QUAKES IN THE EAST

BY CHERYL SIMON

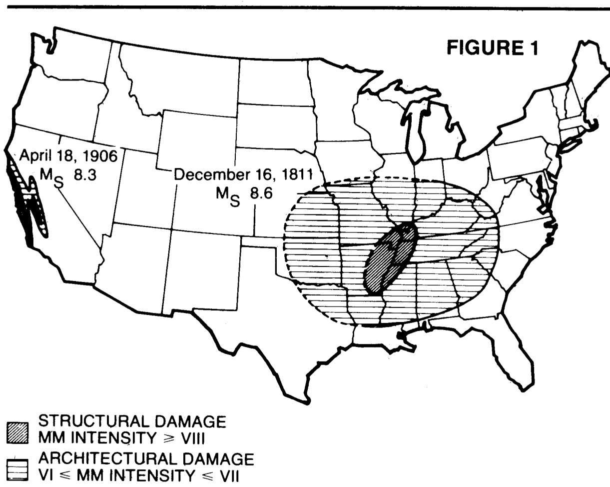
For residents of New Madrid, Mo., it was a very bad year. In less than two months during the winter of 1811-1812 three earthquakes with magnitudes of 8.6, 8.4 and 8.7 shook the town. Water and sand spewed from the earth, turning fertile prairie into marshland. The earth yawned into fissures that horses could not cross. An unknown number of people drowned when their boats capsized in the Mississippi's churning waters.

The three shocks were the largest in United States history. And while the survivors of the earthquakes died long ago, the threat of recurrence lives on: the only question is when. Although the last major quake east of the Rockies occurred nearly a century ago, there is a 25 percent chance that an earthquake of equal size to the New Madrid quakes will occur in the central United States within the next 20 years, and at least a 50 percent chance that an earthquake of 7.5 or larger will occur, says Otto Nuttli of St. Louis University. In the winter of 1811-1812, the quakes devastated an area 150 miles long and 50 miles wide. Although the epicenter was in northeast Arkansas, chimneys toppled as far away as St. Louis, Mo., and Louisville, Ky., and the tremors were felt in New Hampshire and in Quebec City in Canada. Then, many of the affected areas were sparcely populated, and few lives were lost. But now, computers, communication, human services, refrigeration, and power depend on transmission of electricity, easily disrupted by strong ground motion; tall buildings dominate the skylines of the region's cities. An earthquake of comparable size would be much more catastrophic in terms of loss of life and property.

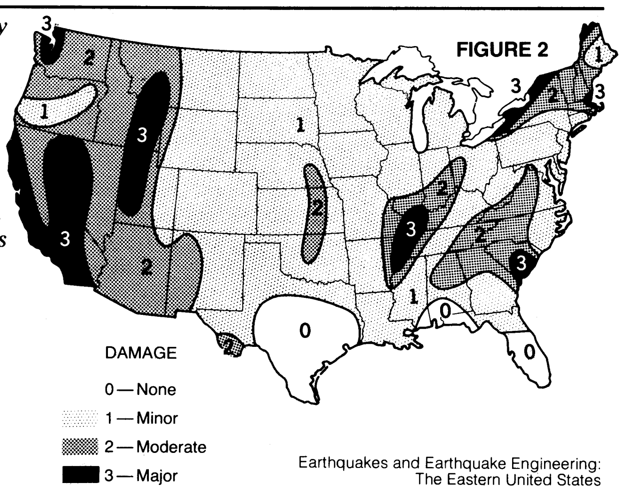
The possibility of a damaging earthquake is remote from the thoughts of most Americans, who perceive the earthquake threat as exclusive to the West Coast. But scientists who study seismicity, engineers who build to withstand it, and the policymakers who must draft and enforce building codes are concerned by the complacency that marks awareness of the earthquake hazard in the eastern and central states.

