

## Earthquakes

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An earthquake is the rapid shaking of the Earth's surface that follows the sudden release of energy within the Earth. Most commonly, earthquakes are due to sudden movements along the edges of tectonic plates, the vast sections of rock that make up the Earth's crust and upper mantle. There are roughly 50 of these plates, which are slowly moving against one another. Over millions of years, these movements cause stresses and distortions that lead to the building of mountains and drifting apart of the continents. Under the influence of these forces, rocks gradually bend or stretch. When the stress is greater than the strength of the rocks, they break. The stress is released when the rocks move suddenly along these breaks or faults into a new position. The movement creates vibrations or seismic waves. It is these vibrations that one feels as an earthquake when they reach the surface of the Earth.

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The place at which the energy is released is called the focus, or hypocentre of the earthquake. The focus is underground — in Canada earthquake depths can range from 1 to 100 kilometres. The point on the earth's surface directly above the focus of the earthquake is called the epicentre. The ground motion produced when the waves from an earthquake reach the surface around the epicentre can vary a great deal. The motion depends on the depth of the focus, local surface and subsurface conditions (such as whether the local ground is loose clay or solid bedrock) and the magnitude of the earthquake. The intensity of these ground motions is usually most severe near the epicentre and decreases with distance.

## Measuring Earthquakes

The magnitude, or size, of an earthquake is measured on the Richter Scale. This is not a physical measuring device, like a ruler, but a mathematical formula that determines the amount of energy released by the earthquake. Earthquakes with a magnitude of 2 or less are usually called micro-earthquakes and are normally too small to be felt. Earthquakes of magnitude 5 or greater are strong enough to be felt over distances of several hundred kilometres and recorded by seismographs all over the world. Earthquakes of magnitude 6 or greater can cause significant damage, while great earthquakes of magnitude of 8 or greater can cause massive destruction.

The intensity of the effects of an earthquake at the surface of the Earth is measured on the Modified Mercalli Scale. This scale measures the intensity of the earthquake as felt by people and based on an assessment of the observed structural damage to buildings and infrastructure. People at different locations can experience the same earthquake with very different intensities, depending on where they are and what they are doing at the time of the event. The Modified Mercalli Scale uses Roman



numerals to distinguish it from magnitude values. It ranges from I (not usually felt but recorded by instruments) to XII (catastrophic).

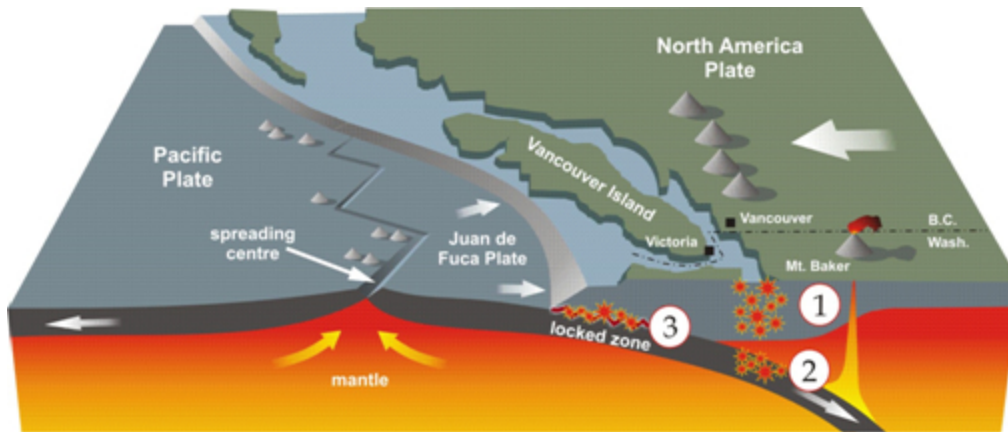
Instrumental recording of earthquakes in Canada began in the late 1890s. The network of seismograph stations grew slowly and, by 1950, there were only about a dozen instruments scattered across the country. In general, early recordings of earthquakes were made on photographic paper on revolving drums. Digital instruments began to be installed in the 1970s, and data are now sent directly to offices in Ottawa, Ontario and Sidney, British Columbia via satellite, telephone, radio and the Internet. The network of seismographs has increased significantly in the past two decades. The Geological Survey of Canada now helps to operate approximately 220 stations and collects more than 6 gigabytes of recorded seismic data every day.

### **Are there many earthquakes in Canada?**

Each year, more than 3500 earthquakes in or near Canada are recorded and located by seismologists. More than half of these occur in British Columbia and the neighbouring Pacific Ocean. Since most earthquakes are very small and many occur in unpopulated areas, only about 50 earthquakes each year are reported by the Canadian public. Most earthquakes that can be felt are too small or too remote to cause damage. In the entire twentieth century, only about 20 earthquakes have caused significant damage in this country.

