

Volcanoes



Did you know that one of Canada's most deadly known natural disasters was volcanic in origin? More than two thousand First Nations people lost their lives in a devastating eruption in northern British Columbia in 1775. This eruption is just one of hundreds that have modified the landscape of western Canada over the past million years. Geologically recent, these volcanoes are part of a dynamic process of mountain building and earthquakes that affects Canada's westernmost landmasses — British Columbia and the Yukon. A host of volcanic landforms dot the region, some of them lava flows (like the Islands of Hawaii) and others the result of more explosive eruptions (like the 1980 eruption of Mount St. Helens in Washington State). However, Canadians don't have to travel to distant lands to see volcanoes. If you live in British Columbia or the Yukon, they are close by. For example, just north of Vancouver, Mount Garibaldi can be viewed from the road leading to the resort municipality of Whistler. From the viewpoint on Highway 99, five kilometres south of Squamish, the volcano's prominent twin peaks are easily recognized. In Brandywine Falls Provincial Park, just south of Whistler, Brandywine Creek has carved a canyon through lava flows 35 000 years old that form a spectacular waterfall at the head of the canyon.

Distribution of the Main Volcanic Complexes in Canada and the World

Volcanoes do not seem to be part of the everyday reality of Canadians; however, there are many volcanoes in the Canadian Cordillera (British Columbia and the Yukon) that remain geologically active.



Figure 1. Eve Cone

Source: Photograph by C.J. Hickson, Geological Survey of Canada

Recurrent earthquakes below our feet and gigantic mountain ranges rising majestically upward remind us that this part of Canada is geologically active. The possibility of an eruption, even a large explosive one, cannot be ruled out. Quiet as they currently seem, Canada's western volcanoes are part of the Pacific 'Ring of Fire'.

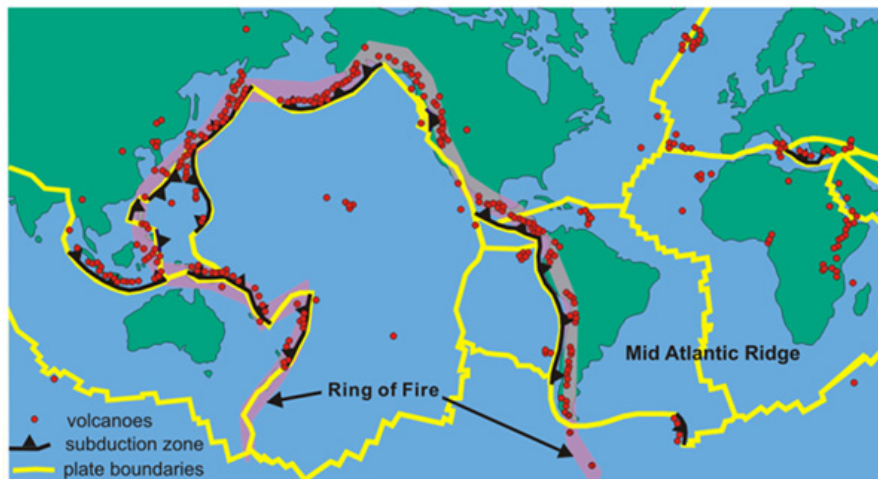


Figure 2. Pacific 'Ring of Fire' and Plate Tectonics

Source: Hickson, C.J. 2005, Geological Survey of Canada

The crust of the Earth is broken into large regions called 'plates'. The plates move in different directions, crashing into each other along subduction zones (black hachured lines) or moving apart along spreading zones, such as the mid-Atlantic Ridge that

bisects the Atlantic Ocean. The multitude of volcanoes that surrounds the Pacific Ocean is called the Pacific 'Ring of Fire'.

In fact, in southwestern British Columbia and adjacent parts of the United States, an offshore tectonic plate is forcing its way under the edge of the continental crust, causing earthquakes and creating mountain ranges. As part of this process, molten rock rises to the surface and forms volcanoes. Volcanoes in the northern end of the Cascade chain include Mount Garibaldi and Mount Meager, both located north of Vancouver, and Mount St. Helens, Mount Baker and Mount Rainier, all in Washington State.

