EARTHQUAKES IN DELAWARE

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CAUSES OF EARTHQUAKES

Delaware is not in a seismically active region,but, even here, earthquakes occur because of sudden adjustments in the earth's crust. Even though such movements can be startling they yield important information about the behavior of the earth and the potential for future events. The Delaware Geological Survey continually monitors seismicity in the State because of both the scientific value of the information and to help address the concern of residents and other agencies over possible effects.

When an earthquake occurs, the earth's crust breaks along a surface known as the fault plane. Faults are not always visible at the surface of the earth, and the existence of a fault does not necessarily imply that earthquakes are occurring along it today. The majority of faults that have been mapped are currently inactive. However, there are certain areas in the world, some in the United States, where earthquakes occur frequently and are easily identified with active faults. This is especially true in the western portion of the country. In other areas, such as the eastern United States, few active faults have surface expressions and the causes of earthquakes are not readily known. There are no surface features and no geologic structures now positively associated with the events in Delaware. Several lines of evidence suggest that the Fall Zone (the boundary between the Coastal Plain and Piedmont provinces) and locations of major changes in the direction of streams in northern Delaware may be associated with these earthquakes. Possibly the geomorphic features are the result of movement in response to persistent internal stresses. The stresses are relieved periodically by the occurrence of an earthquake. The original driving force was probably the opening of the Atlantic Ocean and the separation of Africa and North America, some 150-200 million years ago. Other local conditions, such as lubrication of deep rock surfaces by infiltrating ground water, may provide the actual trigger for these events.

RECORDING OF EARTHQUAKES

Much of the data gathered on earthquakes comes from the measurement of ground motion recorded by seismographs. The motions are due to the arrival of waves of various frequencies and types generated by fracturing along the fault plane. The first waves to reach the recording station are generally "P" or compressional waves (see Figure 1). They displace material directly ahead of them in the same direction of travel as the waves. Shear or "S" waves travel at slower speeds and displace material at right angles to the direction of travel. The difference in arrival times of the P and S waves can be used as a measure of distance to the epicenter (location on the earth's surface above the earthquake) and the focus (depth beneath the epicenter). Both P and S waves are known as body waves and travel through the interior of the earth. Surface waves are lower frequency waves that travel at still slower speeds along the earth's surface and are usually responsible for much of the damage caused by larger earthquakes (see Figure 2).

INTENSITY AND MAGNITUDE

Earthquakes can be classified by both their effects (intensity) and their magnitude (size). In the United States, the intensity is measured by the Modified Mercalli Scale. This is a subjective scale in which a location affected by an earthquake is assigned a number from I to XII depending on the effects of an event or how it was felt by local residents. For instance, Intensity I denotes that an earthquake was generally not felt except under very quiet conditions. Intensity V indicates it was felt by nearly everyone and caused minor damage. The intensity values vary with distance from the epicenter but also may vary with population density and type of underlying rock or soil. The DGS determines intensity by distributing questionnaires or soliciting citizen response. Area residents may telephone earthquake reports to the Survey's office at the University of Delaware (451-2833). For large events the National Earthquake Information Center of the U. S. Geological Survey (USGS) also distributes response forms through local post offices. These responses are

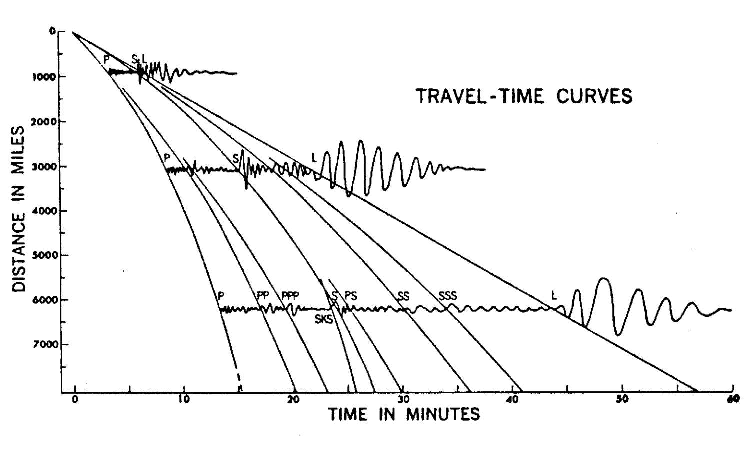

Figure 1. Travel-time curves with idealized seismograms superimposed. From: Earthquake Investigations in the United States, U. S. Dept. Commerce, 1969.

