

Predicting earthquakes and earthquake hazards: why so little success?

Charles Richter's observation that "only fools and charlatans predict earthquakes," reflects that fact that despite more than 100 years of effort, seismologists remain unable to do so. Meaningful prediction involves specifying the location, time, and size of an earthquake before it occurs, to greater precision than expected purely by chance from the known statistics of earthquakes in an area. To date, highly touted and expensive programs in the U.S. and elsewhere have failed. Two approaches have been used. In one, the known rate of motion accumulating across a fault and the amount of slip in past earthquakes is used to infer when the next earthquake will occur. Unfortunately, the intervals between earthquakes are so variable that the predictions are accurate to no better than a hundred years. The second approach is to identify observable changes in the earth that precede earthquakes. Various precursors have been suggested, and may have been real in certain cases, but none have proved to be a general feature preceding all earthquakes, or to stand out convincingly from the normal variability of the earth's behavior. Thus it is unclear whether earthquake prediction is possible. In one hypothesis, all earthquakes start off as tiny earthquakes, which happen frequently, but only a few cascade via random failure into large earthquakes. If there is nothing special about those tiny earthquakes that happen to grow into large ones, the interval between large earthquakes is highly variable and no observable precursors should precede them. This hypothesis draws on ideas from nonlinear dynamics or chaos theory, in which small perturbations can grow to have unpredictable large consequences. Thus earthquakes would be analogous to the meteorological idea in which the flap of a butterfly's wings in Brazil might set off a tornado in Texas, or in general that minuscule disturbances do not affect the overall frequency of storms but can modify when they occur. The frustrations of this search have led to the observation that "it is difficult to predict earthquakes, especially before they happen."

As a result, seismologists have largely abandoned efforts to predict earthquakes on time scales less than a few years, and turned to trying to make longer-term forecasts. The challenge is illustrated by the 2011 Tohoku earthquake. This was another striking example - after the 2008 Wenchuan and 2010 Haiti earthquakes - of highly destructive earthquakes that occurred in areas predicted by earthquake hazard maps to have significantly lower hazard than nearby supposedly high-risk areas which have been essentially quiescent. Given the limited seismic record available and limited understanding of earthquake mechanics, hazard maps have to depend heavily on poorly constrained parameters and the mapmakers' preconceptions. However, because these preconceptions are often incorrect, hazard maps often fail.