NOTES ON THE EARTHQUAKE OF NOVEMBER 9, 1968, IN SOUTHERN ILLINOIS

Paul C. Heigold

ILLINOIS STATE GEOLOGICAL SURVEY

JOHN C. FRYE, Chief

Urbana 61801
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INTRODUCTION

On the morning of November 9, 1968, an earthquake shook a large area of the central and southeastern United States, extending from Nebraska to North Carolina and from Michigan to the Gulf of Mexico. The earthquake was centered in southern Illinois, northwest of Broughton in Hamilton County, approximately 100 miles southeast of St. Louis, Missouri. The center of the shock was about 107 miles northeast of the town of New Madrid, Missouri, where the largest earthquake in the history of the continental United States was centered in 1811.

Seismograph stations throughout the world recorded the November 9 shock. Analysis of seismograms provided the following initial data:

- **Origin time:** \(17^h01^m41^s\) Greenwich Mean Time (\(11^h01^m41^s\) Central Standard Time)
- **Epicenter:** Latitude 37.96° N., longitude 88.46° W. Near the town of Broughton, Hamilton County, Illinois
- **Depth of focus (Hypocenter):** About 19 kilometers (12 miles)
- **Magnitude:** 5.5 on the Richter scale
- **Intensity:** About VII on the Modified Mercalli scale (table 1)

The seismograph at St. Louis University recorded an aftershock of Richter magnitude 4.0 at \(12^h45^m\) Central Standard Time, according to Dr. Otto Nuttli, professor of geophysics at St. Louis University.
In response to the wide interest in the earthquake, the Illinois State Geological Survey has prepared this note on the subject of earthquakes in general and on the results of a canvass of personnel of the mineral industries, geologists, engineers, and members of various government agencies regarding the effects of the November 9 quake. Telephone inquiries and questionnaires mailed out by the Survey, field visits by Survey personnel, news releases, and a letter from Leonard K. Murphy of the U. S. Coast and Geodetic Survey were the basis of this report. The Illinois State Water Survey conducted the investigation of the effect of the earthquake on groundwater levels and water wells. The results indicate that most observations were related to ground motion and, with the exception of a few structures in the immediate vicinity of the epicenter, only minor damage occurred.

A bibliography pertinent to earthquakes appears at the end of the report.

SEISMOLOGY

The focus, or hypocenter, of an earthquake is the source of the waves that form the earthquake. The depth of focus is the depth of the source below the surface.

Earthquakes are classified by depth of focus as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>0-70 km (43 mi)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>70-300 km (186 mi)</td>
</tr>
<tr>
<td>Deep</td>
<td>300-700 km (435 mi)</td>
</tr>
</tbody>
</table>

The epicenter is the point on the earth's surface above the focus of the earthquake.

The magnitude of an earthquake is a measure of ground movement recorded at a seismic station. The term was originally defined by Richter (1935) to facilitate comparison of the amount of energy released in earthquakes. Richter's original work was done with data from shallow earthquakes in southern California and adjoining states.

Magnitude is defined as the logarithm (base 10) of the largest amplitude measured in microns (.001 mm) on the record made by a standard Wood-Anderson torsion seismometer (period = 8.0 sec, magnification = 2800, and damping factor = 0.8) at a distance of 100 km (62 mi) from the epicenter of the earthquake. The magnitude of an earthquake recorded at other distances can be determined if it is known how the largest amplitude varies with distance.

Gutenberg (1955) and Gutenberg and Richter (1956) investigated the relation between the energy released by an earthquake and its magnitude and found that

$$\log_{10} E = 5.8 + 2.4M$$

where $E$ = total energy released by an earthquake in ergs, and $M$ = magnitude of an earthquake determined by body waves (Richter scale).
Their equation was used to compare the amount of energy released in the recent southern Illinois earthquake (magnitude 5.5 on the Richter scale) with that of the 1811 New Madrid earthquake (estimated as magnitude 8.5 on the Richter scale) and of the Alaskan earthquake of March 27, 1964 (approximate magnitude 8.5 on the Richter scale). The total energy released by the November 9, 1968, earthquake is calculated as $10^{19}$ ergs, whereas the total energy of the New Madrid earthquake, and also of the Alaskan earthquake, is calculated as $10^{26}$ ergs. In other words, the energy released in the November 9, 1968, earthquake was approximately one ten millionth of the energy released by each of the other two earthquakes.