West of Vancouver Island, there is also an undersea ridge called the Juan de Fuca Ridge, where the earth's crust is being stretched and pulled apart, and where new magma (liquid rock) wells up to form oceanic crust. This ridge is really a long linear volcano, segments of which erupt frequently. On a geological time scale of millions of years, the new oceanic crust will soon be destroyed in the subduction zone underlying the west coast. As the oceanic crust moves beneath the continent, rising heat and pressure yields a rich brew of fluids from the descending crust. These fluids melt the overlying rocks, creating magma that eventually reaches the earth's surface and creates volcanoes.

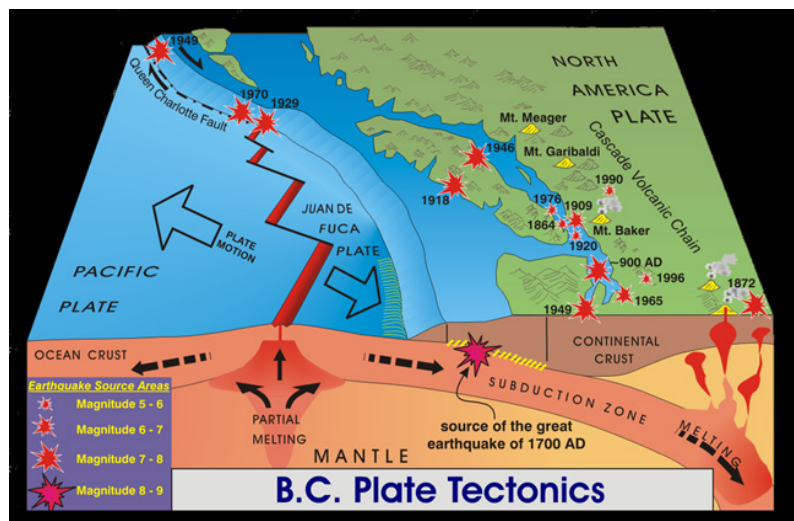


Figure 3. Subduction

Source: Geological Survey of Canada

Off the shores of Vancouver Island, a small crustal plate, called the Juan de Fuca plate, is slowly moving eastward. At the same time, the North American plate is moving westward. This colossal collision forces the thin Juan de Fuca plate beneath the North American plate. The process is called subduction and creates mountain ranges, earthquakes and volcanoes.

In addition to oceanic ridges and subduction zones, there are other ways to create volcanoes, and Canada is host to these types of volcanoes as well. Sometimes the crust of the continent is pulled apart by the gigantic forces taking place below the surface. These regions 'leak' lava to the surface, creating a 'continental rift zone'. The Stikine volcanic belt of northern British Columbia is one such zone. This is where Canada's most recent volcanism has occurred.

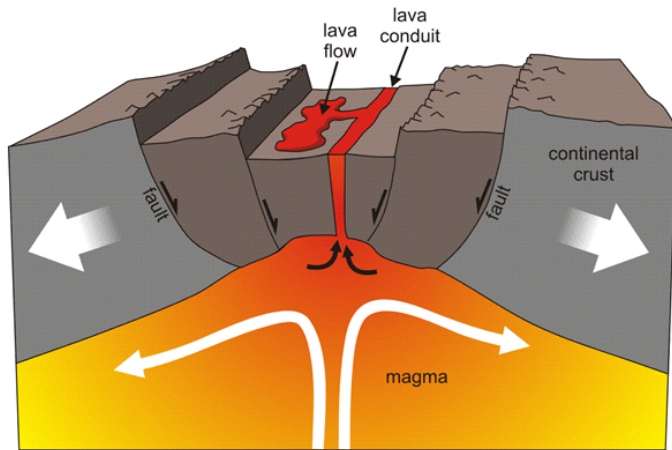


Figure 4. Continental Rifting

Source: Clague et. al. 2006. *At Risk: Earthquakes and Tsunamis on the West Coast*. Tricouni Press, Vancouver, Canada

In some places, the continental crust is subjected to great tensional stress — enough stress to start stretching it and breaking it apart. These areas are called 'continental rift zones'. Magma rises to the surface and emerges along zones of weakness (fractures) created by the pulling apart of the crust. These types of zones also occur in the ocean. The most famous is the mid-Atlantic ridge.

