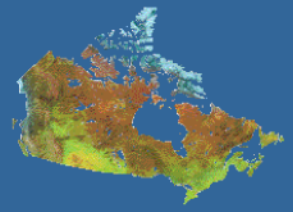
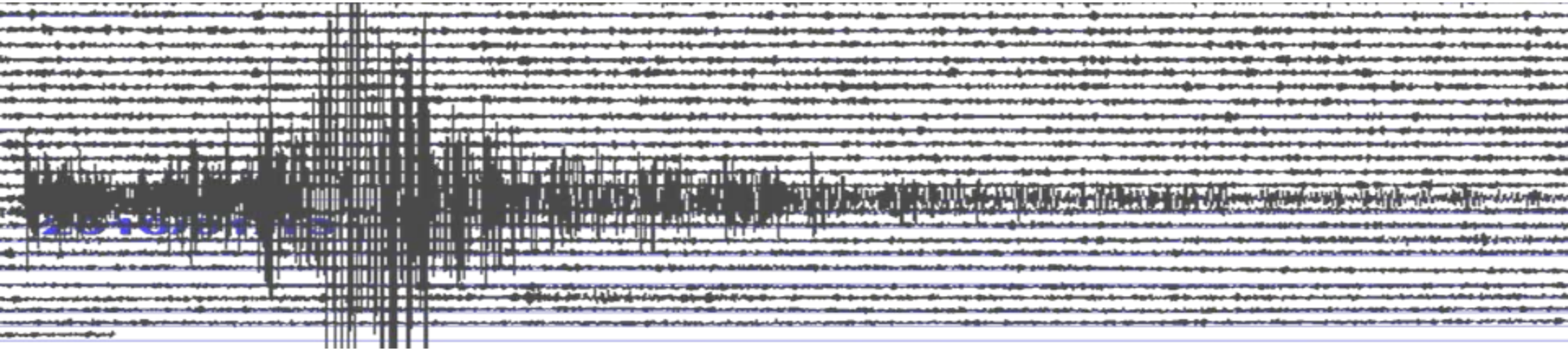


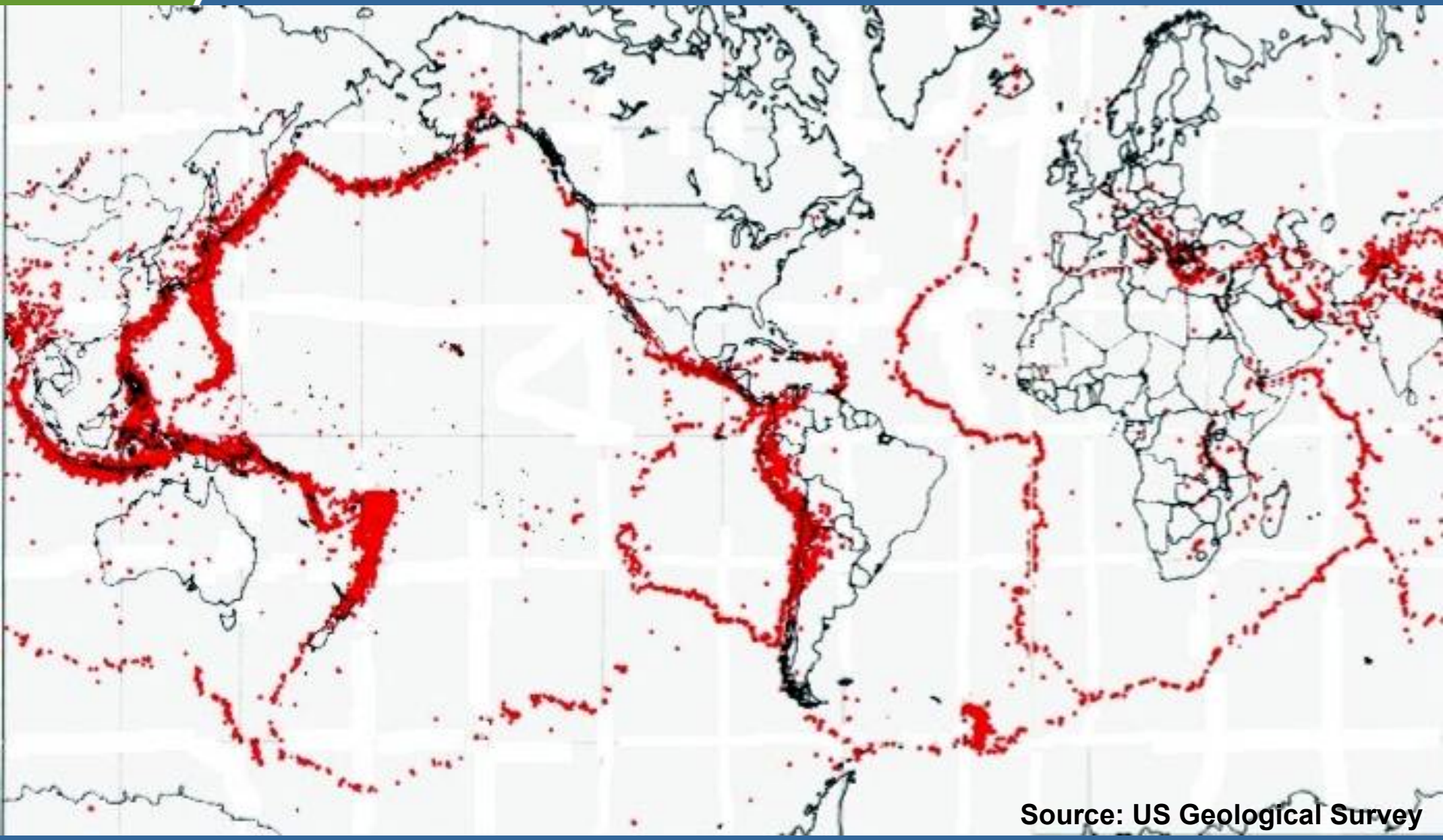
Shake it up !
Earthquakes in Canada



J. Aylsworth
Geological Survey of Canada
Natural Resources Canada

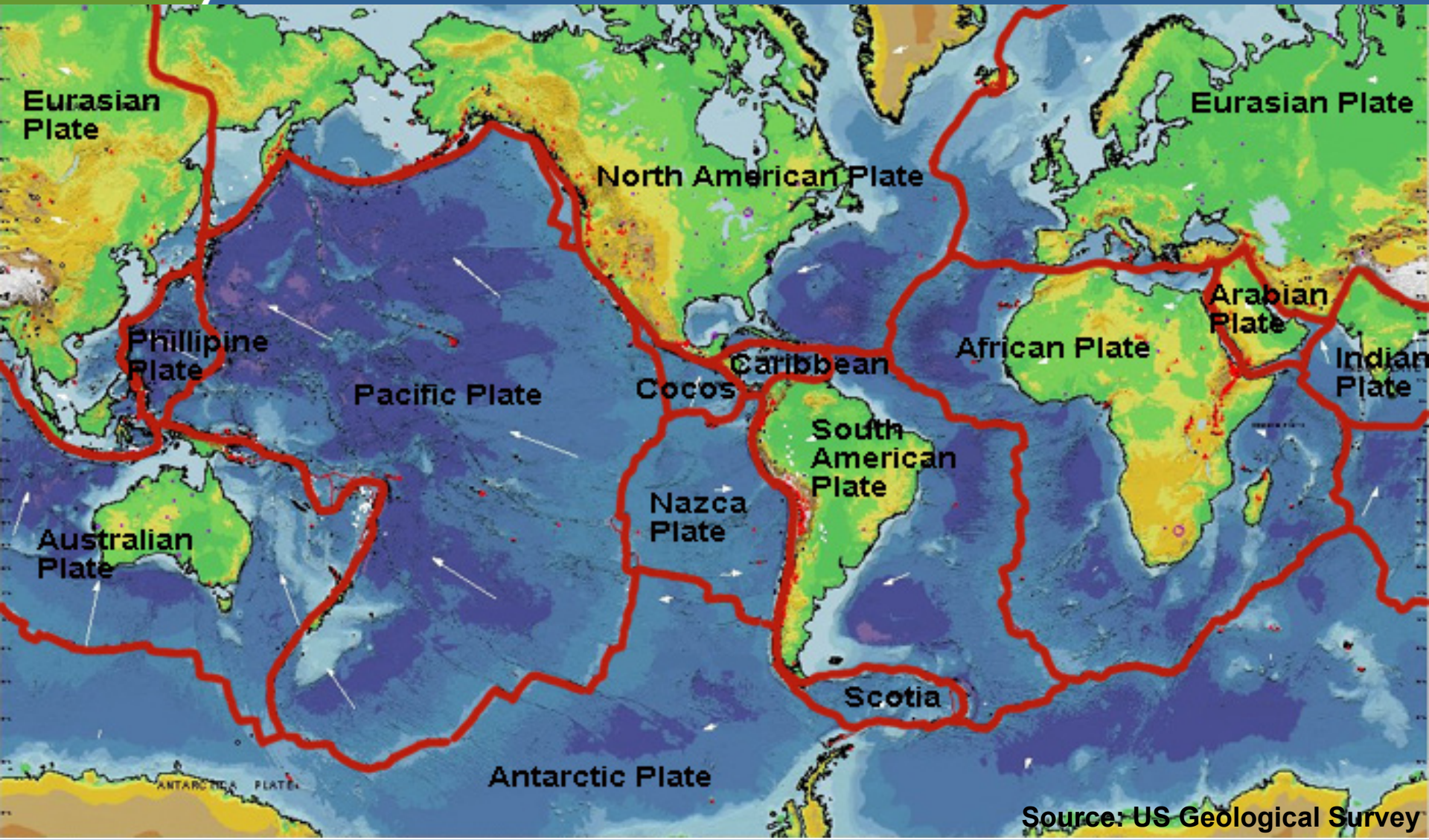
Where do earthquakes happen?

Earthquakes: 1978 - 1987



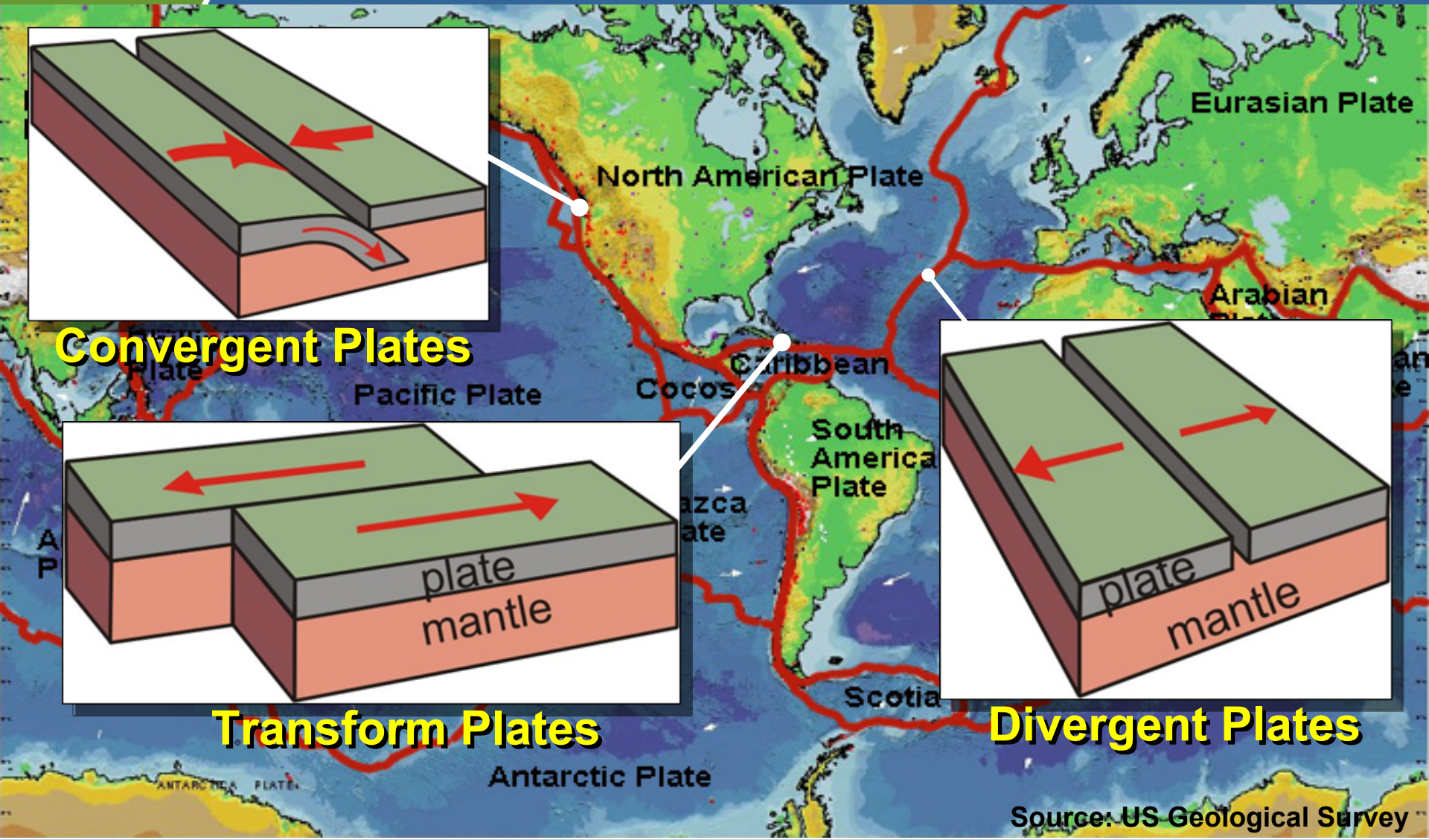
Source: US Geological Survey

Tectonic Plates

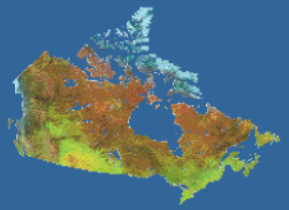


Source: US Geological Survey

Tectonic Plates : Movements



Tectonic Plates : Movements

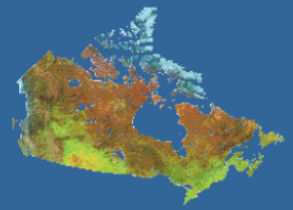


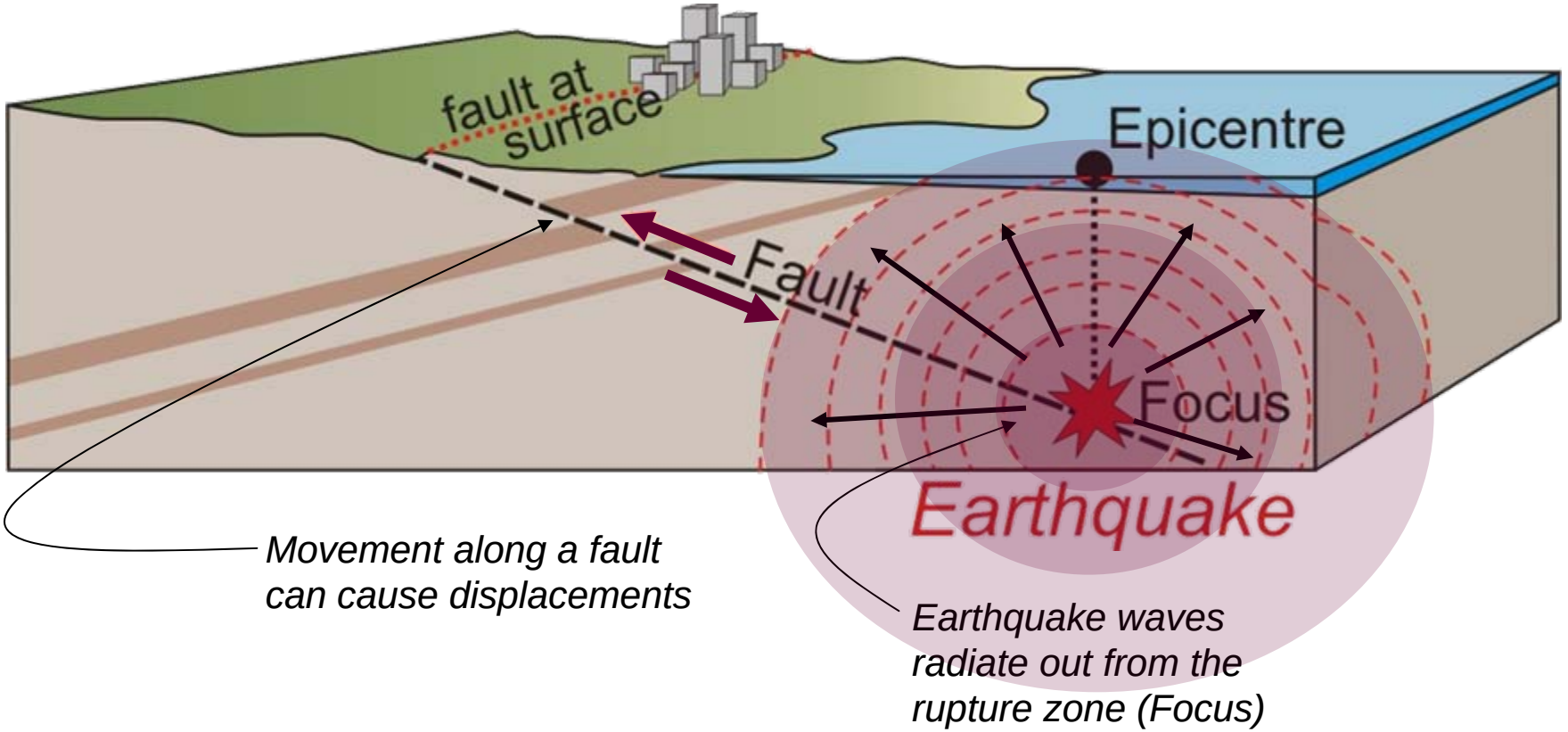
The tectonic plates are constantly moving.