The intensity of an earthquake is the amount of shaking, damage to property, and earth deformation felt or observed at a given place. Intensity is measured in terms of arbitrarily defined scales. The most widely used intensity scale is the Modified Mercalli scale shown in table 1.

In the immediate vicinity of the epicenter of the November earthquake, some chimneys fell down, facings on a number of buildings were damaged, plaster and foundations cracked, plate glass windows were shattered, furniture was disarranged, objects fell from shelves, and pendulum clocks stopped. From this type of information a maximum intensity of VII on the Modified Mercalli scale was assigned to the earthquake.

**MECHANISM OF EARTHQUAKES**

Earthquakes result from the build-up of large stresses in various parts of the earth. The mechanism by which this build-up occurs is a very complex problem on which geologists and geophysicists are still not in complete agreement. However, it is generally believed that the stresses produce faulting (relative movement of blocks of rock along a fracture surface), which is the major immediate cause of earthquakes. This belief is based on the fact that many earthquakes have occurred in the vicinity of known faults, and intensities of these earthquakes are greatest in elongated strips along the intersection of the fault plane with the surface of the earth. In some regions displacement has been observed on the fault at the time of the earthquake. Faulting is a result of the gradual accumulation of shearing stress, which builds up until the breaking strength of the rock is exceeded or until the frictional resistance along a pre-existing fault is exceeded.

Most likely, faulting starts at a point and spreads in all directions along the fault plane with a speed not exceeding that of the elastic waves through the rocks. The initial movement along the fault plane may involve a relatively small area. After a short interval of time a shift over a much larger area of the fault plane follows. If the time interval between these two events is long enough to allow both events to be distinguished, the first one is called a foreshock.

The energy radiated from a fault consists of a series of vibrations resulting from the complex original motion. Shaking lasts at least as long as the earth takes to complete its shift. However, because energy travels through the ground at several different velocities and can also travel along different paths, the duration of the earthquake will be longer than the fault
<table>
<thead>
<tr>
<th>Intensity</th>
<th>Description of characteristic effects</th>
<th>Richter scale magnitude corresponding to highest intensity reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Instrumental: detected only by seismography</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Feeble: noticed only by sensitive people</td>
<td>3.5 to</td>
</tr>
<tr>
<td>III</td>
<td>Slight: like the vibrations due to a passing lorry; felt by people at rest, especially on upper floors</td>
<td>4.2</td>
</tr>
<tr>
<td>IV</td>
<td>Moderate: felt by people while walking; rocking of loose objects, including standing vehicles</td>
<td>4.3 to</td>
</tr>
<tr>
<td>V</td>
<td>Rather strong: felt generally; most sleepers are wakened and bells ring</td>
<td>4.8</td>
</tr>
<tr>
<td>VI</td>
<td>Strong: trees sway and all suspended objects swing; damage by overturning and falling of loose objects</td>
<td>4.9-5.4</td>
</tr>
<tr>
<td>VII</td>
<td>Very strong: general alarm; walls crack; plaster falls</td>
<td>5.5-6.1</td>
</tr>
<tr>
<td>VIII</td>
<td>Destructive: car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed buildings damaged</td>
<td>6.2 to</td>
</tr>
<tr>
<td>IX</td>
<td>Ruinous: some houses collapse where ground begins to crack, and pipes break open</td>
<td>6.9</td>
</tr>
<tr>
<td>X</td>
<td>Disastrous: ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes</td>
<td>7.0-7.3</td>
</tr>
<tr>
<td>XI</td>
<td>Very disastrous: few buildings remain standing; bridges destroyed; all services (railway, pipes and cables) out of action; great landslides and floods</td>
<td>7.4-8.1</td>
</tr>
<tr>
<td>XII</td>
<td>Catastrophic: total destruction; objects thrown into air; ground rises and falls in waves</td>
<td>8.1+</td>
</tr>
</tbody>
</table>
movement. In general, the greater the distance from the fault, the longer the shaking lasts. The ground motion from an earthquake has been known to take several hours to die out. Near the epicenter, the duration is usually from a few seconds to several minutes.

