# Tsunamis

Tsunami is Japanese for harbour wave, with tsu meaning harbour and nami, wave. A tsunami is a sea wave or series of waves, often called a wave train, produced by a large disturbance of the sea floor that is of relatively short duration. Such disturbances cause the water column to move vertically and the resulting wave energy to spread outwards across the ocean at high speed (up to 950 kilometres per hour, the speed of a jet plane).

Tsunamis are most commonly triggered by earthquakes, but can also be caused by volcanoes, landslides or, less commonly, meteorite impacts (see Figures 1 to 5).

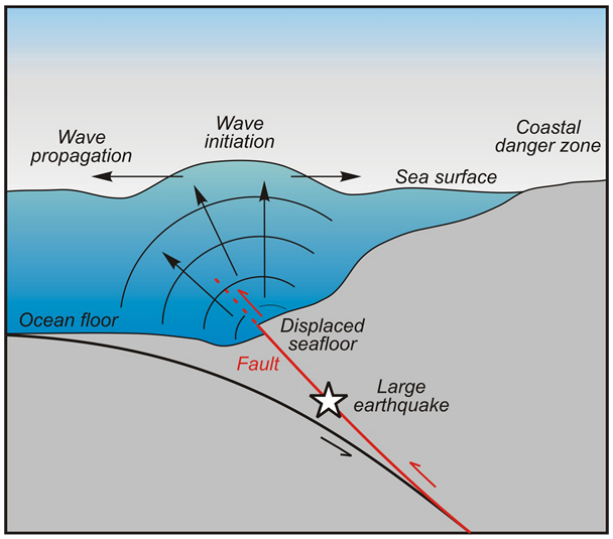


**Figure 1**. Tsunami caused by large thrust earthquake (for example, Sumatra, December 26, 2004)
**Source**: Geological Survey of Canada

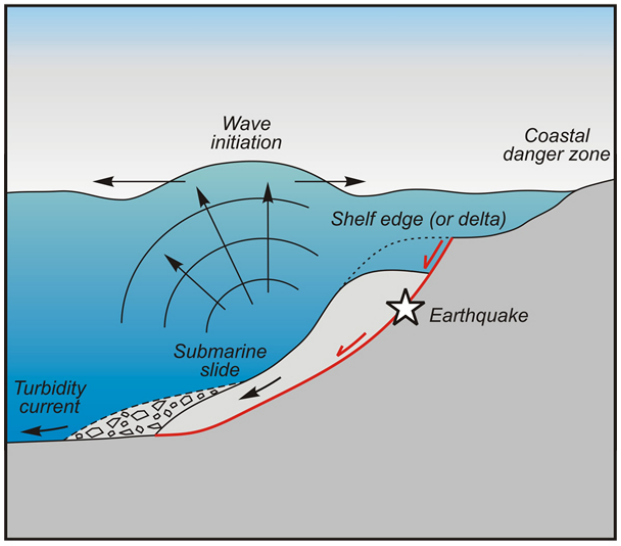


**Figure 2**. Tsunami caused by large slide beneath the sea or in a large lake (for example, Newfoundland, November 18, 1929)
**Source**: Geological Survey of Canada

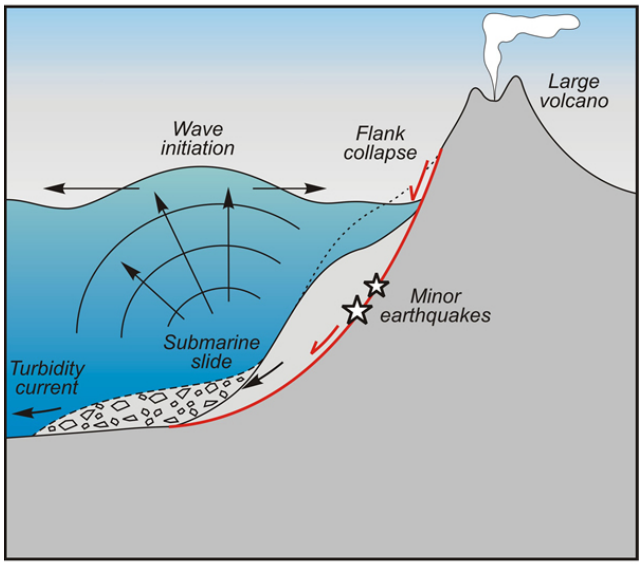


**Figure 3**. Tsunami caused by collapse of the flank of a large volcano (for example, Hawaii or the Canary Islands)
**Source**: Geological Survey of Canada

