EARTHQUAKES

in British Columbia

BC

Ministry of
Energy, Mines and
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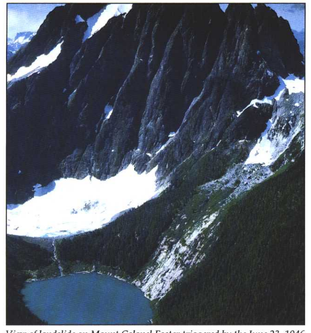


View of landslide on Mount Colonel Foster triggered by the June 23, 1946 Vancouver Island earthquake (photo courtesy of the Geological Survey of Canada).

Earthquakes in British Columbia?

British Columbia experiences an earthquake every day, but only a small number of these quakes are noticeable and even fewer result in damage.

Several major earthquakes have hit B.C. in the last 100 years and there is a very good chance we will experience large earthquakes in the future. We live in a high-risk zone because of the geological processes that take place within the crust of the earth in B.C. Plates in the earths surface shift to produce earthquakes and the science of geology can help determine which ground types will be most affected by a quake. An important step in ensuring your own safety is to understand the answers to the following questions:

- **What causes earthquakes?**
- **Where do they occur?**
- **What are their effects?**
- **How can geology be used to minimize risk?**

What causes earthquakes?

The shaking motion of an earthquake is the result of a sudden release of energy. Earthquakes are caused when stress, building up within rocks of the earth's crust, is released in a sudden jolt. Rocks crack and slip past each other causing the ground to vibrate.

Cracks along which rocks slip are called *faults*. They may break through the ground surface, or be deep within the earth. The location on a fault where slip first occurs is called the *focus*, whereas the position directly above it on the ground surface is called the *epicentre*.

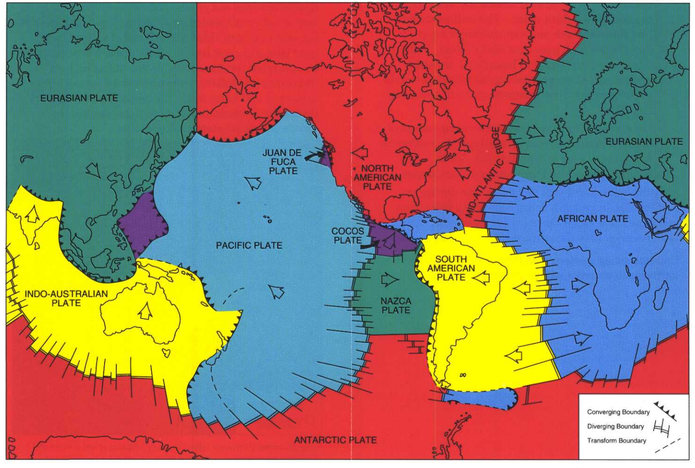
View of local damage to building structures in Courtenay resulting from the 1946 earthquake (photo courtesy of the Geological Survey of Canada).

Geologists studying sediments for evidence of prehistoric earthquakes.

Where do earthquakes occur?

Stress that causes earthquakes is created by movement of almost rigid plates that fit together and make up the outer shell of the earth. These plates "float" on a dense, more liquid layer just beneath them. The plates move at such a slow rate, about the same rate as a fingernail grows, that we do not notice it in our everyday lives. For instance, the Juan de Fuca plate off the coast of B.C. moves only about 4-5 cm/year relative to the North American plate. Over time, however, this small movement can build up enough stress to produce significant earthquakes.

Earthquakes occur most frequently on, or near the edges of plates where stress is most concentrated.



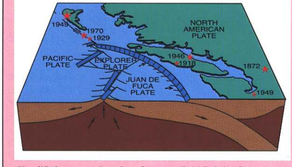
The plates of the world *Map illustrating the various plates and plate boundaries which constitute the surface of the earth.*

BRITISH COLUMBIA PLATE TECTONICS

Just off the west coast, four plates meet and interact making offshore B.C. the most active earthquake zone in Canada.

Plates move towards each other at *converging*, apart at *diverging* and past each other at *transform* boundaries. All three of these boundary types occur in offshore B.C.

- About 200 kilometres off the west coast of Vancouver Island, the *Juan de Fuca plate* and *Pacific plate* are diverging or spreading apart along the Juan de Fuca ridge.
- Further east, the Juan de Fuca plate is converging with and sliding beneath the *North American plate.*
- Another small plate, the *Explorer*, is also sliding underneath the North American plate, and at the same time the Juan de Fuca plate is sliding past it along the Nootka fault.
- In the north, there is a major transform fault boundary between the Pacific and the North American plates called the Queen Charlotte fault. *This fault was the site, in 1949, of Canada's largest earthquake.*

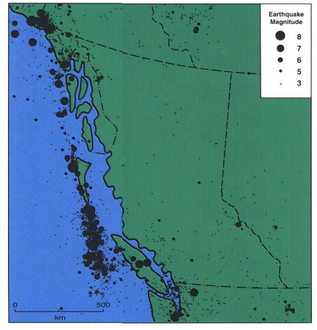


Simplified cross-section of southwestern British Columbia illustrates the Juan de Fuca and Explorer plates sliding beneath the North American plate off the west coast of Vancouver Island.