### **What causes earthquakes in Canada?**

Earthquakes along Canada's west coast are caused by the slow movement of a series of major tectonic plates. In the area of the Queen Charlotte Islands, two of the Earth's largest plates, the North American Plate and the Pacific Plate, are sliding past each other at about 6 millimetres per year. Farther south, near Vancouver Island, the Juan de Fuca Plate is thrusting beneath the North American Plate at about 4 centimetres per year, eventually melting to produce the Cascade Range of volcanoes. This range includes Mount St. Helens, an active volcano in Washington State. The regions where earthquakes occur in southwestern British Columbia are shown in Figure 1.



**Figure 1.** Earthquakes in southwest British Columbia. Earthquakes in southwestern British Columbia occur in three distinct source regions:

- relatively close to the surface in the North American Plate (continental crust)
- deeper in the subducting Juan de Fuca Plate (oceanic crust)
- along the boundary between the North American Plate and the subducting Juan de Fuca Plate (locked zone)

**Source:** Natural Resources Canada. Geofacts sheet "Earthquakes in Southwestern British Columbia".

By contrast, eastern Canada lies entirely within the North American Plate and is far from its active boundaries, which are in the mid-Atlantic (eastern boundary) and just off British Columbia (western boundary). The forces producing earthquakes in eastern Canada are not as easily understood. The slow movement of the North American Plate away from the Mid-Atlantic Ridge may activate old zones of weakness and faults such as the St. Lawrence Valley. Earthquakes preferentially occur in these zones of weakness in response to the build up of strain in the North American Plate.

In the Arctic, earthquakes also seem to be associated with older geological features. They may, however, also be related to stresses produced during uplift of the land following removal of the vast ice sheets from the last continental glaciation of this area.

## Earthquakes that have Shaken Canada

Many large earthquakes have occurred in Canada's relatively short recorded history. Aboriginal legends suggest that earthquakes occur regularly in some parts of Canada. The magnitude of ancient earthquakes has been evaluated according to the description of damage and ground shaking recorded in historical documents. Instrumentally determined magnitudes have only been available during the past century.

The first known damaging event to have occurred in Canada was the 1663 earthquake in the Charlevoix, Quebec region near the mouth of the Saguenay River.

In the past 350 years, this has been one of Canada's most active seismic regions, with five earthquakes of magnitude 6 or greater. The 1663 earthquake had an estimated magnitude of close to 7 and caused major landslides along the St. Lawrence River and several of its tributaries. Nearly 600 kilometres away in Boston, items were knocked off shelves and chimneys were damaged.

A combination of Aboriginal oral traditions, Japanese historical documents and scientific investigations of drowned trees and mud layers helped scientists to pinpoint one of the largest known earthquakes to the Cascadia subduction zone in January, 1700. This giant earthquake off the coast of Vancouver Island had an estimated magnitude of 9, one of the largest ever recorded in the world. It ruptured an offshore fault that extended more than 1000 kilometres from Vancouver Island to northern California and released almost the same amount of energy as the entire country uses in one year. The resulting tsunami from this earthquake destroyed the entire winter village of the Pachena people on Vancouver Island and swept across the Pacific Ocean, causing destruction along the coast of Japan.

In the twentieth century, the largest recorded earthquake in Canada occurred off the Queen Charlotte Islands in 1949. This magnitude 8.1 event ruptured a 500 kilometre long fault and caused extensive damage both on the Queen Charlottes and the neighbouring mainland. In 1946, a magnitude 7.3 earthquake caused significant damage to communities on Vancouver Island, while another Charlevoix region event in 1925 (magnitude 6.2) had severe effects as far away as the city of Québec (120 kilometres distant) and Shawinigan (230 kilometres distant). In 1929, a magnitude 7.2 earthquake off the coast of Newfoundland triggered a huge submarine landslide that generated a tsunami (a large induced sea wave). The tsunami struck the southern end of the Burin Peninsula in Newfoundland, where it destroyed numerous homes and businesses and claimed a total of 28 lives. The most recent event to cause significant damage in Canada was the magnitude 5.8 earthquake in Saguenay, Quebec in 1988. Damage exceeding 25 million dollars in damage was caused by the shaking. Some of the damage resulting from large twentieth century Canadian earthquakes can be seen in Figures 2 to 7.



