates that constitute the earth's surface. Hence methods for the prediction and control of earthquakes, and measures to limit the destruction when they do occur, are accorded a high priority by many earth scientists. And after many years of fragmentary governmental support for this research, it appears that an expanded program may finally be forthcoming.

Interest in earthquake prediction has been renewed by the advent of plate tectonics. Most of the deformation in the earth's crust and most of the world's earthquakes are now known to occur along the boundaries between the plates, which are moving relative to each other at average rates of between 1 and 15 centimeters per year. In the short term —tens or hundreds of years—this movement becomes blocked in certain areas; the accumulated strain is often released by very large earthquakes.

Prior to plate tectonics, most attention had been concentrated on regions where earthquakes had occurred in the last 50 years, on the assumption that these were likely sites of future seismic activity; now, however, the opposite view prevails. The San Andreas fault in California, for example, is thought to have been moving at the rate of 5 to 6 centimeters per year for thousands of years, but there are places where no movement has been observed for the last 100 years. These locked sections of the fault—identified by their "seismic gaps," or the lack of recent large earthquakes and slippage along the fault—are now thought to be likely sites for future earthquakes. Only the statistical probability of high earthquake risk can be determined, and it is not possible to say precisely when an earthquake will occur in a given area. But seismologists can locate crucial areas to instrument for earthquake studies.

Three types of instruments—accelerometers, strain gauges, and tilt meters (that record changes in the slope of a piece of ground)—are commonly used to study earth motions. New instruments are being developed, such as strain gauges that are based on laser interferometry and that can be placed in seismically interesting areas more readily than older instruments. Seismologists hope that observations before and during an earthquake will reveal some premonitory deformation or other characteristic signals that could be used to predict future quakes. To date, however, relatively few instruments are in place and are actively monitoring; even fewer earthquakes have occurred near enough to these instruments to provide useful information. In Japan, where an earthquake prediction program has been in existence for several years, scientists have observed what seems to be an accelerating movement of the earth's surface just before the event; they have also apparently been able to predict moderate earthquakes in one area several months in advance. But in the United States, research on quake prediction is still in a very preliminary stage. More rapid progress may occur if a larger program of earthquake research—for which a supplemental budget request is now being considered—is approved.

Earthquake Experiments

In 1966, Denver, Colorado, began experiencing a series of small and medium-sized earthquakes. These quakes were later attributed to fluid being pumped under high pressure into deep wells which were being used by the U.S. Army to dispose of nerve gas waste products. Several geophysicists proposed that the quakes, which did not cease until some months after pumping was halted, could have been stopped by reversing the pumping on the wells. The proximity of Denver ruled out any active experiments, however, and a more remote site was sought.

In 1969, Barry Raleigh and Jack Healy of the U.S. Geological Survey in Menlo Park, California, began monitoring small earthquakes that were occurring along a fault system in the Rangely oil field in western Colorado at the rate of 15 to 20 per week. The fluid pressure in the field had been raised as much as 60 percent above the normal hydrostatic pressure by fluid injection, as part of the secondary production of oil from the field. After a year of monitoring, the flow was reversed and water was pumped out of wells near the fault for a 6-month period. The result, according to Raleigh, was a dramatic drop in the number of earthquakes, which have stopped altogether near the wells and have decreased to about one per week further away. Pumping has now been reversed again, to see whether the quakes increase as pressure builds up.

The basic idea underlying the experiments, and the results so far seem to confirm this idea, is that the fracture strength of the rock (and hence the resistance to sliding along the fault) is inversely related to the pore pressure in the rock, so that raising the fluid pressure will lower the point at which the rock will fracture under stress. Very little is known about the type of rock or fluid pressure in the major fault zones, such as the San Andreas (which is in most places much deeper than the Rangely fault), and therefore it is too early to say whether these techniques could be applied to control large earthquakes. But seismologists are excited about the possibilities; part of a fault, for example, might be locked by pumping water out at two locations, and the intervening section caused to slip by injecting water along it. Since the size of an earthquake depends on the length of a fault that ruptures at one time, the goal would be to limit earthquakes to magnitude 4 or 5 on the Richter scale by controlling the length of the fault that was allowed to slip at one time.

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