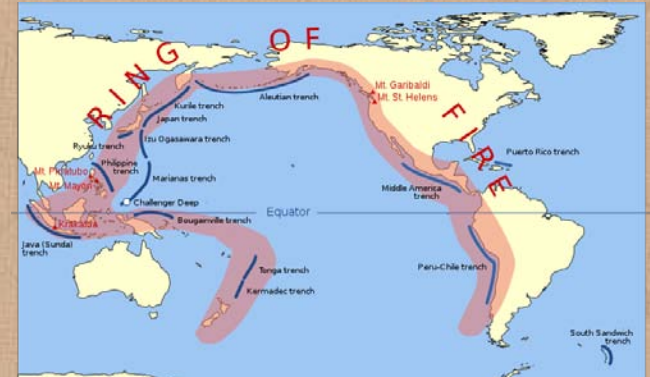


Earthquakes

Redpath Museum, McGill University



Earthquakes

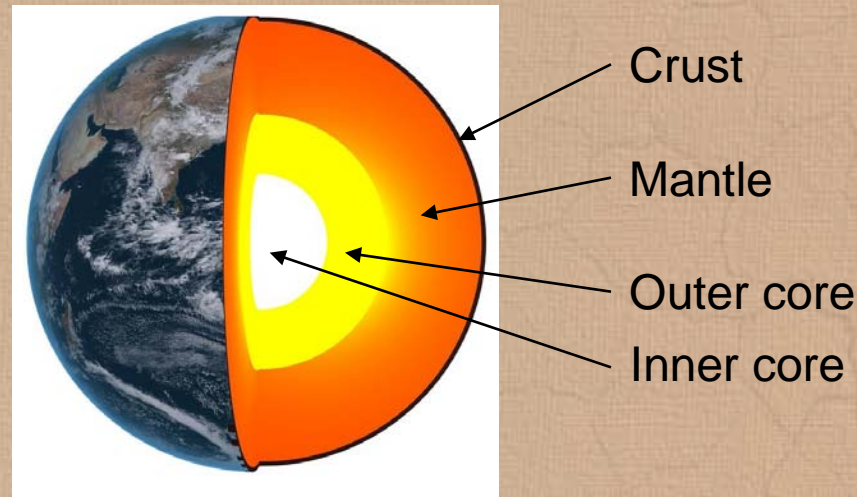
- Parts of the Earth are always moving, usually so slowly that we do not feel anything.
- Most earthquakes happen when parts of the Earth move quickly: rocks break and slip along a fault (a crack in the Earth's surface).
- Aftershocks are the shocks that people feel for hours or even days after an earthquake.



San Andreas Fault, California
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How does the Earth move?

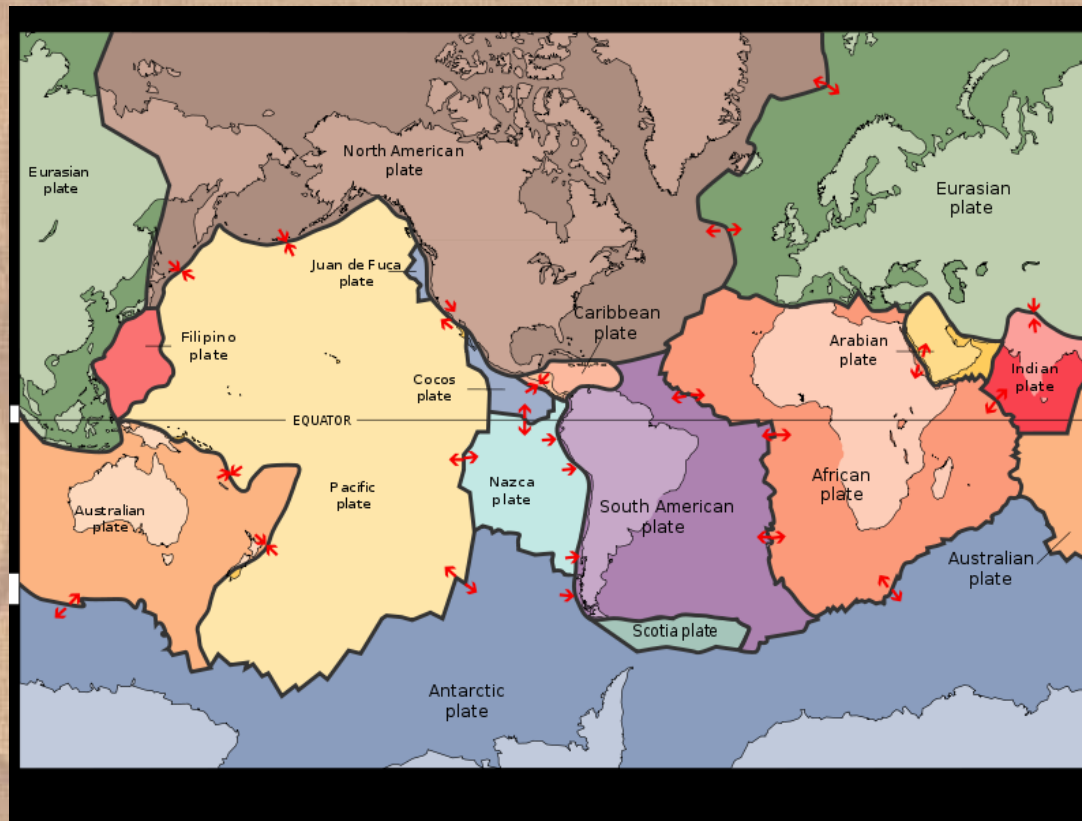
- The crust is the Earth's outermost layer.