Although the shift of the rocks at the time of the principal break or main shock relieves the main stress in the rocks, new stresses are likely to be set up in adjoining places. Following the main shock, a series of adjustments results in a sequence of aftershocks of gradually decreasing magnitude and frequency.

Gutenberg and Richter (1949) have analyzed the frequency and energy distributions of 412 shocks of magnitude 6.0 or more on the Richter scale that occurred throughout the world from 1904 through 1947. The results, in general, show that the number of earthquakes and the energy associated with the earthquakes decrease with depth of focus. In fact, no earthquake has ever been recorded below 700 km (435 mi), which seems to indicate that the earth is incapable of accumulating appreciable amounts of shear stress below this depth.

EARTHQUAKES IN SOUTHERN ILLINOIS

As mentioned previously, the focal depth of the November 9, 1968, earthquake was approximately 19 km (12 mi). This places the focus within the earth's crust, which seismological data have shown to be about 35 km (22 mi) thick for that area of southern Illinois (Heigold, 1960). The continental crust consists of sedimentary rocks overlying denser, crystalline, granitic and basic igneous rocks.

At the base of the crust there is a transition zone between the crust and the mantle below. In this zone, seismic velocities increase sharply and rock types change to denser varieties. The mantle extends to a depth of approximately 2900 km (1800 mi), at which depth the core of the earth is encountered. The core extends to the center of the earth, about 6371 km (3960 mi) from the surface. All observed earthquakes have occurred in the crust or mantle of the earth.

The epicenter of the November 9 earthquake is located at the extreme southern end of the oval-shaped sedimentary basin known as the Fairfield Basin (fig. 1). The sedimentary rocks of the basin attain a maximum thickness of about 14,000 feet in White County. A deep well in southern Hamilton County just a few miles north of the epicenter penetrated the complete sedimentary column and found it to be approximately 13,000 feet thick.

Major Fault Zones

Several zones of faulting mark the southern edge of the Fairfield Basin (fig. 1). The Shawneetown - Rough Creek Fault Zone is composed of high-angle faults, traceable from Kentucky across the Ohio River and into Illinois near Shawneetown. It has a maximum displacement of 3000 feet or more (up on the south side) just west of the Saline-Gallatin County line (fig. 1). South of the Shawneetown - Rough Creek Fault Zone is an area of intense faulting where most of the major faults trend southwest-northeast.

The Cottage Grove Fault Zone, which is considered the westward extension of the Shawneetown - Rough Creek System, extends from southern Gallatin
Fig. 1 - Regional faulting map of southeastern Illinois. (After Willman and others, 1967.)
County, just a few miles north of the Shawmeetown - Rough Creek Fault Zone, westward to and beyond the flexure known as the DuQuoin Monocline, which forms the western boundary of the Fairfield Basin. The Cottage Grove System consists of high-angle faults with less displacement than the Shawmeetown - Rough Creek Fault. The epicenter of the November 9 earthquake is about 12 miles north of the Cottage Grove Fault System.

The third fault system of note in the area of the epicenter is the Wabash Valley Fault System. It contains a series of high-angle faults that extend northward from the Cottage Grove and Shawmeetown - Rough Creek Fault Zones through Saline, Gallatin, White, Edwards, and Wabash Counties, Illinois.