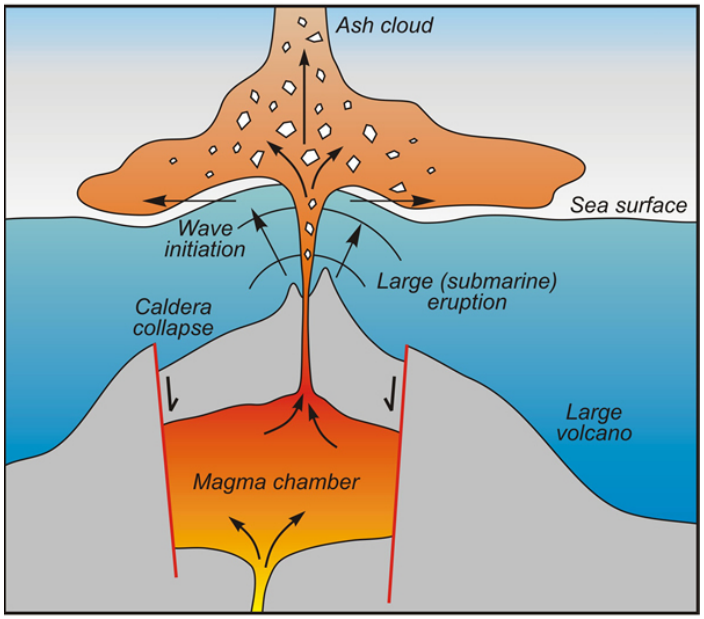


**Figure 4**. Tsunami caused by volcanic eruption or explosion (for example, Krakatoa, August 26, 1883)
**Source**: Geological Survey of Canada.

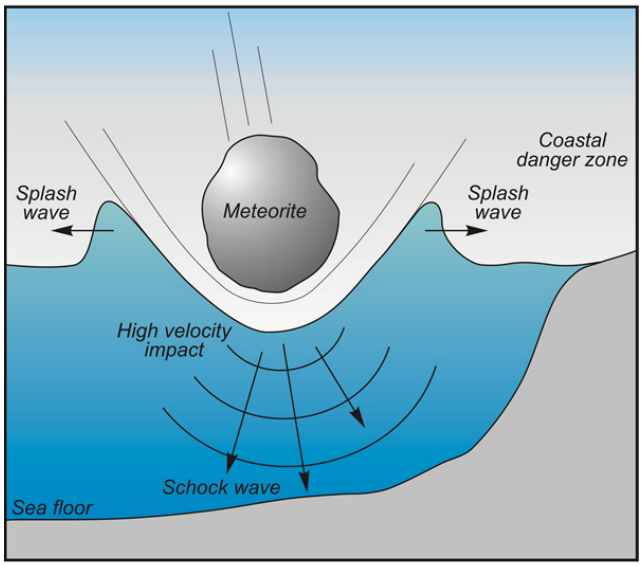


**Figure 5**. Tsunami caused by meteorite impact (for example, the Cretaceous–Tertiary boundary)
**Source**: Geological Survey of Canada

Tsunamis can also occur in large lakes and can be triggered by sufficiently powerful man-made explosions. Although tsunami occurrences in Canada are rare, they do occur and can cause major damage and loss of life.

## How big is a tsunami?

Most tsunami waves are hardly noticeable in the open ocean because their height is relatively low (about 50 centimetres) and their length (the distance between wave crests) can be hundreds of kilometres. As a tsunami approaches the shore, it starts interacting with the shallowing sea floor, which causes wave height to increase and wave length to decrease (see Figure 6).