Earthquake patterns

The locations of several hundred earthquakes caused by the complex plate motions within B.C. are shown on the map below. Most of these were minor earthquakes in unpopulated regions and were not noticed by many people.

Along the Canadian west coast, earthquakes large enough to cause damage occur about every ten years. *In the last 100 years, several major earthquakes have occurred in B.C. or along its coast.* In addition, large earthquakes occurring near the borders with Alaska and Washington were strongly felt in B.C. The largest dots on the map indicate the locations of large, historic quakes. Property damage from these large quakes was minimal because the affected regions had only small populations at that time. However, if one of these large earthquakes occurred near an urban centre, the results could be disastrous.



Simplified map of British Columbia and adjacent areas illustrating the location of earthquakes of magnitude 3 and greater up to the end of 1986. Dot size relates to earthquake magnitude. (Modified from information supplied by the Geological Survey of Canada).

EARTHQUAKES in British Columbia

Emergency Preparedness

This brochure has been produced by the Geological Survey Branch of the B.C. Ministry of Energy, Mines and Petroleum Resources in cooperation with the B.C. Ministry of Environment, the B.C. Provincial Emergency Program and with the assistance of the Geological Survey of Canada.

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Earthquake intensity

Earthquake effects can include strong ground shaking, ground failure, and tsunami. The intensity of shaking at a given location depends upon several factors:

- *The magnitude of the quake*
- *Distance from the focus*
- *Type of soil underlying the site*

Because of these factors, the damage caused by a quake will vary from one area to another. *Earthquakes are most destructive when they are located near cities.* Since about 70 per cent of B.C.'s population lives in earthquake prone southwestern B.C., there is an obvious need for emergency planning and earthquake research.

LARGE EARTHQUAKES IN THE PAST

YEAR	REGION	MAGNITUDE	COMMENT
1872	Washington-B.C. border	7.4	Widely felt in B.C.
1899	Yukon-Alaska border	8.0	Widely felt in northwestern B.C.
1918	Vancouver Island	7.0	Widely felt, minor damage.
1929	Queen Charlotte Islands	7.0	Widely felt, minor damage.
1946	Vancouver Island	7.3	Widely felt, most damaging quake in western Canada.
1949	Queen Charlotte Islands	8.1	**Largest quake in Canada**, one of the world's great quakes.
1949	Washington	7.0	Much damage in Washington and felt in southwestern B.C.
1958	Alaska-B.C. border	7.9	Damage in Alaska, widely felt in northwestern B.C.
1964	Alaska	9.2	Tsunami damage on Vancouver Island.
1970	Queen Charlotte Islands	7.4	Widely felt.

Geology and earthquake impact

The damage resulting from an earthquake is influenced by three important geologic processes:

- *Amplification* The type and depth of soil at a site affects the severity of ground shaking. In most cases, shaking on soil is greater than shaking on rock. In some situations a resonance can occur in deep soil layers, markedly amplifying the shaking at certain frequencies. If the frequencies are potentially damaging to a structure, the results can be disastrous.
- *Liquefaction* Shaking caused by an earthquake can cause the transformation of some loosely packed, water saturated sediments, such as sand or mud, into a fluid mass. The sediments thus lose their strength and can no longer support buildings which may then sink or lean. Soils which are most likely to liquefy are recently deposited sediments that can be found in certain parts of deltas, river channels and uncompacted landfills.
- *Landslides* These are one of the major causes of damage resulting from an earthquake, and occur most often in areas with unstable loose sediments, such as steep mountainous slopes.

Although no area will be totally safe during an earthquake, in general, zones containing loose, wet sediments will suffer the most severe effects. Areas with bedrock near the surface tend to be more stable.

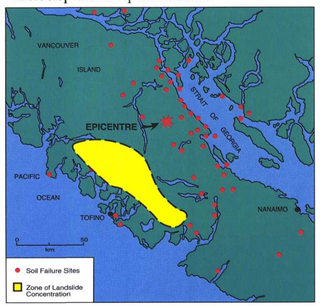
Understanding geology can help predict where earthquake damage will be greatest.

The 1946 Quake!!

