HIDDEN FURY

The New Madrid Earthquake Zone

A documentary by Doug Prose
of Earth Images Foundation

STUDY GUIDE

By Nina Luttinger
and Doug Prose

HIDDEN FURY: THE NEW MADRID EARTHQUAKE ZONE

a 27-minute video produced by
Doug Prose of Earth Images Foundation
available from:
Bullfrog Films
Oley, PA 19547
(215) 779-8226

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A. Introduction

"All nature seemed running into chaos."

— John Bradbury, eyewitness to the New Madrid earthquakes of 1811-12

HIDDEN FURY brings us to the Mississippi River Valley in the heart of America. This area was struck by the most powerful series of earthquakes ever known on earth in late 1811 and early 1812. Few people lost their lives in the great New Madrid earthquakes because the region was still an undeveloped wilderness. However, tremendous population growth and industrial development in the central United States since that time has heightened the earthquake danger considerably.

This guide discusses key terms and concepts that are presented in the program. For classroom viewers, several questions are provided to stimulate discussion of the topic before and after viewing of the program. The last section of the guide lists technical and nontechnical books and articles about the New Madrid earthquake zone, and earthquakes in general.

B. For Classroom Discussion

Before Viewing

1. Did you know that an active earthquake zone exists in the central United States? Where else do earthquakes occur in the US, besides California?

2. Do earthquakes tend to occur in certain regions of the world? What is similar about the places where most earthquakes occur?

3. How far can earthquake waves travel? What might cause these waves to break up?

4. Does the *type* of ground affect how much the land shakes during an earthquake? For instance, will the ground shake as much in a region with loose, sandy soils as it will in a region with hard bedrock?

5. Are certain kinds of buildings and other man-made structures more susceptible to damage from earthquakes than others?

After Viewing

1. Why did seismic waves travel so far during the New Madrid earthquakes of 1811-1812?

2. Why did the New Madrid earthquakes and the San Francisco earthquake of 1906 affect the surrounding region so differently?

3. What role does plate tectonics play in determining the locations of earthquake zones around the world? Why is the New Madrid earthquake zone in a part of the earth's crust that is not normally found to be seismically active?

4. Why is it important to learn the geologic history of a region in order to fully understand why earthquakes occur? What are some of the challenges that scientists encounter when studying ancient earthquake zones like the one at New Madrid?

5. What are the three main geologic effects of earthquakes in the New Madrid region?

6. Why is the central United States so vulnerable to earthquakes? Why are seismic building codes weak or even non-existent in this part of the country? Should building codes be strengthened?

7. Why is it important that the type of ground (sandy soils vs. bedrock, for example) be considered before building in an earthquake-prone region?

C. Earthquakes and Plate Tectonics

The Earth's surface is made up of twelve major plates. These plates form the Earth's rigid outer shell, known as the **crust**. Situated on a partially molten, plastic-like layer of the Earth called the **mantle**, these plates can be up to 60 miles thick.

Plate tectonics refers to the movement of crustal plates with respect to each other. To help visualize this concept, imagine the plates as floating rafts. Scientists have a limited understanding of the forces that cause the plates to move, but the leading theory suggests that heat from the earth's interior cycles up, down, and around through the mantle in a 'conveyor-belt' fashion, which in turn causes the crustal plates above to be jostled about.

While all of the plates are constantly in motion and are moving at varying speeds, the average speed at which a plate moves is 2-3 inches per year— about as fast as your fingernails grow. This may seem slow and inconsequential, but over billions of years, plate tectonics has radically altered the face of the earth. And all of this action is what causes earthquakes.

The New Madrid earthquake zone was created by plate tectonic forces, though we will see that it is kept alive by an unusual set of circumstances. The jostling of crustal plates causes interesting things to happen at the plates' edges. The heat that moves the plates from below does not act evenly on the plates' undersides. One plate may be driven to the west, for example, but the next plate over may be driven east. Consequently, the two plates are pulled apart.

The two types of plate dynamics that will be discussed here, because they figure most significantly in the formation of the New Madrid earthquake zone, are **divergence** and **transform faulting**.

Divergence is the process by which oceans are created. In divergence, a plate is stretched apart to create a **rift zone.** As the plate rifts apart, the crust weakens and cracks, allowing molten magma to rise and sometimes erupt on the surface, forming volcanoes. The thinned crust then sinks and if rifting continues for millions of years, the ocean eventually invades the sinking trough. The Red Sea between Africa and Saudi Arabia is an example of an ocean that invaded a well-developed rift zone. An example of a relatively young rift zone is found in East Africa, where the continental crust is rifting apart to form the East African Rift Zone. Mount Kilimanjaro, the world's highest volcano at 19,342 feet, formed as a result of rifting.

Rifting plays a key role in causing earthquakes in the New Madrid earthquake zone. The zone first formed about 500-600 million years ago when this mid-continent region began to rift apart. This was the formation of the Reelfoot Rift, which probably had physical features like the African Rift though on a somewhat smaller scale. But the continent did not rift long enough to allow the crust to cool and sink so deep that the ocean could permanently invade. For this reason, scientists refer to Reelfoot Rift as a **failed rift.** After rifting stopped, the Reelfoot Rift actually went through a period where the crust was squeezed together, or compressed. There have been several episodes of rifting and squeezing through the eons, with the last period of rifting ending about 60 million years ago.