Where parts of the plates are locked and can not move, the crust is under a great deal of stress.

At first the rocks stick together and do not move. Suddenly they move with a jerk before becoming stuck again. The energy released in this stick-slip movement is an earthquake.

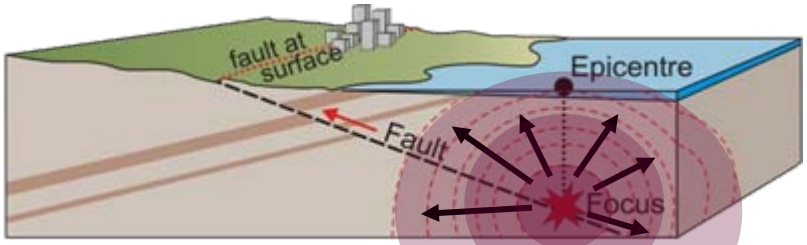
What happens?



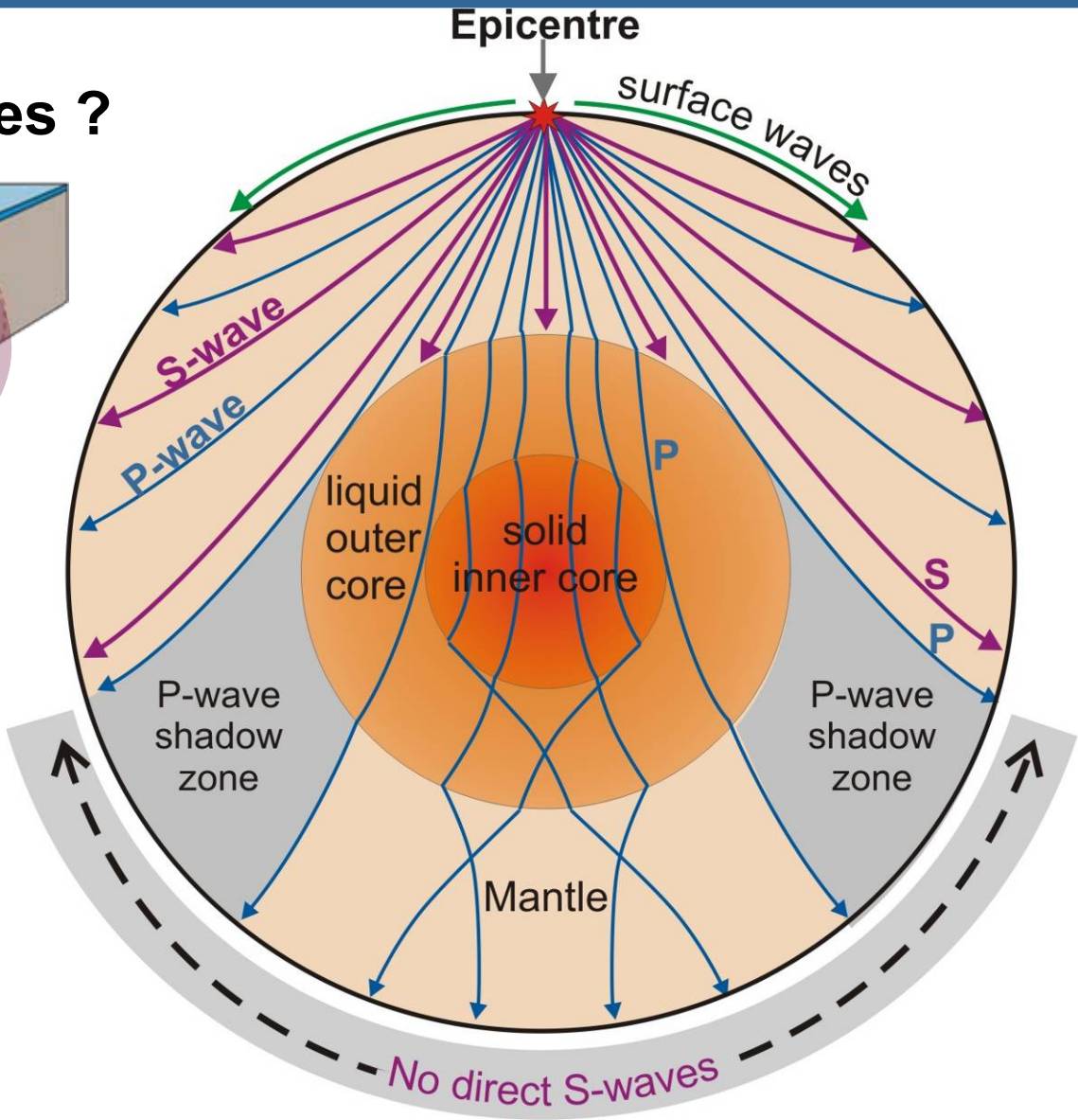


Earthquake Waves

What are seismic waves ?



Waves of energy radiate out from the rupture zone (Focus)

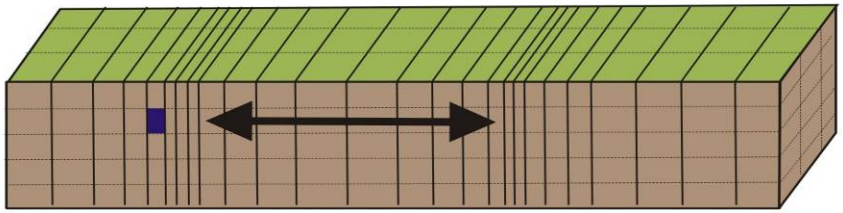


Earthquake Waves

1. BODY WAVES

P-wave (compressional wave)

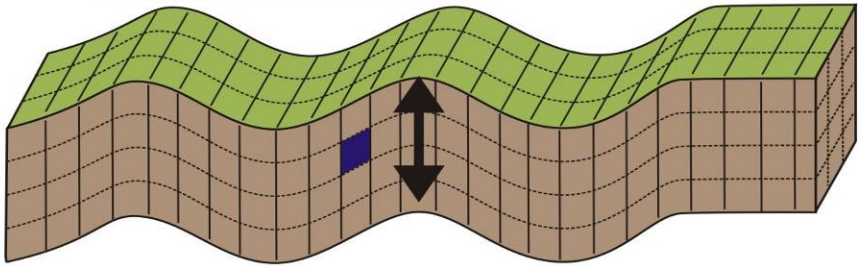
First to arrive !



particle motion: 'push-pull'.

S-wave (secondary wave)

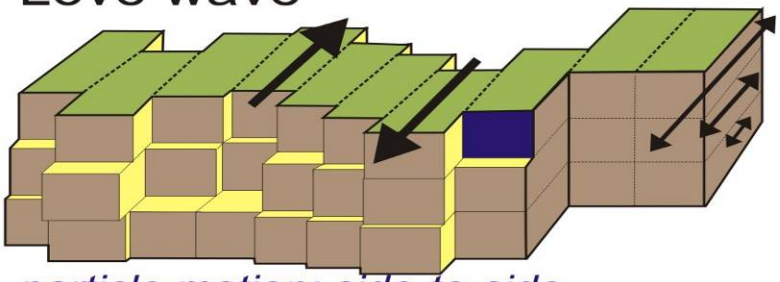
Second to arrive.



particle motion: up & down.

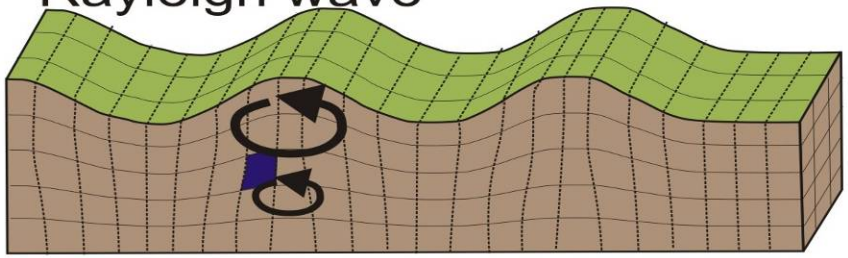
2. SURFACE WAVES

Love wave



particle motion: side-to-side

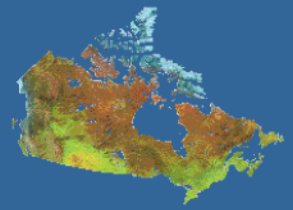
Rayleigh wave



particle motion: up & down and side-to-side

Direction of Propagation

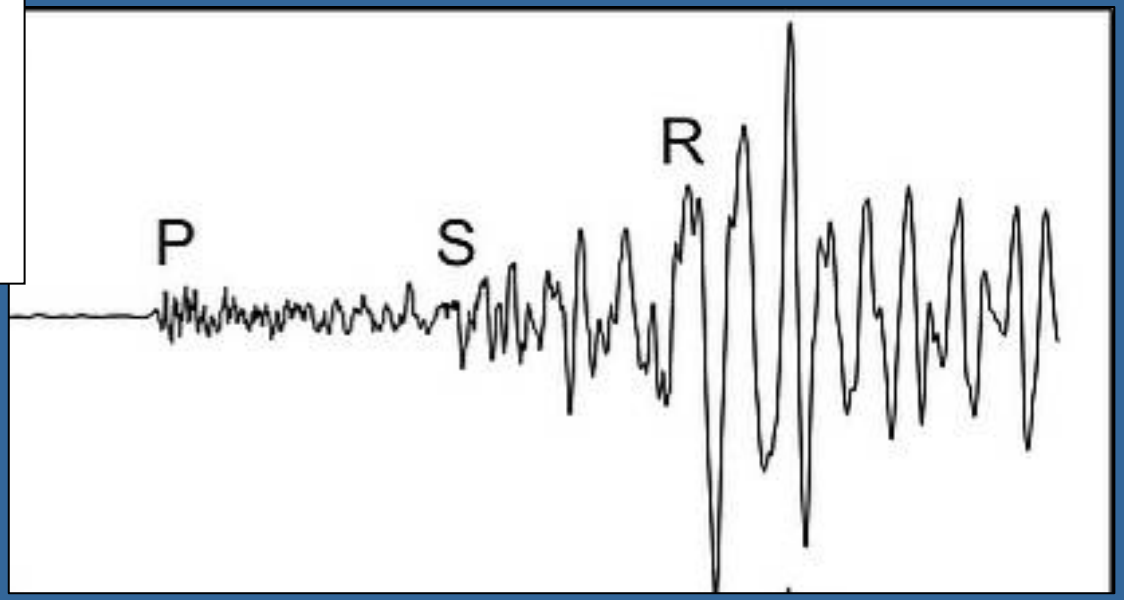
Seismograms



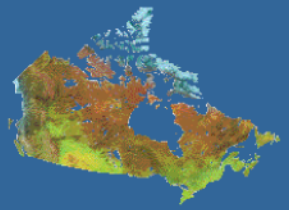
P waves ⟷

S waves ↕

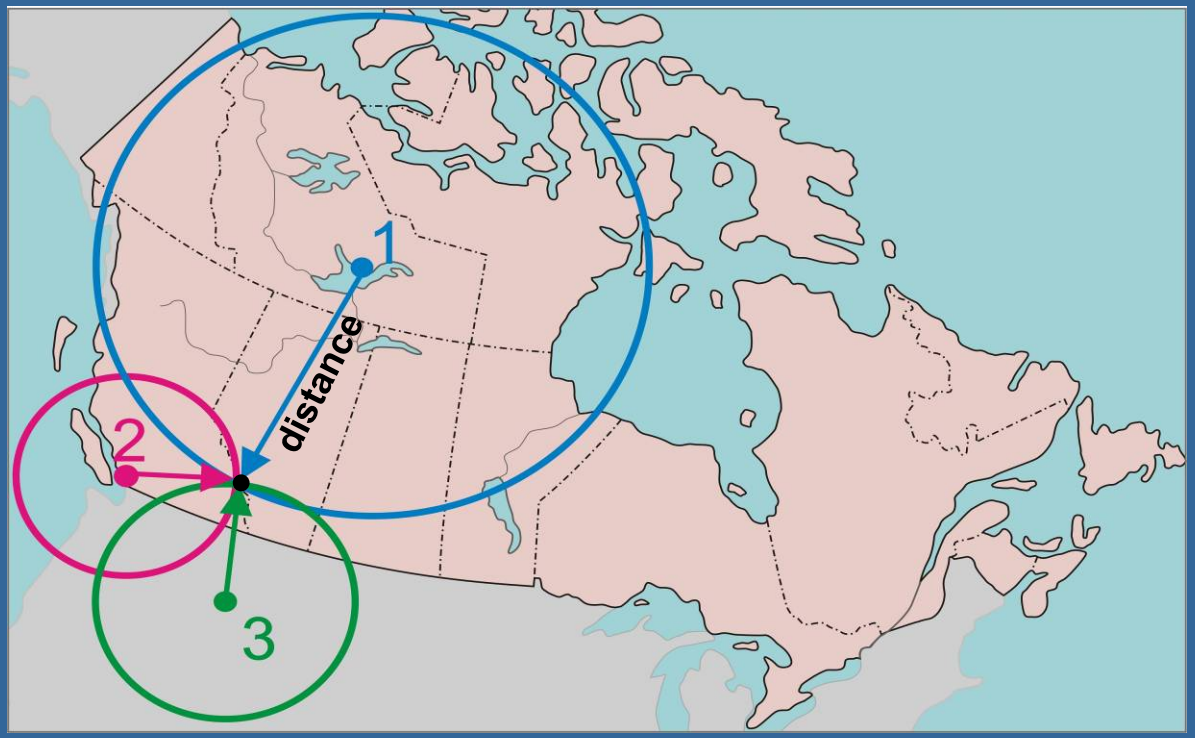
Rayleigh waves ⟲



Seismograms are used to:

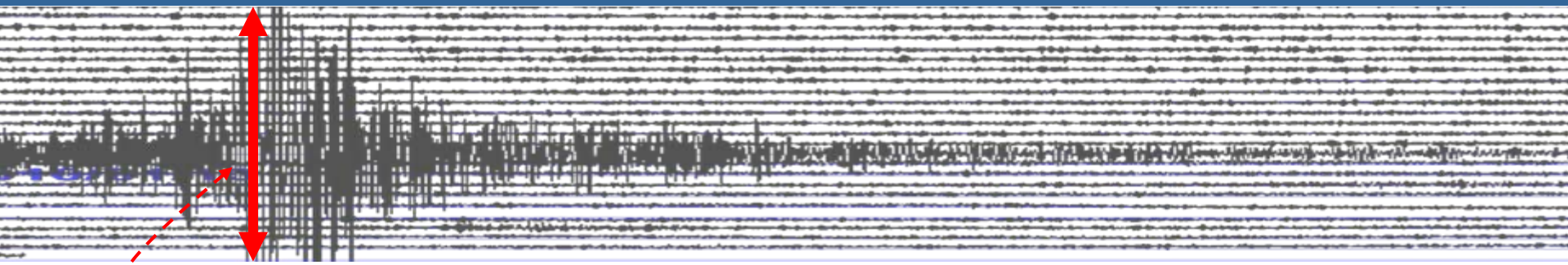


1. Locate the epicentre
2. Calculate the magnitude



1, 2, 3 are recording stations (seismometers)

Magnitude & Amplitude



Magnitude **is a measure of the amount of energy released during an earthquake.**

Magnitude is calculated based on the *amplitude* of earthquake waves recorded by a seismograph.