- The crust is made up of huge rocks broken into large sections called tectonic plates. It lies on top of the mantle, which consists in part of molten rock.

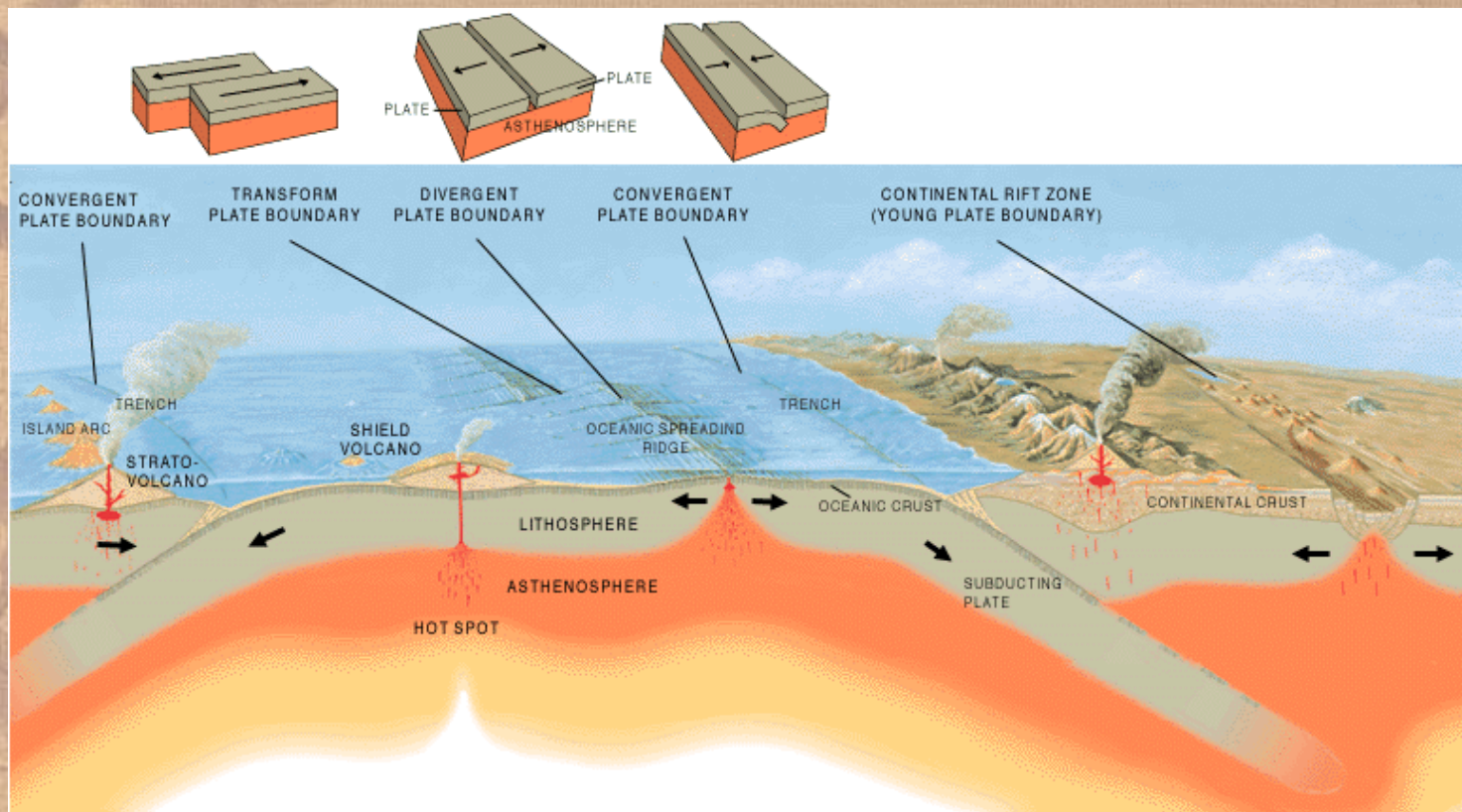
Tectonic plates (i)

- The tectonic plates are always moving slowly (2-12 cm/year).