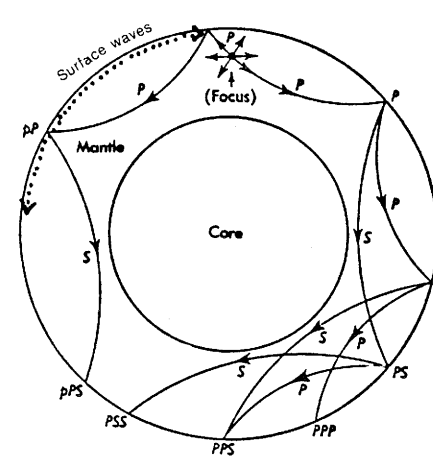

Figure 2. Travel path of earthquake waves. After: Earthquake Information Bull. July-August 1977, Vol. 9, No. 4.

an invaluable aid in assessing earthquake intensity, location, and future risk.

The magnitude of an earthquake can be calculated from one of several formulas that involve a measure of the amplitude or height of a particular wave group as recorded on a seismograph. The amplitude is directly proportional to the actual ground movement at the detector. This calculation takes into account the distance of the instrument from the epicenter so that the calculated value refers to the size of the earthquake only at the epicenter. The earliest magnitude scale was developed in 1935 by Charles Richter for California events and hence bears his name. Since then modifications and extensions of the scale have been generated for other areas and for various types of detectors. The difference between two magnitude units on the Richter scale represents a 10x difference in ground motion but over a 30x increase in energy released. Delaware's recorded events over the last twenty years have ranged from Richter magnitude 1 to 3.8. The 1871 earthquake in Wilmington probably exceeded a magnitude 4 with a maximum intensity of VII.

DELAWARE EVENTS

Newspaper articles and historical accounts document the occurrences of earthquakes in and near the State from at least the early 1700s. Since 1971, seismic detection equipment in Delaware has provided additional verification, particularly when combined with reports received from area residents.

The largest Delaware event in historical times was on October 9, 1871, and was centered in the Wilmington area. Damage was reported throughout northeastern Delaware and as far away as Oxford, Pennsylvania, about 25 miles northwest of Wilmington. Other smaller events took place east of Dover in March 1879, near Seaford in May 1906, in Delaware Bay(?) in 1937, and again in Wilmington in January 1944. The most recent series of earthquakes began in July 1971 with residents of the Wilmington area frequently reporting "booms," sometimes accompanied by rattling of windows. Field monitoring later that year by DGS, other universities, and the federal government confirmed that small earthquakes were indeed occurring. These events continue sporadically to the present.

The largest earthquake in recent years (magnitude 3.8) occurred on February 28, 1973, beneath or close to the Delaware River at the Pennsylvania-Delaware border. It was felt along the east coast from eastern New Jersey to Washington, D.C., and caused some minor damage in the Wilmington area (Figure 3). The most recent event strong enough to be felt took place in the Wilmington area on October 20, 1985, and registered a magnitude 1.7.

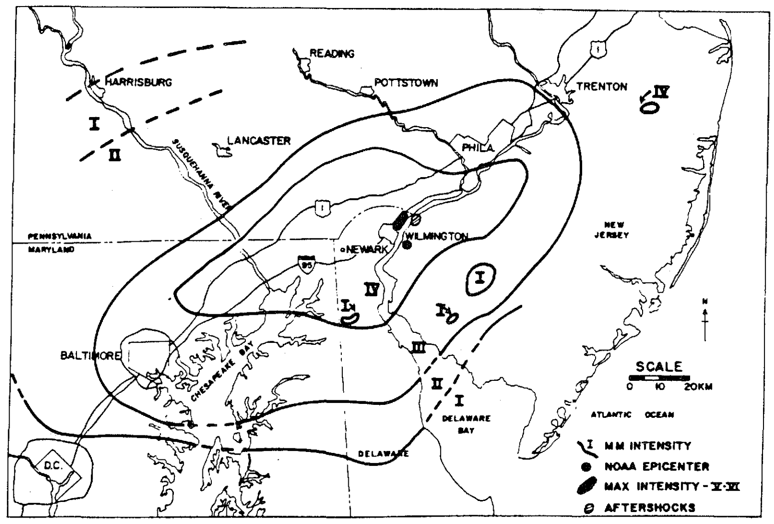

Figure 3. Map showing isoseismals on the Modified Mercalli scale for the February 28, 1973 earthquake. From: Sbar and others, 1973.

