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Understanding Earthquake Hazards in the Central U.S.

Soil cover magnifies earthquake energy at great distances across the Midwestern United States

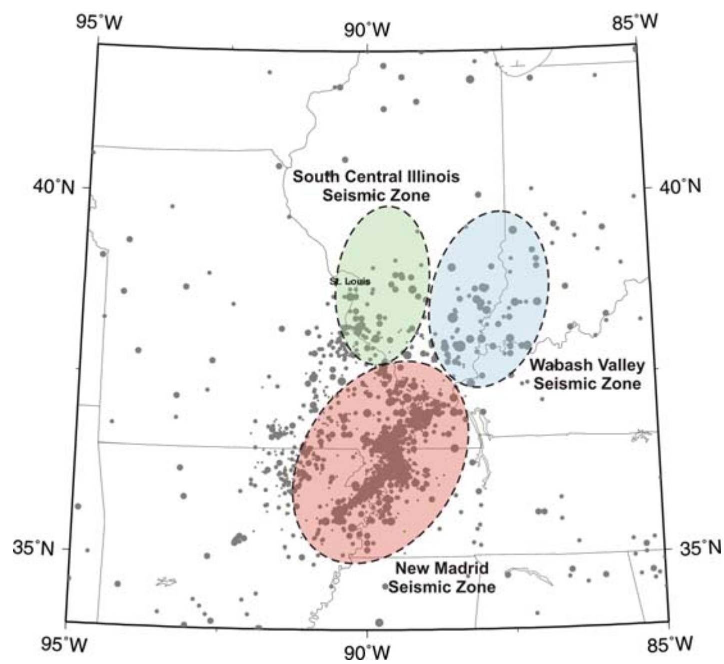
The New Madrid Seismic Zone (NMSZ) is historically recognized for spawning periodic moderate to large size earthquakes. It lies within the upper Mississippi Embayment and extends from northeast Arkansas through southeast Missouri, western Tennessee, and western Kentucky, up into southern Illinois. The NMSZ lies within a 70 km-wide, 200 km-long SW-NE trending graben (known as the Reelfoot Rift) which is interpreted to have formed during an episode of continental rifting that began in late Cambrian time, 523 to 505 million years ago. The NMSZ dominates central U.S seismicity and has the highest seismic moment release rate of any seismic zone in a stable continental region in the world. This region is the source of the 1811–1812 quakes (16 December 1811 M 7.6, 23 January 1812 M 7.5 and 7 February 1812 M 7.8) that occurred early in the recorded history of the American Midwest which are the largest earthquakes in historical time in the Central and Eastern U.S.

Paleoseismic investigations also suggest that the largest 1811-1812 earthquakes were not unique in magnitude because paleoliquefaction features provide convincing physical evidence that no less than four similar-size earthquake sequences have occurred in the last 2000 years, with an average recurrence of 500±300 years for the New Madrid Seismic Zone events (Tuttle *et al.*, 2002, 2005). Figure 1 shows the location of the New Madrid Seismic Zone.

The Wabash Valley Seismic Zone (WVSZ) is located along the southern border of Illinois and Indiana. Candidate active westward dipping thrust faults from seismic reflection profiles and paleoliquefaction studies are identified in this region and recent data suggests that they are capable of producing repeated large-magnitude earthquakes from M 7.0 to 7.8. The magnitude of the largest paleoearthquake in this area, known as Vincennes-Bridgeport earthquake, occurred 6,011 ± 200 yr BP likely between M 7.5 to 7.8. The next-largest earthquake (known as Skelton-Mt Carmel earthquake) occurred 12,000 ± 1000 yr BP This earthquake size is estimated to be M 7.1 to 7.3.

