

Significant Earthquakes and Seismic Hazard

Abstract

An earthquake is the rapid shaking of the Earth's surface that follows the sudden release of energy within the Earth. They are most commonly caused by movements along the edges of the plates that make up the Earth's crust. Each year, more than 3500 mostly small earthquakes are recorded in or near Canada, 50 of which can be felt. More than half of all the earthquakes in Canada occur along the west coast. There is also scattered activity in southeastern Canada and in the Arctic. The size of an earthquake is measured on a magnitude scale, and its intensity is measured on the Modified Mercalli Scale. This map shows the most significant earthquakes recorded in Canada.

Seismic Hazard

The damage potential of an earthquake is determined by how the ground moves and how the buildings within the affected region are constructed. Expected ground motion can be calculated on the basis of probability, and the expected ground motions are referred to as seismic hazard. The seismic hazard map layer indicates the relative seismic hazard across Canada. The map is a simplification of the National Building Code of Canada seismic hazard map for spectral acceleration at a 0.2 second period (5 cycles per second), and shows the ground motions that might damage one- to two-storey buildings. The probability of strong shaking (strong enough to cause significant damage in these buildings) is more than 30 times greater in the regions of highest hazard (at least a 30 per cent chance of significant damage every 50 years) than in the regions of lowest hazard (less than 1 per cent chance in 50 years). In the region of moderate hazard, there is a 5 to 15 per cent chance that this level of significant damage will occur every 50 years.

The seismic hazard maps and earthquake load guidelines included in the National Building Code are used to design and construct buildings to be as earthquake-proof as possible. The provisions of the building code are intended as a minimum standard.

They are meant to prevent structural collapse during major earthquakes and thereby to protect human life. The provisions may not, however, prevent serious damage to individual buildings.

Selected Earthquakes

At the end of 2006, Canada's earthquake database contained more than 60 000 events, with more than 3000 earthquakes being located in or near Canada every

year. Since this map is used to enhance the awareness of the Canadian public to earthquake hazards, it was decided to choose events that caused at least some minimal damage, or could have caused damage had they occurred close to inhabited regions. For this reason, all known earthquakes with a magnitude larger than 6.0 were chosen. Additionally, a few smaller magnitude 4 and 5 earthquakes were selected that had some impact on people or the terrain. There are a total of 160 earthquakes shown on this map.

Each earthquake selected for the map meets one or more of the following criteria:

- The magnitude (either instrumental magnitude or estimated magnitude from historical damage or felt-area information) is 6.0 or greater.
- The earthquake had some impact on the built environment (at least causing minimum damage at a level of Modified Mercalli Intensity VI or higher) or on the natural environment (landslides, rock falls, liquefaction, tsunamis).
- The earthquake was felt by a significant number of Canadians.
- The earthquake occurrence is supported by paleoseismological evidence (only the 1700 Cascadia earthquake met this criterion, since other paleo-earthquakes are too uncertain in location, origin time and magnitude).

Significant Earthquakes

Each of the selected earthquakes was subjectively qualified as being 'significant' or not, based on its magnitude and impact. As an example, a moderate earthquake near a large metropolitan area (such as the 1997 magnitude 5.1 event near the city of Québec) was considered to be of higher significance than a much larger earthquake occurring more than 100 kilometres offshore (such as the 2004 magnitude 6.6 earthquake offshore from Vancouver Island). Using this subjective criterion, there are a total of 51 earthquakes in the list of selected events that are considered to be 'significant'. They are indicated by a star on the map.

Impacts of Earthquakes

Only two possible deaths can be directly attributed to earthquakes in Canada, both of which occurred on October 20, 1870. In addition to these deaths, the 1929 tsunami resulted in the drowning of 27 persons. Other indirect casualties include people who die of heart attacks.

Earthquakes can impact the natural and societal environments through:

- landslides, which include any mass movement triggered by the earthquake-generated ground vibrations (such as earth flows, rock avalanches, rock falls, rotational landslides, slumps); note that liquefaction and sand expulsions are included in this group; for further information, refer to the text on landslides

- tsunamis, which are sea waves generated by the motion of the sea floor through direct rupture, by mass movement induced by the associated ground vibrations or by co-seismic rupture; for further information, refer to the text on tsunamis
- damage, ranging from light damage (for example, cracks in plaster of walls) through cracked chimneys to collapse of buildings

Mapping Notes

On the map, the size of an earthquake is expressed using a magnitude scale. The magnitude for early earthquakes is estimated and may be given to the nearest whole or half unit. Also, the date and time are provided for each earthquake except the three early historical events, where the time is not known. The location of an earthquake refers to the position of its epicentre, given in terms of its geographic latitude (decimal degrees North) and longitude (decimal degrees West). On this map, earthquakes that occurred prior to the twentieth century are given locations that may be accurate only to the nearest degree, whereas modern events are given to 1/100th of a degree.

The origin time of earthquakes is provided in local and in Coordinated Universal Time (UTC), the modern equivalent of Greenwich Mean Time (GMT). One must subtract 5 hours from UTC to obtain Eastern Standard Time (EST), or 8 hours for Pacific Standard Time (PST). The difference is 4 and 7 hours, respectively, when compared with Daylight Savings Time. The local time is generally provided when the earthquake was felt in Canada.