Tectonic plates (ii)

- The plates can separate, collide, or slide past one another.



Tectonic plates (iii)

- When two plates meet and try to slide past each other or push against each other, pressure can build below the surface. This pressure builds until it is too strong and must be released.
- The plates shift suddenly, energy is released, and shock waves are sent out that produce an earthquake.



Volcanoes and human activity

- Volcanoes and human activity also cause earthquakes:
 - Volcanic eruptions can release huge amounts of energy that can be felt as earthquakes.
 - Human activities such as mining, dam reservoirs, and nuclear explosions can trigger minor earthquakes. Earthquakes caused by humans always occur close to the site where an activity is being carried out. They are not felt far away.



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Reinhard Jahn. www.wikipedia.org. License: [Creative Commons Attribution-Share Alike 2.0 Germany](https://creativecommons.org/licenses/by-sa/2.0/de)

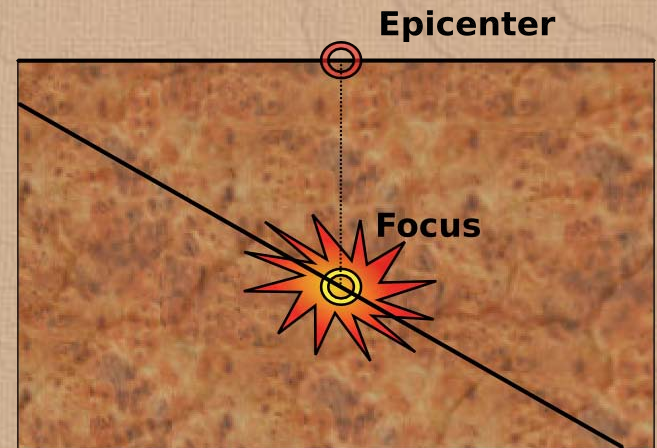
What happens during an earthquake?

- During an earthquake, energy is released:
 - as movement along the fault
 - as heat
 - as seismic waves that radiate out in all directions and cause the ground to shake when they reach the surface. The word “seismic” comes from the Greek work “seismos”, which means “a shaking”.



Hypocentre vs. epicentre (i)

- The focus, or hypocentre, of the earthquake is the place at which the energy is released. The focus is underground — in Canada it ranges from 1 to 100 km deep.
- The epicentre is the point on the Earth's surface directly above the focus of the earthquake.



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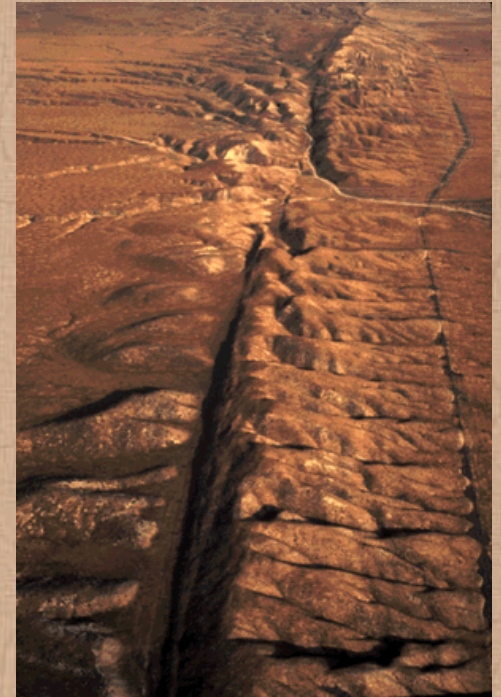
Hypocentre vs. epicentre (ii)

- Ground motions caused by seismic waves reaching the surface will depend on:
 - the depth of the focus
 - the type of rock found locally
 - the magnitude of the earthquake



Faults

- Faults, or breaks in the Earth's crust, form where rocks have broken from the forces created by the moving tectonic plates.
- Some faults are large enough that they split open the ground.
- Fault lines range in length from a few centimeters to hundreds of kilometers.



San Andreas Fault, California

www.wikipedia.org. Public domain.