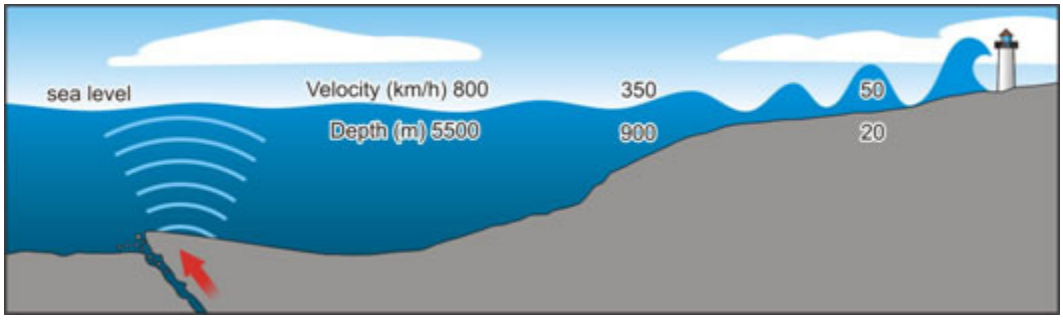


**Figure 6**. Diagram showing a tsunami triggered by rupturing of the sea floor along a fault during an earthquake
**Source**: Clague, J.J., Yorath, C.J.J., Franklin, R., and Turner, R.J.W. 2006. At risk. Earthquakes and tsunamis on the west coast, Tricouni Press, Vancouver, 200 p.

Figure 6 shows a tsunami triggered by rupturing of the sea floor along a fault during an earthquake. The sudden upward displacement of the sea floor initiates waves of energy that move upward and outward from the source. As the waves get closer to the shore, they interact with the shallowing sea floor, slowing down and becoming higher.

The great increase in height near the shoreline reflects the conservation of energy. As the tsunami wave train approaches the shore, shoaling (shallowing of the sea floor) causes the waves to slow down but also to increase in height. The shape of the shoreline can affect a tsunami. For example, in a fjord, a tsunami may increase in height as the wave energy becomes concentrated by the narrowing sides of the fjord. Refer to the example from Port Alberni, British Columbia described below.

## How fast is a tsunami?

The speed at which a tsunami travels varies considerably depending on water depth. In the open ocean, where the water can be thousands of metres deep, wave speed

can be many hundreds of kilometres per hour (for example, as much as 800 to 1000 kilometres per hour). As the tsunami approaches the shoreline and water depth decreases, it slows down but the wave height will increase as wave length decreases. In 20 metres of water, wave speed will be 50 kilometres per hour.

## Why are tsunamis a natural hazard to Canadians?

Tsunamis can affect people by taking lives and destroying natural resources such as fishing, aquaculture, forestry, agriculture and mining. Similarly, tsunamis can destroy infrastructure such as transportation corridors, telecommunication and hydroelectric cables, communities, and recreation and tourism facilities. Since many of these natural resources and infrastructure are located along or near Canada's coastlines and lakes, the effects of a major tsunami can be devastating.

Tsunami events have occurred on Canada's Pacific and Atlantic coasts, but more frequently on the Pacific coast. The west coast is located within the Pacific 'Ring of Fire', which consists of seismically active continental margins surrounding the Pacific basin. Thus, the potential for tsunamis is greater in the Pacific than the Atlantic Ocean. Nevertheless, Canada's worst tsunami disaster occurred on the east coast, along the southern coast of Newfoundland in 1929.

Since the catastrophic Indian Ocean tsunami of December 2004, there has been greater awareness of the potential for damage to coastal areas even at great distances from the source of the tsunami. For example, the Cumbre Vieja volcano, located in the Canary Islands off the coast of northwest Africa, poses a potential threat of collapsing and generating a very large submarine landslide. This could trigger a tsunami that would travel across the Atlantic (see Figure 3). Hence, there is now an established tsunami warning system for the Atlantic Ocean.

