RESEARCH UPDATE

Intraplate earthquakes

Intraplate (within the plate) earthquakes occur far removed from the plate boundaries. Although nearly two-thirds of the Earth's continental crust is stable interior crust, less than 10% of all earthquakes are intraplate earthquakes. The causes of intraplate earthquakes are poorly understood, but it is likely that they relate to the driving forces of plate tectonics. As the plates collide, separate, or slide past one another, some plates gain and other plates lose material at their edges, and the plate boundaries change over geologic time. Weakened former plate boundaries become part of the interiors of plates. Stresses originating at the edges of the plates or in the deeper crust may be localized (concentrated) by these weaker structures, causing intraplate earthquakes. Other, more localized possible causes of intraplate earthquakes include growing or shrinking glaciers, impoundment or drawdown of reservoirs, and upwelling of mantle plumes.

Characteristics

Intraplate earthquakes differ from interplate (between the plates) earthquakes, which occur at plate boundaries, in a number of ways. First, recurrence times of intraplate earthquakes are usually much longer than those of interplate earthquakes. Second, intraplate earthquake faults are rarely recognized at the surface. This is because the faults are generally buried under several kilometers of surface materials and the longer recurrence intervals allow any surface expression of faulting to be eroded. Third, intraplate earthquakes release more stress (force per unit area) than interplate earthquakes. The effects of intraplate earthquakes differ from those of interplate earthquakes in one very important aspect: the ground motion caused by intraplate earthquake seismic waves dissipates more slowly. The strong, coherent rocks that make up the interiors of plates transmit seismic energy more efficiently over longer distances than the less coherent, weaker rocks near plate boundaries.

The locations of intraplate earthquakes are not randomly distributed throughout the stable continental crust. Intraplate earthquakes, particularly those that are magnitude 6 or larger on the Richter scale, tend to occur in parts of continents that have undergone extension in the past. Extension occurs when tectonic forces stretch the crust of the Earth, causing the crust to become thinner and broken into fault-bounded blocks. Thinned extended crust within the continents is called a rift. Thinned extended crust along the edges of continents but not near a plate boundary is called a passive margin. Most of the earthquakes in and around the United States are in the west, along the plate-boundary faults and the wide zone of deformation associated with them (**Fig. 1**). Plate-boundary tectonics affects the United States from the Rocky Mountain front (between approximately 105° and 110°W) to the Pacific Ocean. The eastern two-thirds of the United States is stable continent. Thus, earthquakes located east of the Rocky Mountain front are intraplate earthquakes.

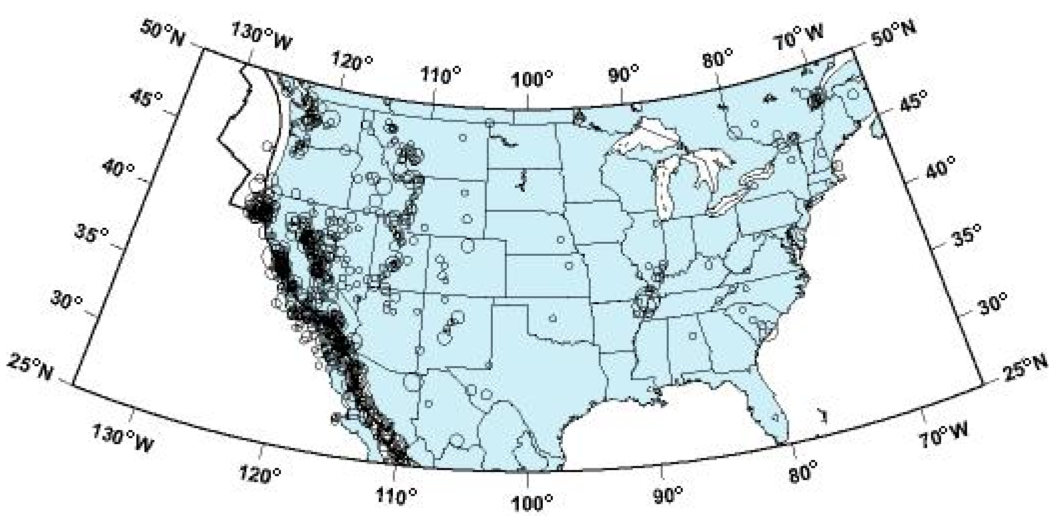

Fig. 1 Locations of magnitude 5 or greater earthquakes that occurred in and around the United States between 1701 and 1996 are shown as circles, whose size is proportional to the magnitude of the earthquake. The western plate boundary of the North American plate is shown by the heavy line near the west coast. The eastern plate boundary of the North American plate (not shown) is in the middle of the Atlantic Ocean. The three large circles near 90°W and about 36°N show the locations of the 1811–1812 New Madrid earthquakes, the largest intraplate earthquakes known to have occurred in the United States.