An important effect of repeated stretching and squeezing of the crust in the Reelfoot Rift has been to weaken the rock units and produce major cracks, or **faults**, in the rift zone. Today, the rift is being squeezed together in a roughly east-west direction. Uneven movement of the North American crustal plate, which contains the Reelfoot Rift, is the primary cause of this squeezing, or **stress**. When stress is great enough, one or several of the faults in the Rift slip suddenly, creating an earthquake. This is a rather unique earthquake-generating situation on the earth.

Earthquakes rarely occur in the interior of the earth's crustal plates, known as **cratons**. This is because the cratons have been relatively stable through geologic time, while most of the action has been happening at the edges of the plates. The ancient rocks of the cratons were left to become very hard, and consequently active earthquake faults are rare. The Reelfoot

Rift, however, tried to become a plate boundary byrifting apart in ancient history. It eventually failed, but its long period of upheaval left behind many ancient scars in the craton of North America. This created a weak spot in the otherwise stable continental interior, and this weak spot is vulnerable to the subtle tectonic forces driving the North American plate.

Another type of plate dynamic occurs when two plates slide past each other along what is known as a **transform fault.** Stress builds up at the plate boundaries as the plates grind together, often creating earthquakes. In California, the North American Plate meets the Pacific Plate along an active transform fault called the San Andreas Fault. In the New Madrid earthquake zone, the ancient faults in the northern and southern parts of the Reelfoot Rift are transform faults.

When stress on the faults causes an earthquake, the faults slip in a right-lateral motion. This means that as you face the fault from the side, the ground on the opposite side moves to the right during an earthquake. Scientists have recently measured a buildup of stress at the southern end of the New Madrid earthquake zone, while the northern end seems to be inactive. This situation has led scientists to speculate that the southern end of the zone is the most likely segment to experience the next major earthquake. This is cause for concern, because the large metropolis of Memphis, Tennessee, and scores of smaller towns are located in this area.

D. Earthquakes and Geology

When an earthquake strikes, tremendous energy is released in the form of **seismic waves**. These waves radiate away from an earthquake's center at great velocities, reaching speeds between 4,500 to 15,700 miles per hour. As they travel through the earth's crust, the waves meet resistance from rocks, sediments, and soils and begin to slow down. This is called **attenuation**. Because the crust is made of a very complicated mix of different materials, with different densities and different structural makeup, the amount of attenuation also varies. In hard, dense bedrock, seismic waves can only move the rigid rocks slightly so they tend to speed through with minor attenuation. Softer materials, like sand and soils, have lots of pores and commonly contain fluids, so they are easily shaken by seismic waves. This creates a dampening effect on the energy of the waves, while at the same time greatly increasing the size, or wavelength of the waves.

In the New Madrid earthquake zone and throughout the central U.S., the crust is made of very old, hard bedrock with low attenuation characteristics. At the surface, the region is dissected by many rivers and streams. These waterways have deposited thick layers of wet, sandy materials in their drainage basins, so the ground is susceptible to severe ground shaking. There is also a blanket of fine, silty material found throughout the central U.S. called 'loess', which was deposited by the great continental glaciers that once advanced as far south as the New Madrid earthquake zone during the Ice Ages. Loess is also susceptible to severe ground shaking during an earthquake.

The combination of hard bedrock below, and loose materials at the surface makes the potential for damage relatively high and widespread if a major earthquake strikes in the New Madrid earthquake zone. Seismic waves will travel great distances through the rigid crustal rocks and upon arriving at the surface, will attenuate quickly and build to destructive size, especially in the river valleys. Several cities located along rivers, such as Memphis and St. Louis, Missouri, are beginning to take steps to increase their readiness for earthquakes.

E. The New Madrid Earthquakes of 1811-12

The New Madrid earthquakes are often cited as the strongest *series* of earthquakes ever known. There have been larger individual earthquakes that occurred elsewhere, but there are no known occurrences of related, consecutive earthquakes that were as powerful as the three great New Madrid shocks of 1811-12. Furthermore, the New Madrid sequence created the largest "felt areas" (areas where people reported shaking) and damage areas of any earthquakes on record. Total felt area is estimated to be 2 million square miles, or half the United States, while the damage area is estimated at 200,000 square miles.

Jared Brooks, a citizen of Louisville, Kentucky, counted a total of 1,874 shocks between December 16, 1811, and March 15, 1812, using a very primitive instrument . Of these, he rated 8 violent, 10 severe, and 35 moderate. If modern seismic recording instruments had been installed during the 1811-1812 quake sequence, many thousands of earthquakes would have been recorded. Aftershocks would also have been recorded for many years following the main sequence.

F. History of Earthquakes

Earthquakes > Mag. 5.0 in the Central United States after 1812

Southern Illinois:
June 9, 1838 — magnitude 5.1

Marked Tree, Arkansas:
January 4, 1843 — magnitude 6.4

Southern Illinois:
October 8, 1857 — magnitude 5.1

Southeastern Missouri:
August 17, 1865 — magnitude 5.2

Southern Illinois:
September 27, 1891 — magnitude 5.5

Charleston, Missouri:
April 12, 1895 — magnitude 6.8

Southeastern Missouri:
November 4, 1903 — magnitude 5.0

Illinois:
May 26, 1909 — magnitude 5.2

South-central Illinois:
November 9, 1968 — magnitude 5.4

Southeastern Illinois:
June 6, 1987 — magnitude 5.0

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