ENVIRONMENTAL
Fact Sheet
NEW HAMPSHIRE DEPARTMENT OF Environmental Services
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GEO-3 2019

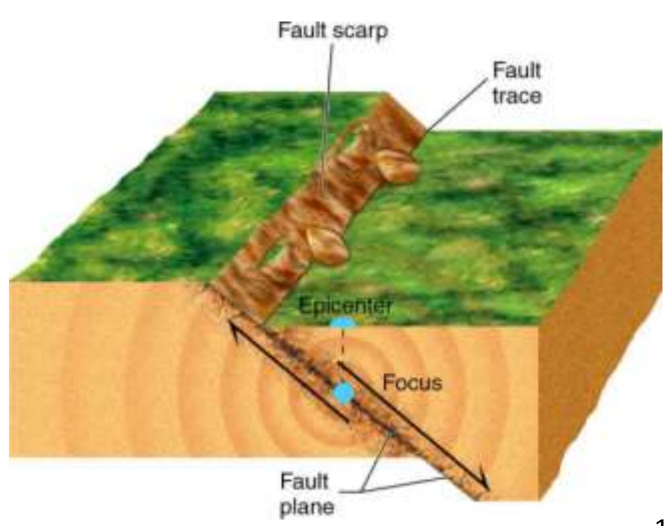
Earthquakes in New Hampshire

Causes of Earthquakes

The Earth's crust constantly transmits elastic wave energy, sensed as ground motion, generated from any number of sources that are either natural or man-made. The least energetic of these events are called tremors, which can be felt by humans, and microseisms, which can be sensed only by seismometers. If an event is relatively vigorous, it is usually called an earthquake. An earthquake is a sudden motion or trembling caused by an abrupt release of slowly accumulated strain. Shock from an explosion can produce a similar effect.

The most energetic of human-caused earthquakes are nuclear detonations; the most energetic naturally-caused earthquakes are triggered by crustal deformation, such as fault motion. The explosion of an asteroid in the earths atmosphere over Siberia in 1912 produced an unusual seismic event that was felt over a large part of the Earth. Events such as blasting, the boom from supersonic aircraft, mine cave-ins, and heavy traffic can cause humanly sensed, but generally not widely destructive, earth motion. The injection of wastewater deep underground in areas of intense oil and gas drilling has recently been attributed to a boom of earthquakes in the mid- to southwest United States.

In short, many causes of earthquakes, tremors, and microseisms can be recognized. However, most natural earthquakes are associated with crustal-scale tectonic events related to the instant release of strain built up within the earth from a combination of compressional, transpressional, and extensional stress. Crustal rupture (breakage) and sliding of crustal rock segments past one another (faulting) are of principle concern to us in New England. Volcanic activity is also a major source of seismic energy generated by the movement of magma as it migrates within the upper levels of the earths crust. This phenomenon does **not** occur east of the Rocky Mountains, however, and it can be dismissed from our list of causes.



Characteristics of Earthquakes

Two major elements of earthquakes are: (1) the ***focus,*** which is the rupture point within the earth where the earthquake originates, and (2) the ***epicenter,*** which is the hypothetical point on the surface of the earth above the focus.

Many faults are mapped in New Hampshire as well as the rest of New England. Areas where many surface ruptures coincide (fault zones) are becoming more appreciated in the scientific community as areas susceptible to further earthquakes. To date, no earthquake focus in New Hampshire can be directly correlated to any structural feature on the surface such as a fault. Observations along mapped faults in the state indicate that they probably have not been active for approximately 90 million years or more. However, recent work using a combination of historical accounts and computer modeling may have identified a linear fault in central New Hampshire (Ebel and Starr, 2018). This is discussed in more detail below.

Wherever you are on Earth, there is some probability of an earthquake, but the exact risk is difficult to assess. The numerical probability can be forecast, but this can be done with confidence only in regions where the **frequency** of earthquakes is relatively high.