Measuring an earthquake's magnitude (i)

- The magnitude is a measure of energy released by an earthquake.
- The magnitude scale first defined by scientist C.F. Richter has been replaced by the “Moment Magnitude Scale”.
- Scientists determine the magnitude based on the measurement of the waves from earthquakes recorded by a seismograph.



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Measuring an earthquake's magnitude (ii)

- The largest earthquake ever recorded by seismographs occurred in southern Chile in May, 1960: its magnitude was $M_w = 9.5$.
- The second largest occurred near Anchorage, Alaska, in March, 1964: its magnitude was $M_w = 9.2$.

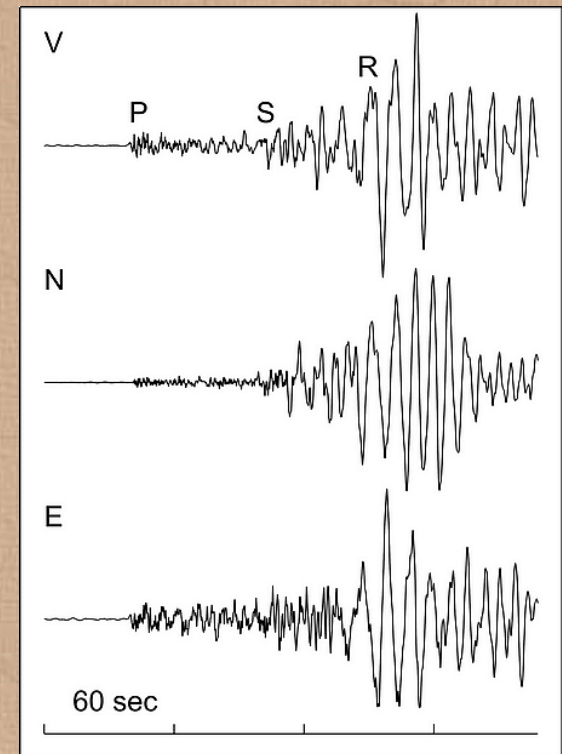
Measuring an earthquake's magnitude (iii)

- Each full step on the Moment Magnitude Scale (for example from $M_w = 8$ to $M_w = 9$) represents an increase by a factor of 32 in the “size” of the earthquake.

Earthquake monitoring

- Canada began recording earthquakes with instruments in the late 1890s.
- Today, the Geological Survey of Canada helps to operate approximately 220 stations equipped with seismographs.

Double-click or right-click on the image and open the hyperlink to [view real-time seismograms](#) from Collège Jean de Brébeuf.



Earthquakes in Canada (i)

- In Canada, most earthquakes are small. There are approximately 4000 earthquakes recorded here per year: only 50 are felt.
- From 1900-2000, only about 20 earthquakes caused significant damage in Canada.
- The Pacific Coast is the most earthquake-prone region, followed by Eastern Canada. Saskatchewan and Manitoba are the least earthquake-prone areas in the country.



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Earthquakes in Canada (ii)

- The largest Canadian earthquake to date occurred off Vancouver Island on January 26, 1700. It was recorded in the oral traditions of Vancouver Island's First Nations, and the resulting tsunami was recorded by the Japanese when it reached their shores.
- This was one of the world's largest earthquakes in the world to date, with an estimated magnitude of 9.

