

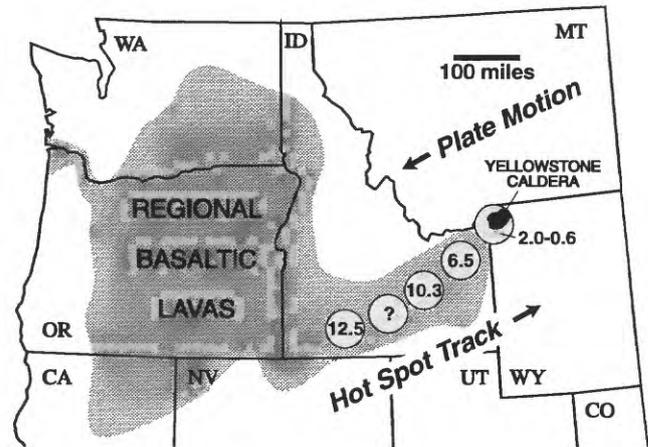
## Yellowstone: Restless Volcanic Giant

Three million visitors each year marvel at Yellowstone's Rocky Mountain splendor, including its thousands of steaming geysers, shimmering thermal pools, and bubbling mudpots. But the greatest wonder of all goes mostly unnoticed. Hidden underground, powerful volcanic, tectonic, and hydrothermal forces are continually reshaping the landscape of America's first and foremost national park. Symptoms of the underground turmoil include numerous earthquakes (most too small to be felt), uplift and subsidence of the ground surface, and persistent but ever-changing hydrothermal activity. Eventually, the unrest will culminate in another large earthquake or volcanic eruption, both of which have occurred many times before in Yellowstone's geologic past. Scientists from the U.S. Geological Survey and the University of Utah are studying the Yellowstone region to assess the potential hazards from future earthquakes and eruptions and to provide warning if the current level of unrest should intensify.

### YELLOWSTONE'S ROOTS

Scientists have traced Yellowstone's origin to a *hot spot* in the mantle, one of a few dozen such hot spots on Earth. Buoyant material from a hot spot rises through the upper mantle, bringing heat from the Earth's interior closer to the surface. The Yellowstone hot spot impinges on the base of the North American plate, one of several rigid plates that make up the Earth's crust. These plates move a few inches per year with respect to the stationary hot spots and each other, sometimes causing great earthquakes as the plates collide, grind past one another, or split apart.

The Yellowstone hot spot has interacted with the North American plate for perhaps as long as 17 million years, causing widespread outpourings of basalt that bury about 200,000 square miles in Washington, Oregon, California, Nevada, and Idaho under stacks of lava flows half a mile or more thick. Some of the basaltic melt, or *magma*, produced by the hot spot accumulates near the base of the plate, where its heat melts rocks from the Earth's lower crust. These melts, in turn, rise closer to the surface to form large reservoirs of potentially explosive rhyolite magma. Catastrophic eruptions have partly emptied some of these reservoirs, causing their roofs to collapse. The resulting craters, some of which are more than 30 miles (50 kilometers) across, are known as volcanic *calderas*. Because the plate was moving an inch or so per year southwestward over the hot spot for millions of years as the calderas formed, groups of calderas are strung out like beads on a string across parts of Idaho and Wyoming (fig. 1).



**Figure 1.** Regional basaltic lavas (stippling) and chain of rhyolitic caldera groups (circles), with ages in millions of years, along track of Yellowstone hot spot.

### THE YELLOWSTONE CALDERA

The most recent caldera-forming eruption about 650,000 years ago produced a caldera 53 x 28 miles (85 x 45 kilometers) across in what is now Yellowstone National Park (fig. 2). During that eruption, ground-hugging flows of hot volcanic ash, pumice, and gases swept across an area of more than 3,000 square miles. When these enormous *pyroclastic flows* finally stopped, they solidified to form a layer of rock called the *Lava Creek Tuff*. Its volume was about 240 cubic miles (1,000 cubic kilometers), enough material to cover Wyoming with a layer 13 feet thick or the entire conterminous United States with a layer 5 inches thick. The Lava Creek Tuff has been exposed by erosion at Tuff Cliff, a popular Yellowstone attraction along the lower Gibbon River.

The eruption also shot a column of volcanic ash and gases high into Earth's stratosphere. This volcanic cloud circled the globe many times and affected Earth's climate by reducing the intensity of solar radiation reaching the lower atmosphere and surface. Fine volcanic ash that fell downwind from the eruption site blanketed much of North America. This ash layer is still preserved in deposits as far away as Iowa, where it is a few inches thick, and the Gulf of Mexico, where it is recognizable in drill cores from the sea floor.