Geophysical and Geological Considerations

Geophysical data from the area surrounding the epicenter provide evidence that faults in the area may extend deep into the crust. Regional gravity and magnetic data (figs. 2 and 3) show gravity and magnetic highs along the upthrown sides of the Shawmeetown - Rough Creek, Cottage Grove, and Wabash River Valley Fault Systems. The magnetic highs are much sharper and more definitive than the gravity highs. The size and regional extent of these anomalies can mean only that their source is in the crust and/or upper mantle.

The evidence suggests that faulting occurred in both the crust and upper mantle; the magnetically susceptible and dense rocks of the crust and upper mantle have moved upward in relation to less magnetically susceptible and less dense rocks of the crust.

The epicenter of the earthquake actually falls within a closed magnetic high (fig. 3) that correlates well with the known northeast-southwest trending structural high that extends from the town of Dale on the northeast to Rural Hill on the southwest. Evidence that this structure is also present at the base of the sedimentary column was given by the deep well at Dale that penetrated the entire thickness of sediments and found that the Cambrian Mt. Simon Sandstone, the oldest sediments in the basin, was missing, possibly as a result of non-deposition or erosion on a Precambrian high.

In support of the hypothesis that forces originate deep in the crust and upper mantle, several basic dikes (iron- and magnesium-rich intrusive rocks) intersect the sedimentary rocks in and just north of the Cottage Grove Fault System west of Eldorado in Saline County (fig. 1). The dikes show that molten basic rock from the upper mantle or lower crust has been forced upward under great heat and pressure through zones of weakness such as faults and fissures.

Triggering Mechanisms

Among the possible triggering mechanisms for earthquakes, several may apply to earthquakes in southern Illinois:

1) sudden changes in barometric pressure
2) changes in surface-water loads
3) earth tides
4) crustal rebound from unloading of glacial ice
5) crustal sinking due to Recent deposition in the Mississippi Embayment region
Density used in calculation of Bouguer Gravity Anomaly = 2.67 GM/CM$^3$
Contour interval = 5 MGAL.

Fig. 2 - Bouguer gravity map of southeastern Illinois.
Corrected for regional and diurnal variation
Flown at 3000 feet, measured sea level
Contour interval = 100 gammas

Fig. 3 - Total field aeromagnetic map of southeastern Illinois.
(After R. W. Patenaude, 1964.)
The latter two mechanisms may be of sufficient magnitude to produce the stresses causing earthquakes.

Energy Release

The much faulted region of southeast Missouri, northeast Arkansas, western Tennessee and Kentucky, and extreme southern Illinois has been a source of more or less frequent release of energy in the form of earthquakes. This type of area led Benioff (1951) to state that the total amount of energy released through earthquakes over a certain period of time is constant within a given area. The longer the period of time without a shock, the greater will be the amount of energy released during subsequent shocks. In the southern Illinois area, the release of energy occurs as numerous small shocks, so small that they cause little or no damage to man-made structures.

A summary of earthquakes in the Mississippi Valley region and their estimated intensities on the Modified Mercalli scale was made by McGinnis (1963) and includes earthquakes from the earliest reports to 1962. This summary and more recent data show that ever since the New Madrid earthquake of 1811 (intensity XII) no earthquakes have occurred in the region with intensities greater than VIII on the Modified Mercalli scale, which is the lower limit of serious damage to man-made structures.

CANVASS OF EARTHQUAKE EFFECTS

The Illinois State Geological Survey and the Illinois State Water Survey conducted inquiries concerning the damage and unusual effects resulting from the southern Illinois earthquake. Only a small percentage of the reports received by the Geological Survey has as yet been verified. No major damage was reported except at the epicenter.

Data obtained in the canvass, including examples of the types of damage done and observations made, are summarized in the following pages.

Reports from the Coal Industry

Members of the Coal Section of the Geological Survey personally queried representatives of the coal companies engaged in underground and strip-mining operations, particularly in southern Illinois, about damage resulting from the November earthquake. Although no major damage occurred, minor damage and other effects were reported in some mines.

