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Earthquakes in Virginia and Vicinity 1774 – 2004

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This map summarizes two and a third centuries of earthquake activity. The seismic history consists of letters, journals, diaries, and newspaper and scholarly articles that supplement seismograph recordings (seismograms) dating from the early twentieth century to the present. All of the pre- instrumental (historical) earthquakes were large enough to be felt by people or to cause shaking damage to buildings and their contents. Later, widespread use of seismographs meant that tremors too small or distant to be felt could be detected and accurately located.

Earthquakes are a legitimate concern in Virginia and parts of adjacent States. Moderate earthquakes cause slight local damage somewhere in the map area about twice a decade on the average. Additionally, many buildings in the map area were constructed before earthquake protection was added to local building codes. The large map shows all historical and instrumentally located earthquakes from 1774 through 2004.

Earthquakes

Plate tectonics cause most of the Earth's earthquakes at boundaries between moving plates. However, the map area is in the middle of the North American plate, far from plate boundaries. Eastern U.S. earthquakes occur on faults, typically kilometers underground, but usually we cannot tell which fault slips to cause an individual earthquake. Accordingly, the best guides to earthquake hazards in the map area are the earthquakes themselves, not faults or plate motions.

Our estimate of the location of an earthquake within the Earth is uncertain, typically by several kilometers or more, except where dense monitoring networks exist, such as in the urban areas of California. Uncertainties are larger where seismographs are spaced far apart, and for pre-instrumental earthquakes. Despite the uncertain locations of some earthquakes, the map shows that people in most parts of the map area have felt earthquakes over at least the last century or two.

The most common measure of earthquake size is its magnitude (M), which reflects the total energy released as seismic waves. There are several ways to measure magnitude. The frequently cited "Richter scale" was the first, although the name is too often applied indiscriminately. Use of different magnitude types can give slightly different values for the same earthquake. Differences of several tenths of a magnitude unit are common.

While the size of an earthquake is characterized by a single number (magnitude), the effect of seismic shaking on people, buildings, and the landscape is characterized by a quantity called intensity that varies spatially. Intensity on the Modified Mercalli Intensity (MMI) scale ranges from I (barely felt or not felt) to XII (total destruction). MMI VI marks the onset of slight damage to poorly built structures, whereas MMI VIII or higher generally involves considerable damage to some buildings, even collapse. Maps of intensity values, such as the small maps of the 1897 and 2003 earthquakes, demonstrate that the intensity, highest at the place above where the earthquake occurred underground, falls off with distance. As the maps illustrate, intensity also varies with local ground conditions.

Eastern U.S. Earthquakes

Earthquakes are less common east of the Rocky Mountains than in California, but because of differences in crustal properties, an eastern earthquake affects an area about ten times as large as a California earthquake of the same magnitude. A M4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A M5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

Earthquakes in and Near Virginia

A pattern of Virginia and nearby seismicity has emerged from the collection of historical records and instrumental detection and location of small earthquakes. Three loose clusters of earthquakes (seismic zones) and a small component of scattered, background seismicity contribute to the seismic hazard of Virginia and adjoining States. The color and size of each earthquake symbol designates the magnitude on the large map.

The Eastern Tennessee seismic zone extends southwestward beyond the map area. The largest known damaging earthquake in the zone (M4.6) occurred on April 29, 2003, near Fort Payne, Alabama, and was felt in westernmost Virginia. Earthquakes too small to cause damage are felt about once a year in the seismic zone, although most of them are outside the map area.

Since at least 1828, earthquakes have been reported in the Giles County seismic zone. The largest known damaging earthquake (M5.6) in the zone occurred in 1897. Smaller earthquakes are felt or cause light damage once or twice a decade.

Since at least 1774, people in the Central Virginia seismic zone have felt small earthquakes and suffered damage from infrequent larger ones. The largest known damaging earthquake in the zone (M4.8) occurred in 1875. Smaller earthquakes that cause little or no damage are felt each year or two. The February 21, 1774, Petersburg earthquake recorded by Thomas Jefferson in his memorandum book was located in this zone.