Before the invention of the seismometer there was only the historic record to support studies of earthquake probability. Inquiry into earthquake risk to address environmental concerns has much to do with the frequency of occurrence, but a more important criterion is the strength of an earthquake usually referred to as either intensity or magnitude. The **intensity** of an earthquake is established by observing the degree of damage from an earthquake at a specified location. The **magnitude**, on the other hand, is a measure of the total energy released and can only be determined by the use of a seismometer which plots a manifest of ground motion. Seismologists have codified both criteria into scales. The intensity scale is called the **Mercalli,** named for its originator, and the magnitude scale is called the **Richter Magnitude** also named for its inventor. The seismic record for New Hampshire is reported entirely in Mercalli values prior to 1940. After 1940, Richter values began to be reported, and in 1963 nearly all the values were reported as magnitude. In 1979, another classification method was introduced called **Moment Magnitude** (M_w), and has become the most commonly used method for describing the size of an earthquake, especially large-scale events. Moment magnitude measures the size of a quake based on how much energy is released during the event, and the magnitude increases exponentially with each number. The below table details the original two scales:

Mercalli Intensity Scale	Characteristic Effects	Richter Magnitude Scale
I Instrumental	Detected only by sensitive instruments	Less than 3.0
II Feeble	Felt only by few at rest	Less than 3.0
III Slight	Felt indoors, like the vibration of a truck	3.0
IV Moderate	People awakened, objects rock, windows rattled	3.7
V Rather Strong	Plaster falls, windows broken, plaster falls	4.3
VI Strong	Felt by all, objects fall, many frightened	5.0
VII Very Strong	Walls crack, plaster falls, waves on ponds	5.6
VIII Destructive	General alarm, buildings damaged, chimneys fall	6.3
IX Ruinous	Many buildings destroyed, underground pipes fail	7.0
X Disasterous	Only best buildings and structures survive	7.7
XI Very Disasterous	Few buildings survive, bridges destroyed	8.4
XII Catastrophic	Total destruction, objects thrown into air	9.0

The Earth's Crust and Earthquake Risk

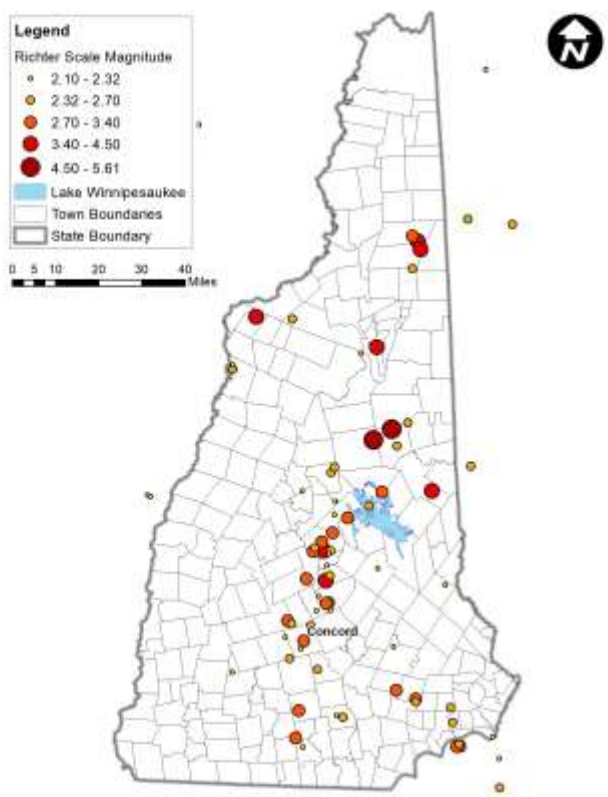
The Earth's crust is subdivided into discrete segments called plates. Each of these plates can be characterized by its own internal seismic characteristics wherein earthquake risk varies from low to moderate. The highest risk occurs along the interactive margins of plates, where they grind against each other producing the highest frequency of earthquakes. In contrast, the stable Precambrian-age hearts of continents such as the Canadian shield are the most seismically calm. New Hampshire has a medial position in the North American plate and is rated to have a moderate earthquake risk.