Definitions of underlined terms

Coordinated Universal Time (UTC): The time disseminated by all countries of the world that is based on International Atomic Time (TAI). TAI is based on the atomic second, which is defined in terms of a transition in the ground state of the cesium 133 atom. TAI is calculated by the Bureau International de l'Heure in Paris, France, from a weighted average of the time of atomic clocks throughout the world. For navigation and survey purposes, UTC is stepped by integral seconds from TAI by the insertion or deletion of leap seconds to keep it within 0.9 seconds of the astronomical time UT1. The standard meridian for the UTC zone is the Greenwich meridian of 0 degree.

Co-seismic: A feature associated with the occurrence of an earthquake. Co-seismic rupture is created by the instantaneous rupture of the fault that generates the earthquake. The term is used to distinguish it from rupture caused by non-tectonic phenomena (collapse, landslides, etc.) or by aseismic deformation (slow slip along a fault).

Earthquake Magnitude Scale: Earthquake magnitude is a number that represents the 'size' (or energy release) of an earthquake. Magnitude is determined from the measurement of the amplitude of waves recorded by seismographs and the distance between the seismographs and the epicentre of the earthquake. One of the first earthquake magnitude scales was developed in 1935 by Charles Richter as a mathematical device to compare the amount of energy released by different earthquakes in California. Magnitude values typically fall between 0 and 9, but it is possible to have negative values determined for very small events. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy. There are several magnitude scales in use today, all of which expand on Richter's original idea. In the media, these different scales are often collectively (but incorrectly) referred to as Richter magnitude.

Epicentre: The point on the earth's surface directly above the focus of the earthquake. Location where the earthquake has been the most intense.

Greenwich Mean Time: Term that refers to the mean solar time at the Greenwich meridian, which passes at the Royal Observatory located in Greenwich, near London in England.

Liquefaction: The sudden large decrease of the shearing resistance of a cohesionless soil. It is caused by a collapse of the structure by shock or other strain and is associated with a sudden, temporary increase of the interstitial water pressure. It involves a temporary transformation of the material into a fluid mass. (Source: Glossary of terms in soil science. Ottawa: Research Branch, Canada Dept. of Agriculture, 1976.)

Modified Mercalli Intensity Scale: The modified Mercalli intensity (MMI) scale rates the intensity of shaking from an earthquake at different sites. This scale, composed of 12 increasing levels of intensity that range from almost imperceptible shaking (MMI I) to catastrophic destruction (MMI XII), uses Roman numerals to distinguish it from magnitude

Paleo-earthquake: Ancient earthquake

Paleoseismological: Related to the study of ancient earthquakes. values (which measure the amount of energy released by the earthquake). It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.

Map Sources

Major Earthquakes in Canada

The information was taken from the Disaster Database (2006) from Emergency Preparedness Canada, from the map no. 15 of the Canadian Geophysical Atlas (Geological Survey of Canada, 1987) and the Natural Hazard Poster Map (1996) from GeoAccess Division, Natural Resources Canada.

References

Clague, J.J., P.T. Bobrowsky R.D. Hyndman 1995. The Threat of a Great Earthquake in Southwestern British Columbia. The BC Professional Engineer (v. 46, no. 9, p. 4-8)

Lamontagne, M; Halchuk, S; Cassidy, J F; Rogers, G C. 2007. Significant Canadian earthquakes 1600-2006. Geological Survey of Canada, Open File 5539, 32 (+ ill.) pages. <http://earthquakescanada.nrcan.gc.ca/histor/GSCOF5539/index-eng.php>

Related Web sites (1999 – 2009)

Federal Government

Natural Resources Canada. Canadian Hazard Information Service. Earthquakes Canada

<http://earthquakescanada.nrcan.gc.ca/>

Earthquakes occurring in and near Canada are monitored 24/7 by the Pacific Division of the Geological Survey of Canada from offices in Ottawa ON and Sidney BC. The goal of Earthquakes Canada is to understand the causes of, and hazards associated with earthquakes in Canada.

Natural Resources Canada. Damage photographs from the M7.3 Vancouver Island Earthquake of 1946

<http://earthquakescanada.nrcan.gc.ca/histor/20th-eme/1946/1946photos-eng.php>

Natural Resources Canada. The 1925 Charlevoix-Kamouraska earthquake

<http://earthquakescanada.nrcan.gc.ca/histor/20th-eme/1925/19250301-eng.php>

Natural Resources Canada. The M6.2 1935 Timiskaming earthquake

<http://earthquakescanada.nrcan.gc.ca/histor/20th-eme/1935/1935-eng.php>

Natural Resources Canada. The Magnitude 5.9 1988 Saguenay earthquake

<http://earthquakescanada.nrcan.gc.ca/histor/20th-eme/saguenay88/saguenay88-eng.php>

Natural Resources Canada. The Magnitude 7.2 1929 "Grand Banks" earthquake and tsunami

<http://earthquakescanada.nrcan.gc.ca/histor/20th-eme/1929/1929-eng.php>

Public Safety Canada. Is your family prepared?

<http://www.getprepared.gc.ca/index-eng.aspx>

Provincial/Territorial Government

Government of British Columbia. Ministry of Public Safety and Solicitor General.
Provincial Emergency Program
<http://www.pep.bc.ca/index.html>

Sécurité publique Québec, Emergency Preparedness for Youth
http://www.msp.gouv.qc.ca/jeunesse/index_en.html