Seismic Hazard

Engineers who design buildings, bridges, and other structures with earthquake resistance in mind, need to estimate the vertical and horizontal shaking from an earthquake that a structure is likely to undergo. The Generalized Seismic Hazard map portrays seismic hazard (calculated by the USGS) as bands of color (cooler for lower hazard, warmer colors for higher hazard). Hazard is expressed as percentage of the acceleration of gravity (% g). In addition, the hazard value is computed for sites on firm rock for particular time intervals (here, 50 years) and probability of exceedance (here, 2%). For example, the hazard value at Roanoke is between 16% g and 18% g. That means that a structure built on firm rock has 1 in 50 odds (2% probability) of undergoing ground shaking of 16% – 18% g (the threshold for structural damage in poorly constructed buildings) or higher in the next 50 years.

Abbreviated Modified Mercalli Intensity Scale

I. Not felt except by a very few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Intensity and Magnitude

Intensity is a measure of the effects of shaking upon people, buildings, and in extreme cases, the landscape. For a given earthquake, the intensity ranges from a maximum value, usually observed near the epicenter of the earthquake, to increasingly smaller values at greater distances. The intensity distributions for the notable 1897 and 2003 earthquakes are portrayed on two small maps below. As noted elsewhere on this map, the magnitude of an earthquake is single- valued, representing the total energy released by the earthquake. Thus, an earthquake can have many intensity values but only one maximum intensity and one magnitude. The symbols plotted on the large map represent the best estimates of time, location, and magnitude that are tabulated in several earthquake catalogs (see TECHNICAL NOTES).

Authorities differ on the magnitude inferred from intensity patterns of pre- instrumental earthquakes, and some degree of uncertainty accompanies the computation of instrumental magnitudes. In both cases, this uncertainty may be several tenths of a magnitude unit or even larger, depending upon the method, quality of available data, and assumptions made during the determination.

Technical Notes

The earthquakes shown on the maps were drawn from three catalogs: SIGUS; PDE; and SEUSSN. SIGUS, the Significant Earthquakes in the U.S. catalog (Stover and Coffman, 1993), lists earthquakes from the historical period (1754 is the earliest earthquake in Virginia) through 1989. The PDE (Preliminary Determination of Epicenters) catalog covers the overlapping period 1973- 2004. Both catalogs are maintained by the USGS (see DATA SOURCES). The SEUSSN (Southeastern U.S. Seismic Networks) catalog covers the southeastern U.S. for the period 1977 – 2003. While considered authoritative, the SEUSSN catalog is less accurate at the edges of its coverage area, especially for small magnitude shocks. In addition, all the catalogs may contain mining- related seismic events, such as blasts and roof collapses. Mining events are typically small magnitude, however, and may not be differentiated from small earthquakes (see Street and others, 2002). Two of the largest mining events are found in the SIGNIFICANT SEISMIC EVENTS listing.

Selected events from the USGS National Seismic Hazard Maps (NSHM) project earthquake catalog were added when these events were not listed in either the SIGUS or the PDE catalog.

The following selection rules were used to minimize duplicate events during periods of overlap:

1754 - 1972 SIGUS + NSHM (selected)
1973 - 1976 PDE + NSHM (selected)
1977 - 2003 SEUSSN (36° - 39° N.); PDE otherwise
2004 PDE

In cases of duplication, the NSHM event parameters were favored above the SIGUS or PDE determinations.

A Note on the Intensities of the 1897 Giles County Earthquake

The May 31, 1897, Giles County earthquake is one of the most important to have occur in the eastern United States principally because of the large area over which it was felt. This M5.6 shock was located in the heart of the Appalachian Mountains. Contemporary accounts, culled from newspapers, journals, and diaries, are the sources of the intensity observations, plotted on the map as color-coded circles. Each observation is assigned a Modified Mercalli Intensity (MMI) and the results are contoured. An observation is coded “F” if the earthquake was felt but no MMI was assigned and “N” if a source document indicated that the event was not felt. Although the contours are approximate, the pronounced asymmetry of the pattern of higher intensity values (roughly parallel with the trend of the Appalachians) is similar to that of the December 9, 2003, central Virginia earthquake.

