UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

Earthquake Information Bulletin

November-December 1983, Volume 15, Number 6

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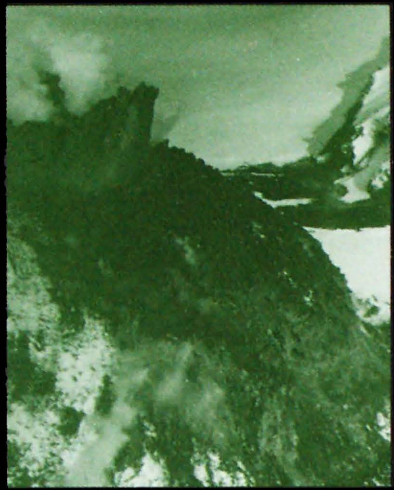

Cover: *The dome in the crater of Mount St. Helens showing the Peléan spine that grew in February 1983; Mount Rainier is in the background. (Photograph by Tom Casadevall.)*

Faulting Arrested by Control of Ground-Water Withdrawal in Houston, Texas

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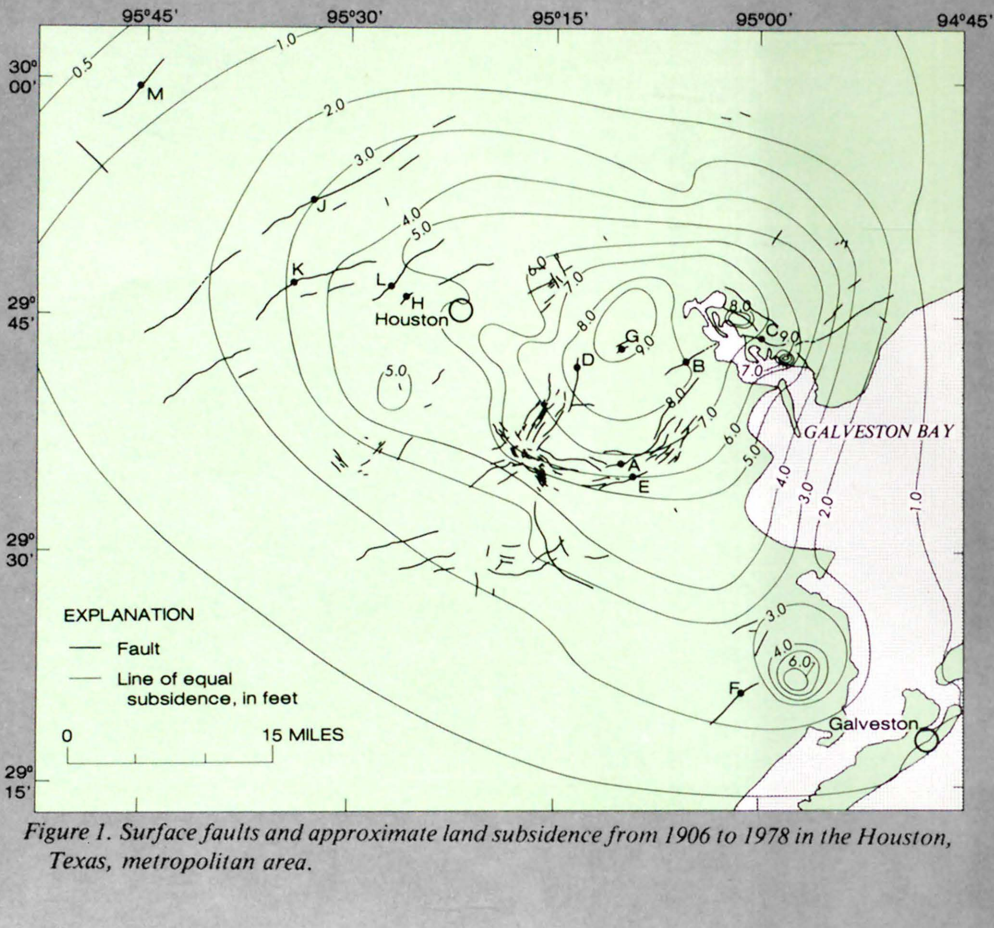


Figure 1. Surface faults and approximate land subsidence from 1906 to 1978 in the Houston, Texas, metropolitan area.

Figure 2. House damaged by a fault in northwest Houston. Fault has deformed garage and has required patch in road.