Beneath the solid crust of the earth is a semimolten region called the mantle. The mantle moves on a gigantic scale, upwelling heat in some areas and carrying it downward in others. Where heat is coming up, it creates 'hot spot' volcanoes. The upwelling areas are relatively stationary in the mantle, but above them, the crust is moving inexorably along. This process creates a chain of volcanoes that is oldest at the leading edge of the continental crust and younger farther inland. The Anahim belt of volcanoes in central British Columbia formed from such a process.

All of these tectonic forces have created volcanic regions in British Columbia that host a large variety of volcanoes. The subduction-related regions (Wrangell and Garibaldi belts) are dominated by large explosive volcanoes, whereas the continental rift zone of the Stikine belt is dominated by smaller volcanic centres (cinder cones)

and large, but not particularly violent volcanoes called shield volcanoes. The Anahim belt has both cinder cones and shield volcanoes.

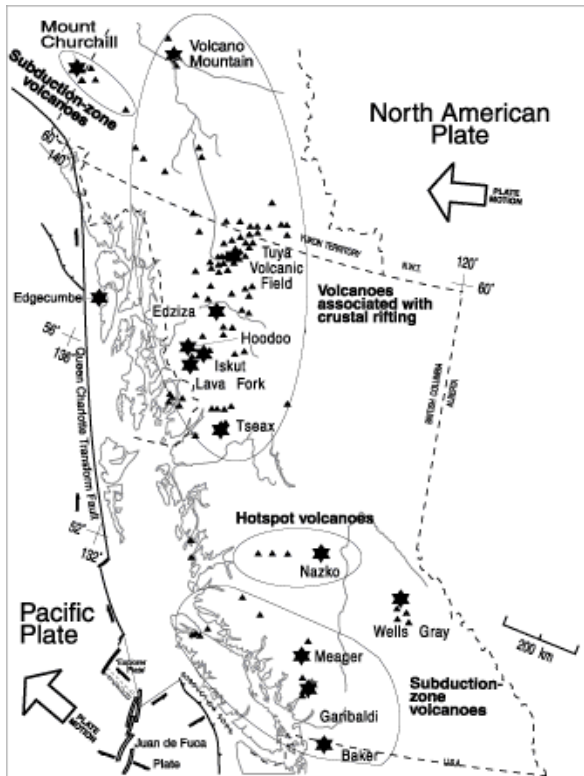


Figure 5. Canada's Geologically Young Volcanoes

Source: Geological Survey of Canada

Geologically young volcanoes are those less than 1 million years old. Although this seems old in human terms, geologically it represents areas that are still tectonically active and have the potential to erupt in the future. In the north, the Wrangell belt owes its origin to subduction taking place beneath Alaska. The Stikine belt forms from crustal rifting, the Anahim belt from a hot spot and the Garibaldi belt from subduction. The major, long-lived volcanoes are shown as stars.

Volcanic Hazards

Most of Canada's volcanoes could be described as sleeping giants. Past volcanic activity has created regions of incredible beauty. Stunning topography, waterfalls and rainbow-coloured rock formations have been preserved in a number of British Columbia's provincial parks (for example, Tweedsmuir, Wells Gray and Garibaldi). This beauty masks the underlying volcano's propensity for destruction.



Figure 6. Helmcken Falls

Source: Photograph by C.J. Hickson, Geological Survey of Canada

The majestic Helmcken Falls, dropping 137 metres, is Canada's fifth highest water fall. It owes its origin to the layers of volcanic rock that were laid down in the broad valley of the Murtle River. Layer upon layer of cooling lava created flat expanses, over which gigantic floods coursed in the dying days of the last glaciation. These floods carved the vertical cliff in the lava flows over which the river now plunges. The preservation of Helmcken Falls was one of the main reasons for the formation of Wells Gray Provincial Park. Thus, if it had not been for volcanism, it is unlikely that such a huge wilderness area would have been preserved.

Volcanoes are the source of many different kinds of hazards linked to the process and aftermath of eruptions. Probably most familiar are lava flows. Lava flows are very destructive, but are not, in fact, the most deadly kind of volcanic hazard. People and animals can usually easily out-walk a lava flow. At the vent (where the magma is escaping) incandescent fountains of lava shoot several hundred metres into the air, but can be watched in relative safety from distances of hundreds of metres. In Canada, most of our volcanoes have erupted in this way, and these types of eruptions can be expected in the Stikine volcanic belt every 100 years or so – the last eruption in the area being about 150 years ago.