Magnitude

Magnitude is measured on a special scale (logarithmic) in which each number represents a value that is ten times greater than the value before

For example, assuming the same distance from the epicentre, ***the ground displacement****, at the instrument, of a Magnitude 6 earthquake is:*

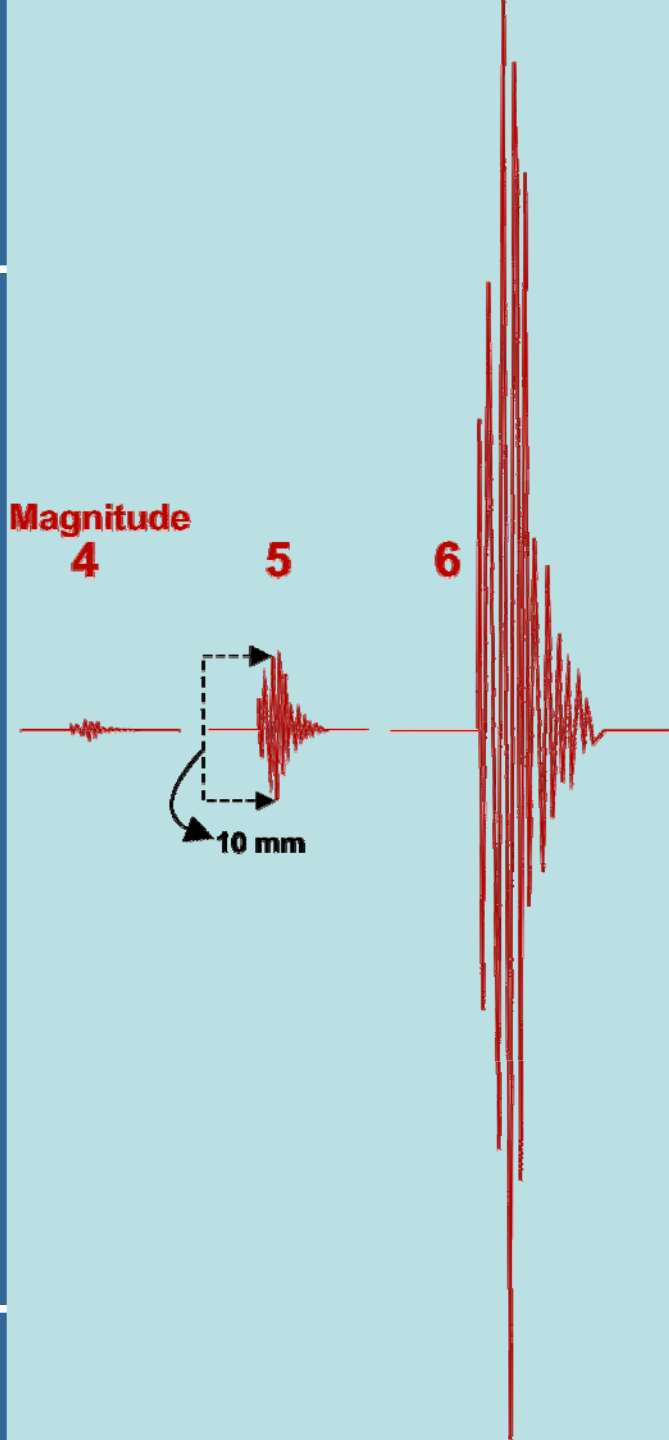
10 times greater than a Magnitude 5

100 times greater than a Magnitude 4

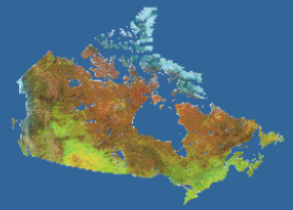
In terms of energy, **the energy** released by a Magnitude 6 earthquake is:

about 30 times greater than a Magnitude 5

about 1000 times greater than a Magnitude 4

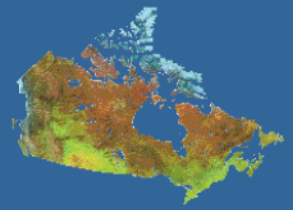


Magnitude



Magnitude	*Effect*
9 +	Rare great earthquake. Can cause major damage over a large region greater than 1000 km across.
8.0 - 8.9	"Great" earthquake. Can cause serious damage and loss of life in areas several hundred kilometers across.
7.0 - 7.9	"Major" earthquake. Can cause serious damage over larger areas.
6.1 - 6.9	Can cause damage to poorly constructed buildings and other structures in areas up to about 100 kilometers across where people live.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
3.5 - 5.4	Often felt, but rarely cause damage.
Under 3.5	Recorded on local seismographs, but generally not felt.

Intensity



Earthquakes are measured in two ways:

1. **Magnitude** is a measure of the amount of fault movement at the source of the quake.

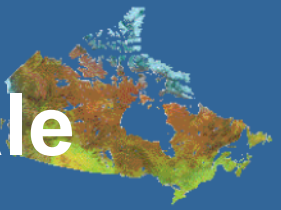
2. **Intensity** is what we feel when an earthquake occurs and it varies from place to place.

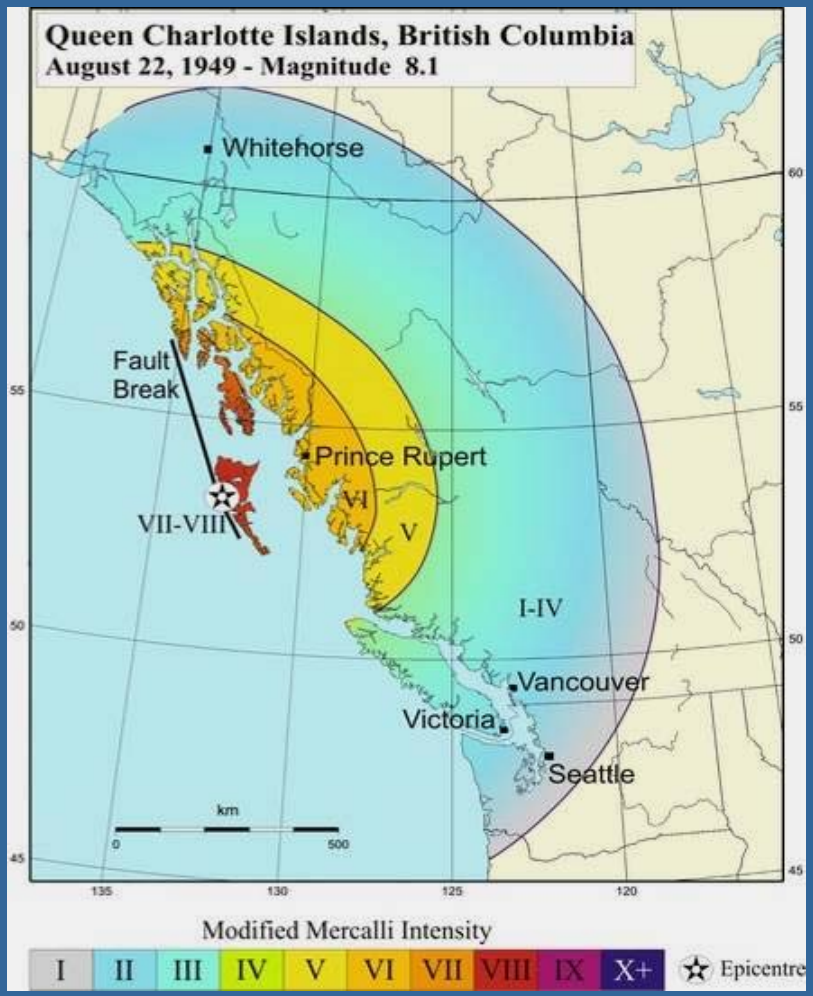
Modified Mercalli Intensity Scale

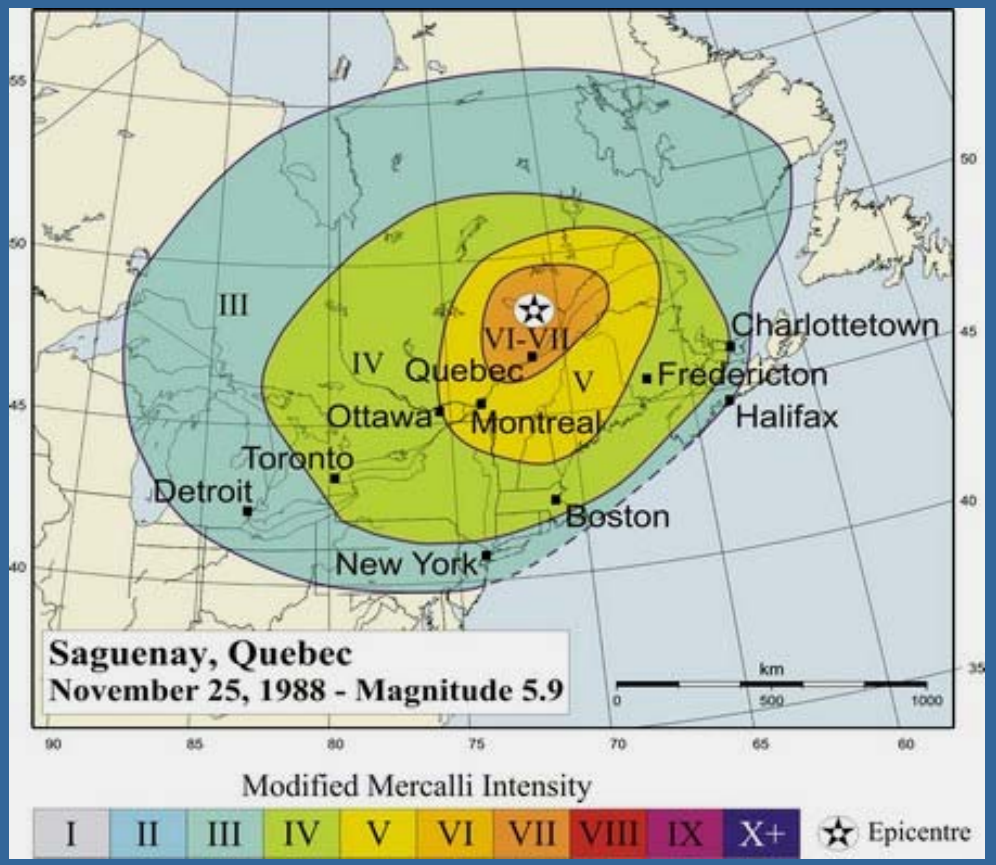
	XII
	XI
Extreme	X
Violent	IX
Severe	VIII
Very Strong	VII
Strong	VI
Moderate	V
Light	IV
Weak	III
	II
Not felt	I

- **Almost everything is destroyed.**
- **Most buildings collapse.** Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed. Railroad tracks are badly bent.
- **Most buildings and their foundations and some bridges are destroyed.** Dams are seriously damaged. Large landslides occur. Railroad tracks are bent slightly.
- **Well-built buildings suffer considerable damage**. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.
- **Severe damage in poorly built structures**. Well-built buildings suffer slight damage. Drivers have trouble steering. Houses that are not bolted down might shift on their foundations. Towers and chimneys might twist and fall. Tree branches break.
- **People have difficulty standing**. Drivers feel their cars shaking. Loose bricks fall from buildings. Considerable damage in poorly built buildings.
- **Everyone** feels movement. People have trouble walking. Objects fall from shelves. Furniture moves. Plaster walls might crack.
- **Almost everyone** feels movement. Sleeping people wake up. Doors swing open. Dishes break. Pictures on the wall move. Trees shake.
- **Most people indoors** feel movement. Dishes & windows rattle. Feels like a heavy truck hit the walls. A **few people outdoors** feel movement. Parked cars rock.
- **Many people indoors** feel movement. Hanging objects swing.
- **A few people indoors** might notice movement
- Not felt

Modified Mercalli Intensity Scale

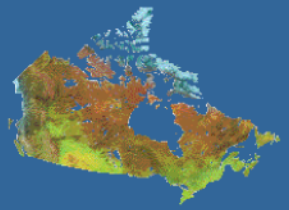




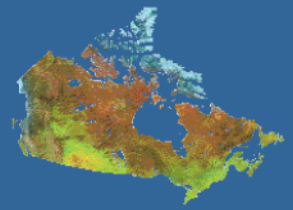


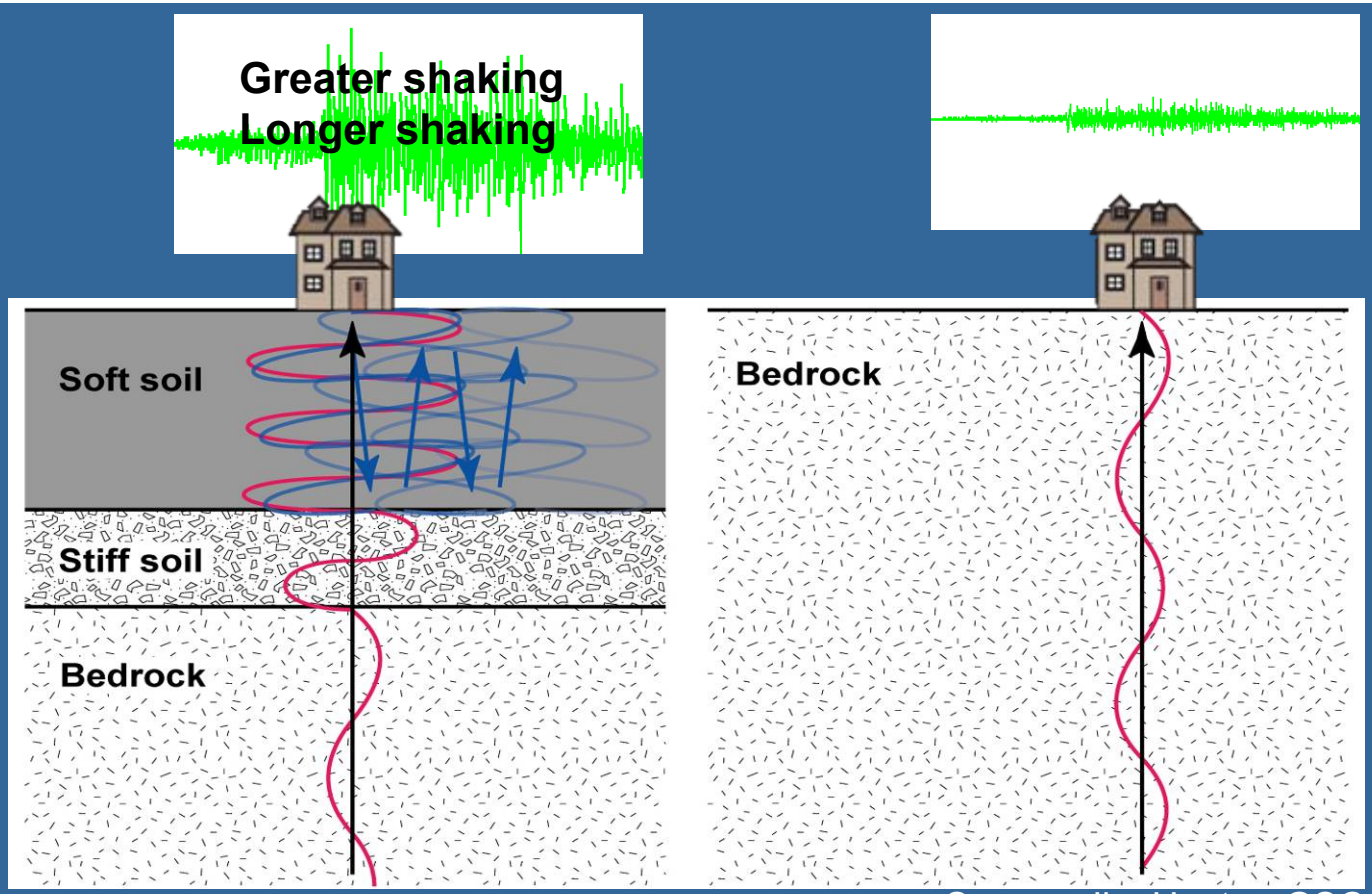
Source: EarthquakesCanada.NRCan.gc.ca

Intensity – What you feel!



Amplification effects

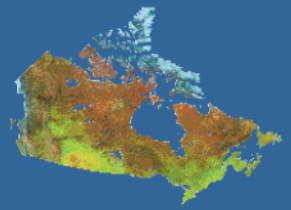




Source: Jim Hunter, GSC

Shaking intensity depends on the size of the earthquake, the distance from the epicentre, and the underlying geology. Soft soils experience longer and greater shaking than do bedrock or stiff soils.