Jefferson County
Sec. 7, T. 4 S., R. 2 E.
Freeman Coal Company

One of four legs supporting a coal hopper located at the foot of the shaft of Peabody Coal Company's underground mine No. 6 was somewhat bent. The concrete base on which the leg rested was adjacent to a previously known fault
that had about 18 inches displacement. A company representative was of the opinion that additional movement had occurred in the fault as a result of the quake.

Gallatin County
Sec. 8, T. 10 S., R. 9 E.
Peabody Coal Company

Slight heaving occurred in the floor, evidenced by the bending of the steel track in an entry of the Peabody Coal Company's underground Eagle Mine.

Gallatin County
Sec. 21, T. 9 S., R. 9 E.
Peabody Coal Company

In Peabody Coal Company's underground mine No. 90, leakage occurred in the concrete water seal in the air shaft at a depth of about 80 feet.

Saline County
Secs. 13 and 19, T. 9 S., R. 5 E.
Sahara Coal Company

A few minor roof falls that may have been related to the earthquake took place in underground mines No. 5 and No. 16 of the Sahara Coal Company.

Franklin County
Sec. 11, T. 6 S., R. 2 E.
Old Ben Coal Company

A crew working in the eastern part of the Old Ben Coal Company mine No. 24, near Benton, reported feeling rather intense earth movements. Another crew in the western part of the mine, on the opposite side of a north-south fault zone, felt no movement.

Reports from the Oil and Gas Industry

Questionnaires were sent from the Survey's Oil and Gas Section to members of the Engineering Committee of the Oil and Gas Association, to companies with underground gas storage operations or LPG underground storage, to companies operating crude oil pipe lines, and to all refineries. Numerous oil well operators were interviewed. In addition, a few reports on changes in production rate were obtained from the December 5, 1968, issue of Scout Check, Inc. The exact causes of such changes will take some time to determine.

Bond County
Sec. 23, T. 5 N., R. 4 W.

An old, plugged gas well, 1060 feet deep, on the farm of Warren M. File, Pocahontas, suffered cracks in its casing, apparently as a result of the earthquake. Shortly after the earthquake, the cracked casing set up a gas-ground-
water system, making the well spout water like a geyser. The frequency at which the "geyser" erupts—at first about every 15 minutes—is apparently decreasing with time.

Hamilton County
Sec. 4, T. 7 S., R. 5 E.
C. E. Brehm Drilling and Producing Company of Mt. Vernon

One of the 3-inch plastic nipples extending from the valve out to the right-angle elbow broke completely through at the P. M. Smith unit.

Hamilton County
Sec. 13, T. 6 S., R. 5 E.
Clarence Sherman

Production of Clarence Sherman's No. 7 Sloan well increased from 25 barrels to 40 barrels of oil per day.

Hamilton County
North of Dale
Texaco, Inc.

Cracks were opened in a large tank used in waterflood operation. Steel rods girding the tank were visibly strained.

Hamilton County
North of Walpole, near Tuckers Corner
Shell Oil Company

Breakage occurred in a pump coupling rod.

St. Clair County
East St. Louis
Socony-Mobil Oil Company, Inc.

A centrifugal high-speed compressor was knocked out of alignment.

Marion County
Sec. 9, T. 1 N., R. 3 E.
National Associated Petroleum Company of Mt. Vernon

Two wells in Exchange West field increased production from 20 to 40 barrels per day, then decreased to 30 barrels per day.

White County
Sec. 1, T. 5 S., R. 10 E.
Jarvis Bros. and Marcel

A recently installed water injection well (Jarvis Bros. and Marcel No. 5 Cleveland) in the center of the Phillips Consolidated pool, 3 miles
south of Crossville, with a water input of 96 barrels at 1480 psi, had a pressure drop to 1300 psi at the time of the earthquake.

Alexander County
Sec. 13, T. 15 S., R. 3 W.
Mrs. Robert H. Parish, Route 1, Thebes

Water in a 900-foot deep well became muddy shortly after the quake.

Several other similar incidents have been reported.

