Vermont Geological Survey

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Earthquakes in Vermont

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Damaging earthquakes in and around the Green Mountain State do occur and, as with any natural hazard, it's wise to understand the risk and to be prepared. Earthquakes have been reported from all of the New England states, New York, and Quebec. They range from tiny events which can only be detected with sensitive seismographs to moderately large earthquakes which have caused serious structural damage. This fact sheet describes what earthquakes are, gives a brief history of their occurrence in and near our state, and gives suggestions for what you can do to be prepared before the next quake.

What is an earthquake?
An earthquake is the sudden shaking of the Earth caused by shifting of rock beneath the surface.

What causes an earthquake?
The majority of quakes worldwide occur at the boundaries of Earth's tectonic plates. The Earth's lithosphere or outer shell is believed to be comprised of thin slabs or plates of solid rock which move over, under, and past each other by sliding over a zone of soft rock known as the asthenosphere. This movement of plates occurs at rates of from 10 to 185 mm per year. As the plates grind past each other, the motion generates earthquake waves.

However, earthquakes also occur in regions such as New England, which is not near a present-day plate boundary. How can this be so? Several theories exist but none have been completely satisfactory. Figure 1 shows the locations of earthquakes observed in New England.

Where do earthquakes occur?
Earthquakes occur throughout the world, on all continents and in the ocean basins as well. Worldwide, 98% of earthquakes occur at the boundaries of Earth's tectonic plates. In the United States, most earthquakes occur west of the Rocky Mountains along the junctions between the North American plate and those to the west. The quakes occurring in the Eastern U.S. are not located along plate boundaries and their causes are unclear

When do earthquakes occur?
Earthquakes can occur at any season of the year and at any time of the day or night.

How are earthquakes measured?
There are two principal ways in which the strength of an earthquake is measured: intensity and magnitude. The intensity of an earthquake is a measure of how strong it feels to the observer. The most commonly used intensity scale is the Modified Mercalli (MMI) scale shown in Table

1. This scale classifies an earthquake into one of 12 categories (specified by Roman numerals). The further the observer is from the epicenter of the quake, the lower the felt intensity will be. A quake with a Modified Mercalli Intensity of I cannot be felt (it can only be detected by instruments). One with an Intensity of XII would destroy most structures and cause massive damage. Intensity VI is the rough lower threshold for causing damage to buildings.

Modified Mercalli Intensity Scale

Intensity	Characteristic effects	Magnitude
I Instrumental	Detected only by sensitive instruments	Less than 3.0
II Feeble	Felt only by a few at rest	Less than 3.0
III Slight	Felt indoors, like a vibration of a truck	3.0
IV Moderate	People awakened, objects, rock, windows rattled	3.7
V Rather strong	Plaster Falls, windows broken	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 Disastrous	Only best buildings and structures survive	7.7
XI Very Disastrous	Few buildings survive, bridges destroyed	8.4
XII Catastrophic	Total destruction, objects thrown up into air	9.0

The second way of specifying the strength of an earthquake is magnitude. This is what is commonly called the “Richter Scale” after Dr. Charles Richter, the developer of the first magnitude scale. The magnitude specifies the energy released during the quake and is intended to be independent of the distance from the epicenter to the observer. Table 2 lists the magnitudes of several U.S. earthquakes. Magnitude is determined by measuring characteristics of the seismic waves generated by an earthquake. Because several different ways of measuring magnitude have

been developed and because preliminary reports of earthquakes may have to be made with partial data, several different values of magnitude for the same earthquake may exist. Technical reports will spell out exactly how the magnitude was determined but this information often doesn't make it's way into the popular press.

Moderate to large earthquakes have occurred in several locations in the eastern U.S. since the mid 1500s. Several are described below.

Cape Ann, Massachusetts
In the year 1755 a major earthquake shook the New England colonies. It was centered near Cape Anne Massachusetts and had a magnitude of approximately 6.0. Heavy damage to chimneys occurred in the region between Cape Ann and Boston.

New Madrid, Missouri
In 1811 and 1812 the three largest known earthquakes in the United States occurred in New Madrid, Missouri, in the heart of the North American plate. Magnitudes are estimated to have been approximately 8.6, 8.4, and 8.8. Numerous aftershocks were also recorded. The strongest shock waves were felt as far away as Boston, where the shaking caused church bells to ring. There was little loss of life, but only because the region was very sparsely populated at that time.