Impact



Jefferson Elementary School

Calexico, California

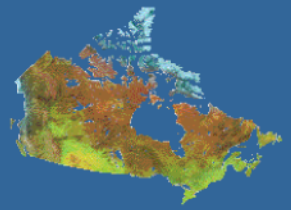
50 km from the epicentre of a M 7.2 earthquake on

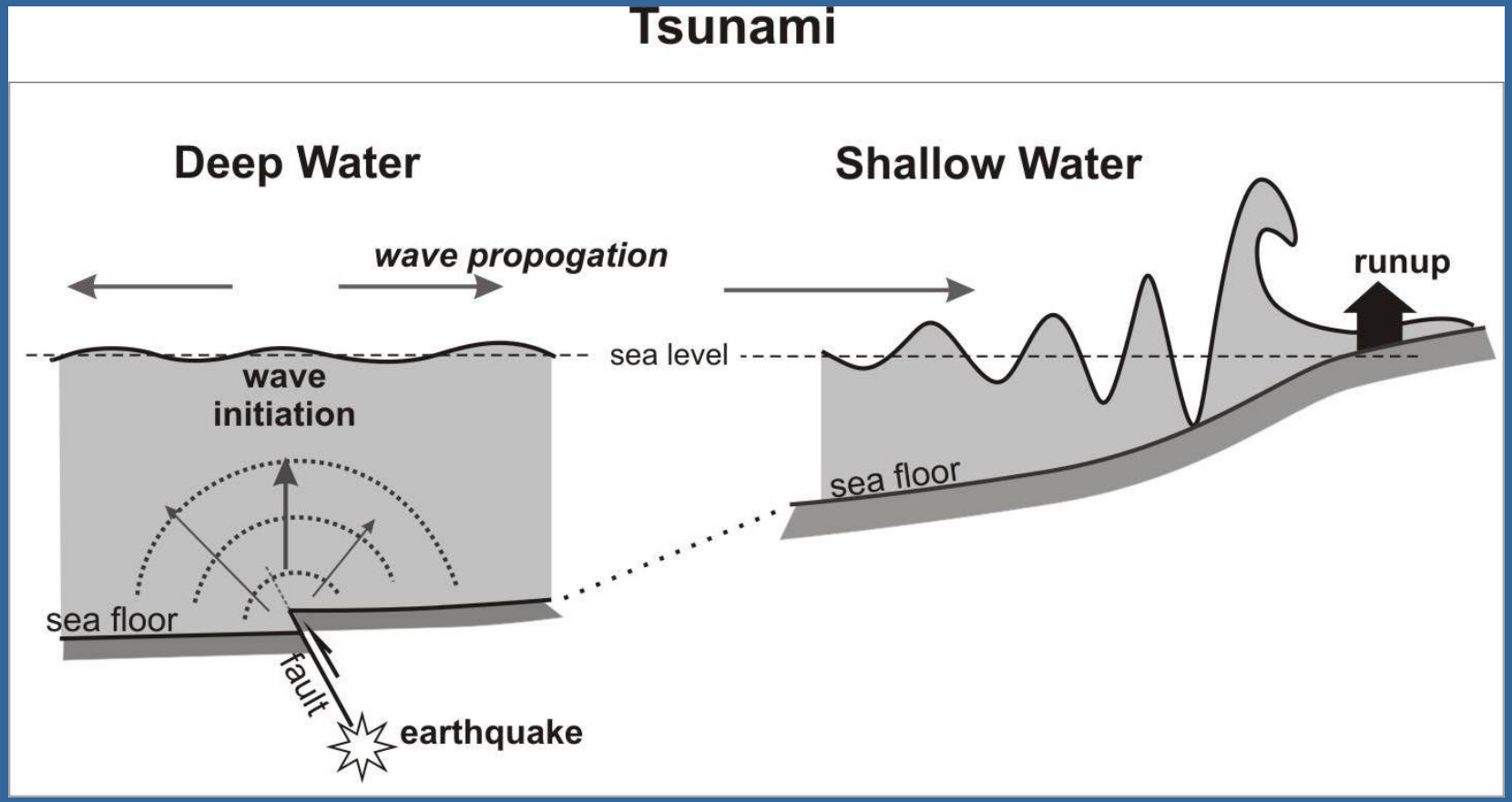
Sunday Apr. 4, 2010

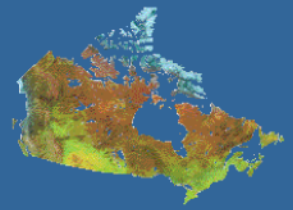
Falling objects present a major hazard in an earthquake

Photo: Kelly Huston California Emergency Management Agency

Impact

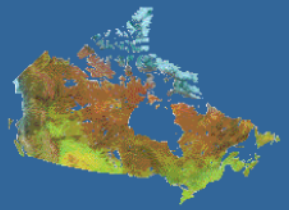



Tsunami
Deep Water
Shallow Water
wave propogation
runup
sea level
wave
initiation
sea floor
sea floor
fault
earthquake



Recent Earthquake Disasters

HAITI Magnitude 7.0 Tuesday, January 12, 2010



"Thousands of people were feared dead today after a powerful earthquake struck Haiti's capital, leaving tens of thousands homeless and buried beneath rubble." *The Gazette, U.K.*

Map Source: USGS

Nursing School destroyed

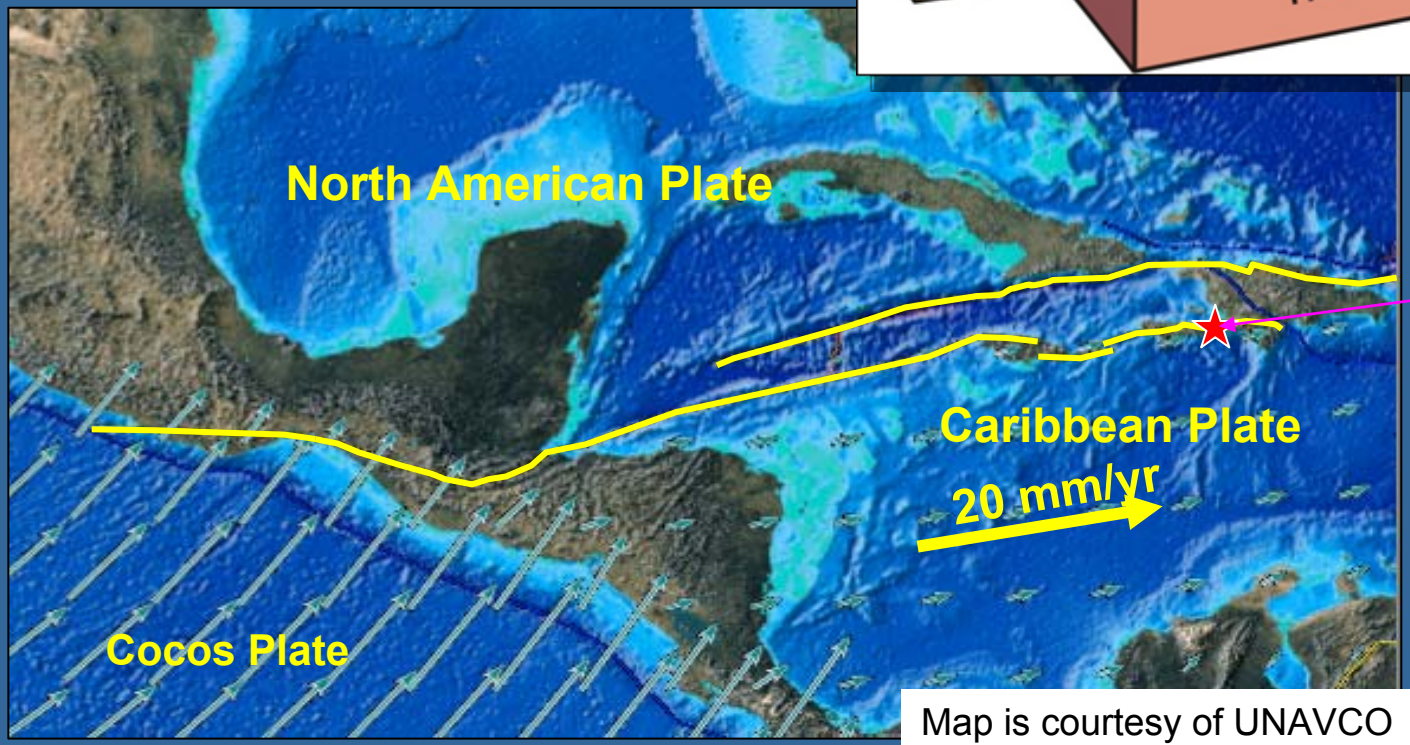
"A powerful earthquake hit the impoverished country of Haiti on Tuesday, collapsing the presidential palace and numerous other critical government buildings and raising fears of substantial casualties in what a witness called "a major, major disaster." *NBC News*

University destroyed

Presidential Palace in Port-au-Prince, Haiti

(Source for photos: AIDG)

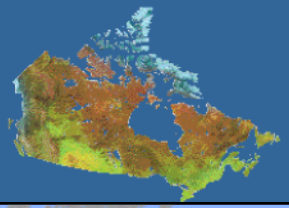
HAITI
Regional Tectonics

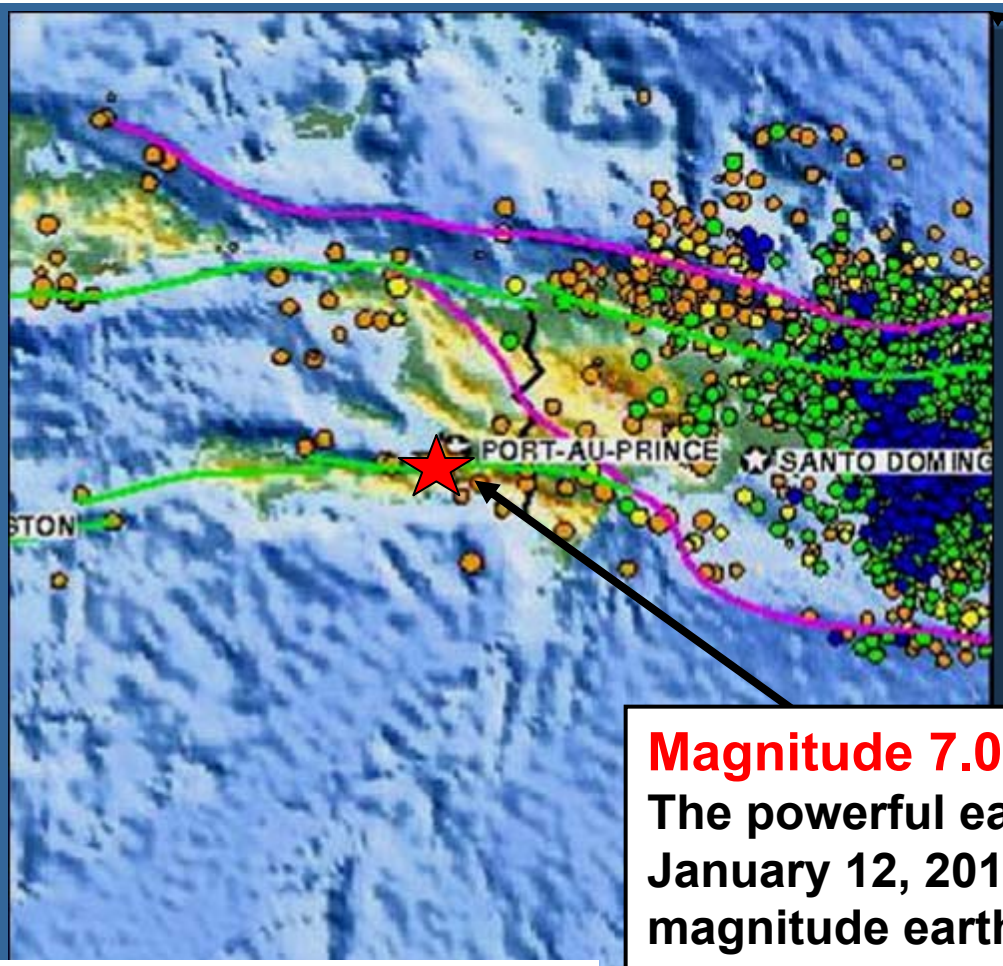


Map is courtesy of UNAVCO

- Motion between the Caribbean and North American plates occurs along two major east-west trending, strike-slip fault systems.
- The earthquake was a left-lateral strike slip faulting on the southern fault system. This fault system moves about 7 mm/yr.

HAITI Earthquake History (1990 to 2010)



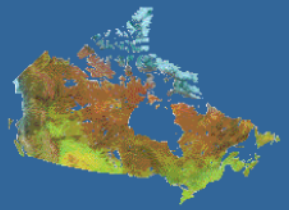


Map courtesy of U.S. Geological Survey

Magnitude 7.0

The powerful earthquake on January 12, 2010, was the largest magnitude earthquake that this region has seen in two centuries.

HAITI Shaking Intensity Map

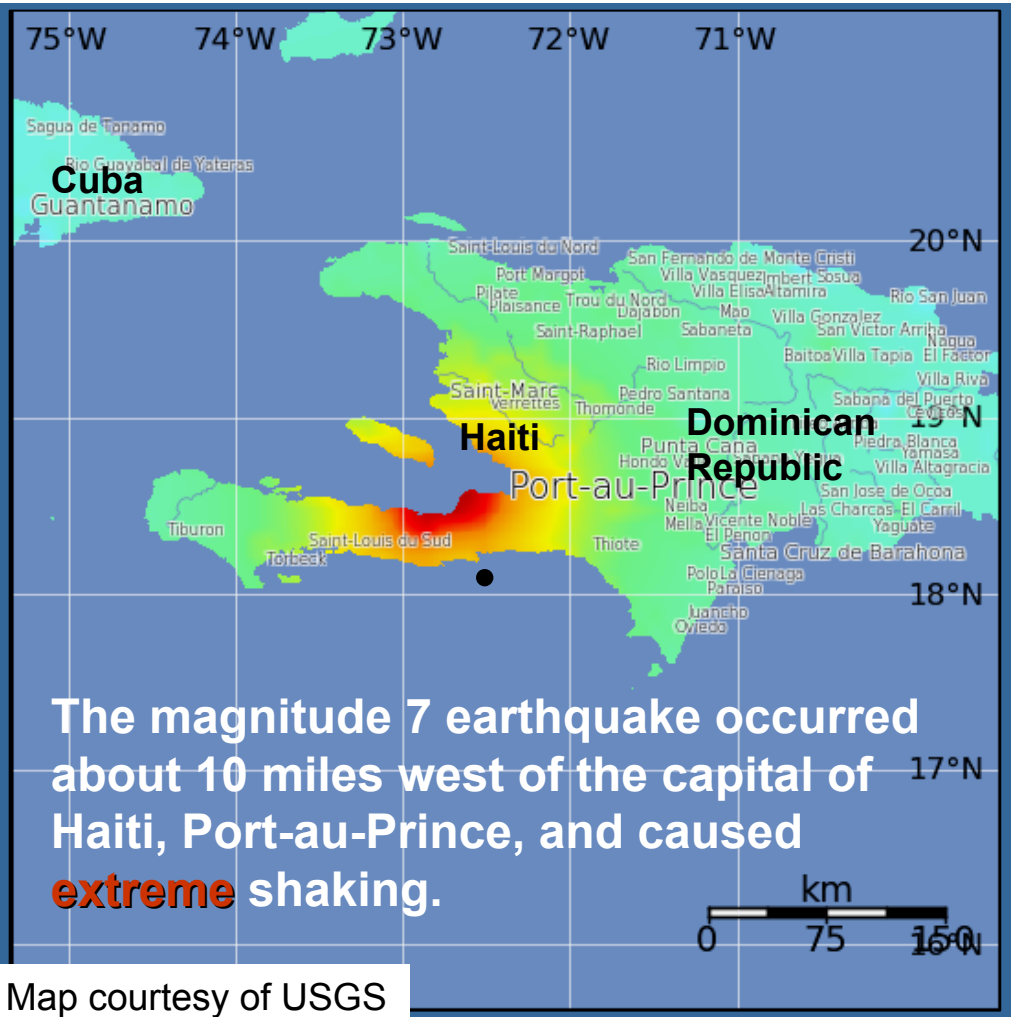


Modified Mercalli Intensity	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt

IX Well-built buildings suffer considerable damage. The ground cracks.

VIII Towers and chimneys may twist and fall. Well-built buildings suffer slight damage. Poorly built buildings suffer severe damage.

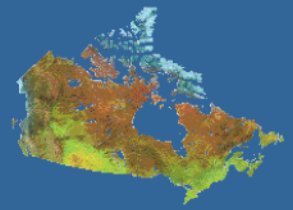
VII People have difficulty standing. Loose bricks fall from buildings. Considerable damage in poorly built buildings.



The magnitude 7 earthquake occurred about 10 miles west of the capital of Haiti, Port-au-Prince, and caused extreme shaking.