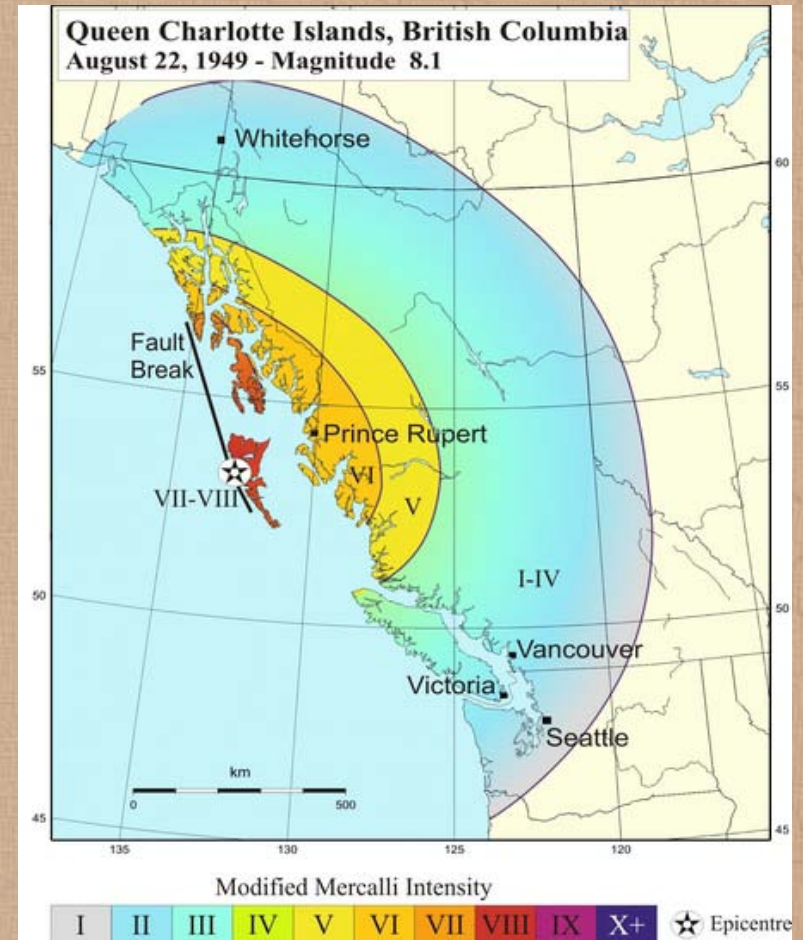


Earthquakes in Canada (iii)

- The largest Canadian earthquake ever recorded with a seismograph occurred off Haida Gwaii (the Queen Charlotte Islands , BC) on August 22, 1949.

It had a magnitude of 8.1 and was felt throughout BC, the Yukon, and the state of Oregon in the US.

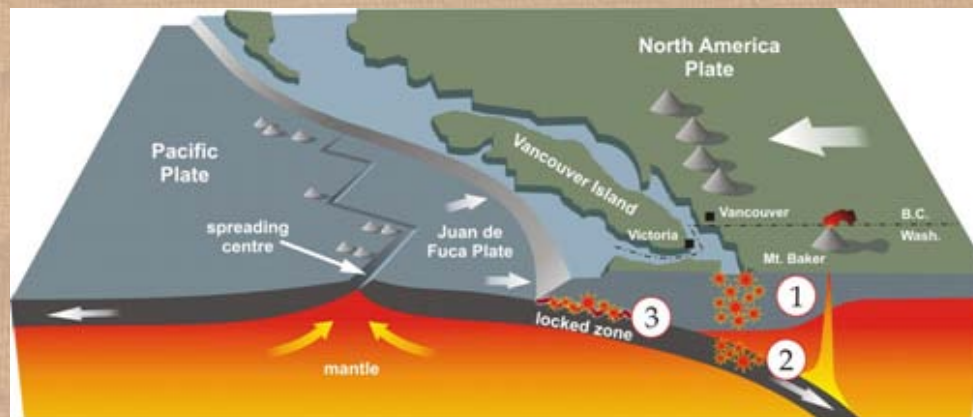
- The shaking was so severe that cows on Haida Gwaii were knocked off their feet.



[Natural Resources Canada](http://www.nrc.ca/geofacts). Geofacts sheet "Earthquakes in Southwestern British Columbia". This reproduction is a copy of an official work published by the Government of Canada. This reproduction has not been produced in affiliation with, or with the endorsement of, the Government of Canada.