Earthquakes in Delaware are noisy events. Residents close to the source usually describe the sound as an "explosion" or noise like a "passing truck." The events occurred at depths from about 1 to 5 kilometers (about 0.6 to 3 miles) below the earth's surface and these relatively shallow depths undoubtedly account for some of the noise. Also, eastern United States earthquakes are felt farther away from the source than those of comparable magnitude in the west. Differences in physical characteristics between rocks of the eastern and western United States probably account for the stronger intensity of eastern events.

DELAWARE SEISMIC NETWORK

The DGS currently operates a network of five seismic stations within the State (Figure 4). One station is near Georgetown in Sussex County, one in southern New Castle County, and three in the Newark-Wilmington area. Only the detectors (seismometers) are located at these field sites. The signals from the detectors are transmitted by telephone line to the Survey's offices at the University of Delaware. Maintenance of the network and the record processing are daily tasks that require a long-term commitment of both funds and manpower. The Delaware network is part of the U. S. Northeast and the Southeast Seismic networks. These are formal coalitions of individual networks organized to exchange data, provide mutual assistance in investigation of events, and standardize reporting procedures. The DGS is also a collaborator with the U. S. Geological Survey's Earthquake Information Service.

The ultimate goal of earthquake investigations is to assess the chance of the occurrence of an earthquake of a given size and to determine the risk presented by such an event. This is a long and often tedious task usually requiring a great deal of personal judgment. Instrumental records are only available for the past few decades and historical records are often incomplete. Thus, investigators are never certain that the recorded seismic history is an adequate representation of the long-term seismicity of an area. Recent advances in electronics and personal computers have greatly enhanced data processing and reduced dependency on large computers. Nevertheless, the continued acquisition of reliable data on earthquake parameters (location, size, depth, fault plane attitude, and frequency content) is essential for the assessment of earthquake risk. In the process of arriving at the goal of prediction and risk assessment the networks continue to provide data that contribute to the solution of other problems, such as the design of large structures and deciphering the local structure of the earth's crust.

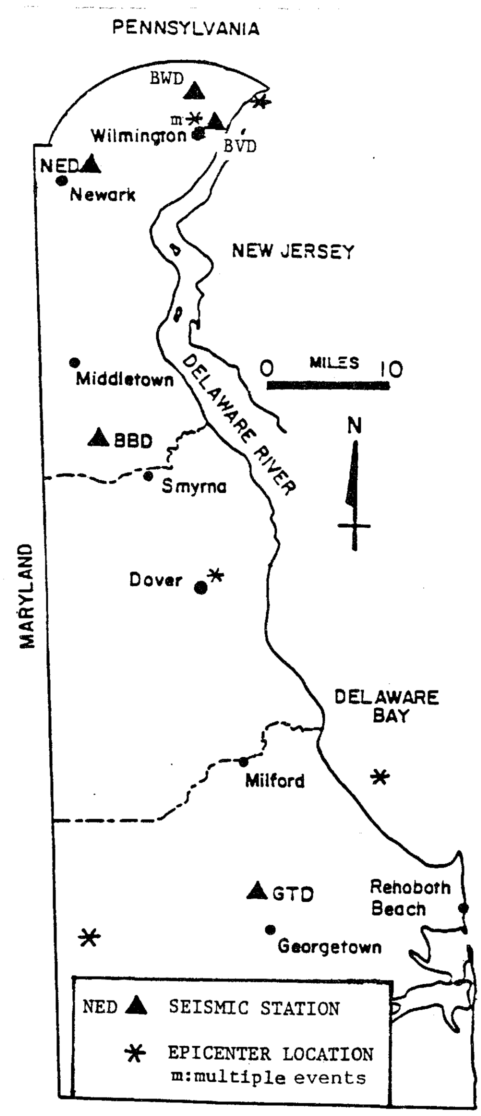

Figure 4. Map of Delaware showing locations of epicenters and seismic stations.