Representatives of these three professional groups met recently in Knoxville, Tenn., to report new data in the developing field of seismology east of the Rockies, and to familiarize each other with their sepa-

A severe earthquake in Charleston, S.C., in 1886 left the town a shambles of demolished buildings. Today, improved building standards and practices could minimize damage to structures.



Seismic energy spreads efficiently in the East so that larger areas than in the West (figure 1). Figure 2 shows the probable severity of quakes across the nation.

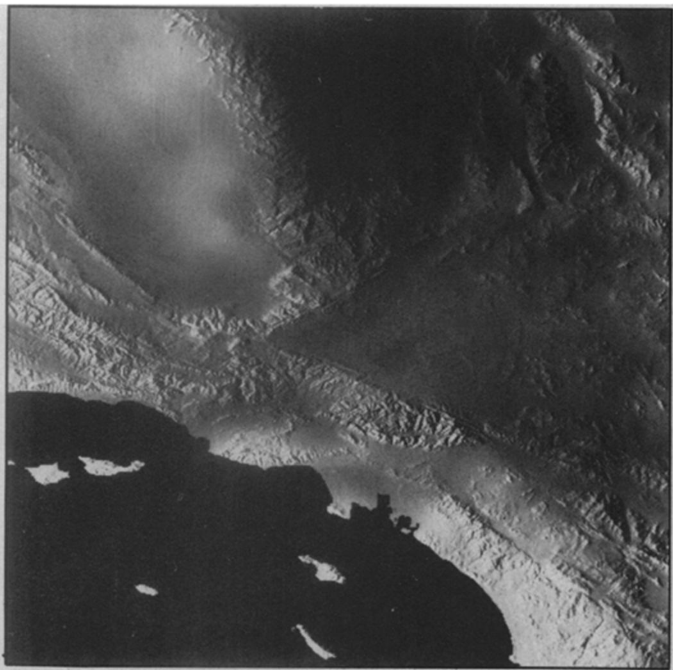


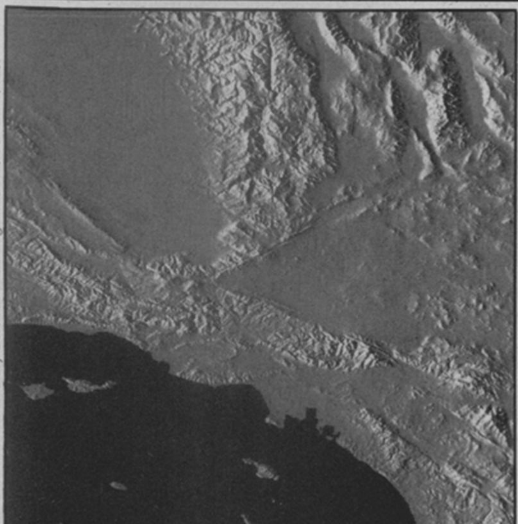
Earthquakes and Earthquake Engineering: The Eastern United States rate but associated fields of expertise. While there are many areas of disagreement and incomplete data, no one present seemed to deny that a damaging earthquake will occur in the future.

Part of the difficulty in assessing the risk stems from the lack of instrumental data on severe eastern quakes. It is only in the last 10 years that strong-motion seismographs, instruments that can record large ground movements capable of damaging buildings, have been installed in active zones in the East. Data from strong-motion earthquakes in the western states often are modified and then used in estimating the risk of eastern earthquakes. But earthquakes in the East differ from those in the West. Unlike western quakes, which occur at the Pacific plate margin, most eastern earthquakes occur mid-plate where ancient fault systems that formed as early as Precambrian time are reactivated, presumably by the spread of the Atlantic seafloor.