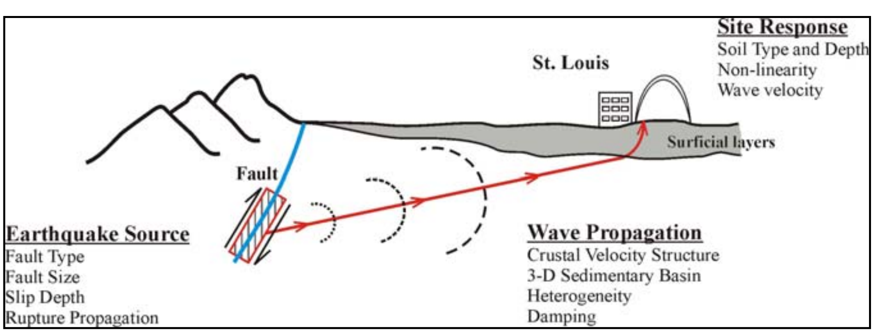
South Central Illinois spawned M 5+ quakes in 1838, 1857, and 1891. Paleoliquefaction data and basement faults identified in seismic-reflection data in south Central Illinois suggested this region is capable of generating earthquakes with a maximum possible moment magnitude of 6 to 7, nucleating in the Paleozoic age basement. This area has spawned two strong mid-Holocene events, known as the Springfield and Shoal Creek earthquakes, which have been identified in recent paleoliquefaction studies. It has been documented that one moderate-size earthquake (M 6.2 to 6.8) and a second smaller event (~M 5.5) occurred in the Springfield, IL region between 5,900 and 7,400 yr BP. There is also documented evidence of paleoliquefaction caused by the Shoal Creek earthquake, believed to have occurred in southwest Illinois around 4,520 BC ± 160 yr exceeding M 6.0.

Is America's heartland overdue for a damaging earthquake?



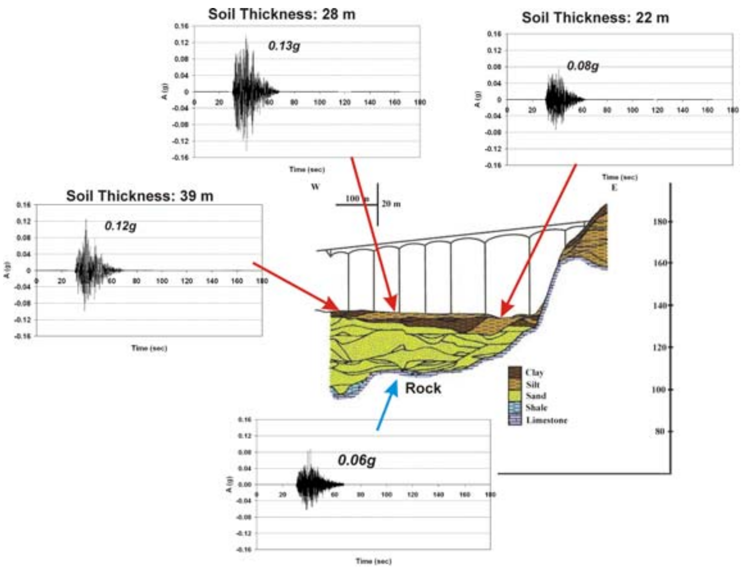
In the 50 years the most likely earthquake to impact St. Louis will likely be something similar to the Magnitude 6.6 Charleston, MO quake of 1895, which has a recurrence frequency of 70+/- 15 years (overdue since 1980). It could emanate from either the New Madrid, Wabash Valley, or South Central Illinois Seismic Zones.

What is site response?



The propagation of seismic energy through the Earth's crust can be magnified or damped by the thickness and consistency of surficial soils the shaking propagates through on its path to the ground surface. These combinations of factors are collectively referred to as the seismic site response.