Historic examples

During the winter of 1811– 1812, three large intraplate earthquakes, each estimated to be approximately magnitude 8, occurred near the "boot heel" region of Missouri in the central United States. These earthquakes and thousands of aftershocks are known as the New Madrid earthquake sequence. Shaking from the mainshocks of this sequence was felt as far away as Montreal, Canada. Shaking from one of the mainshocks was strong enough to collapse scaffolding erected around the U.S. Capitol in Washington, DC. The New Madrid earthquakes altered the landscape tremendously. The course of the Mississippi River was changed as several waterfalls formed within the river and the land along the banks sank as much as 5 m (16 ft). Reelfoot Lake (3000 km^2) formed in northwest Tennessee when the Reelfoot River access to the Mississippi River was blocked by uplifted land. Fortunately, few people lived in the central United States in the early 1800s. A repeat of even one of the large New Madrid earthquakes today would be devastating.

Another large intraplate earthquake, estimated to be approximately magnitude 7, occurred near Charleston, South Carolina, in 1886. At least 60 people died and the city suffered extensive damage. Shaking from the Charleston earthquake was felt as far away as northern New York and eastern Iowa. Plaster was shaken from walls in a building in Chicago, Illinois. Smaller earthquakes continue to occur in both the New Madrid and Charleston regions today.

Even though the numerous and widespread effects from both of these large intraplate earthquake sequences have been carefully and fully documented, no faults large enough to be the sources of the mainshocks have been clearly identified. The Charleston earthquake occurred in the passive margin along the east coast of the United States. The New Madrid earthquakes occurred in a buried rift that underlies part of Arkansas, Kentucky, Missouri, and Tennessee. But there is no surface expression of the faulting in either region.

Recurrence studies

A repeat of any of these earthquakes or the occurrence of a large intraplate earthquake in a previously inactive region poses enormous hazards. This has motivated scientific investigations to determine where and how often intraplate earthquakes occur and how big these earthquakes are expected to be. Scientists apply statistical methods using assumptions developed by studying the rate of earthquakes worldwide to estimate average recurrence intervals of large intraplate earthquakes in regions where repeat events have not occurred. For the New Madrid region, these statistical studies produce an estimated 500–600-year recurrence interval for an earthquake the size of those in 1811–1812.

Seismicity studies

The locations of the New Madrid and Charleston mainshock faults are inferred from the locations of the earthquakes recorded in those regions during the last several decades. The locations of earthquakes recorded in the New Madrid region since 1974 are concentrated along several linear trends (**Fig. 2**). A long southwest-northeast linear trend of earthquakes runs from northeast Arkansas to the Missouri-Tennessee border, where it terminates against a southeast-northwest linear trend of earthquakes. These two trends of earthquakes are assumed to represent faults, as are several of the smaller linear trends. For the most part, surface expressions of faulting along these trends of earthquakes are either absent or ambiguous. Over time, the Mississippi River and its tributaries have eroded uneven surfaces and covered the entire region with several kilometers of sediments. Thus, scientists must look below the surface to find evidence of faults.

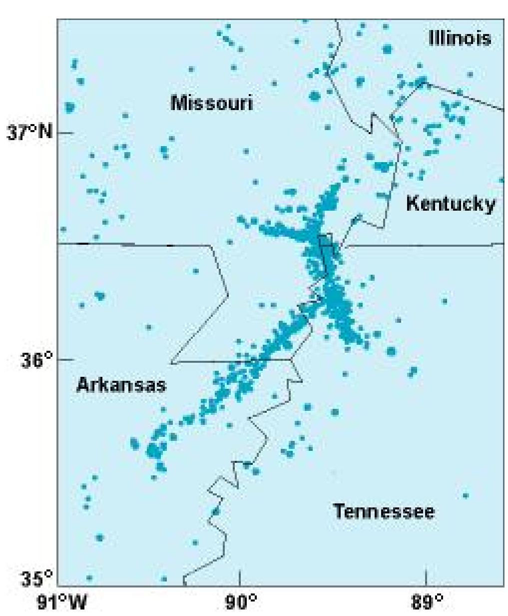

Fig. 2 Locations of earthquakes recorded in the New Madrid region since 1974 are shown as black dots, whose size is proportional to the magnitude of the earthquake. The earthquakes were recorded and located by the Cooperative New Madrid Seismic Network, operated by the University of Mamphis Center for Earthquake Research and information and St. Louis University.