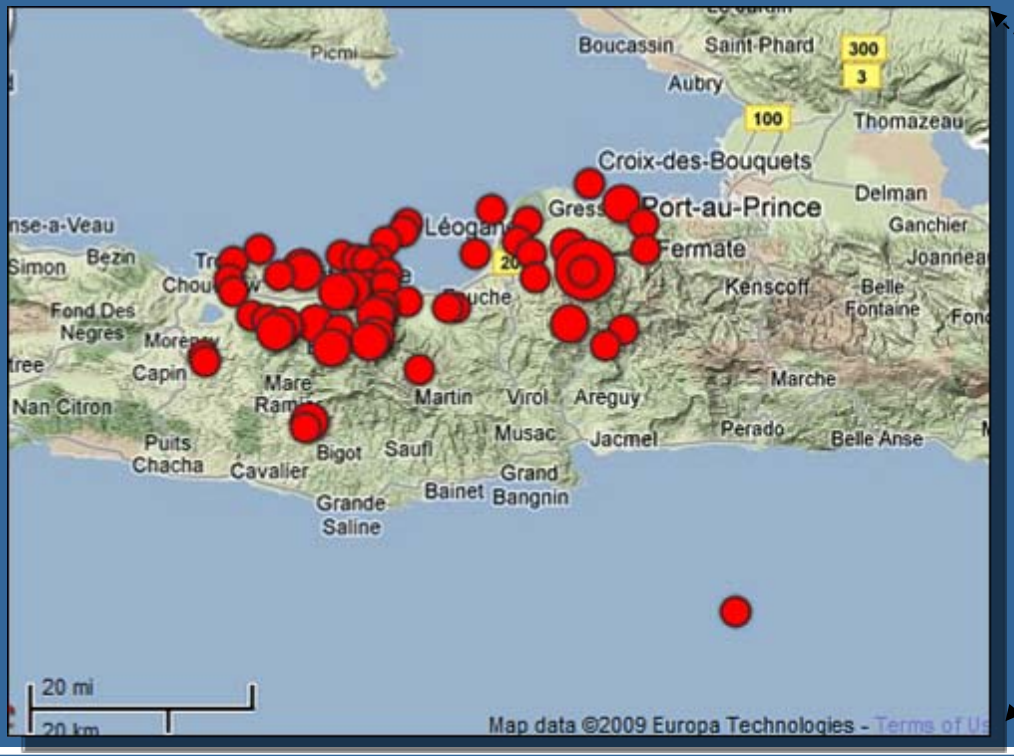
Map courtesy of USGS

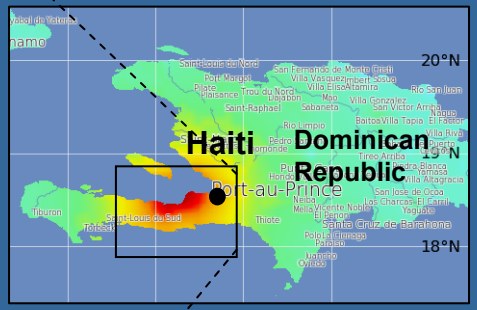
HAITI Aftershocks



Aftershocks, with magnitude 4.0 to 5.9

- **In the first two hours... 5**
- **In the first 11 hours... 32**
- **In the first 3 weeks ... 63**





Last updated Jan. 25, 2010

Source : USGS

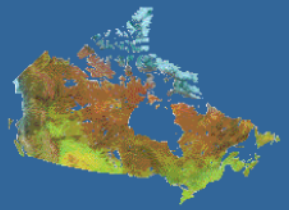
HAITI Impact

Photo source: UN Photo/Logan Abass, The United Nations

◄ Low income housing with little or no reinforced masonry.

Further complicating the situation, many people live in structures that are vulnerable to earthquake shaking.

CHILE A 'Great' Earthquake



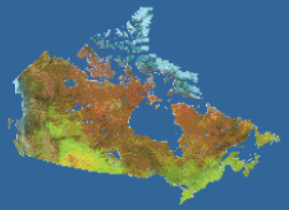
Magnitude 8.8

Saturday, February 27, 2010

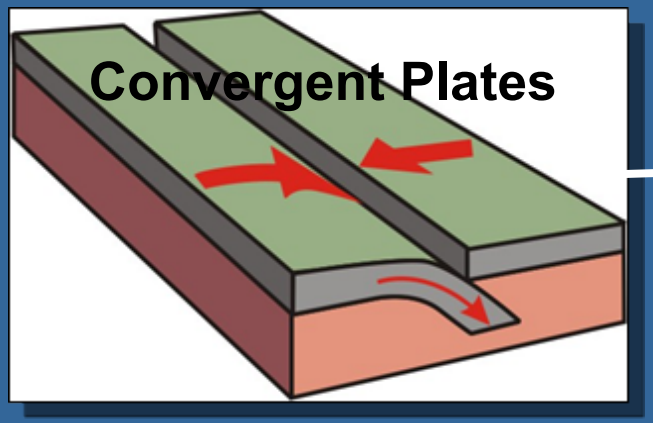
- The most powerful tremor to hit Chile in 50 years
- The 6th largest earthquake in the world for the last 100 years
- 500 times more forceful than the earthquake in Haiti
- Epicentre was 115 km from Concepcion, Chile's second-largest city and 325 km southwest of the capital, Santiago

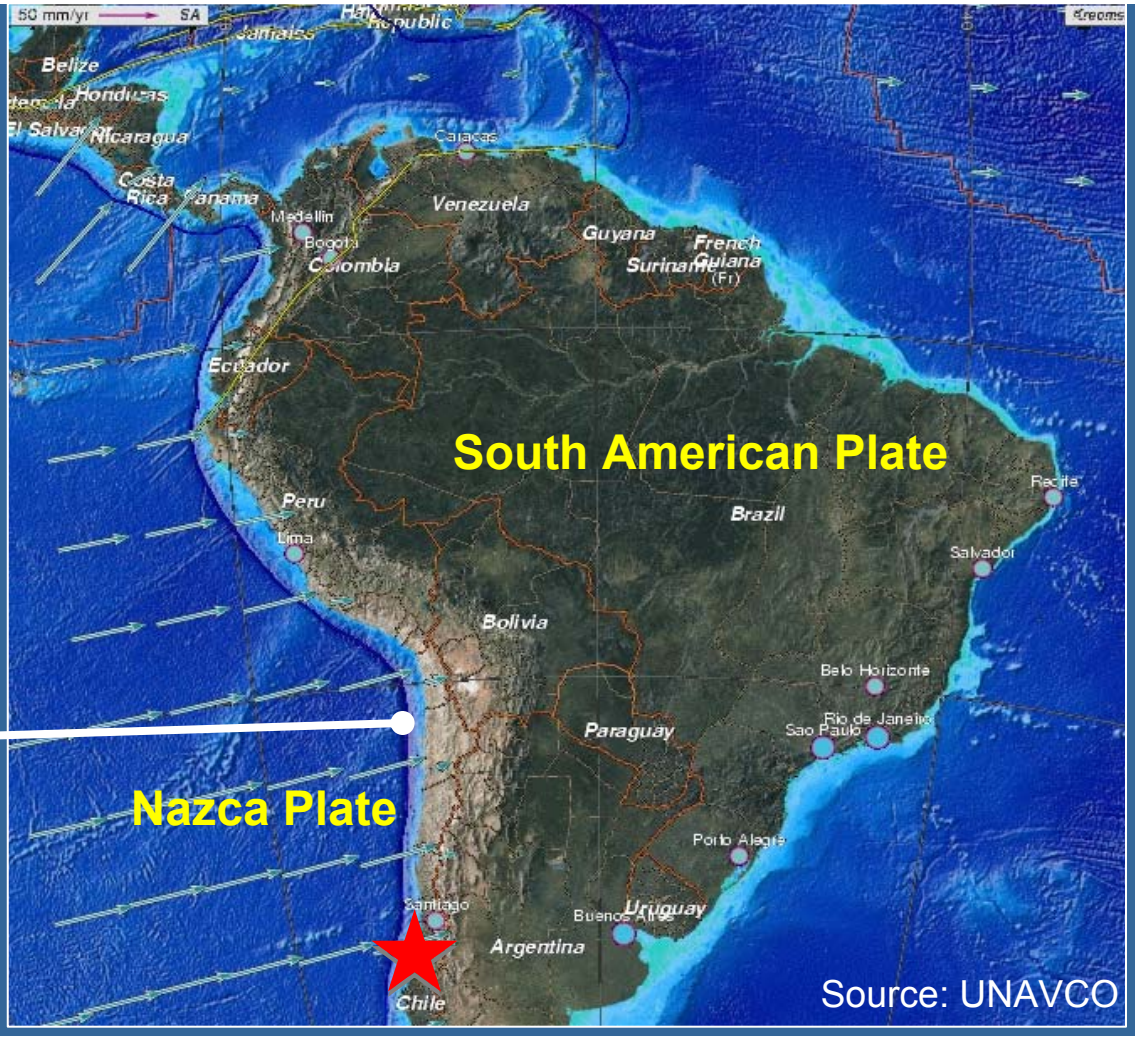
Maps source: USGS

CHILE Tectonics

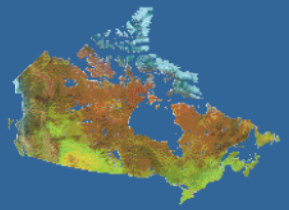


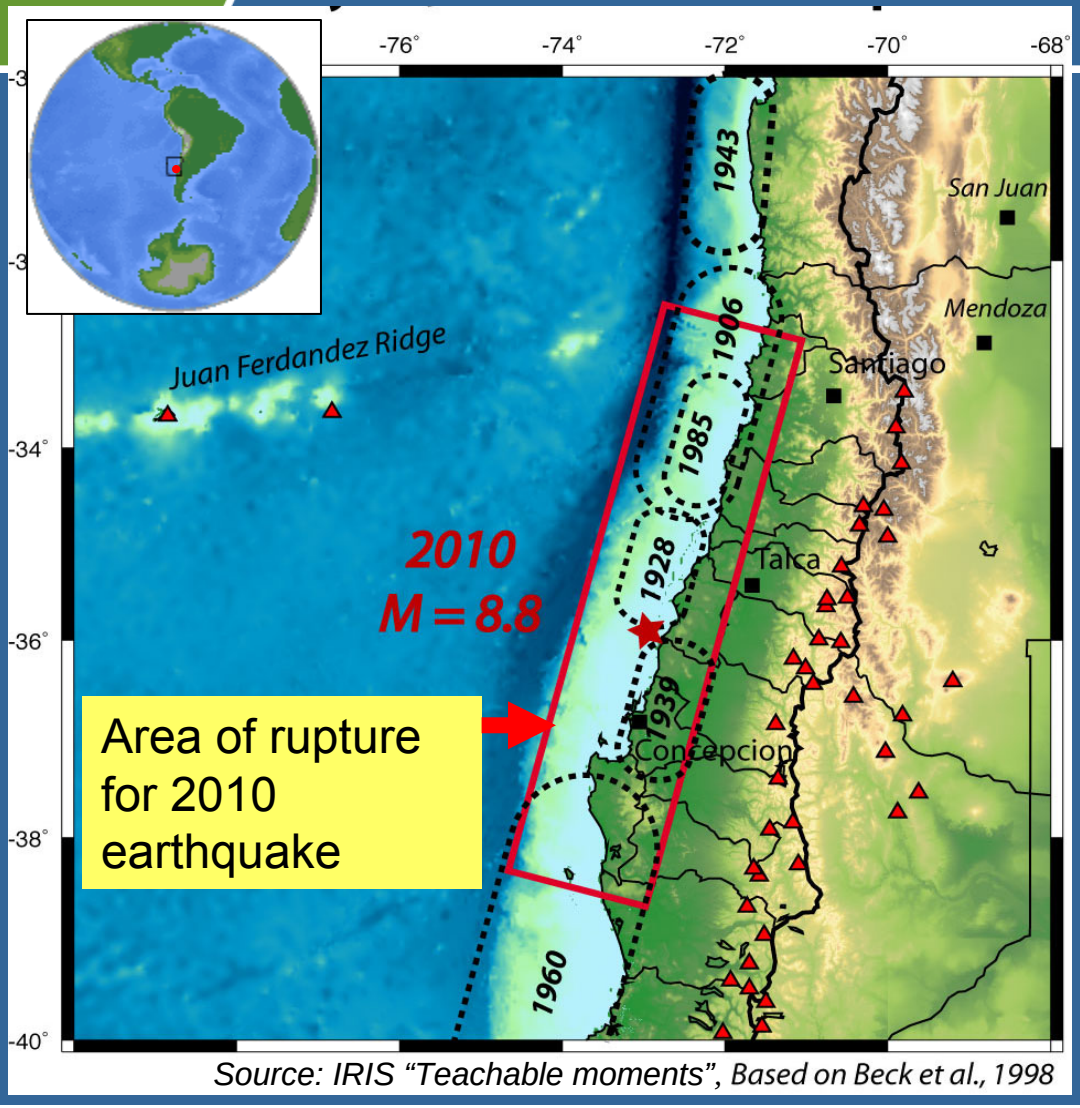
Chilean earthquakes occur on the subduction zone plate boundary, where the oceanic **Nazca Plate** subducts beneath the continental **South American Plate**.





CHILE





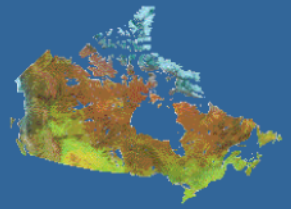
Source: IRIS "Teachable moments", Based on Beck et al., 1998

Coastal Chile has a history of very large earthquakes

- 13 events of magnitude 7.0 or greater since 1973
- 1960 Valdivia Quake (Magnitude 9.5) – the strongest earthquake ever measured in the world

◄ An outline of the approximate rupture from this Magnitude 8.8 earthquake and its relationship to the largest earthquakes along the coast of Chile this century.

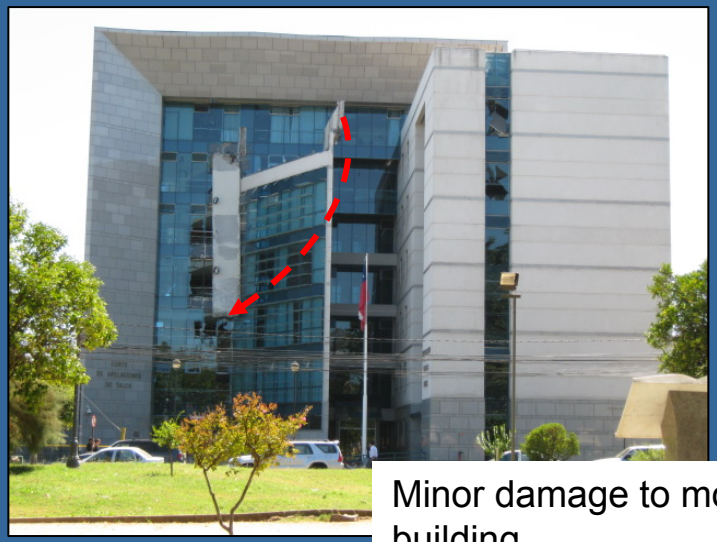
CHILE IMPACT



Adobe building destroyed

Tsunami debris

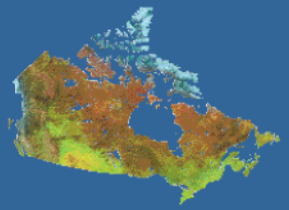
- Severe shaking
- Tsunami
- 521 deaths
- Buildings, roads, bridges, ports and airport damaged
- Power and phone lines down



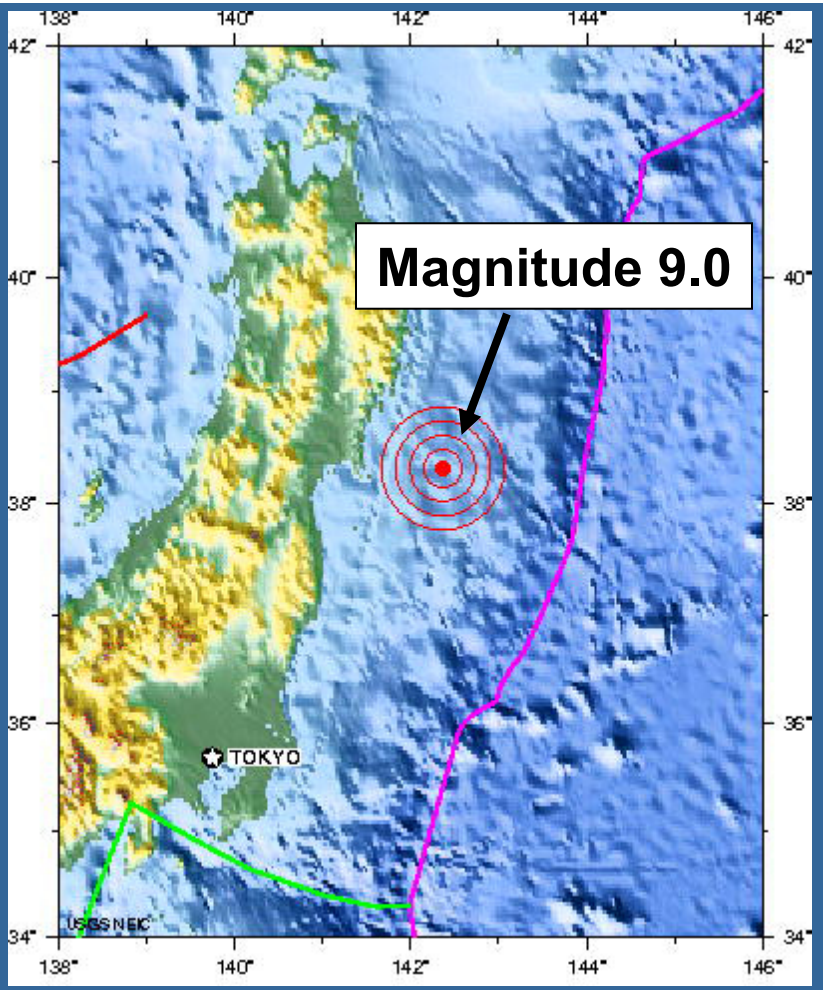
Minor damage to modern building

JAPAN

Friday, March 11, 2011
02:46:23 PM local time



This earthquake occurred 130 km (80 miles) east of Sendai, Honshu, Japan and 373 km (231 miles) northeast of Tokyo, Japan.