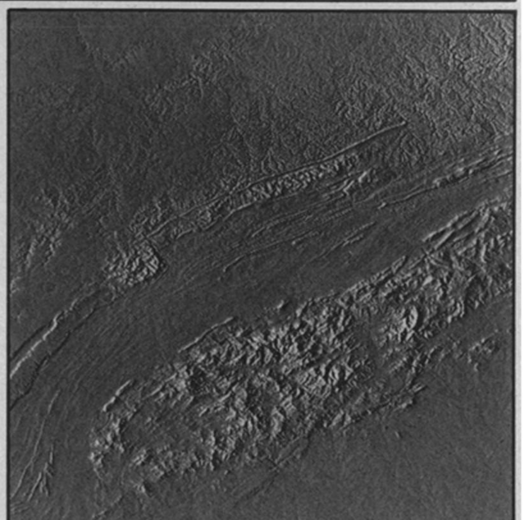
Nuttli, who has studied the New Madrid zone extensively, explained some of the basic differences between western earthquakes and those east of the Rockies. First, earthquakes in the East occur approximately five times less frequently than those in the West — part of the reason for the general perception that little, if any, hazard exists. Second, unlike eastern quakes, earthquakes in the West actually break ground. Consequently, faults in the West can be identified with ease, while in the East often the best scientists can do is define a source zone where seismicity is fairly uniform. The other major difference, yet to be fully explained, is that seismic energy attenuates more effectively in the East, allowing seismic waves to travel hundreds of miles and still be powerful enough to damage buildings. For quakes with magnitudes of 8.0 or more, structural damage in the central United States is five times greater than in California. Architectural damage, which exacts the highest tolls in losses of life and property, is 25 times as great. Some scientists suggest that the comparative youth of western rock and the greater amount of water that the rocks contain may contribute to the differences.

Quakes in the East and West share two characteristics: In both regions, the quakes usually are focused between 5 to 15





Faults in the East are less clearly defined than those in the West. Left, shaded relief maps highlight topography of the San Andreas fault region. Right, the less dramatic relief of the Pine Mountain thrust in eastern Tennessee. The top images were obtained when a computer was instructed to overlay the shaded relief maps with maps of the same regions indicating gravity highs and lows. Gravity lows, dark, mark mass deficiencies in the earth's lithosphere. Light areas mark gravity highs. Lack of equilibrium in the lithosphere may lead to seismic events.



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kilometers and occur mostly at strike-slip faults, which move horizontally rather than vertically.

Until the last 10 years, little progress had been made in collecting data on seismicity east of the Rockies, even though a major earthquake occurs there every 50 to 100 years. That same 10 years also has seen a proliferation of nuclear power plants, structures that must be built to withstand earthquakes. But how does one design for a hazard when its magnitude can only be guessed? The need for solid information has prompted scientists to collect data, and at last a clearer picture of the origins of seismicity in the middle and eastern states is emerging.

Although the quakes are scattered, most seem to be caused by minor adjustments in the earth's crust, nudged into activity by the continued opening of the Atlantic basin. Patrick Barosh, a geologist at Boston College, heads the New England Seismotectonic Study, now in its sixth year and funded by the Nuclear Regulatory Commission. So far results of the study suggest two broad, northeast-trending alignments in the eastern United States, one moving from northeastern Arkansas to the lower St. Lawrence River, and the other from northern Alabama through New England.

Most major clusters of earthquakes in the eastern states are located above embayments in subsiding, lowland areas along the Cretaceous continental margin. Earthquakes in these areas tend to be in proportion to the size of the embayments, Barosh says. He cites examples such as the 1811-1812 New Madrid quakes concentrated at the head of the Mississippi embayment, and the severe 1886 Charleston, S.C., quake, which occurred on the flank of the southeast Georgia embayment. Cape Ann, Mass., is in a seismically active area on the edge of an offshore embayment into the pre-Cretaceous continent.

As the embayments subsided, sediments from the Lower Tertiary began to extend inward over the underlying Cretaceous sediments to the inner edge of the coastal plain, where the continental margin has sagged. This may, in part, account for the apparent concentration of earthquakes in lowland areas with altitudes below 300 meters. There is evidence that subsidence continues. Passamaquoddy Bay, Maine, for example, is going down at a clip of nine millimeters per year. Exceptions, such as mild seismic activity in the Great Smoky Mountains, the Adirondack Mountains, and the White Mountains, are in areas of uplift rather than subsidence, Barosh says.