More than 86 historically active faults with an aggregate length of 150 miles have been identified within and adjacent to the Houston, Texas, metropolitan area (fig. 1). Although scarps of these faults grow gradually and without causing damaging earthquakes, historical fault offset has caused millions of dollars in damage to houses and other buildings, utilities, and highways that were built on or across the faults (fig. 2). The historical fault activity results from renewed movement along preexisting faults and appears to be caused principally by withdrawal of ground water for municipal, industrial, and agricultural uses in the Houston area. Approximately one-half of the area's water supply is obtained from local ground water. Monitoring by the U.S. Geological Survey of heights of fault scarps indicates that many of the scarps have recently stopped increasing in height. The area where faulting has ceased coincides with the area where ground-water pumping was cut back in the mid-1970's to slow the damage caused by land subsidence along Galveston Bay and the Houston Ship Channel. Thus, it appears that efforts to halt land subsidence in the coastal area have provided the additional benefit of arresting damaging surface faulting.

The Houston area is the largest metropolitan area in the United States dependent chiefly on local ground water for its municipal and industrial water supply. Not surprisingly, water levels in the freshwater-bearing sediments beneath the area have declined significantly since the beginning of the 20th century. These declines, in turn, have caused the water-bearing sediments to compact and the land surface to subside or sink over an area of more than 4,700 square miles. Maximum historical subsidence in the region exceeds 9 feet. The subsidence is particularly acute near Galveston Bay and along the Houston Ship Channel, where more than 31 square miles of low-lying coastal land has been permanently inundated. In addition, as the land sinks, the area susceptible to tidal flooding by tropical storms and hurricanes is increased greatly. For example, C. W. Kreitler of the Texas Bureau of Economic Geology estimated that Hurricane Carla, which struck the area in 1961, would have flooded at least 21 percent more land, a total of 146 square miles, if it had occurred in 1976. Today, more than 300,000 people would be affected by a similar event in an area where, in 1900, the worst natural disaster in United States' history occurred when a hurricane made landfall near Galveston Bay and killed more than 6,000 people. Even without a major hurricane, a study by L. L. Jones of Texas A & M University revealed property losses and flood damage attributable to subsidence in the coastal area from 1969 to 1974 were $31.7 million per year.

To reduce or stop future subsidence, surface-water supplies have been augmented by tapping local rivers. In addition, the Harris-Galveston Coastal Subsidence District was organized and empowered to regulate ground-water pumping. As a result of these efforts, water levels in the water-bearing sediments beneath the coastal area have partially recovered from their former low levels. Despite a slowdown in pumping, however, water levels continue to decline in the western part of the subsidence area. Changes in water levels since 1977 in both areas are shown in figure 3.

The first scarp probably related to ground-water pumping was recognized in 1936, and the number of active faults slowly increased as pumping and subsidence continued. The Geological Survey began to map the faults in late 1974. Most of the 50 or so faults known prior to that time had been recognized as a re-

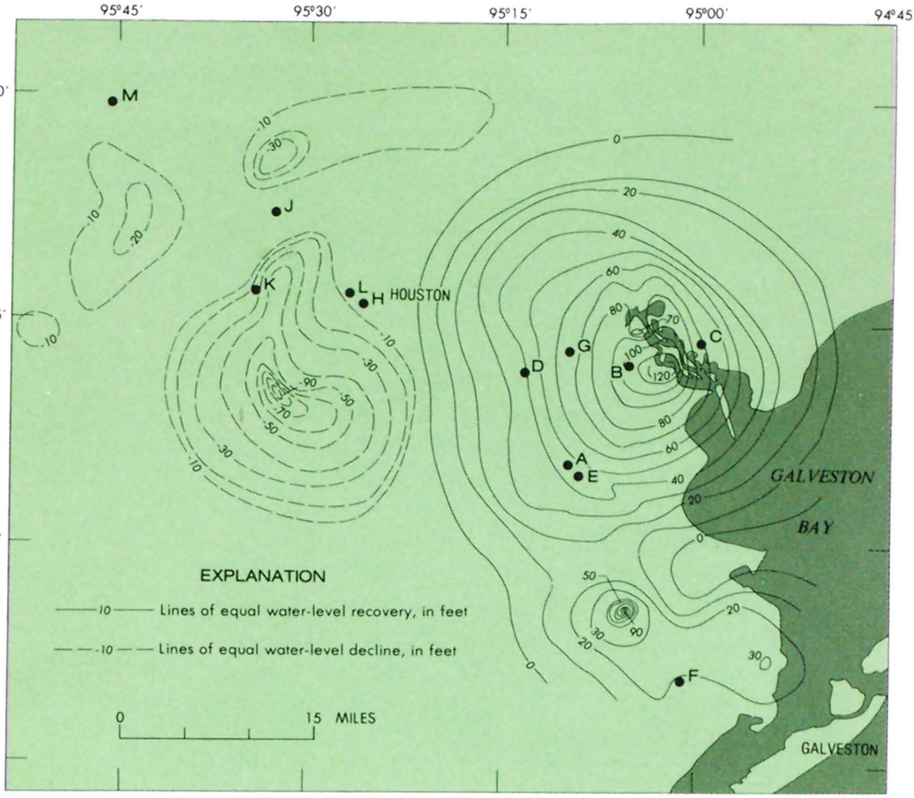
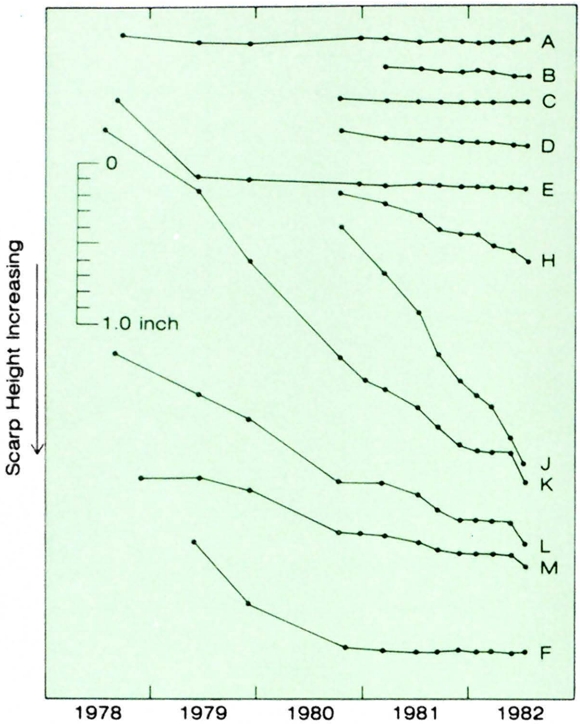