It has been observed that the rating of risk is somewhat misleading because its a frequency-based concept. Powerful earthquakes can occur within all risk categories, and there is growing recognition that some of the most powerful earthquakes have occurred in the low and moderate crustal categories. There is a general rule that the longer an earthquake waits to happen (as the strain builds up), the more powerful the earthquake will be. There is also a corresponding observation that the deeper in the crust the focus of the earthquake is, the more powerful it will be. Clearly, New Hampshire is vulnerable to destructive earthquakes. It is, however, impossible to calculate the probability accurately because the seismic record (less than three centuries) is of relatively short duration.

The earthquakes felt in New Hampshire do not necessarily relate to epicenters within the state. Epicenters in other surrounding states, Canada, and on the Atlantic sea floor have contributed to the record. The crystalline rocks of northeastern United States and Canada are relatively cooler in crustal context, and propagate seismic energy as much as ten times further than, for comparison, the crustally warmer rocks of the California coast. With this in mind, it is important to point out that the strongest quakes to hit the state had external epicenters.

Frequency of Earthquakes in New Hampshire

Since 1638, 65 earthquakes in New Hampshire were above 2.1 on the Richter scale according to the USGS Earthquake Catalog (earthquake.usgs.gov). Historical records document that a large quake in 1638 caused severe shaking as distant as Trois Rivieres, Quebec to the north and eastern Massachusetts to the south. Based on these accounts, and using computer modeling, the event is hypothesized to have occurred on June 6, 1638, with a magnitude of 6.5 and an epicenter located in central New Hampshire (Ebel, 1996; Ebel and Starr, 2018). Ebel and Starr (2018) proposed that the epicenter of the 1638 quake as well as others within an epicenter cluster extending from Concord to Lake Winnipesaukee (Fig. 2) lie on a previously unmapped fault plane. The latest earthquake epicenter occurring within this cluster was on January 6, 2020.



The earliest known damaging event occurred on October 29, 1727, with an epicenter off the coastline of New Hampshire or Maine. This was followed by a quake of at least equal intensity in 1755 known as the Cape Ann epicenter with a magnitude estimated to be 5.8. The strongest quake to be felt in the state occurred near La Malbaie, Quebec, in 1925 measured at magnitude 6.6 at the epicenter. The strongest damaging quakes with an epicenter in the state occurred at Tamworth on December 20 and 24, 1940, both with a measured magnitude of 5.8. At least 262 earthquakes with magnitudes greater than 1.4 and epicenters within New Hampshire have occurred since 1728 (Kathleen Langone, unpublished compilation, 1992). Perhaps the most memorable quake (Gaza Epicenter) was recorded with a magnitude of 4.7 west of Laconia on January 19, 1982, but only minor damage occurred.

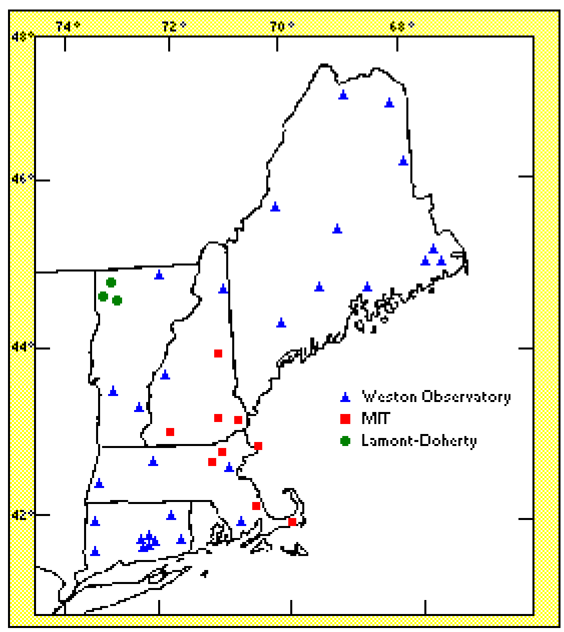
The record is complete enough to allow seismologists to compute occurrence probabilities for earthquakes in New England ranging from magnitude 4.6 to 6.0. Thus, earthquakes will continue to occur in New Hampshire with **at least** the same frequency and magnitude as in the past.

