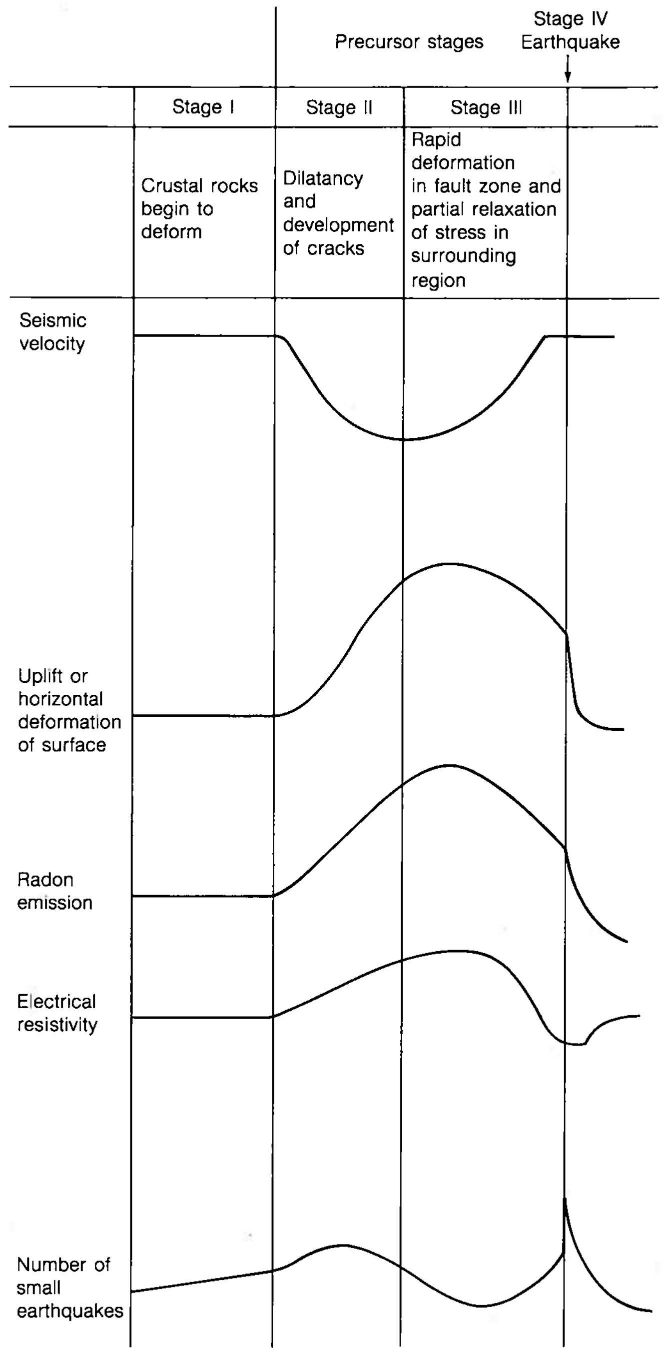

Figure 17-27
Earthquake precursors and their relation to dilatancy. When rocks are stressed by crustal forces, they are deformed elastically (stage I). Before faulting occurs, cracks open up, the rocks become dilatant and expand (stage II). This expansion is manifested as uplifting or tilting of the surface. The opening of cracks also results in a reduction in seismic velocity and an increase in the transfer of radioactive radon gas to water percolating through the rock. Small earthquakes increase in number. Stage II can serve for long-term predictions, years in advance of a great earthquake. In the third stage, rapid deformation occurs along portions of the fault that will break, relaxing the stress in the surrounding rock, so that cracks close. Uplift or tilting would decrease or reverse in direction, seismic velocity would increase, and small earthquakes would decrease in number. Days or hours before the fault breaks, the number of small earthquakes increases rapidly, signalling the imminence of the earthquake. [Modified from the work of V. I. Myachkin and G. A. Sobolev of the USSR.]

