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SCIENCE

Observing and Predicting Earthquakes

We live on a restless planet. Continents are in motion, as they have been for at least 130 million years and as they are likely to be for a long, long time. These motions give rise to earthquakes, notably around the rim of the Pacific Ocean, but also in other areas. During this century, earthquakes have killed hundreds of thousands of people and caused tremendous property damage. Most are of small intensity, and these occur frequently. In a given locality, the really large events come at intervals of perhaps 50 years or more. Experts believe that, by the end of this century, California will probably experience a killer earthquake causing as much as $20 billion in damage.

After large earthquakes in the past, there have been in-depth studies of the event and its sequel (for example, the Alaskan earthquake). However, studies aimed at prediction have enjoyed relatively less attention. We have learned some lessons from past observations, but we must learn much more if we are to minimize future damage and loss of life.

One desirable goal is the ability to predict both the timing and the intensity of major earthquakes. Recent research has been moving us closer to this goal. Earlier work had indicated that premonitory events precede earthquakes. There have been reports of a change in frequency of occurrence of small local earthquakes preceding a large one. Other effects noted have included changes in tilt, fluid pressures, radon emission, and electric and magnetic fields. Japanese and Soviet scientists have been particularly active in observing these phenomena. In 1969, the Soviet scientists found an effect that seems especially important—a premonitory change in ratios of two seismic velocities, the compressional velocity (V_p) and the shear velocity (V_s). The ratio of V_p to V_s changed by about 15 percent in the periods preceding moderate-sized earthquakes in the Garm region of central Asia. American geophysicists attending the 1971 international meeting in Moscow learned of these findings and have now made similar observations in the United States.

American geophysicists have also developed a model to explain the premonitory phenomena (see p. 851). This involves the changes in strength and in velocities of seismic waves in rocks that are related to the presence or absence of water.

The new explanations tie in very well with field observations that have been made in Colorado. The Denver earthquakes of the 1960's were triggered by deep injection of waste fluids. More recently, experimental injections and withdrawals have been conducted in the Rangely Oil Field. These have demonstrated that stresses can be relieved by injections of water which trigger small, harmless events. On withdrawal of fluid, the earthquakes stopped.

These evidences of progress in prediction are important and interesting, but they are only a beginning. The new information seems applicable to shallow earthquakes but may not be relevant to deep events. Moreover, even with the shallow earthquakes, there may be differences in those that are strike-slip and those that represent overthrusting.

Moreover, the very large events could have features that are qualitatively different from the smaller earthquakes, which are readily studied. If we wish to understand and be able to predict the rare, large earthquakes, we should be seeking premonitory signals everywhere that earthquakes have been known to occur. We should invest in new ideas, development of new instrumentation, and in the establishment of observing networks. Other countries should be encouraged to do likewise, and we should assist them whenever feasible.

The task of minimizing earthquake disasters is a large one and may require decades to complete, but what are decades in a span of millions of years?—PHILIP H. ABELSON