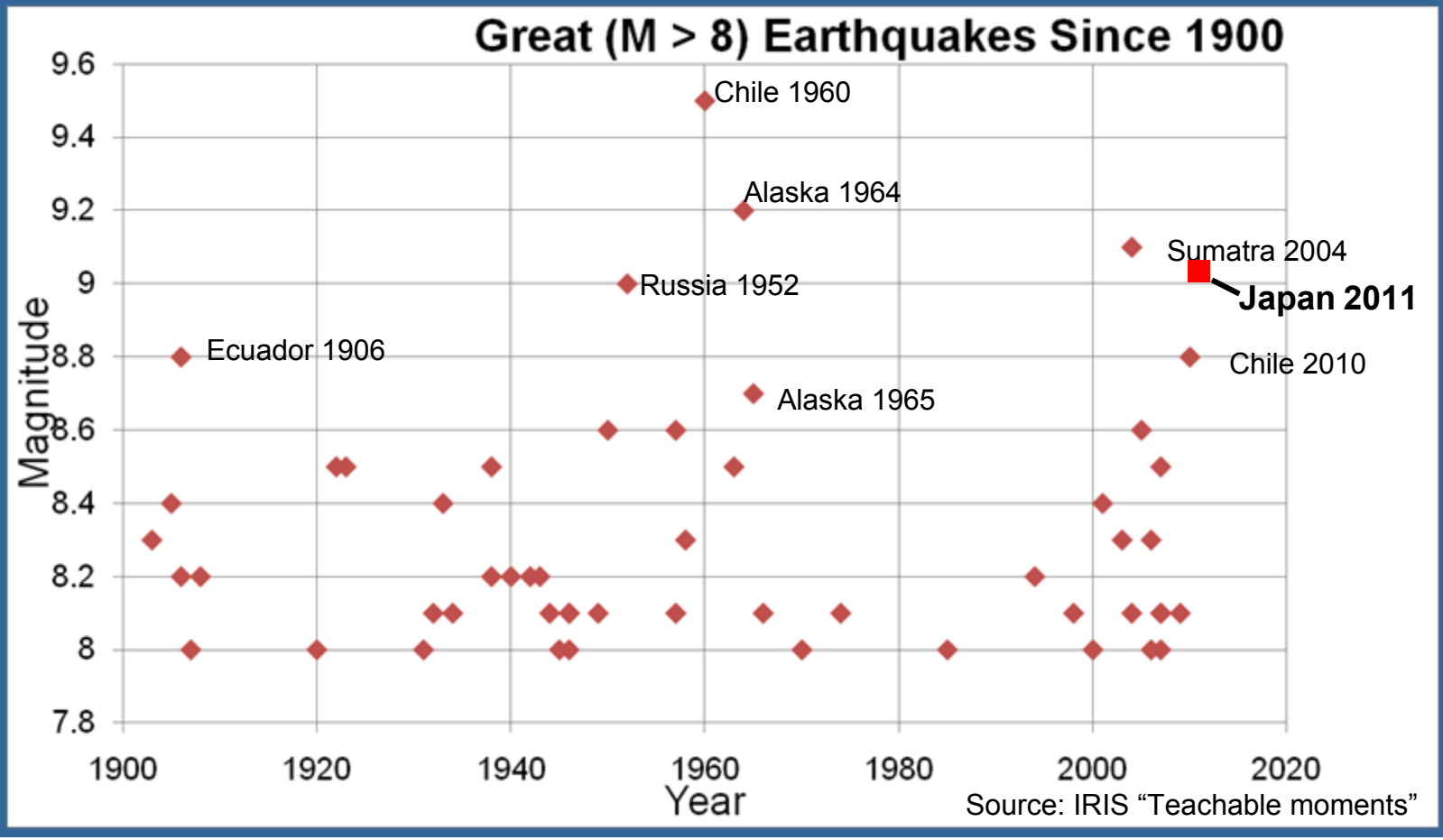


Images courtesy of the US Geological Survey

JAPAN

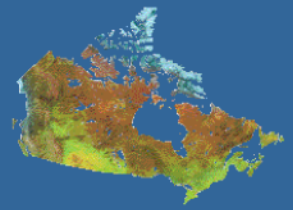
Magnitude 9.0
March 11, 2011

Globally, this is the 4th largest earthquake since 1900.



JAPAN

Magnitude 9.0
March 11, 2011



Tsunami waves swept away houses and cars in northern Japan and pushed ships aground.

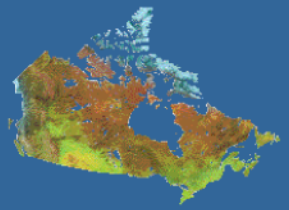
The tsunami waves traveled far inland, the wave of debris racing across the farmland, carrying boats and houses with it.

CNN reported “The quake rattled buildings and toppled cars off bridges and into waters underneath. Waves of debris flowed like lava across farmland, pushing boats, houses and trailers toward highways.”

Additionally, a number of fires broke out including one at an oil refinery.

JAPAN

Magnitude 9.0
March 11, 2011



TEPCO

The Fukushima Dai-ichi Nuclear Power Station was damaged by the tsunami

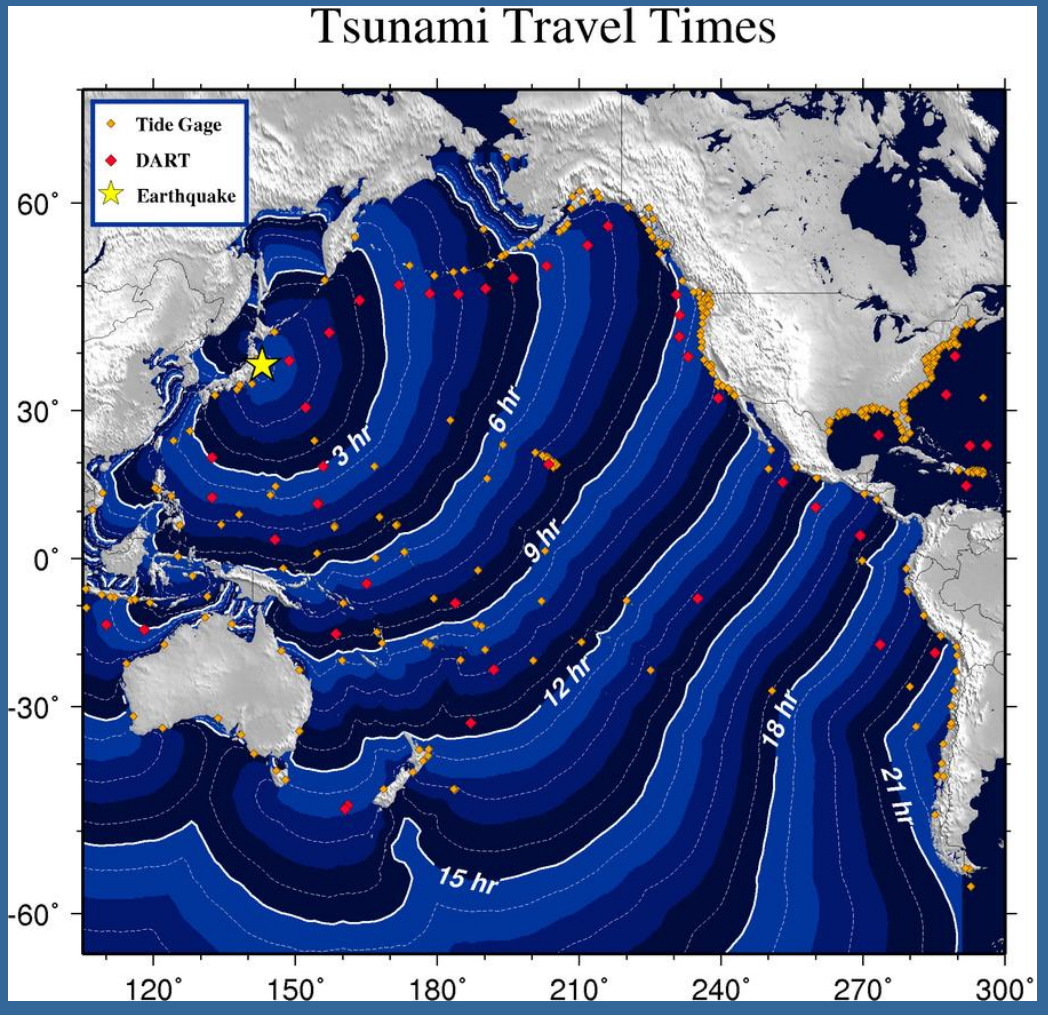
Air Photo Service Inc (Myoko, Niigata Japan)

Photos taken from a situation update given April 6, 2011 by the Ministry of Economy, Trade and Industry, Government of Japan

JAPAN

Magnitude 9.0
March 11, 2011

Damage from the earthquake was minor compared to the destruction from the tsunami that was generated by the earthquake



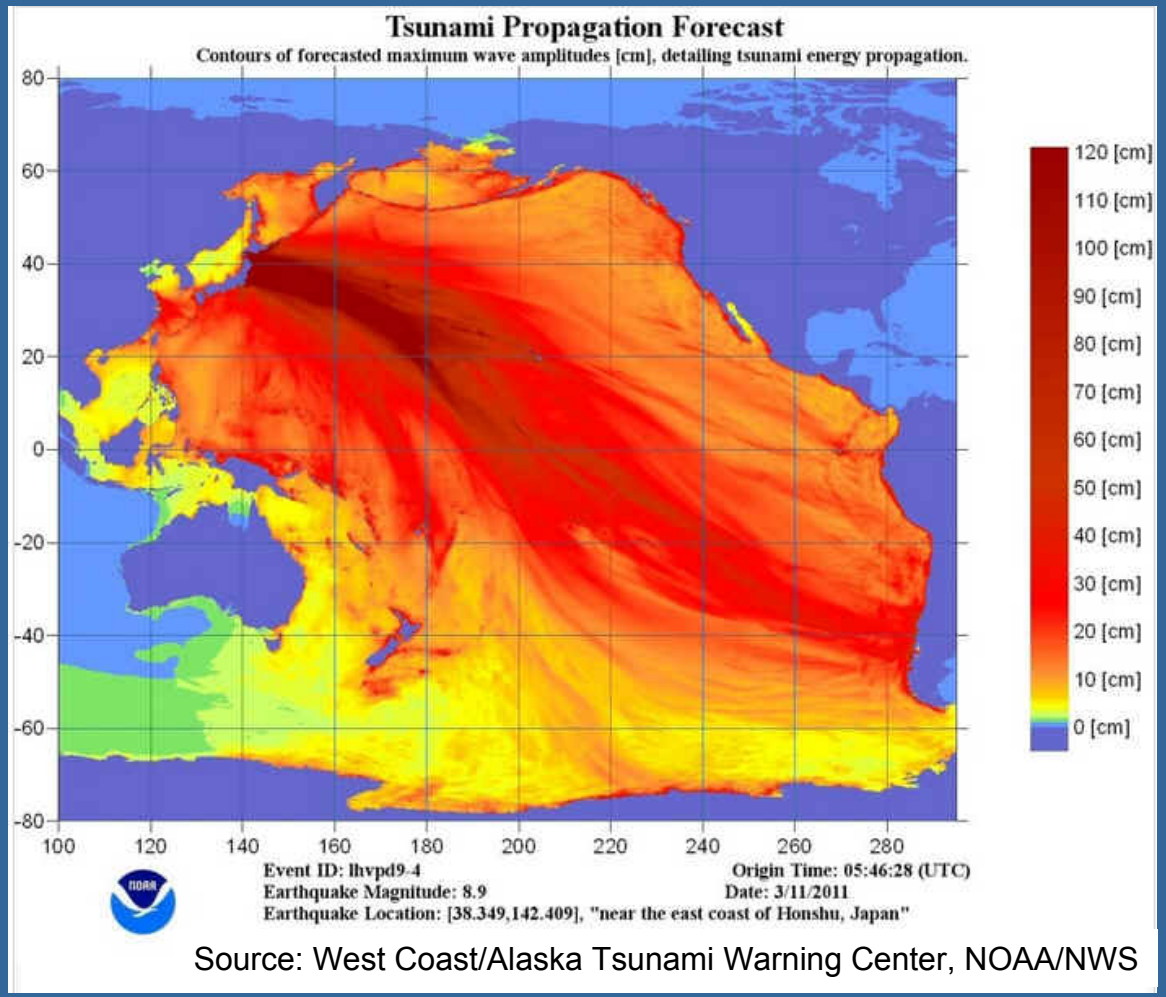
Source: West Coast/Alaska Tsunami Warning Center, NOAA/NWS

JAPAN

Magnitude 9.0
March 11, 2011

This tsunami propagation forecast model shows the forecast maximum tsunami wave height (in cm). Ocean floor bathymetry affects the wave height because a tsunami moves the seawater all the way to the floor of the ocean.

A Pacific wide tsunami warning was issued.



Source: West Coast/Alaska Tsunami Warning Center, NOAA/NWS

JAPAN

Magnitude 9.0
March 11, 2011

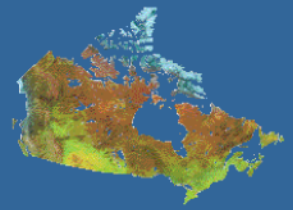
Tsunami hits Japanese coast
Source: Kyodo PhotoID: 149180

IMPACT

Tsunami damage in Natori, Japan
Source: Kyodo Photo ID: 149172

Tsunami debris with people awaiting rescue on terrace, March 12
Source: Kyodo PhotoID: 149226

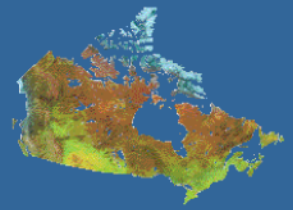
Earthquake



Could it happen in Canada?