## What are the signs that a tsunami is approaching?

One of the signs is the occurrence of a very large earthquake that lasts for more than 20 seconds. If an area has been shaken by a very large earthquake, the shorelines located within the radius of the earthquake from the centre of the epicentre may be hit by a tsunami. A more immediate and ominous sign of an approaching tsunami is a rapid and unexpected recession of water levels below the expected low tide. This can occur minutes before the shoreline is struck by a tsunami and can be the only warning sign along coastlines that are located too far from the earthquake epicentre to have felt the shaking.

## Has an earthquake on Canada's west coast ever generated a major tsunami?

On January 26, 1700, an earthquake of estimated magnitude 9 was triggered by the rupture of the Cascadia Subduction Zone, which extends offshore from Vancouver Island to California (see Figure 7).

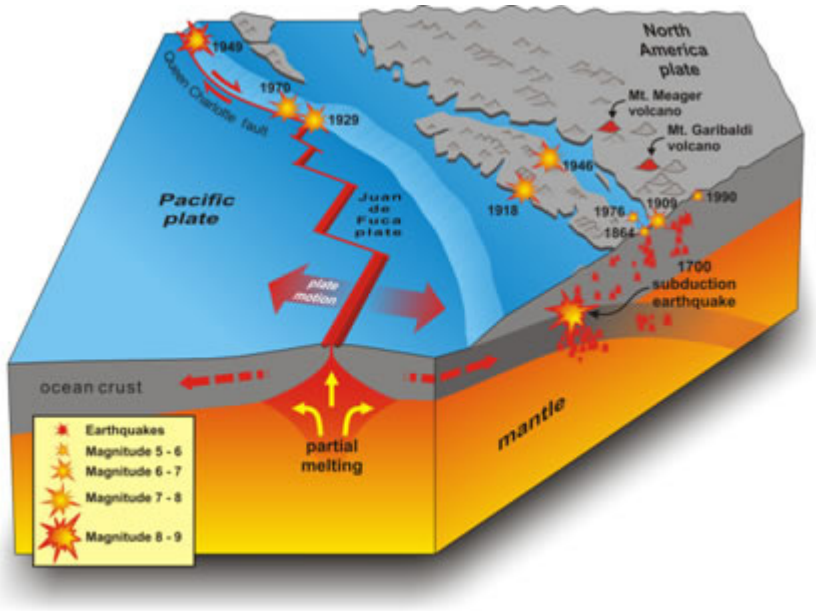


**Figure 7**. Block diagram showing the Cascadia Subduction Zone located off the west coast of British Columbia. The yellow and red explosion symbols indicate epicentres of historical earthquakes.
**Source**: Clague, J.J., Yorath, C.J.J., Franklin, R., and Turner, R.J.W. 2006. At Risk: Earthquakes and Tsunamis on the West Coast. Tricouni Press, Vancouver, 200 p.

This earthquake generated a tsunami that travelled across the Pacific Northwest and was recorded in Japan and in Aboriginal oral history. Geological evidence of this tsunami along the west coast of North America is a thick (roughly 10 centimetres) sand sheet, often containing marine fossils and overlying a buried soil (see Figure 8).