**Figure 2.** Damage to brick wall in Shawinigan, Quebec, more than 200 kilometres from the epicentre of a magnitude 6.2 earthquake, Charlevoix, Quebec, 1925  
**Source:** Photo from Lamontagne, M. and Bruneau, M. 1993

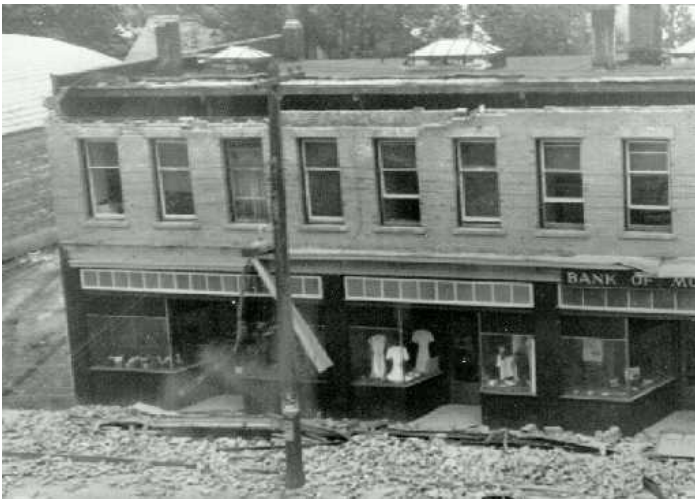


**Figure 3.** Magnitude 7.2, Laurentian slope, offshore Newfoundland, 1929. Buildings in Lords Cove, Newfoundland tossed and smashed by the tsunami  
**Source:** Photograph by H.M. Mosdell, from the collection of W.M. Chisholm; published in GSC Bulletin 548 "A Synthesis of Geological Hazards in Canada" G.R. Brooks, Editor



**Figure 4.** Magnitude 6.2, Témiscaming, Quebec, 1935. Some 300 kilometres away from the epicentre, near Parent, Quebec, vibrations from this earthquake triggered a 30 metre slide of a railroad embankment

**Source:** Photo from CN Railway, collected by E.A. Hodgson, Natural Resources Canada



**Figure 5.** Magnitude 7.3, Vancouver Island, 1946. Masonry failure of the Bank of Montreal in Port Alberni, British Columbia

**Source:** Natural Resources Canada, Earth Physics Branch Photo Collection: Photo collected by E. A. Hodgson in 1946. Photographer unknown





**Figure 6.** Magnitude 7.3, Vancouver Island, 1946. Soil Failure on the Kelsey Bay Highway, north of Campbell River, British Columbia

**Source:** Natural Resources Canada, Earth Physics Branch Photo Collection: Photo sent to E.A. Hodgson October 22, 1946. Photographer William Jones, Sayward school teacher.



**Figure 7.** Magnitude 5.9, Saguenay, Quebec, 1988. Masonry damage to the former Montréal East city hall. More than 300 kilometres from the epicentre, this structure is founded on 17 metres of clay which amplified the earthquake vibrations

**Source:** Photo courtesy of D. Mitchell, R. Tinawi, and T. Law

## Preparing for Earthquakes

Although seismologists are unable to predict when large earthquakes are going to occur, they are able to look at geological evidence and historical patterns of seismic

activity to determine where future earthquakes are most likely to occur. This information is used to develop seismic hazard models, which provide the design requirements for the National Building Code of Canada. The building code helps to ensure that buildings are constructed as earthquake resistant as possible. The simplified seismic hazard layer of the 'Significant Earthquakes and Seismic Hazard' map shows the likelihood of experiencing strong earthquake across the country. Individuals can help to reduce the effect of an earthquake by checking with local emergency management organizations to understand the risks in their region. Make a plan so that you know what to do in case of an earthquake and prepare an emergency kit to help you and your family survive for 72 hours.

The Public Safety Canada website "Is your family prepared?" (<http://www.getprepared.gc.ca/index-eng.aspx>) has excellent advice on what to include in both an emergency plan and an emergency kit - these can be put to good use in any natural disaster or emergency.

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## Definitions of underlined terms

**Earth crust:** The outermost layer or shell of the Earth. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

**Mantle:** The zone of the Earth below the crust and above the core.

**Richter scale:** The Richter scale was developed by Charles Richter. This scale measure the magnitude of earthquakes. It is a logarithmic scale used to express the total amount of energy released by an earthquake. Its values typically fall between 0 and 9, with each increase of 1 representing a 10-fold increase in energy.

**Seismic wave:** Shock wave in the Earth which issue from the focus of an earthquake.

**Seismograph:** A device for detecting vibrations in the Earth. This instrument records the time, the duration and the size of earthquakes.

**Tectonic plate:** Broad thick plate composed of areas of both continental and oceanic crust and mantle. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)