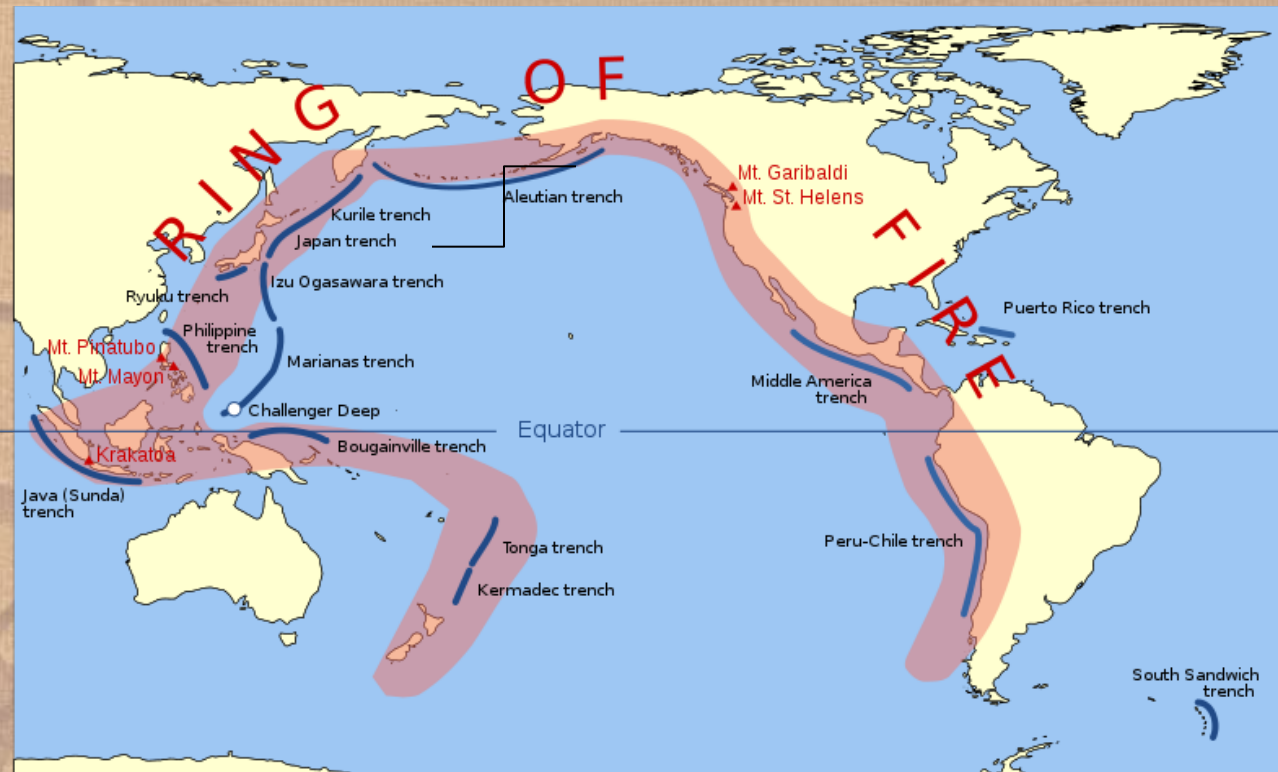
Earthquakes in Canada: West Coast (i)

- The West coast of Canada is more prone to earthquakes because there are active faults there. Earthquakes occur in three major zones in southwestern British Columbia:
 - 1) in the North American Plate, relatively close to the surface
 - 2) deeper, in the Juan de Fuca Plate
 - 3) where the Juan de Fuca Plate is moving under the North American Plate) = the locked zone



Earthquakes in Canada: West Coast (ii)

- The West Coast is part of the Pacific Ring of Fire, where approximately 90% of the world's earthquakes and 75% of the world's volcanoes occur.



Earthquakes in eastern Canada

(i)

- Eastern Canada is located in a stable continental area within the North American Plate: it is far from the plate boundaries that lie in the mid-Atlantic and on the Pacific coast.



www.wikipedia.org. Public domain.

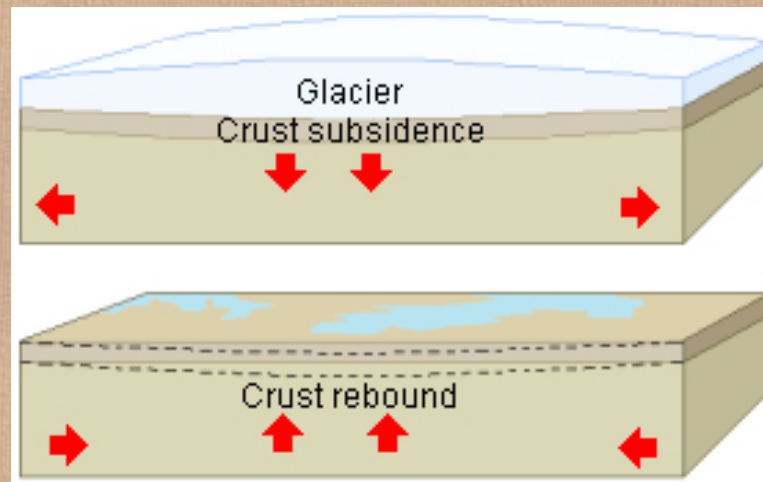
Earthquakes in eastern Canada

(ii)

- Then what causes earthquakes in Eastern Canada? Scientists do not yet have a complete explanation.
 - Stresses from pushing at the boundaries can build up within a plate: when that stress is relieved, an earthquake can occur.
 - Postglacial rebound can also cause earthquakes as the land that was depressed by glaciers slowly rises.

Postglacial rebound

- When a large mass such as an ice sheet covers part of the Earth, it causes that part of the crust underneath to depress, and the mantle to displace.
- When the glacier melts, the mantle slowly flows back to its original position: this pushes the crust back up to its original position as well.