Geophysical methods

Various methods of subsurface imaging and remote sensing have been used in intraplate regions to see below the surface. Seismic reflection and refraction methods image the rock layers in the subsurface using recordings of waves generated by explosive or vibrating sources. Other geophysical techniques, such as mapping the variations in the strength of the Earth's gravity or magnetic fields or differences in the electrical conductivity of rocks, can produce clear images of buried features such as rifts or large bodies of igneous rock. All of these methods have been used to look below the surface in the central and eastern United States. The long southwest-northeast linear trend of earthquakes in the New Madrid region coincides with the center of a buried rift. The terminus of this trend and the southeast-northwest linear trend of earthquakes coincide with a large, buried mass of igneous rock.

Paleoseismology

Paleoseismology is the study of prehistoric earthquakes, especially their size, location, and recurrence times, using the geologic record. Paleoseismologists collect detailed structural and stratigraphic information about near-surface rock layers and faults that are either naturally exposed at the surface (in an outcrop) or artificially exposed by shallow excavations. Fault movement during an earthquake can create offsets (abrupt changes in levels) in buried rock layers. In areas where sediments contain water, strong shaking during a large earthquake can transform the sediments into a liquid, a phenomenon called liquefaction. The differences in pressure between any buried liquefied and nonliquefied sediments force the liquefied sediments upward and onto the ground surface, forming a sand blow. Sand blows have the surface appearance and subsurface features of a volcano, but are composed of sand (**Fig. 3**). Various methods are used to estimate the ages of small pieces of organic materials (such as wood, charcoal, or shells) buried by sand blows. The ages of the buried materials provide estimates of the date of the earthquakes. The thickness of the overlying A-horizons, which are soils that develop after a sand blow was deposited, provides an estimate of the amount of time between the deposition of the upper and lower sand blows. The geographical distribution of liquefaction features of the same age can be used to estimate the epicenter and magnitude of the prehistoric earthquake that created the features. Evidence of liquefaction from about the year 900 in the New Madrid region covers an area nearly the same length as the liquefaction area documented from the 1811–1812 earthquake sequence. Paleoseismologists have also found evidence of liquefaction dating from about 1300 that covers a smaller area. They interpret these results to mean that a large New Madrid earthquake occurs about every 1000 or so years, and smaller but still damaging earthquakes occur more often.

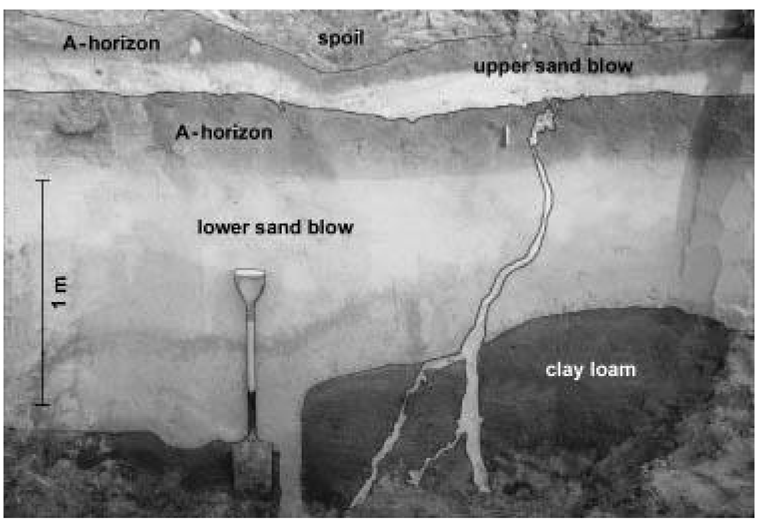

Fig. 3 Stacked sand blows in the walls of a drainage ditch in the New Madrid seismic zone. Sand was vented through cracks in the lower clay loam. Both of the sand blows were exposed at the ground surface long enough to form thick soil A-horizons, or accumulations of organic matter. The lower sand blow is probably from about the year 900; the upper sand blow is probably from the 1811–1812 New Madrid earthquakes. (*Courtesy of E. S. Schweig*)

Each type of study of intraplate earthquakes yields estimates of the sizes, locations, and recurrence intervals of large or damaging earthquakes. Unfortunately, there are large uncertainties associated with these estimates. Thus, many intraplate earthquake researchers currently are undertaking studies designed to reduce these uncertainties.

See also: Earthquake; Paleoseismology; Plate tectonics

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Additional Readings

- U.S. Geological Survey Earthquake Information
- University of Memphis Center for Earthquake Research and Information

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