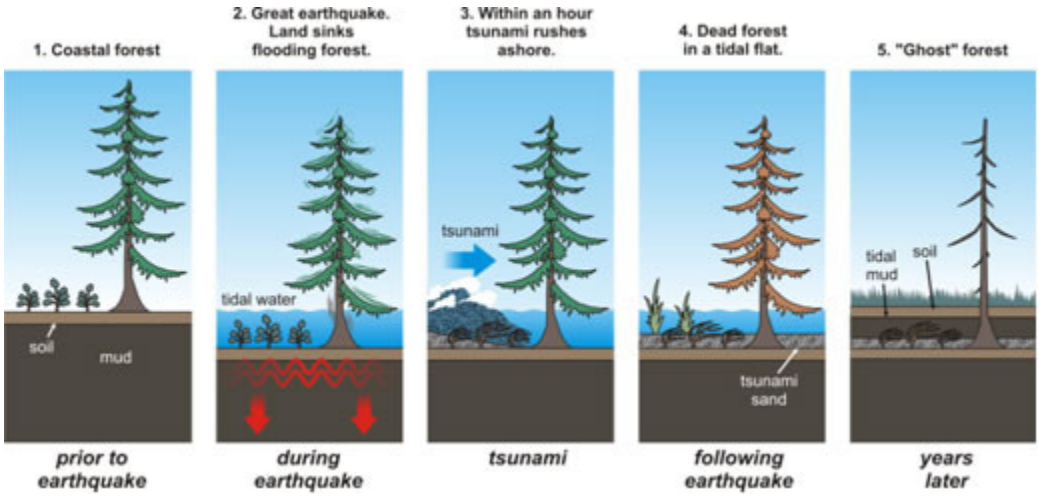


**Figure 8**. Series of images showing submergence of a tidal marsh and forest during a Cascadia earthquake. The succession of sediments produced by these events reveals the geological signature of a great earthquake followed by a tsunami. **Source**: Clague, J.J., Yorath, C.J.J., Franklin, R., and Turner, R.J.W. 2006. At Risk: Earthquakes and Tsunamis on the West Coast. Tricouni Press, Vancouver, 200 p.

In some of the marshes along the west coast of Vancouver Island, a sequence of more than one of these tsunami sand sheets overlying buried soils indicates the recurrence of tsunamis. There is also sedimentary evidence of an earthquake-generated tsunami from the 1964 Alaska magnitude 9.2 earthquake.

Similarly, on Canada's east coast, tsunami sands were deposited during the 1929 tsunami event off the south coast of Newfoundland. Thus, finding evidence of tsunamis in the geological record can extend the historical record and shed light on the frequency of these events.

## Worst Tsunami Disaster in History

The most devastating tsunami in recent history occurred on December 26, 2004, on the west coast of Sumatra in Indonesia. A devastating tsunami wave train was triggered after a powerful magnitude 9.2 earthquake, which shook and ruptured an estimated 1600 kilometres of faultline along the subduction zone where the India Plate slides beneath the Burma Plate below the Indian Ocean. This tsunami event is considered one of the deadliest natural disasters ever recorded, with a death toll of about 230 000. Countries most affected were Indonesia, Sri Lanka, India and Thailand. Other countries were also affected, with fewer casualties, including the east coast of Africa, several thousands of kilometres away from the epicentre (see Figure 9).

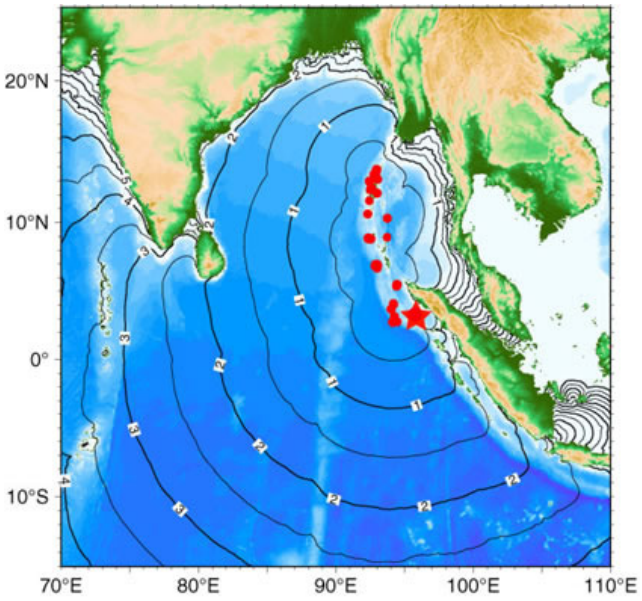


**Figure 9**. Epicentre of the magnitude 9.2 Sumatra earthquake, December 26, 2004. The red star indicates the epicentre of the earthquake. Red circles indicate the location of aftershocks. Computer generated travel times of tsunami propagation waves are shown in black lines. Numbers indicate time in hours.
**Source**: K. Satake, National Institute of Advanced Industrial Science and Technology, Japan. (http://staff.aist.go.jp/kenji.satake/Sumatra-E.html)

## Mitigation/Vulnerability

Although it is impossible to prevent a tsunami, it is possible to estimate the tsunami risk for coastal communities. Tsunami hazard is assessed by calculating magnitude and frequency of tsunamis from geological and historical events. Such computer models of tsunami hazard assessments exist for British Columbia (see Figure 10) and for specific fjords (for example, Kitimat) or deltas (for example, the Fraser Delta). In Atlantic Canada, tsunami hazard assessments exist for areas such as Grand Banks.