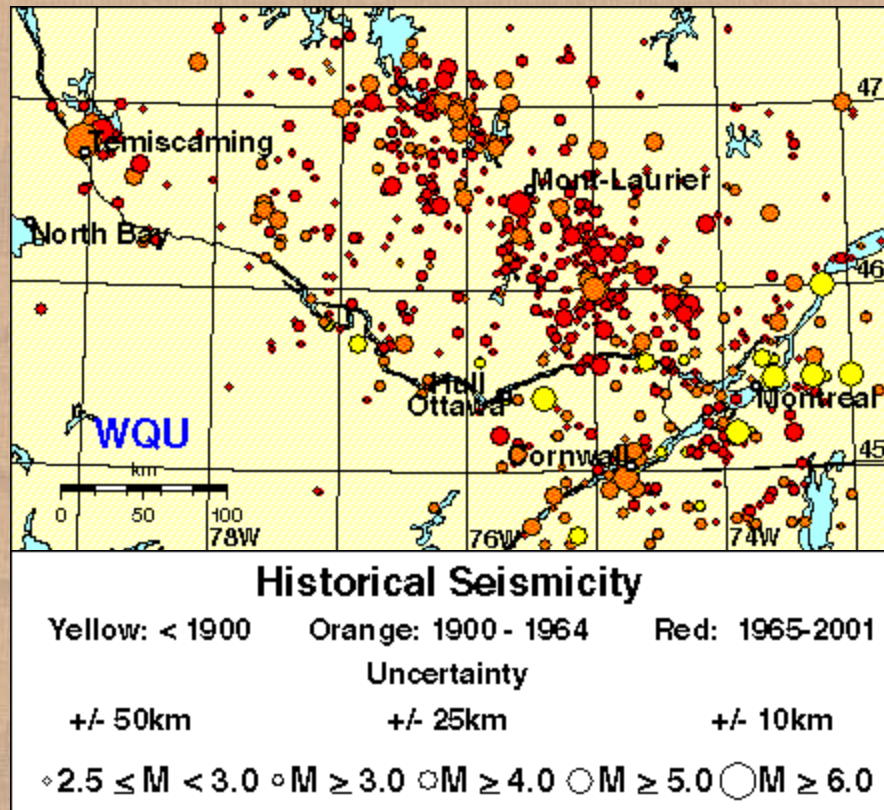
Earthquakes in eastern Canada (iii)

- Eastern Canada has relatively few earthquakes, however some large earthquakes have occurred here.
- Earthquakes in Eastern Canada are felt much further away from their source than those in Western Canada because of differences in the geology of these areas.

Earthquakes in the Montreal area (i)

- Montreal lies in the Western Quebec Seismic Zone, which includes the Ottawa Valley, the Laurentians and Eastern Ontario.
- Earthquakes in this zone are concentrated along the Ottawa River and the Montreal-Maniwaki axis.

Western Quebec Seismic Zone



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Earthquakes in the Montreal area (ii)

- On average, an earthquake occurs every 5 days in the Western Quebec Seismic Zone, some of which are felt by the population. Four large earthquakes of note include:
 - Montreal, QC in 1732: magnitude of 5.8
 - Temiscaming, QC in 1935: magnitude of 6.2
 - Between Cornwall, ON and Massena, NY in 1944: magnitude of 5.6
 - Saguenay, QC in 1988: magnitude of 5.8, causing over \$25 million in damage.

Earthquakes in the Montreal area (iii)

- More recently – on June 23, 2010 – an earthquake with a magnitude of 5.0 hit south of Echo Lake, QC, 60 km north of Ottawa. It was felt across western Quebec, southeastern Ontario, Vermont, New Jersey, New York, Michigan, Ohio, and Pennsylvania.
- Buildings and roads suffered damages.

Earthquakes around the world (i)

- Recent large earthquakes in other countries include:
 - The January 12, 2010 earthquake in Haiti: magnitude 7.0; 3 million people affected; 230 000 people dead; 280 000 buildings destroyed.



Earthquakes around the world (ii)

- The December 26, 2004 Indian Ocean earthquake off Sumatra: magnitude 9.1; devastating tsunami; 230 000 people dead; millions homeless.