Soil thickness beneath a site controls seismic site response. The soil thickness and consistency affects the characteristic site period, spectral acceleration and site amplification. The dynamic response of structures is greatly affected by these characteristics. Structures located at great distances from earthquakes (>160 km) are actually at greatest risk for potentially destructiuve long period ground motions (>1second). The Midwestern U.S. is underlain by extremely old competent rock, which transmits seismic energy much more efficiently than regions on plate boundaries, like California and Alaska. The impedance contrasts can serve to significantly amplify incoming seismic energy at longer periods, which can be extremely dangerous for either long structures like bridges, or structures taller than 10 to 12 stories.



In order to understand the effect of the soil thickness on amplifying seismic energy, synthetic earthquakes can be fed into computer programs that simulate both linear and nonlinear effects of seismic energy at any given site, provided that reliable subsurface information is available for input into the programs. The figure at left illustrates the effect of soil thickness on the peak ground accelerations for a Magnitude 6.5 earthquake 110 km away. Note how the input motion on the underlying rock is only 0.06g, but as the thickness of the soil cover increases, the seismic energy is magnified markedly, up to 0.13 g.

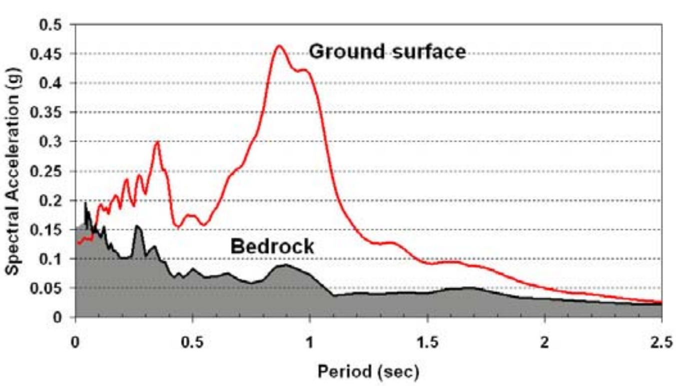
What causes amplification of Ground-motion?

Site amplification is the ratio of the response spectra of a soil site to the response spectra of the underlying bedrock. Structural engineers need to know these parameters when they design a building.

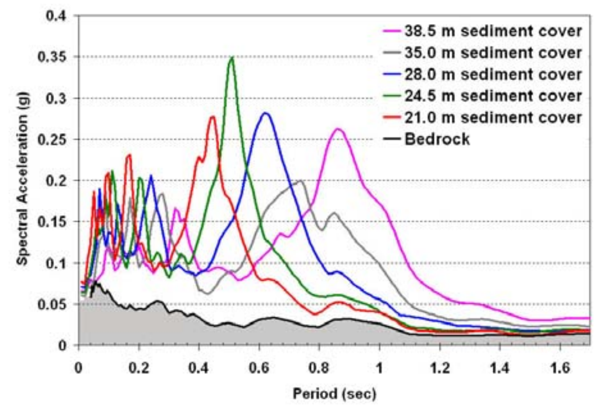
Site amplification is caused by: 1) Resonance within the soil column overlying much stiffer basement rocks; and 2) Impedance Ratio between the rigid basement rock and the unconsolidated soils lying over them.

In the Central United States, the rocks are much older, stiffer and less fractured than rocks elsewhere, like California. The Midwest is much more vulnerable to site amplification. Recent studies have demonstrated that Magnitude 6.0 to 6.8 quakes could be expected to cause 500% to 1200% increase in rock acceleration at the ground surface at distances between 110 and 370 km from epicenter.

Rock and Ground surface spectral accelerations for Creve Coeur Bridge M 6.8 event South Center Illinois at 110 km



The plot above shows site amplification, contrasting the spectral acceleration on the ground surface with that in the underlying rock. Structures founded on bedrock can expect much lower seismic loading.



This above chart shows the impact of soil cover thickness on response spectra for the west St. Louis area, which is 110 to 210 km from the assumed epicenters.

Spectral acceleration is crucial for structural response analyses. Taller structures exhibit longer fundamental periods of vibration than shorter, stiffer structures.

For More Information

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