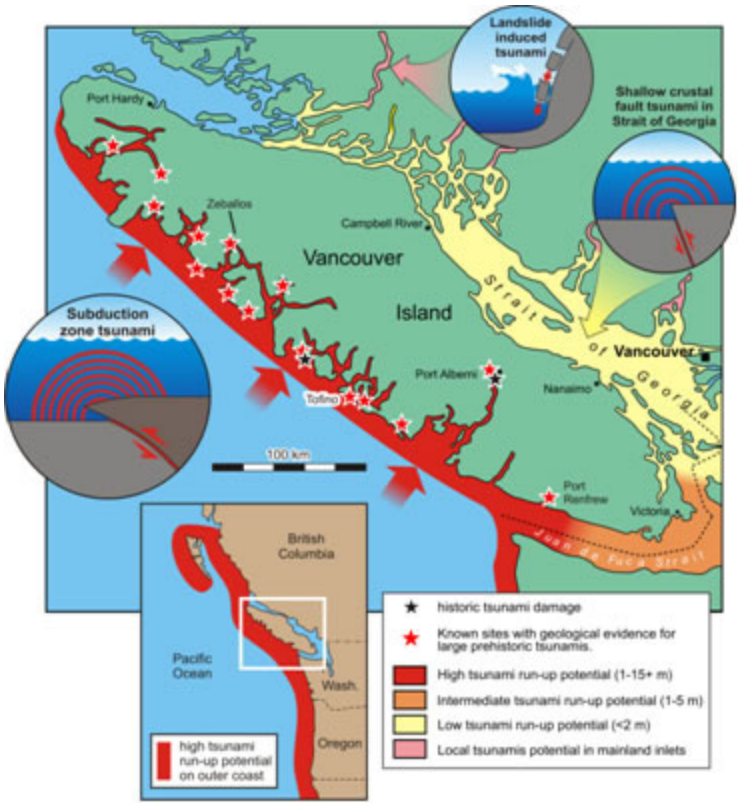


**Figure 10**. Tsunami Hazard Zones for Southwestern British Columbia. Western Vancouver Island is at risk of a tsunami generated by a great Cascadia earthquake. The risk is much lower in the Strait of Georgia and is related to crustal earthquakes or submarine landslides. In the legend, run-up indicates the advance of water up the foreshore of a beach, following the breaking of a wave. Thus, an area of high tsunami run-up potential can have a run-up of 1 to 15 metres.
**Source**: Clague, J.J., Yorath, C.J.J., Franklin, R., and Turner, R.J.W. 2006. At Risk: Earthquakes and Tsunamis on the West Coast. Tricouni Press, Vancouver, 200 p.

Certain actions can be taken to lessen the effects of tsunamis (for example, land-use controls such as zoning, relocation, and property acquisition). Unfortunately, these mitigation measures are often met with resistance by coastal residents. Other means of protecting coastal areas at risk are emergency preparedness, dyking, barrier construction, flood proofing, tsunami-resistant construction, warning systems including signage, and public education. The best information on personal preparedness can be found at the Public Safety Canada 'Is your family prepared?' website (see References and Links). It has excellent advice on what to include in both an emergency plan and an emergency kit, both of which can be put to good use in any natural disaster or emergency. Tsunami warning systems have been in place for several years in the Pacific Ocean. More recently, in the wake of the Sumatra earthquake, a tsunami warning system was implemented for the Atlantic Ocean.

## Definitions of underlined terms

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

**Faultline**: The trace of the fault on the ground surface.

**Subduction**: The process of one crustal block descending beneath another, by folding or faulting or both.