Preparing for an earthquake (i)

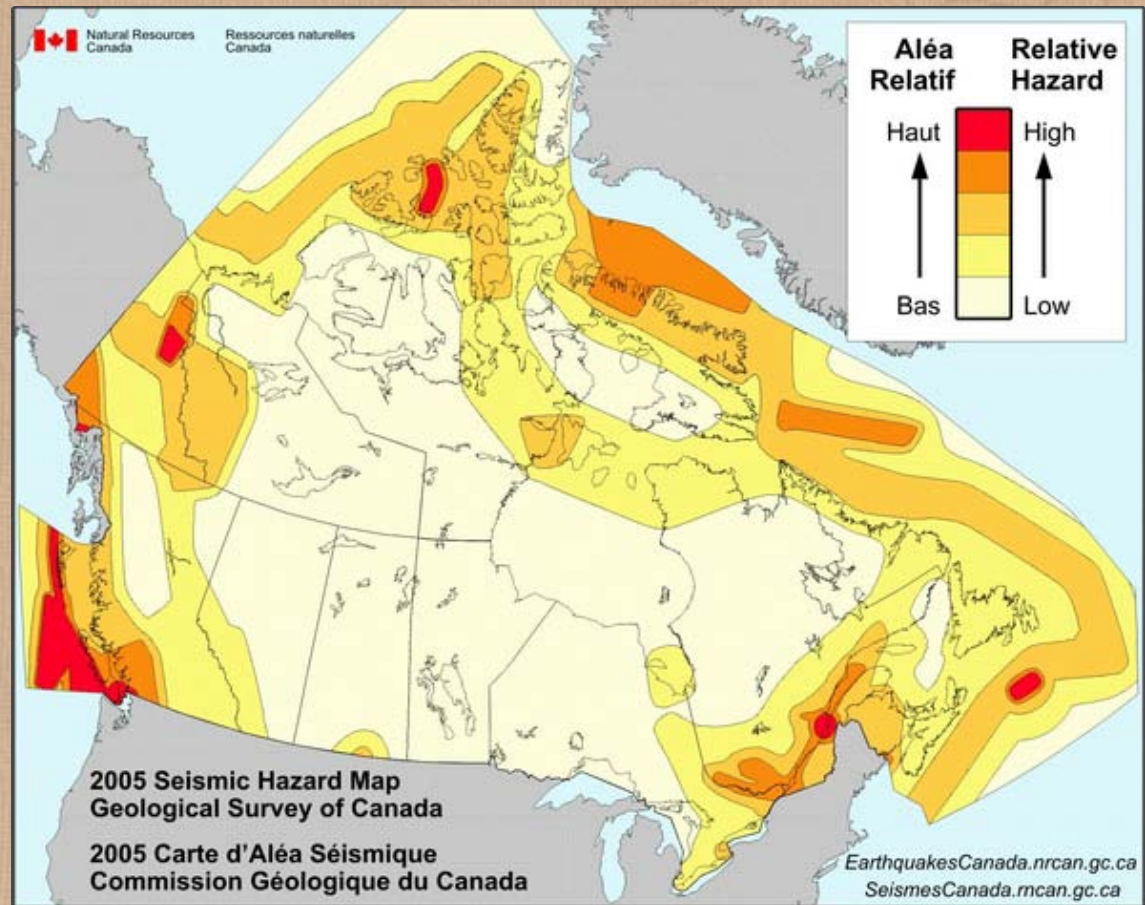
- Looking at geological data and historical patterns of earthquake activity, seismologists can predict where (but not when) future earthquakes are most likely to occur.
- The **National Building Code of Canada** takes this into account, and local building codes are designed to help construct buildings that are as resistant as possible to earthquakes.



Preparing for an earthquake (ii)

You can find out about earthquake risks in your area by contacting your local emergency management organizations.

In Quebec, contact:
Ministère de la sécurité
publique at
1-866-776-8345 or
1-877-644-4545
for general information.



[Natural Resources Canada](http://NaturalResourcesCanada). "2005 Seismic Hazard Map", Geological Survey of Canada. This reproduction is a copy of an official work published by the Government of Canada. This reproduction has not been produced in affiliation with, or with the endorsement of, the Government of Canada.

Preparing for an earthquake (iii)

- Natural Resources Canada recommends using that hazard information to develop an emergency plan so that you know what to do if an earthquake occurs, and to prepare an emergency kit to help you and your family survive for 72 hours.



- Please refer to the following from Public Safety Canada and Natural Resources Canada:
 - [Is your family prepared?](#)
 - [Preparing for Earthquakes](#)
 - [Earthquakes: What to Do?](#)

Acknowledgements and Sources

- Drs. Olivia Jensen and William Minarik, Earth and Planetary Sciences, McGill University
- Natural Resources Canada
 - [Atlas of Canada \(Earthquakes\)](#)
 - [General Earthquake Information](#)
- CBC.ca: [Quake shakes Quebec, Ontario](#)
- New World Encyclopedia: [Glacier/Isostatic Rebound](#)
- Indezine: slide template
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