Earthquake Protection in New Hampshire

The term *built environment* is used by seismologists to characterize the works of man. Earthquake protection has been designed into only a few New Hampshire buildings, public works, or utilities, all of which are particularly vulnerable. The built environment on artificial fill and stratified glacial deposits (sand, gravel, silt and clay) is particularly vulnerable because of the magnified attenuation of earthquake energy by these deposits producing locally increased ground motion. By contrast, buildings built on bedrock and glacial till are less vulnerable.

However, brick buildings on this substrate, because of their brittle nature, are subject to damage unless they are reinforced. Buildings not attached to their foundation are also especially vulnerable. The historical record shows, instructively, that post and beam structures built upon any medium are especially stable because of their inherent flexibility. An earthquake with a magnitude greater than 6.5 would produce an emergency that would be comparable to that produced by a tornado or hurricane. In addition, bridges and dams would likely fail, and fuel storage tanks and water and gas mains would probably rupture. Strong earthquake motion on the sea floor near New Hampshire can generate tsunamis (tidal waves) that could produce damage and risk to life along the coastline.

No warning system for earthquakes is presently possible for New Hampshire, but seismometers constantly record activity. This service is provided by the Northeastern United States Seismic Network managed by the Weston Observatory of Boston College. The network also includes instrument operation and research support by the Massachusetts Institute of Technology and the Lamont-Doherty Observatory of Columbia University. As the inset map shows, there are six seismometer stations in New Hampshire.



The New England Seismic Network, operated by Weston Observatory, MIT, and Lamont-Doherty Geological Observatory.

Earthquake Emergency Management

National earthquake resources and preparedness is directed by the Federal Emergency Management Agency (FEMA). FEMA is coordinated regionally with state agencies such as the Governors Office of Emergency Management (OEM) in New Hampshire. Both agencies are sources of detailed information on earthquake risk, response, and preparation. OEM may be reached via telephone at (603) 271-2231 at State Office Park South, 107 Pleasant Street, Concord, New Hampshire 03301.

Suggestions for Additional Reading

Boudette, E.L., *The Geology of New Hampshire, the Granite State*, Rocks & Minerals, v. 65, no. 4, 1990, pp. 306-312.

Fratto, E.S., Ebel, J.E., and Kadinsky-Cade, K., *Earthquakes in New England*, U.S. Geological Survey, Earthquakes and Volcanoes, v.22, no. 6, 1990, pp. 242-249.

Krinitzsky, E.L. and Dunbar, J.B., *Geological-Seismological Evaluation of Earthquake Hazards at Franklin Falls Damsite, New Hampshire*, U.S. Army Corps of Engineers, Technical Report GL-86-16, 1986, 45p, 4 appendices.

Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B., Jr., 199_, Bedrock geologic map of New Hampshire: Reston, Va., U.S. Geological Survey State Geologic Map, 2 sheets, scale 1:250,000 and 1:500,000.

Stover, C.W., Barnhard, L.M., Reagor, B.G., and Algermissen, S.T., 1980, Seismicity map of the state of New Hampshire, U.S. Geological Survey Map MF-1261, scale 1:1,000,000.

Quarterly Reports of Seismic Activity

Northeastern US Seismic Network, *Seismicity of the Northeastern United States*, Weston, MA.

Earth Resources Laboratory, *A Study of New England Seismicity with Emphasis on Massachusetts and New Hampshire*, Massachusetts Institute of Technology, Cambridge, MA.

Pamphlets

"Earthquakes" Federal Emergency Management Agency, No. L-111/July, 1983.

References

Ebel, J.E., 1996. The seventeenth century seismicity of northeastern North America, Seismological Research Letters, 67(3), 51–68

Ebel, J.E., and Starr, J.C., 2018. AGeophysical and Filed Survey for the Source Region of the 1638 New Hampshire Earthquake, Seismological Research Letters, 89(3): 1197-1211