Engineering Geology Reports

Questionnaires were sent to owners of dams and reservoirs, power companies, district offices of the U. S. Army Corps of Engineers, and the Illinois State Division of Highways.

Christian County
Kincaid, T. 13 N., R. 3 W.
Commonwealth Edison Company

At the Kincaid generating station, two centrifugal air compressors were electrically disconnected and put out of service, sounding an alarm in the control room. This is a protective device set to operate whenever compressor shaft vibration exceeds 1.2 mils.

Illinois Power Company
Macon County - Decatur
St. Clair County - East St. Louis, Belleville
Marion County - Centralia
Jefferson County - Mt. Vernon

During the week immediately following the earthquake, breaks were discovered in buried cast-iron gas mains at the cities listed above. The earth tremor is believed to have been the cause of the breaks, although the incidence of such breaks normally increases when the weather turns cold.

At the Centralia gas storage field compressor station in Marion County, the concrete walls and floor of the compressor pit, the floor of an auxiliary building (in the area of the air compressor), and the air-receiver base all sustained hairline cracks. Four large cracks occurred in the well platform of a water well at the compressor station.

At the Hookdale compressor station in Bond County, the south foundation and pit wall, as well as several motor mounts, sustained hairline cracks. In the odorant building a crack appeared in the floor.

In the Tilden gas storage field in Randolph County, a leak developed in the seal of a down-hole production packer used to seal between the casing and tubing in a gas storage well.
Marion County
Salem and Centralia
Department of Public Works and Buildings, State Division of Highways

Minor cracks developed in masonry walls at the Division of Highways maintenance storage buildings in Salem and Centralia.

Mineral Industries Reports

The Geological Survey sent questionnaires to fluorspar, limestone, silica, lead, and zinc mining companies, but none of them reported damage or unusual effects.

Illinois State Water Survey Report

Shortly after the earthquake, spot checks of water-level recorders were made by Water Survey personnel to see if they recorded any effects of the earthquake in observation wells. Checks were made in the East St. Louis, Champaign-Urbana, Peoria, and Chicago areas. No changes in water levels were recorded, which is in direct contrast to the records of the 1964 Alaska earthquake that showed pronounced changes.

Coles County
Charleston

A break in a 12-inch water main that was observed shortly after the earthquake may have resulted from ground motion related to the shock.

U. S. Coast and Geodetic Survey Report

A reconnaissance of the epicentral area to determine the effect of the earthquake on structures was conducted by David W. Gordon of the U. S. Coast and Geodetic Survey.

The earthquake was most intense in an area roughly bounded by the villages of Dale, Walpole, and Braden in Hamilton County. Bricks were thrown or loosened from approximately 40 percent of the chimneys in that vicinity. Incidences of rotated or fallen tombstones in the area also indicate high intensity. Damage estimated at $5000 to $8000 was reported at the Johnson home, a large, two-story brick house 2½ miles west of Dale. It included cracked interior walls, fallen plaster, and broken chimneys. At Endicott's Shell service station in Dale, shear cracks formed in the exterior concrete-block walls.

In Hamilton County, a television antenna was thrown down at Braden and lag bolts fixing guywires to a roof pulled out. Waves four feet high were reported at a pond near the town.

At McLeansboro, shear cracks formed in a brick exterior wall of the Methodist Church, and cornices were dislodged from the top of the wall of the church. Interior walls cracked at Hamilton County Courthouse.
At Eldorado in Saline County, a small portion of the top of the brick façade of First State Bank collapsed, and there were shear cracks and broken windows in a rear wall. Bricks were loosened above the entrance to the Adult Education Center, and the front of the building had to be roped off. Debris fell from twin 100-foot chimneys at the abandoned Wasson Coal Company mine.

In White County, bricks fell from a parapet wall atop the B and O Cafe in Norris City.

In Gallatin County, a 35-foot long section of wall at the top of the W. M. Speckt building in Ridgeway toppled. The chimney at the Catholic church was damaged.

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* Out of print