Community Internet Intensity Map

The Community Internet Intensity Map (CIIM) summarizes the online questionnaire responses provided by Internet users. An intensity number is assigned to each questionnaire received and reflects the effects of earthquake shaking on the people and structures in the community. The average of the individual intensity values in each ZIP Code zone is plotted on the map in a color-coded format.

Significant Seismic Events 1774-2004 Virginia and Vicinity

Yr Mo Dy Lat(°n) Lon(°w) Mag

1774 2 21 37.2 77.4 4.5

1776 39.6 81.9 4.0

1824 7 15 39.7 80.5 4.1

1828 3 10 37.0 80.0 4.6

1833 8 27 37.7 78.0 4.5
1844 11 28 36.0 84.0 4.2
1852 4 29 36.6 81.6 4.8
1852 11 2 37.6 78.6 4.3
1853 5 2 38.5 79.5 4.6
1861 8 31 36.1 81.1 5.0
1875 12 23 37.8 78.0 4.8
1885 10 10 37.7 78.8 4.4
1889 3 8 40.0 76.6 4.1
1897 5 3 37.1 80.7 4.3FS
1897 5 31 37.3 80.7 5.6
1898 2 5 37.0 81.0 4.4
1898 11 25 37.0 81.0 4.5
1899 2 13 37.0 81.0 4.5
1901 5 17 38.75 83.00 4.2
1907 2 11 37.70 78.30 4.0
1913 3 28 36.20 83.70 4.1
1918 4 10 38.70 78.40 4.6
1924 11 13 36.60 82.20 4.0
1928 11 3 36.112 82.828 4.5
1944 1 8 39.800 75.500 4.2
1952 6 20 39.640 82.023 4.0
1954 1 2 36.600 83.700 4.3
1956 9 7 36.445 83.787 4.1
1957 1 25 36.600 83.700 4.0
1966 5 31 37.660 78.130 4.3
1969 7 13 36.120 83.890 4.1
1969 11 20 37.449 80.932 4.6
1975 2 16 39.050 82.422 4.4
1976 1 19 36.866 83.861 4.0
1976 6 19 37.362 81.624 4.7
1976 9 13 36.624 80.768 4.3
1980 7 27 38.193 83.891 5.2
1984 4 23 39.921 76.355 4.1
1984 8 17 37.868 78.324 4.2
1988 4 14 37.238 81.987 4.1
1988 9 7 38.142 83.834 4.6
1989 4 10 37.136 82.068 4.3ME
1990 8 17 36.934 83.384 4.0
1995 10 26 37.053 83.121 4.0ME
1996 6 29 37.187 81.950 4.1
2003 12 9 37.774 78.100 4.5

FS: Foreshock
ME: Mine event

Map base from U.S. Geological Survey National Elevation Dataset,
National Hydrologic Database, and Digital Chart of the World (ESRI, 1993)

Albers equal- area conic projection, standard parallels 36° 40´ 00´´ and 39° 20´ 00,´´ central meridian 79° 30´ 00,´´ latitude of origin 0° 00´ 00´´

Information Sources on the Web:

(If you lack access to the World Wide Web, your public library may have it.)

U.S. Geological Survey Earthquake Hazards Program: http://earthquake.usgs.gov/ or toll-free 1-888-ASK-USGS. The site contains regional, national, and global earthquake information and links to other sites.

Earthquake Information Network: http://www.eqnet.org/. The site consists of many links to all sorts of information about earthquakes and their hazards.

Virginia Tech Seismological Observatory: http://www.geol.vt.edu/outreach/vtso/. The site concentrates on earthquakes of Virginia and the rest of the Southeast.

Data Sources

SIGUS and PDE earthquake catalogs: http://neic.usgs.gov/neis/epic.html. Search engine for all earthquake catalogs managed by the USGS National Earthquake Information Center.

SEUSSN earthquake catalog: http://www.geol.vt.edu/outreach/vtso/anonftp/catalog/susn2003cat.html.

USGS National Seismic Hazard Maps (NSHM) project: http://earthquake.usgs.gov/hazards/hazmaps/. Overview of the NSHM project and its products.

USGS NSHM seismic hazard data: ftp://hazards.cr.usgs.gov/hazmaps/data2003/ascii/USpga2500v6.asc.

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