Charleston, South Carolina
The year 1886 saw a massive quake strike near Charleston, South Carolina. It had an estimated magnitude of 7.7 and was felt 800 kilometers away. There was widespread damage to buildings and railroads and 60 people were killed. The economic losses due to this quake are estimated to have been approximately $23 million (in 1978 dollars).

La Malbaie, Quebec
In 1925 a magnitude 6.5 quake occurred at La Malbaie in the St. Lawrence River valley in Quebec. Again, damage and loss of life were minimal due to a sparse population in the region near the epicenter.

What is the largest earthquake known to have occurred within the State of Vermont?
Magnitude 4.1 quakes occurred in Swanton in 1943 and in Middlebury in 1962. A magnitude 4.0 event occurred in Brandon in 1953. The Swanton event had a maximum intensity of IV while the Middlebury and Brandon events had maximum intensities of V.

The April 10, 1962 earthquake centered in Middlebury caused MM V effects over a large area. It was felt over about 52,000 square kilometers of Vermont, Maine, Massachusetts, New Hampshire, and New York. At the Vermont State House in Montpelier, a supporting beam was dislodged, two beams under the dome were weakened, and about 20 window panes were cracked.

The table below lists earthquakes which, although centered outside Vermont, were felt in Vermont. The possible repetition of similar quakes in the future poses the chief seismic hazard to Vermonters. In the last 100 years, Brattleboro has experienced Intensity V shaking 5 times, Burlington and Montpelier 6 times, and Rutland 8 times.

Large Earthquakes Felt in Vermont

Date	Location	Magnitude	MMI Range in Vermont
1732	Montreal, Quebec	5.8	VI-IV
1925	La Malbaie, Quebec	6.5	IV-III
1935	Timiskaming, Quebec	6.1	IV-III
1940	Ossipee, N.H.	5.5	VI-IV
1944	Massena, N.Y.	5.2	V-IV
1973	Maine-N.H.-Quebec border	4.8	V-III
1982	Gaza, N.H.	4.7	IV-III
1983	Goodnow, N.Y.	5.1	IV-III
1988	Saguenay, Quebec	6.2	V-IV

Source, Ebel and others, 1995

What are the risks to Vermonters?

The earthquakes which have occurred in our vicinity in the past have only caused minor damage to property. However, given the probability that larger quakes will occur in our vicinity and given the fact that the population density is higher than ever, there is the potential for damage to property and even lives.

Earthquakes do more that just shake buildings. They can also lead to disruptions in electric, gas, and telephone service and cause damage roads, bridges, and other transportation facilities. A significant earthquake may cause many simultaneous emergency situations and thus may severely strain the ability of emergency service providers to respond adequately to all of the accident sites.

According to the National Earthquake Hazard Reduction Program of the U.S. Geological Survey, there is approximately a 10% chance that parts of Vermont will experience shaking of at least 8 to 10% of gravity in any given 50 year period. This level of shaking is sufficient to cause some property damage. There is approximately a 2% chance that parts of Vermont will experience shaking of at least 18-20% of gravity in any given 50 year period. Such shaking is sufficient to cause considerable damage to property. These estimates are for sites directly underlain by solid rock. Sites with thick soils may experience greater shaking due to amplification of seismic

waves. Also, the height and method of construction of a building have a great influence on how it will behave in a quake.

Does everyone in an area experience the same level of shaking during an earthquake?
No. The thickness and strength of soils has a great influence on how strongly an earthquake is felt. Thick deposits of weak sediments can amplify seismic waves and make the quake feel stronger than on sites directly underlain by solid rock. Also, some types of saturated soils may liquefy and deform under the shaking of an earthquake.

The height and method of construction of a building can also influence how it responds to earthquake shaking. Some buildings will shake more than others because they have a natural frequency which resonates with the seismic waves. It's hard to generalize here--the evaluation of soils and buildings in terms of seismic hazard is a job for experts.

What would an earthquake feel like and what happens during an earthquake?
You might notice a gentle shaking, a swaying of plants, light fixtures, and shelves, and a sudden jolt or a low rumbling noise. It may be difficult to move or walk around due to the ground moving under your feet.