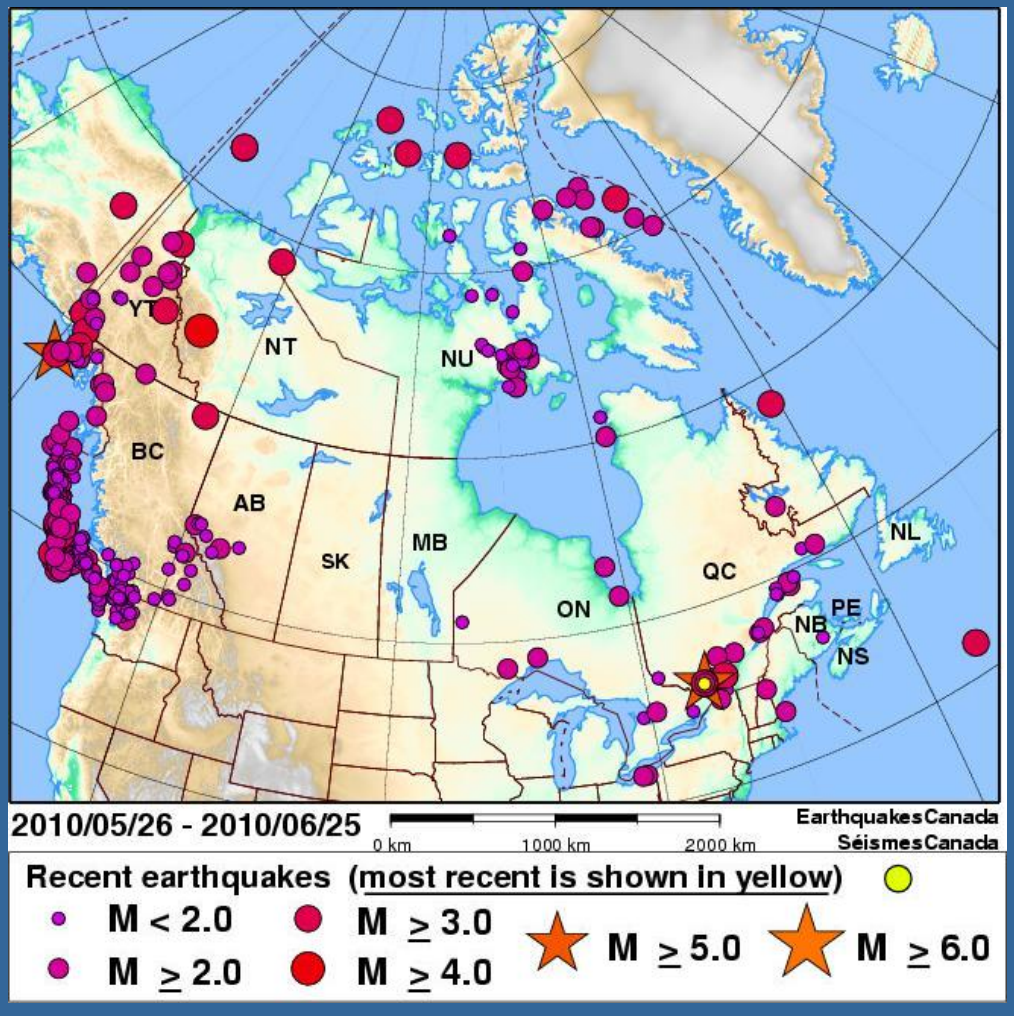
Source: Geoscience Canada

Canada



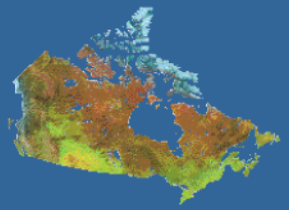
One month of earthquakes

2010/05/26 - 2010/06/25

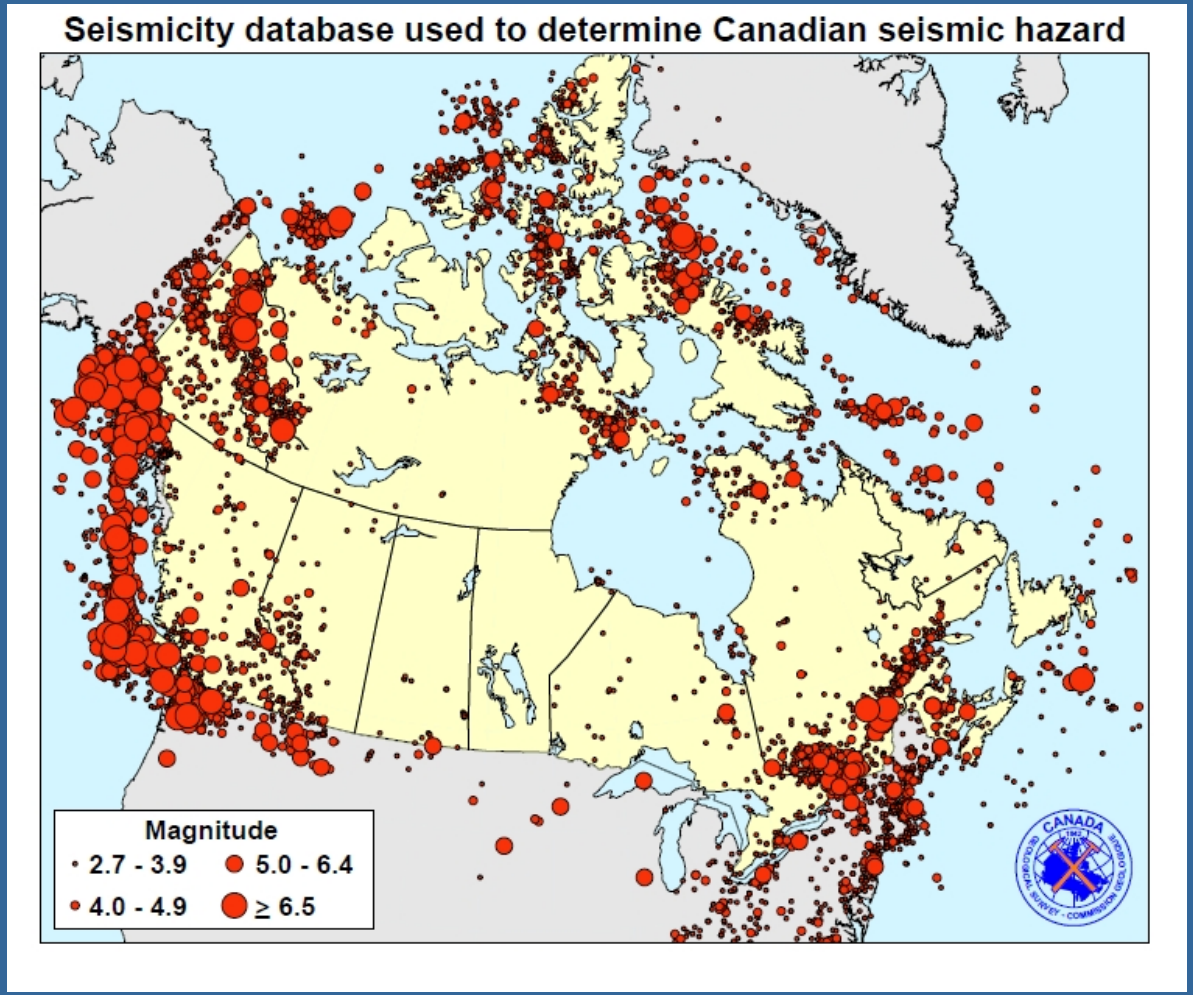


Source: Earthquakes Canada
http://earthquakescanada.nrcan.gc.ca

Canada

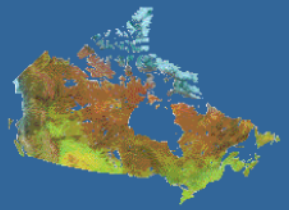


About 4000 earthquakes per year occur in or near Canada

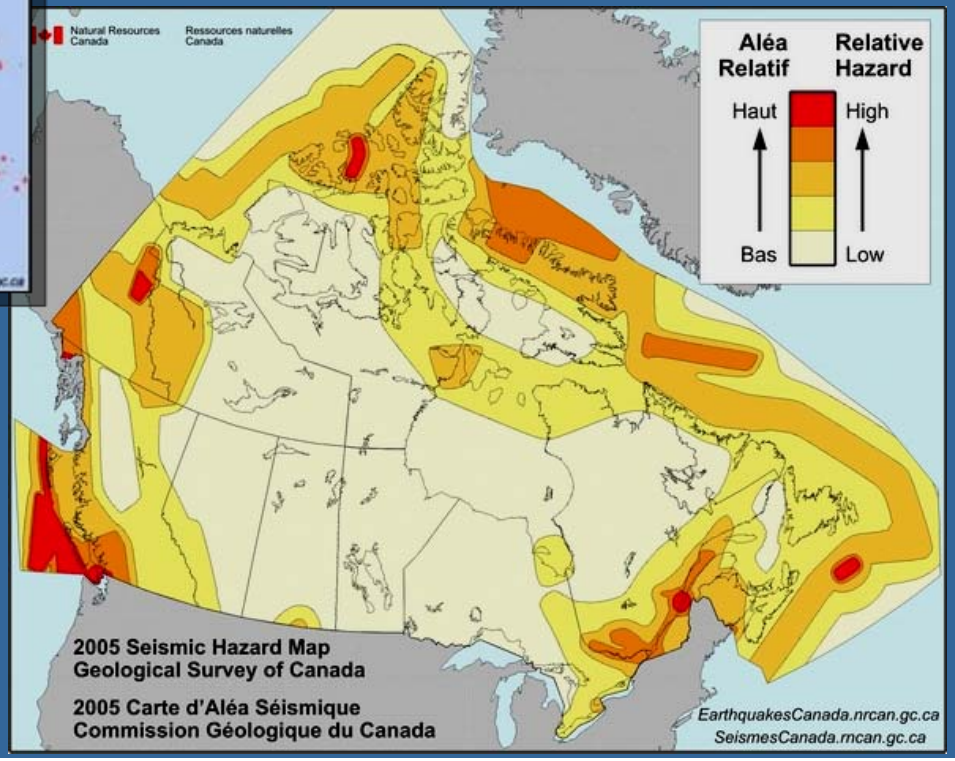


Source: Earthquakes Canada
http://earthquakescanada.nrcan.gc.ca

Canada

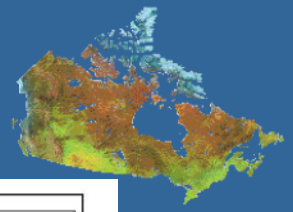


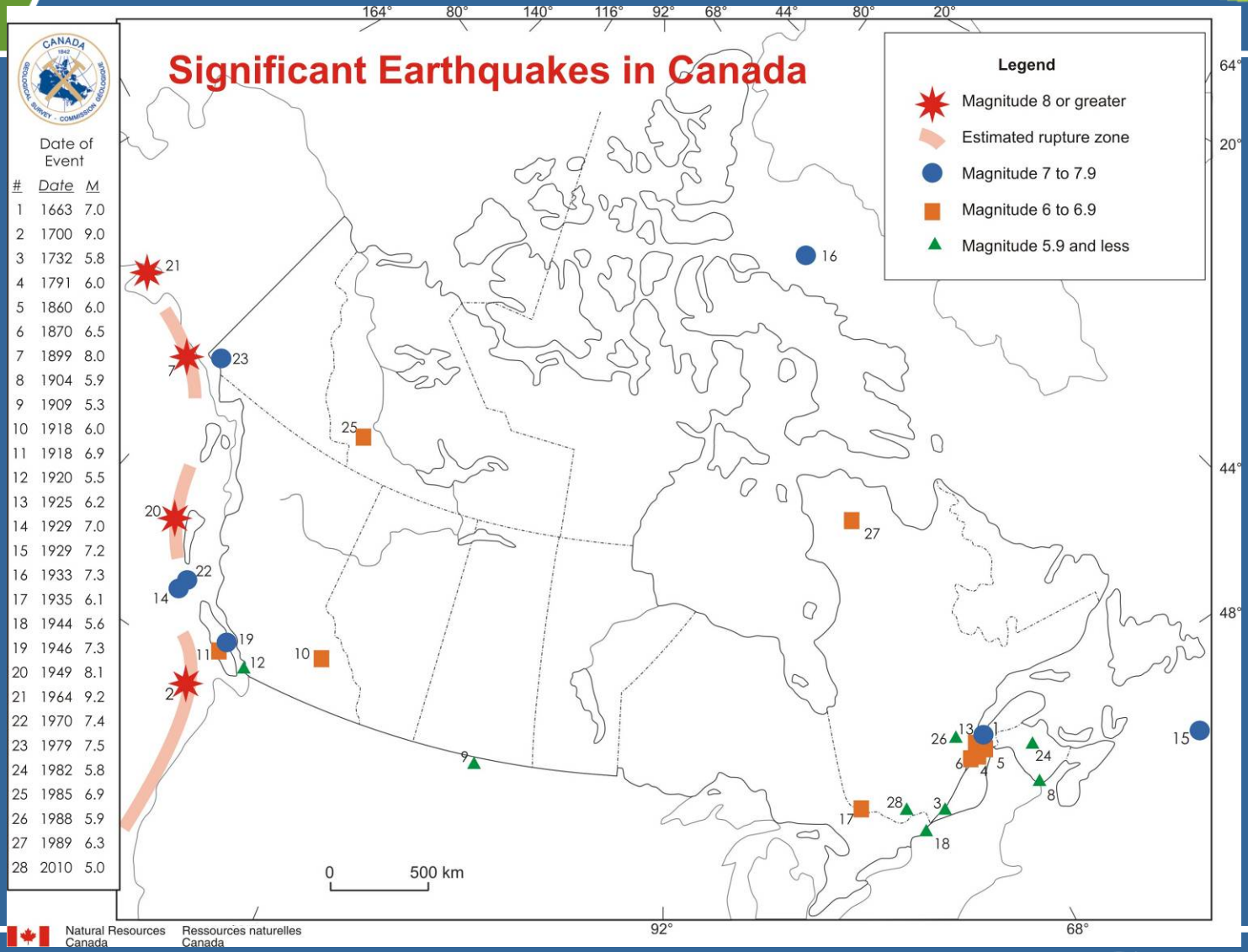
Where do most Canadian earthquakes happen?



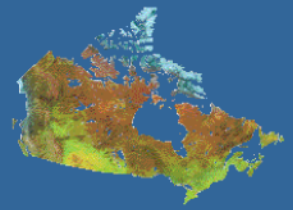
- Western B.C. and offshore
- St. Lawrence Lowlands of eastern Canada
- Arctic Canada

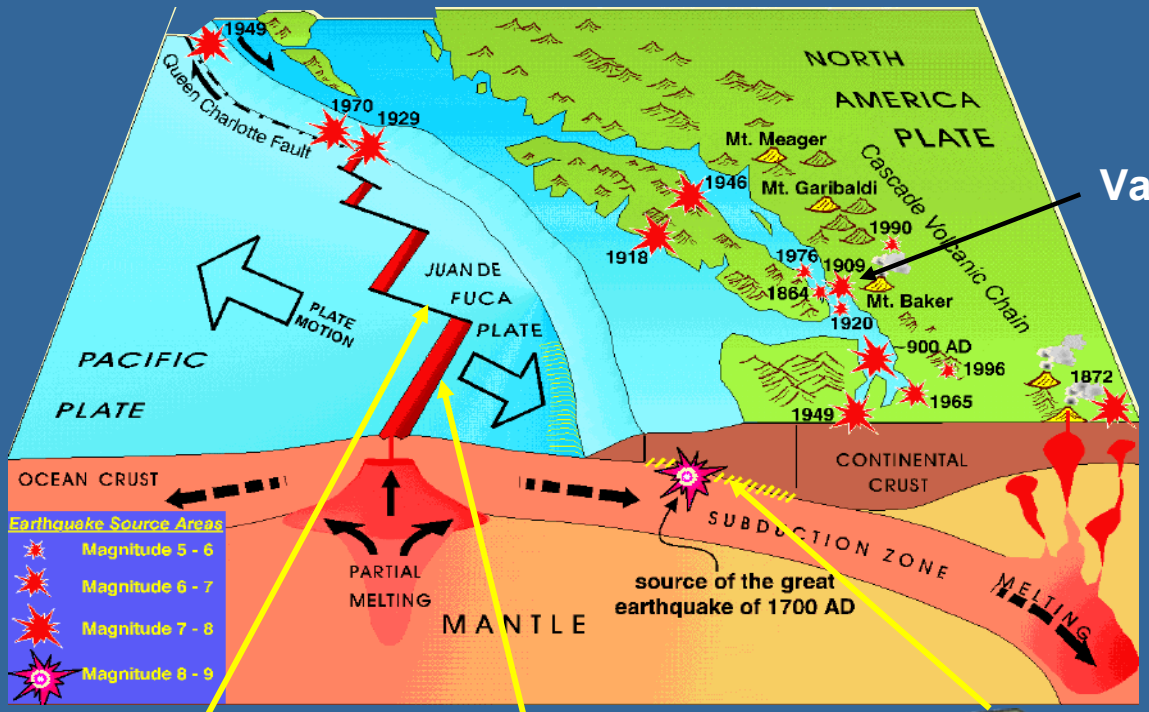
Canada



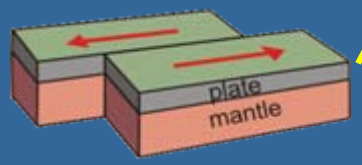

Significant Earthquakes in Canada
Legend
Magnitude 8 or greater
Estimated rupture zone
Magnitude 7 to 7.9
Magnitude 6 to 6.9
Magnitude 5.9 and less
Date of Event
Date M
1 1663 7.0
2 1700 9.0
3 1732 5.8
4 1791 6.0
5 1860 6.0
6 1870 6.5
7 1899 8.0
8 1904 5.9
9 1909 5.3
10 1918 6.0
11 1918 6.9
12 1920 5.5
13 1925 6.2
14 1929 7.0
15 1929 7.2
16 1933 7.3
17 1935 6.1
18 1944 5.6
19 1946 7.3
20 1949 8.1
21 1964 9.2
22 1970 7.4
23 1979 7.5
24 1982 5.8
25 1985 6.9
26 1988 5.9
27 1989 6.3
28 2010 5.0
0 500 km
164° 80° 140° 116° 92° 68° 44° 80° 20°
64° 20° 44° 48° 92° 68°
Natural Resources Canada
Ressources naturelles Canada