Figure 3. Changes of water level in Houston, Texas, aquifer, 1977 to 1982.

sult of damage to manmade structures. Many of the faults mapped since 1974, however, are in undeveloped or recently developed areas, where damage has not yet occurred and could, in principle, be avoided or minimized. Today, more than 160 faults are known, ranging up to 10 miles in length and 3 feet in height. Historical scarp growth has been confirmed on at least 86 of them, and many others are suspected to be active. The fault scarps increase in height at rates that range from 0.2 to 1.1 inches per year, and the average rate of growth is 0.4 inch per year. Because the faults grow gradually and without earthquakes, they generally go unnoticed during construction unless special site investigations are conducted. Thus, houses, utilities, and roads built on a fault are subjected to cumulative structural damage as the slow steady movement continues.



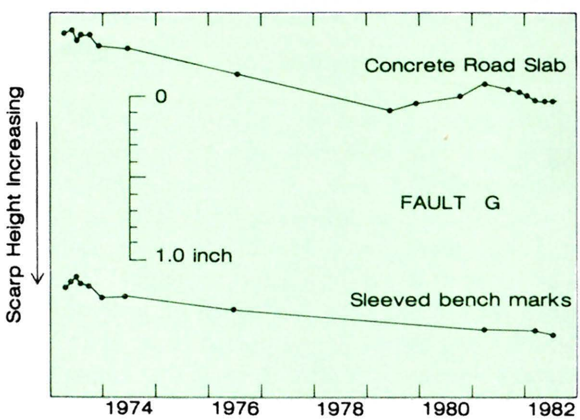


Figure 4. Changes in the height of monitored fault scarps in the Houston, Texas, metropolitan area.

In 1978, the U.S. Geological Survey began to monitor scarp growth of 12 selected faults in the subsidence area. Their measurements revealed that all seven of the monitored faults in the area of water-level recovery (fig. 3) have either completely stopped growing or slowed to rates of less than 0.05 inch per year, rates well below their average during historical time (fig. 4). By contrast, all five faults in the area where water levels have continued to drop have continued to grow at their former annual rates. Although this monitoring program covers only 14 percent of the recognized active faults in the area, the perfect areal correlation between stable or slow-moving faults and the recovery of ground-water levels strongly suggests that continuing efforts to halt subsidence will also halt the growth of historically active faults.

The five faults in the area of falling water levels show annual patterns of movement that further support the link between pumping and faulting. Movement on all five faults varies seasonally; rates of faulting increase as water levels drop rapidly during summer pumping and then decrease as water levels partially recover when pumping declines during the winter. As can be seen in figure 4, fault movement sometimes stops entirely during the winter months.

The response of the Houston faults to water-level changes is similar to the response of monitored surface faults in subsidence areas in Arizona and California. In all of these areas, faulting ceases during periods when pumping declines and water levels recover. Although the fault displacements can never be reversed, it appears that man can at least arrest the subsidence and faulting that he has initiated.