What type of damage occurs during an earthquake?
Potential property damage may be divided into two main classes: Non-structural damage includes damage due to objects falling of shelves, furniture and equipment being knocked over, etc. while structural damage includes damage to homes, stores, offices, bridges, utility systems, and other damage to structures and facilities.

What are the major causes of injury from earthquakes?
In the case of moderate-sized earthquakes, most injuries are caused by falling objects, flying glass, and fire resulting from broken chimneys and ruptured gas and power lines. It is likely that most of the buildings will probably be left standing, although some may not be usable due to structural damage.

What should people do during an earthquake?

- Stay calm and stay put. Even large earthquakes usually only last for less than 30 seconds or a minute.

- If you are indoors, get under a table or desk away from doors, exterior walls and windows, or anything that could fall on you. Cover your head.

- When the shaking stops, carefully make your way outside and stay clear of buildings and utility lines.

- If you are outside when a quake occurs, stay there, trying to move away from buildings and utility lines.

- If you are in a car, stop and stay in the car. Try to stop in an open area away from

power lines, overpasses, tall trees, and buildings.

■ Be prepared for aftershocks. Large quakes are usually accompanied by aftershocks for hours or days afterwards. Although they are usually smaller than the main quake, they may still cause damage.

After a strong earthquake has ended, other safety precautions should be taken:

■ Check all utility lines for damage. If any problems are found, the main gas valve, electrical circuit, or water line should be shut off. Report the problem to authorities. Do not turn your gas line back on yourself. Wait for a professional to do so. Gas lines that are not properly bled before the gas is turned back on can cause explosions.

■ Don't use the telephone unless it is an emergency. Unnecessary phone calls during a natural disaster can prevent critical emergency calls from getting through.

■ Stay away from damaged buildings. Brick or concrete block chimneys and other masonry building elements are especially susceptible to collapse following a strong earthquake.

■ Be prepared for aftershocks. Although they are usually smaller than the main shock, they can still cause considerable damage, especially to structures already weakened by the main shock.

What can you do to prepare for an earthquake?
Make sure that your family has a family disaster plan and a fully stocked emergency kit (see the Red Cross for details).

Businesses, schools, and municipal governments should contact the Vermont Emergency Management Agency for assistance in developing a comprehensive disaster plan.

Inspect your home or place of business to make sure that top-heavy shelves and other furniture will not cause injury if strong shaking occurs. For example, high shelves should be securely attached to the wall and heavy objects should be placed in low positions.

Water heaters and oil tanks should be secured so that they cannot tip over.

You should be familiar with the locations of all utility shutoffs and have any needed tools handy for immediate use.

Publications About Earthquakes:

Bolt, Bruce, 1988, Earthquakes: W.H.Freeman and Co., New York, 282p. An authoritative introduction to the subject of earthquakes around the world.

Ebel, J.E., Richard Bedell, and Alfredo Urzua, 1995, A report on the seismic vulnerability of the State of Vermont: Weston Observatory, Boston, 98p. This document summarizes the known history of earthquakes in the region and provides estimates of the amount of ground shaking which can be expected in different parts of the state.

Snider, Frederic G., 1990, Eastern U.S. earthquakes: Assessing the hazard: Geotimes, November issue, p. 13-15. A good overview of the larger quakes in our region.

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Glossary of Terms

(modified from Bolt, 1988)

asthenosphere The layer below the lithosphere which is characterized by low seismic wave velocities and high seismic wave attenuation. It is a soft layer, probably partly molten.

epicenter The point on the Earth's surface directly above the focus (or hypocenter) of an earthquake.

focus (hypocenter) The place at which an earthquake rupture occurs.

intensity A measure of ground shaking obtained from the damage done to structures built by humans, changes in the Earth's surface, and reports of how strong the earthquake felt to observers. The Modified Mercalli scale is the most commonly used intensity scale.

lithosphere The outer, rigid shell of the Earth above the asthenosphere. It contains the crust, continents, and plates.

magnitude A measure of earthquake energy, determined by measuring the largest ground motion recorded on a seismograph and applying a standard correction for distance to the epicenter.

plate (tectonic) A large, relatively rigid segment of the Earth's lithosphere that moves in relation to other plates over the deeper interior.

seismic wave An elastic wave in the Earth usually generated by an earthquake source or an explosion.

seismograph An instrument for recording as a function of time the motions of the Earth's surface that are caused by seismic waves.