Figure 7. Lava Flows, Mauna Loa Eruption, March 30, 1984

Source: Photograph by Scott Lopez, United States National Park Service

Lava or molten rock at the earth's surface behaves in different ways depending on its composition. Some lava is very fluid, behaving like motor oil as it moves across the landscape, destroying anything in its fiery path. This photograph from Hawaii shows how basaltic lava behaves. Many volcanoes in British Columbia erupt basaltic lavas.

However, other volcanoes, especially those in the subduction-related belts, have erupted explosively in the past. Massive explosions have sent fragmented, pulverized volcanic rock (called tephra or ash) into the stratosphere and devastated areas around the volcano extending outwards for kilometres. The best documented of these is the 2350 BP (years before present) eruption of Mount Meager, about 100 kilometres north of Vancouver. This eruption sent ash across western Canada and utterly destroyed the Lillooet River valley for a distance of tens of kilometres downstream. The good thing about these types of eruptions is that they occur only infrequently in Canada, with a return period of hundreds to thousands of years.



Figure 8. Mount St. Helens, 1980

Source: Photograph copyright Paul Hickson, 1980

Not all lavas behave like motor oil; some are much more viscous — more like toothpaste. Lavas have gases dissolved within them and when thick, viscous magma is rich in gases, it can explode in some of the most violent types of eruptions known. Such an explosive eruption occurred on May 18, 1980 when a dacitic magma erupted from Mount St. Helens in Washington State. This photograph, taken 15 minutes after the start of the eruption, shows the column of ash rising above the volcano to a height of 25 kilometres.

Ash is the farthest reaching volcanic hazard and the most likely to impact Canadians over a broad area of hundreds to thousands of kilometres from the eruption. Ash, which consists of finely pulverized fragments of volcanic rock, is more like fine sand than wood ash and is very abrasive and unhealthy to breath. Rarely causing death, it can nevertheless be extremely disruptive. Ground-based vehicle traffic may be hampered by the 'fog' of ash; moving mechanical parts are worn away; surface water and communication systems are affected; and electrical installations sometimes fail. Ash can also impact the climate. For two years following the 1991 eruption of Mount Pinatubo in the Philippines, there was world-wide cooling. Canada's airspace is directly affected by explosive eruptions that take place anywhere in the world, and occur about once a decade.

Impact

The most recent volcanic eruption in Canada took place about 150 years ago on the border between British Columbia and the Alaskan Panhandle. The small volcano, Lava Forks, erupted in fire-fountaining and lava flows that filled the valley leading

away from the volcano. This eruption had a huge impact on the fish, plant and animal inhabitants of the valley, but there is no record of its impact on humans, nor that it was even witnessed by humans. The 1775 eruption of Tseax volcano, a bit farther south, was different: it had a devastating impact on the Nisga'a people. It killed more than 2000 inhabitants and destroyed two villages, the best salmon spawning streams and significant hunting and berry-picking areas. In today's dollars, the losses would have been in the millions.

Although usually less deadly than lava flows, ash (pulverised volcanic rock) spread by upper atmosphere winds from the volcano can have a huge impact. Modern eruptions, such as the May 18, 1980 eruption of Mount St. Helens, demonstrate how devastating ash can be. The ash permeates everything over a broad area, leading to widespread devastation. Ash fall from an eruption on the Alaska–Yukon boundary (Mount Churchill) 1900 years ago is thought to have led to the migration of the First Nations people living in the area. More than 300 000 square kilometres of the region were buried under ash ranging in thickness from a few millimetres to tens of centimetres. The 'snow that didn't melt' affected vegetation and animals, creating deprivation and death by starvation.

Although no economic figures exist for the Tseax or Churchill eruptions, if such events were to occur today they would cause millions of dollars in damage. An explosive eruption like Mount Churchill would impact much of western Canada and have far-reaching consequences for the Canadian economy.