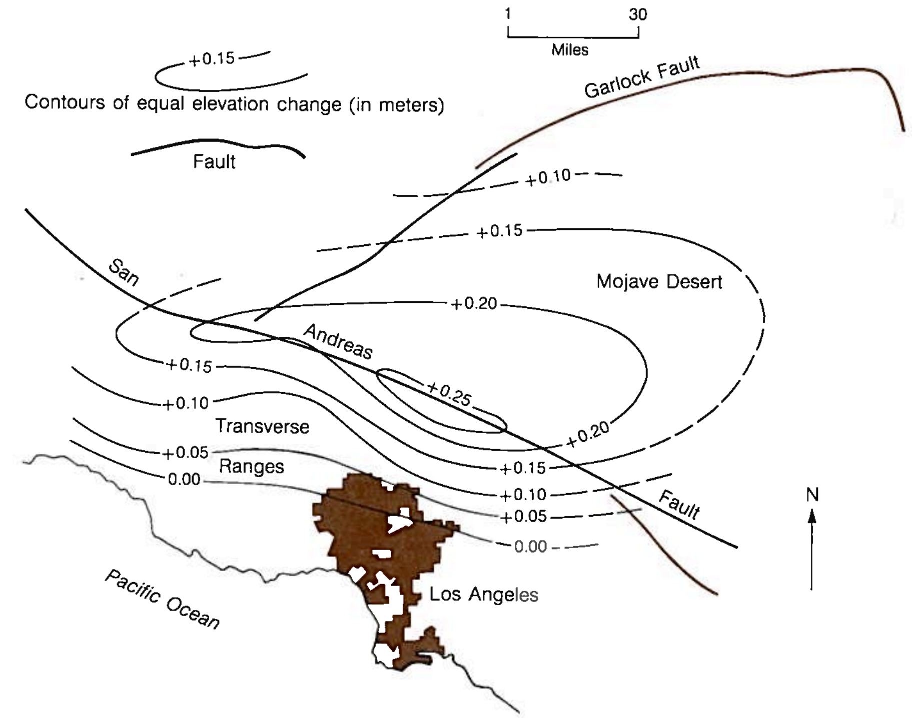

Figure 17-28
Contours of uplift that has taken place in the vicinity of Los Angeles since 1960. Some seismologists are concerned that this extraordinarily large and rapid uplift is indicative of precursory stage II, signalling a major earthquake. [After U.S. Geological Survey.]

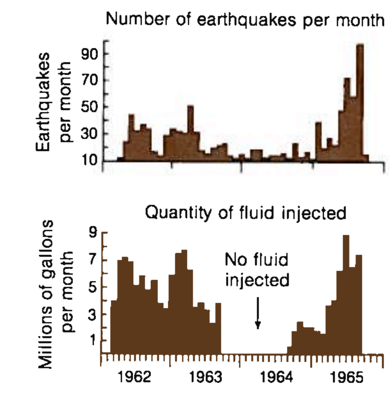

Figure 17-29
Correlation found by D. M. Evans between quantity of waste water injected into a deep well and number of earthquakes per month in the vicinity of Denver, Colorado. This unplanned "experiment" opens the distant possibility of earthquake control by fluid injection.

fluids "unlocked" a pre-existing fault and strains that had built up earlier were released. Perhaps someday earthquake-control wells will be spotted every few miles along the San Andreas fault, and fluid injected so as to cause the fault to creep continuously and slip frequently in controlled earthquakes rather than allowing strain to build up over periods of 50 to 100 years and be released in a large, damaging shock. Much research will be needed to achieve this important (and perhaps impossible) goal; the first steps have already been taken.

EXPLORING THE INTERIOR WITH SEISMIC WAVES

To appreciate the importance of seismic waves in revealing the properties of the interior, one need only reflect on what the state of knowledge would be in the absence of this key tool. We might surmise the existence of a crust from the observation that most surface rocks are generally light and felsic or mafic compared to the more dense ultramafic intrusions that seem to invade the surface layers from below, but we could only speculate on its thickness. The sea-floor crust would of course be terra incognita. We probably would have guessed the mantle to be composed of ultramafic rocks, but could only wonder about its physical state, structure, and thickness. From the clues provided by iron meteorites, the large relative abundance of iron in the cosmos, and our efforts to explain the Earth's density and magnetic field, we might have been led to hypothesize the existence of a molten iron core, but this would have been argued extensively. Its depth would be uncertain, and the inner solid core would be unknown. Continental drift and sea-floor spreading would be debated, but the overall concept of plate tectonics—especially the fate of plates in subduction zones—would probably have escaped us.

Types of Seismic Waves. As early as the 1800's, mathematicians proved with pencil and