In California, frequent tremors continually remind engineers to design according to the state's stringent earthquake safety measures and building regulations. But in the central and eastern states, even when designers are fully aware of the seismic danger, building codes do not require them to incorporate earthquake resistance into structures routinely built to withstand high winds.

Most structures designed for wind in the East are probably capable of withstanding earthquakes, said Eric Elsesser, of Forell/Elsesser, Engineers, Inc. in San Francisco, Calif. As far as building codes are concerned, he said, wind and seismic forces are both considered lateral loads applied to the structure. Generally, the designer will design for the larger of the two loads, usually wind in the East.

Even in the West building codes, weighing cost against risk, specify design for seismic forces considerably smaller than those an earthquake might produce, Elsesser said. Engineers try to understand how structures behave under seismic forces, and then choose a structure that will accommodate the difference between the earthquake they design for and forces that actually might occur. "This procedure isn't codified, but it is understood by experienced structural engineers," he said. "We know that buildings will perform satisfactorily at lower levels, but *how much* do you design for? That's usually the subject of all seismic research."

Mark Fintel, of the Portland Cement Association in Skokie, Ill., reports that when a "typical" 22-story office building designed for gravity loads and wind was subjected to earthquake motions of various levels of intensity, it functioned satisfactorily—to a point. (The measure used here is *acceleration due to gravity*, in which 1.0g equals the acceleration with which a ball falls when released at rest in a vacuum.) Fintel found that the building behaved well during an earthquake with peak ground acceleration of 0.05g. But at earthquake intensities of 0.10g, simple, relatively inexpensive measures such as strengthening columns were needed to make the well-designed wind structure resistant to seismic deflections.

"You can get a lot of earthquake safety by using different engineering practices," said Charles Thiel of the Federal Emergency Management Agency (FEMA). "Improving safety doesn't have to cost much," he said, referring to details such as completing positioning ties by bending them back. "The cost is even less if you think about it at the beginning."

At Case Western Reserve University in Cleveland, civil engineer Arthur Huckelbridge and graduate student Shya Ling Shein are conducting computer simulations to learn how permitting momentary uplift of building foundations can reduce damage to buildings. When a seismic wave passes beneath a building, the ground moves. However, Huckelbridge explains, the building, because of its natural inertia, resists the horizontal movement of the ground, producing forces that may cause the structure to rock back and forth. "Traditionally, we haven't allowed the rocking. We've clamped the building to the ground," he told SCIENCE NEWS. "If we do that, in an earthquake we are exposing the building to ever-greater forces as the magnitude of the quake increases." It is inconceivable that a reasonably sized building with a base greater than a few tens of feet could tip over, he said, because the ground motions are too small. The concept of allowing tipping is relatively new, and so far, he said, is not allowed by building codes.

Few communities outside the western states enforce building codes and regulations for earthquake resistance. But the question nags: What will happen when a large earthquake occurs? According to the Modified Mercalli Intensity Scale of 1931, a widely used scale for measuring earthquakes, during a magnitude 8.0 event specially designed structures would suffer only slight damage, while ordinary, substantial buildings would partially collapse and poorly built ones would suffer great damage. Chimneys, factory stacks, columns, monuments and walls would fall. Heavy furniture would turn over. Driving would be difficult. Building damage alone, given a recurrence of the 1811-1812 New Madrid quakes, would cost \$13 billion to \$14 billion (1980 dollars), estimates William Petak of J.H. Wiggins Co., Redondo Beach, Calif.

The recent flush of data leaves engineers, seismologists, geologists and planners in a better position to assess the risks, benefits, and costs of designing for earthquake resistance.

"We have more data and insight and knowledge than we're applying," Thiel said. He urges a broad effort to alert the public, and public officials, that earthquake hazards exist. "If you know the risks and are willing to accept them, that's OK. But if you don't know, you can't make a decision." □

Most faults in the East are strike-slip faults, which move horizontally.