Case Studies

The oral history of several First Nations people talk about deadly events that took place in the past, but nowhere are these more vivid than in the Nass River valley of west-central British Columbia. There, the 1775 eruption of the Tseax volcano destroyed two villages. The Nisga'a people's oral history talks of a chain of events that started with the disrespectful treatment of a salmon by two boys. This disrespect brought destruction down on the villages. The people talk of earthquakes, rivers of molten rock glowing red and poisonous smoke. The eruption changed their landscape forever and severely impacted their way of life. Loss of some of the best salmon fishing areas and hunting and gathering habitat left the people impoverished and searching for new places to rebuild their villages.



Figure 9. Mask of a Naxnok

Source: Photograph by Terry Spurgeon, Nisga'a Lava Beds Memorial Park Visitors Centre

Naxnok are supernatural spirits regarded as forces for good and bad in the Nisga'a world. The mask represents a Naxnok that, when challenged by another, extended its nose to stop the lava flowing from the Tseax volcano. The nose shape depicts the redirected flow on the lava flats adjacent to the present Nass River. Nisga'a stories tell of the river being relocated by the lava, which forced it into a new channel that formed the canyon fronting Gitwinksihlkw.



Figure 10. Nass River Lava Flows

Source: Photograph by T. Spurgeon, Geological Survey of Canada

The eruption of Tseax volcano filled the Nass River valley with a vast field of uninhabitable lava. The surrounding mountains rise above a lava plain that is flat in

some areas, whereas the lava surface in other areas is broken into great slabs and crevasses, creating an almost impassable terrain.

Mitigation and Vulnerability

The work of understanding the frequency and eruption characteristics of Canada's volcanoes is a slow process. Many of our volcanoes are in remote, rugged areas. The number of researchers and funding is limited. Despite this, we have a basic understanding of our volcanic heritage and how it might impact us in the future. We know that some regions have more volcanoes than others and how eruptions in these areas might affect the lives and livelihoods of the inhabitants. When a volcano starts to show signs of unrest, quick action will be required to better understand the process.

Canada has a volcanic emergency notification plan in place, and was in fact one of the first nations in the world to enact such a plan following a particularly harrowing event in Alaska in 1989. A fully loaded 747 airliner narrowly missed destruction after flying into an ash cloud from Mount Redoubt volcano in Alaska. Canada's plan, called the Interagency 'Volcanic Event Notification Plan', is focused primarily on aviation safety because jet aircraft can quickly enter areas of volcanic ash. Many heavily travelled aircraft routes are close to volcanoes. The plan notifies all impacted agencies that have to deal with the event. Aircraft are rerouted away from hazardous ash and people on the ground are notified of potential ash fall. See the page 'http://gsc.nrcan.gc.ca/volcanoes/images/fig32_e.gif' for a map showing flying routes.

Canadians are generally unlikely to be impacted by volcanic events, although they may be affected by tsunamis, earthquakes and landslides triggered by such events, particularly in British Columbia. Protection from such events is largely common sense and consists of general preparedness for any type of natural emergency and paying attention to public service messaging.

In terms of general preparedness you need an emergency plan for you and your family and an emergency kit. Public Safety Canada's website "Is your family prepared?" (<http://www.getprepared.gc.ca/index-eng.aspx>) has excellent advice on what to include in both and these can be put to good use in any natural disaster or emergency.

Definitions of underlined terms

Cinder cone: Cone formed by the piling of material ejected by the volcano and deposited on tilt layers.

Continental crust: Earth's crust which underlies the continents and the continental shelves. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

Continental rift zone: Zone of crustal fractures.

Earth crust: The outermost layer or shell of the Earth. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

Magma: Fused, molten rock material found beneath the earth's crust from which igneous rocks are formed. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

Oceanic crust: Earth's crust which underlies the oceanic basins. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

Shield volcano: A volcano in the shape of a flattened dome, broad and low, built of very fluid lava.

Stratosphere: Layer of the atmosphere located roughly from 18 to 50 kilometres of altitude.

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

Subduction zone: An area where the rocks making up the sea-floor are forced beneath continental rocks at a plate margin and are reincorporated in the magma beneath the earth's crust. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)

Tectonic: Related to the study of terrain deformations caused by internal forces, after the setting of the rocks.

Tectonic plate: Broad thick plate composed of areas of both continental and oceanic crust and mantle. (Source: The Encyclopaedic Dictionary of Physical Geography, edited by Andrew Goudie et al. Blackwell Reference Ltd. Oxford, 1985.)