Lava flows have since buried and obscured most of the caldera, but the underlying processes responsible for Yellow-

stone's tremendous volcanic eruptions are still at work. Eventually, another "bead" may be added to Yellowstone's 300-mile-long string of calderas, with global consequences that are beyond human experience and impossible to anticipate fully.

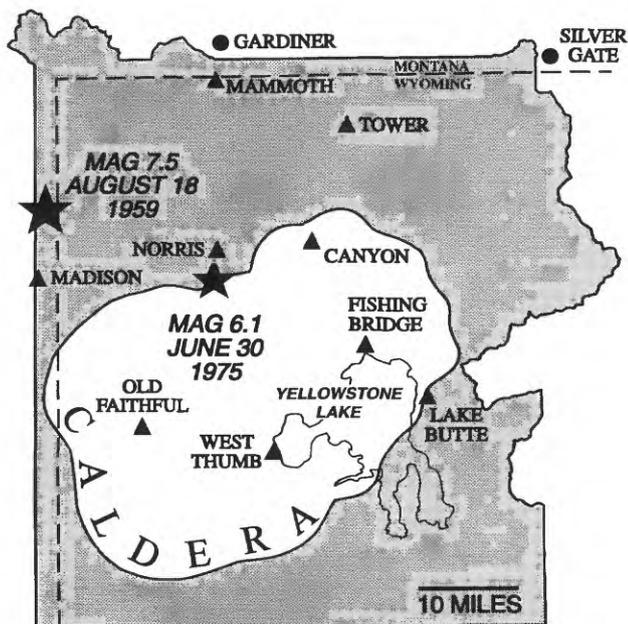


Figure 2. Yellowstone National Park and the 630,000-year-old Yellowstone caldera, with locations of two recent large earthquakes (stars).

### CONTEMPORARY UNREST

In the meantime, the giant is restless. Thousands of small earthquakes rattle the Yellowstone region each year. Most of these are too small to be noticed except by sensitive seismometers, but a few are large enough to cause substantial damage. At least eight magnitude-6 or greater earthquakes have occurred in the Yellowstone region during historical time. The largest of these was the magnitude-7.5 Hebgen Lake earthquake on August 18, 1959, which cost 28 lives and \$11 million in damage. The most recent was a magnitude-6.1 earthquake near the Norris geyser basin on June 30, 1975.

Earthquakes are not the only symptom of unrest. Yellowstone's famous hydrothermal system releases heat energy at an average rate of about 4,500 megawatts — about 50 times the planetary average. In addition, repeated surveys show that the ground surface near the center of the Yellowstone caldera rose more than 3 feet from 1923 to 1985, then subsided about 6 inches from 1985 to 1992 (fig. 3). Studies of shorelines near the outlet of Yellowstone Lake show that the caldera's center has risen and fallen 3 times during the past 10,000 years. The total vertical change during each "breath" of the caldera is estimated to be about 65 feet (20 meters).

### REASON TO WORRY?

The current rates of seismicity, ground deformation, and hydrothermal activity at Yellowstone, although high by most geologic standards, are probably typical of long time periods be-

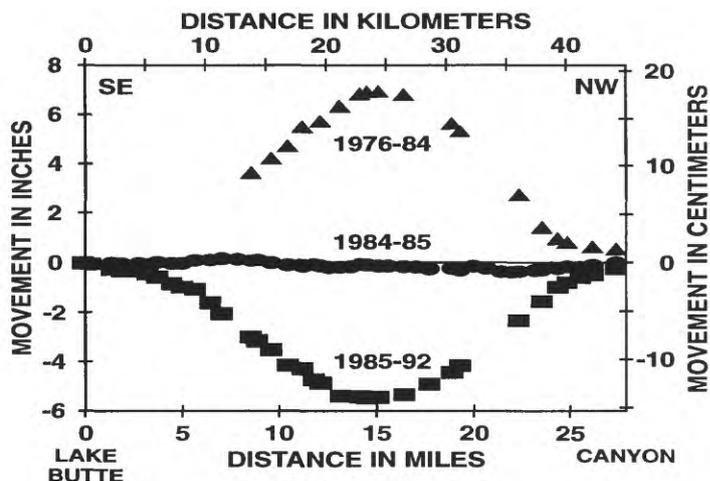


Figure 3. Ground movements between Lake Butte and Canyon (see fig. 2) for the periods 1976-84 (uplift), 1984-85 (quiescence), and 1985-92 (subsidence).

tween eruptions and therefore not a reason for immediate concern. Potentially damaging earthquakes are likely to continue occurring every few decades, as they have in the recent past. Eventually Yellowstone will erupt again, but there is no indication that an eruption is imminent or what kind of eruption may come next. For the foreseeable future, the same powerful forces that created Yellowstone will continue to animate this slumbering, but restless, volcanic giant.

### ADDITIONAL READING

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