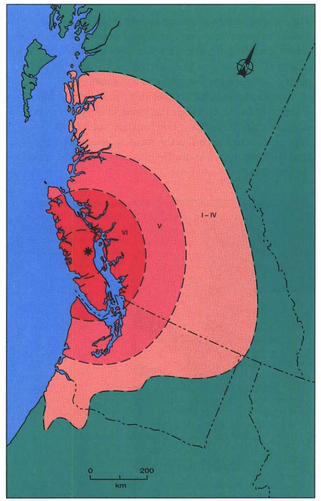
We can learn important lessons about how earthquakes will affect us by examining past events, such as the 1946 Vancouver Island earthquake.

This earthquake, one of the most damaging in B.C.'s history, had a magnitude of 7.3 and an epicentre northwest of Courtenay. It was felt widely throughout B.C. Luckily, damage was restricted because there were no heavily populated areas near the epicentre, where the violent shaking occurred.

It is interesting to note, that some of the areas most affected by this earthquake were not necessarily those closest to the epicentre. Several sites on Vancouver Island suffered damage due to ground amplification, liquefaction and landslides. The distribution of *liquefaction sites and ground failures was influenced by the type of soil or rock underlying the site.* Liquefaction sites occurred on both sides of the Strait of Georgia and near lake and river basins where areas were underlain by saturated sand and clay. Some of the highest intensities of shaking were observed in areas with saturated and loose soils. Likewise, landslides were distinctly concentrated in the coastal mountains where slopes are steep and unstable.



Map of central Vancouver Island showing locations of soil failures and landslide concentration. (Adapted from the Canadian Geotechnical Journal 1980, Volume 17, p. 124 and Bulletin of the Seismological Society of America 1979, Volume 69, p. 446).



Isoseismal contours of approximately equal levels of shaking intensity resulting from the 1946 Vancouver Island earthquake. (Adapted from the Canadian Geotechnical Journal 1980, Volume 17, p. 123).

Megathrust earthquake?

All recorded earthquakes in British Columbia and in the offshore have occurred within the Juan de Fuca and the North American plates, and *not* along the junction where the two plates are actually in contact. Thus most recorded earthquakes represent the response of bedrock to stress accumulation within the plates. Stress accumulation that may occur between two locked plates can result in a different and potentially more damaging type of earthquake, called a megathrust earthquake.

Recent inactivity within the zone of plate contact suggests that either the two plates are locked together and are accumulating strain that could be released in a large megathrust earthquake or that the contact zone is well lubricated and the plates are moving smoothly past each other.

Although no megathrust earthquakes have occurred in B.C.'s recorded history, scientific evidence is accumulating in favour of this possibility:

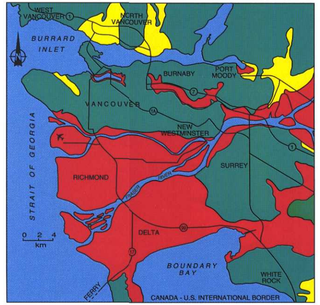
- *Events in similar areas* The area where the Juan de Fuca plate is sliding under the North American plate is strikingly similar to other areas in the world that have experienced major earthquakes, such as Alaska, Chile and Mexico.
- *Past earthquakes* Geological studies of prehistoric soils along the state of Washington coast suggest that, in the past, megathrust quakes may have occurred every few hundred years or so.
- *Stress building up* Detailed geodetic surveys reveal that Vancouver Island is bulging slightly upwards and contracting in an east-west direction, possibly due to strain build up between the two plates.

These could be important indications that we may be due for a megathrust quake sometime in the future.

Minimize risk with geology

Earthquakes can cost billions of dollars and thousands of lives. While we cannot prevent earthquakes, we can reduce the physical effects of such events by using our knowledge of geology to identify and avoid or modify sites where an earthquake can be expected to have the greatest severity. Detailed geological and geotechnical study of the properties and depth of surface sediments can be used to predict amplification of earthquake waves. Geological mapping of areas where landslides and ground liquefaction may occur, can aid in urban planning and in the development of emergency procedures for earthquakes. Ongoing monitoring of seismic activity in the province by geophysicists is essential to further our understanding of earthquake hazards in the province.

Earthquakes are an unavoidable natural hazard, but their destructive power can be reduced by geologic studies, proper planning and a well informed public.



The map of Greater Vancouver illustrates three simplified geologic zones that are incorporated into the National Building Code of Canada for use in the design of large structures. Green: compact or stiff soils < 15 m thick and bedrock. Yellow: compact or stiff soils > 15 m thick; and loose or soft soils < 15 m thick. Red: loose or soft soils > 15 m thick. (Adapted from Ministry of Environment report, 1979).