Canada - West Coast

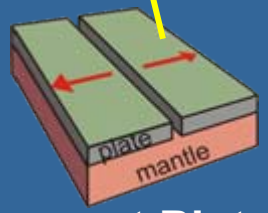




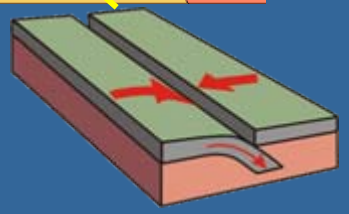
Vancouver



Transform Plates

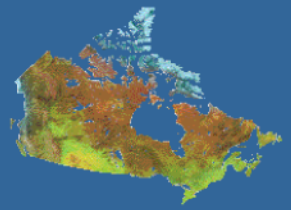


Divergent Plates

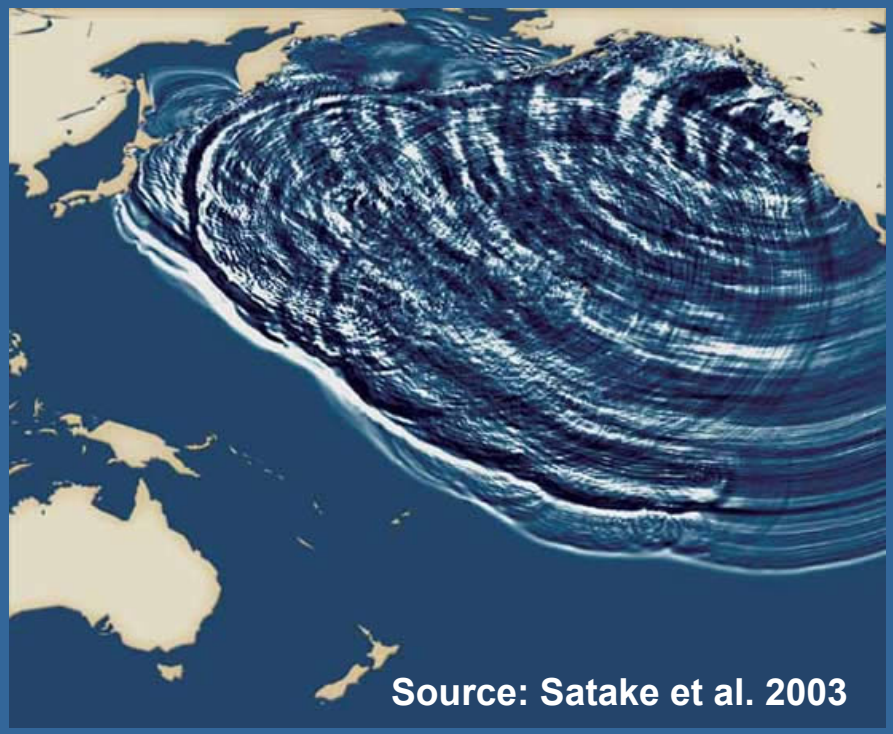


Convergent Plates

Canada - West Coast

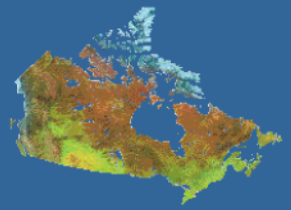


Cascadia Subduction Earthquake
January 26, 1700 at 9 PM
Magnitude 9.0
offshore of Vancouver Island, Washington and Oregon



◄ The 'Orphan' Tsunami
The date is confirmed by records in Japan of a tsunami that was not associated with a known earthquake. The time was back-calculated based on the known velocity of tsunami waves.

Canada - West Coast



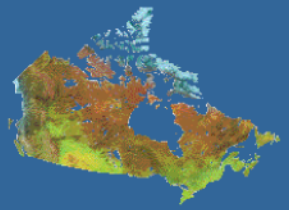
A late 19th century interior ceremonial screen from Port Alberni , B.C. Thunderbird carrying Whale in its talons is a common native symbol of seismic activity.

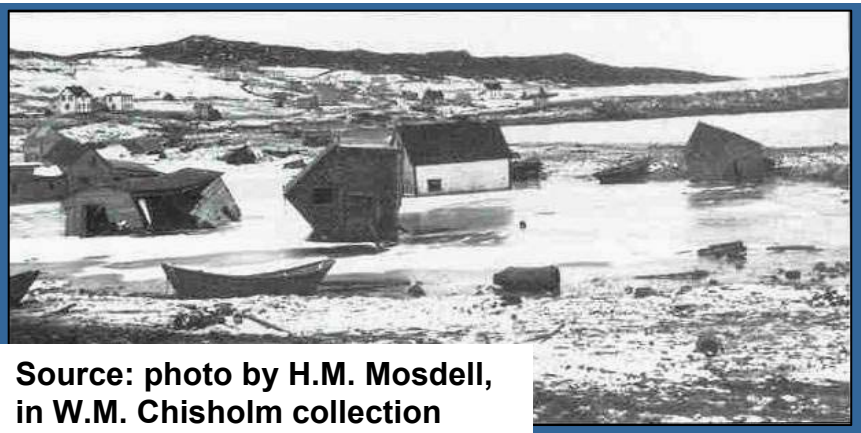
Source: E. Malin, Northwest Coast Indian Painting, used with permission. ►

Source: Royal BC Museum PN11478-A

◄ Nootka Sound Memorial 1902-03 showing Thunderbird carrying Whale in its talons. This is a common native symbol of seismic activity.

Canada - East Coast



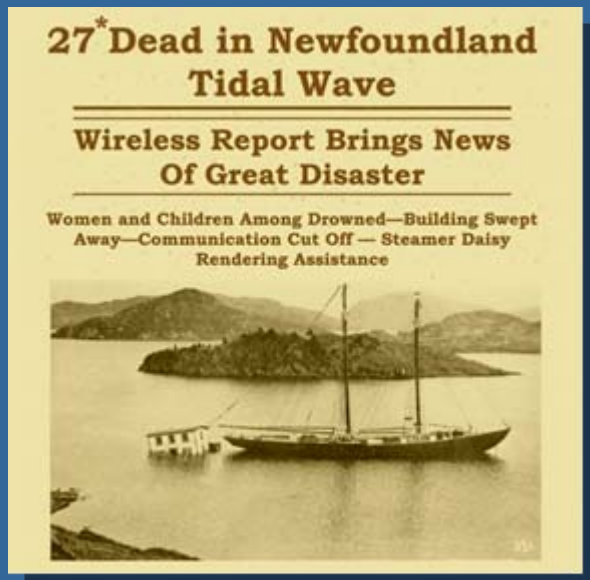


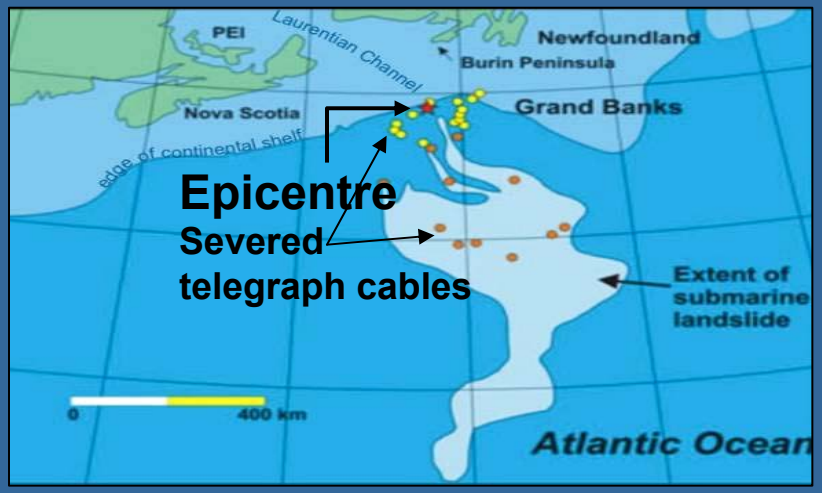
Source: photo by H.M. Mosdell, in W.M. Chisholm collection

Grand Banks Earthquake

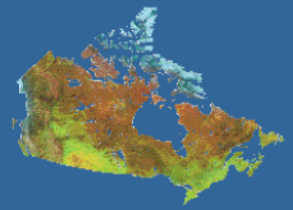
November 18, 1929

A massive submarine landslide off the continental slope south of Newfoundland, triggered by a magnitude 7.2 earthquake, generated a deadly tsunami that struck the shore of the Burin Peninsula, Nfld.





What can we do?



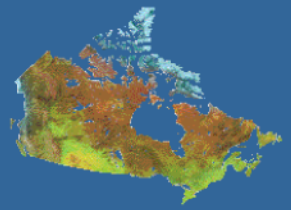
The National Building Code

In Canada, all new buildings must be built to the high standards of the 2005 National Building Code.

Buildings are designed according to the code.

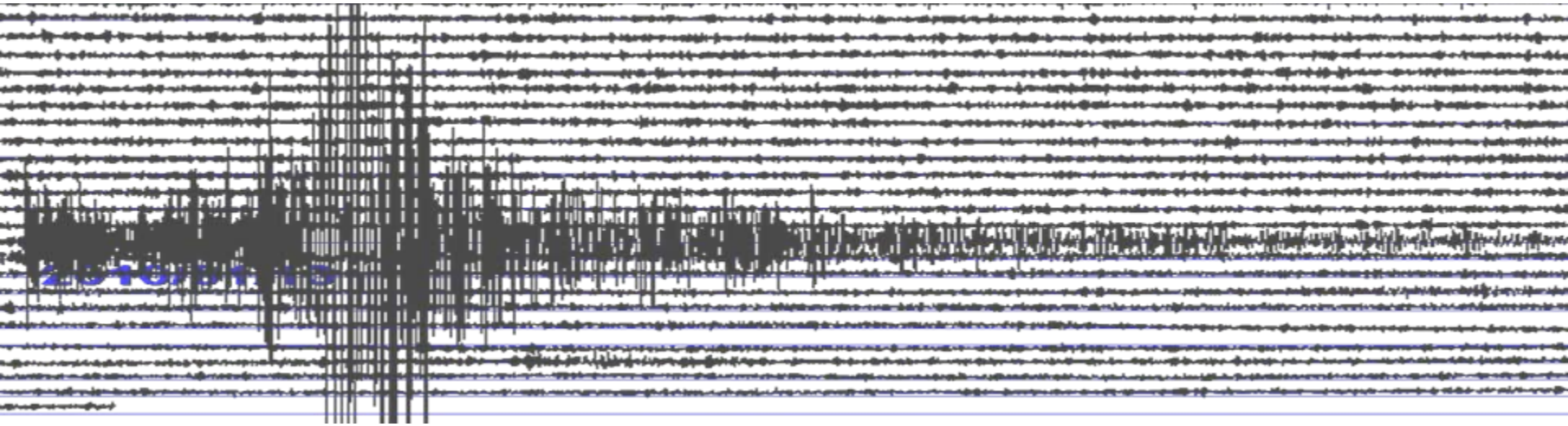
Buildings are inspected during construction.

What should you do during an earthquake?



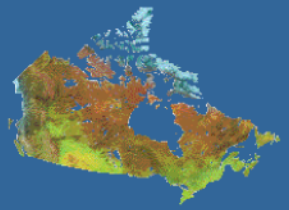
If you are indoors, stay there. Do not run outside: you could be hit by flying debris or bits of glass. Take cover under, and hold on to a sturdy desk, a table, or a bed. Avoid windows and tall furniture.

If you are outdoors, stay there. Keep away from power lines and buildings.

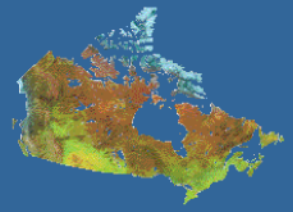


For more information, visit
Earthquakes Canada : http://earthquakescanada.nrcan.gc.ca/index-eng.php
Get Prepared : http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4

Personal Safety



What should you do during an earthquake?

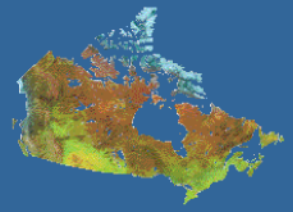


If you are indoors: " DROP, COVER, HOLD "

- Stay inside.
- Drop under heavy furniture such as a table, desk, bed or any solid furniture.
- Cover your head and torso to prevent being hit by falling objects.
- Hold onto the object that you are under so that you remain covered.
- If you can't get under something strong, or if you are in a hallway, flatten yourself or crouch against an interior wall.
- If you are in a shopping mall, go into the nearest store.
- Stay away from windows, and shelves with heavy objects.
- If you are at school, get under a desk or table and hold on. Face away from windows.
- If you are in a wheelchair, lock the wheels and protect the back of your head and neck.

http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4

What should you do during an earthquake?



If you are outdoors

- Stay outside.
- Go to an open area away from buildings.
- If you are in a crowded public place, take cover where you won't be trampled.

If you are in a vehicle

- Pull over to a safe place where you are not blocking the road. Keep roads clear for rescue and emergency vehicles.
- Avoid bridges, overpasses, underpasses, buildings or anything that could collapse.
- Stop the car and stay inside.
- Listen to your car radio for instructions from emergency officials.
- Do not attempt to get out of your car if downed power lines are across it. Wait to be rescued.
- Place a HELP sign in your window if you need assistance.
- If you are on a bus, stay in your seat until the bus stops. Take cover in a protected place. If you can't take cover, sit in a crouched position and protect your head from falling debris.

http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4

What should you do during an earthquake?

AVOID the following in an earthquake

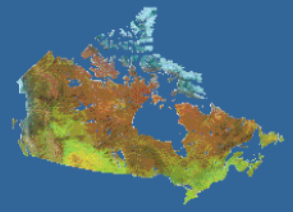
- Doorways. Doors may slam shut and cause injuries.
- Windows, bookcases, tall furniture and light fixtures. You could be hurt by shattered glass or heavy objects.
- Elevators. If you are in an elevator during an earthquake, hit the button for every floor and get out as soon as you can.

AVOID the following after an earthquake

- **Downed power lines** – stay at least 10 metres away to avoid injury.
- **Coastlines** – Earthquakes can trigger large ocean waves called tsunamis. Go to high ground and stay there until told to return by authorities.

http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4

What should you do during an earthquake?

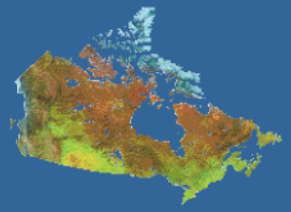


After an earthquake

- Stay calm. Help others if you are able.
- Be prepared for aftershocks.
- Listen to the radio or television for information from authorities. Follow their instructions. Place telephone receivers back in their cradles; only make calls if requiring emergency services.
- Put on sturdy shoes and protective clothing to help prevent injury from debris, especially broken glass.
- Check your home for structural damage and other hazards. If you suspect your home is unsafe, do not re-enter.
- If you have to leave your home, take your emergency kit and other essential items with you. Post a message in clear view, indicating where you can be found. Do not waste food or water as supplies may be interrupted.
- Do not light matches or turn on light switches until you are sure there are no gas leaks or flammable liquids spilled. Use a flashlight to check utilities and do not shut them off unless damaged. Leaking gas will smell.

http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4

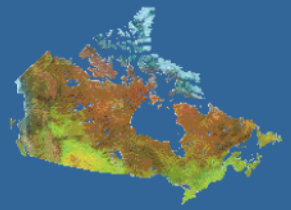
What should you do during an earthquake?



After an earthquake

- If tap water is still available immediately after the earthquake, fill a bathtub and other containers in case the supply gets cut off. If there is no running water, remember that you may have water available in a hot water tank (make sure water is not hot before touching it) and toilet reservoir (not the bowl).
- Do not flush toilets if you suspect sewer lines are broken.
- Carefully clean up any spilled hazardous materials. Wear proper hand and eye protection.
- Check on your neighbours after looking after members of your own household. Organize rescue measures if people are trapped or call for emergency assistance if you cannot safely help them.
- If you have pets, try to find and comfort them. If you have to evacuate, take them to a pre-identified pet-friendly shelter.
- Place a HELP sign in your window if you need assistance.
- Beware of secondary effects. Although ground shaking is the major source of earthquake damage, secondary effects can also be very destructive. These include landslides, saturated sandy soils becoming soft and unstable, flooding of low-lying areas and tsunamis washing over coastlines.

http://www.getprepared.gc.ca/knw/ris/eq-eng.aspx#a4




DROP!
COVER!
HOLD ON!
Protect Yourself During Earthquakes