Explore the geology and landscape along British Columbia's legendary Highway 99, the Sea to Sky Highway. Travel the highway with your own geologist-in-your-pocket to discover the watery origins of Vancouver, the cataclysmic source of the Coast Mountains and mineral riches at Britannia Beach.

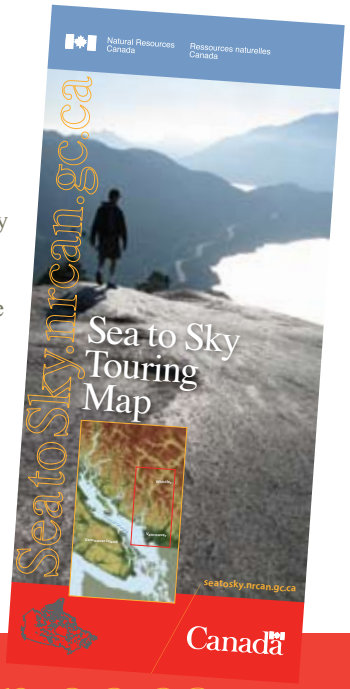
Each section of the guide includes directions to a stop of interest along the highway, an explanation of what you're looking at and a description of the geological history of the area.

In this guide:

- *Travel back 15,000 years to find the site of Vancouver locked under a kilometre of glacial ice.*
- *Stand at Horseshoe Bay and look across Howe Sound to a chain of mountains that reach all the way to Alaska.*
- *Climb 700 metres of granite sculpted by the last Ice Age at Stawamus Chief – or hike the trail for stunning views of volcanic Mount Garibaldi.*
- *Ride the gondola at Whistler and marvel at Fitzsimmons Creek as it creates valleys where a large plateau of mountain and rock once existed.*

Add to your experience with the Sea to Sky Touring Map, available at the Natural Resources Canada Bookstore, 625 Robson Street in Vancouver. This companion to the guidebook presents geological, marine, and forestry points of interest along the Sea to Sky Highway.

Visit the Geological Survey of Canada web site at ***gsc.nrcan.gc.ca*** and the Natural Resources Canada web site at ***nrcan.gc.ca*** for more information on Canada's natural resources.



SeatoSky.nrcan.gc.ca

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Sea to Sky GeoTour

GEOLOGY AND LANDSCAPES ALONG HIGHWAY 99
FROM VANCOUVER TO WHISTLER, BRITISH COLUMBIA

SeatoSky.nrcan.gc.ca

Canada

History of the Highway

IN 1958 HIGHWAY 99 OPENED, CONNECTING SQUAMISH TO VANCOUVER. IT WOULD TAKE ANOTHER 11 YEARS TO REACH WHISTLER AND PEMBERTON AND COMPLETE WHAT WE KNOW TODAY AS THE SPECTACULAR SEA TO SKY HIGHWAY.

However, the history of the region goes back well before the arrival of paved roads. Coast Salish peoples inhabited the area for thousands of years, using trails to trade goods to other First Nations in the Fraser Canyon and on the coast.

In the 1850s, gold prospectors looking for a quick route to the Cariboo built the Heritage Gold Rush Trail. The trail through the mountains was dangerous and not for the faint of heart.

Until the last leg of Highway 99 connected the Sea to Sky communities to Vancouver in the late 1960s, residents of the region relied on horses, boats and the railway to transport passengers and supplies.

Today's Sea to Sky Highway remains at the mercy of the landscape. In the midst of steep rock walls, seismic activity and debris flows from floods, it provides a beautiful visual trip through British Columbia's Coastal Mountains.

Sea to Sky Geologists

THE SEA TO SKY HIGHWAY PRESENTS MANY OPPORTUNITIES FOR SCIENTIFIC RESEARCH. GEOLOGISTS STUDY NATURAL HAZARDS LIKE VOLCANOES, EARTHQUAKES AND LANDSLIDES. THEY PROVIDE ADVICE ON HOW TO MINIMIZE THE RISK TO HUMANS AND STRUCTURES.

Malaika Ulmi is a geologist with Natural Resources Canada. As well as mapping volcanoes in the Garibaldi Volcanic Belt and northern British Columbia, her work has taken her to South America where she was part of a project integrating geoscience into land use and emergency planning for communities at risk from natural hazards. She regularly shares her passion for the connection between geoscience and civilization with students and the public.

Melanie Kelman is a volcanologist with Natural Resources Canada. Pursuing a lifelong interest, Melanie received a Ph.D. in geology from the University of British Columbia, studying volcano-ice interaction in southwestern British Columbia. Today, she studies both large well-known volcanoes like Mount Garibaldi and little-known volcanoes like tiny Abbott Creek cone. She enjoys sharing her work in volcanic hazards with the public, especially through school visits.

Bob Turner is a geoscientist with Natural Resources Canada in Vancouver. His work educates British Columbians about their landscapes, mineral and water resources, changing climate, natural hazards and environment. Bob has been honoured by the Geological Association of Canada for his contributions to earth science education. Bob lives on Bowen Island in the Sea to Sky corridor.

Sea to Sky GeoTour

1 CYPRESS LOOKOUT
2 HORSESHOE BAY
3 LIONS BAY
4 PORTEAU COVE PROVINCIAL PARK
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7 SHANNON FALLS PROVINCIAL PARK
8 STAWAMUS CHIEF PROVINCIAL PARK
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11 WHISTLER MOUNTAIN

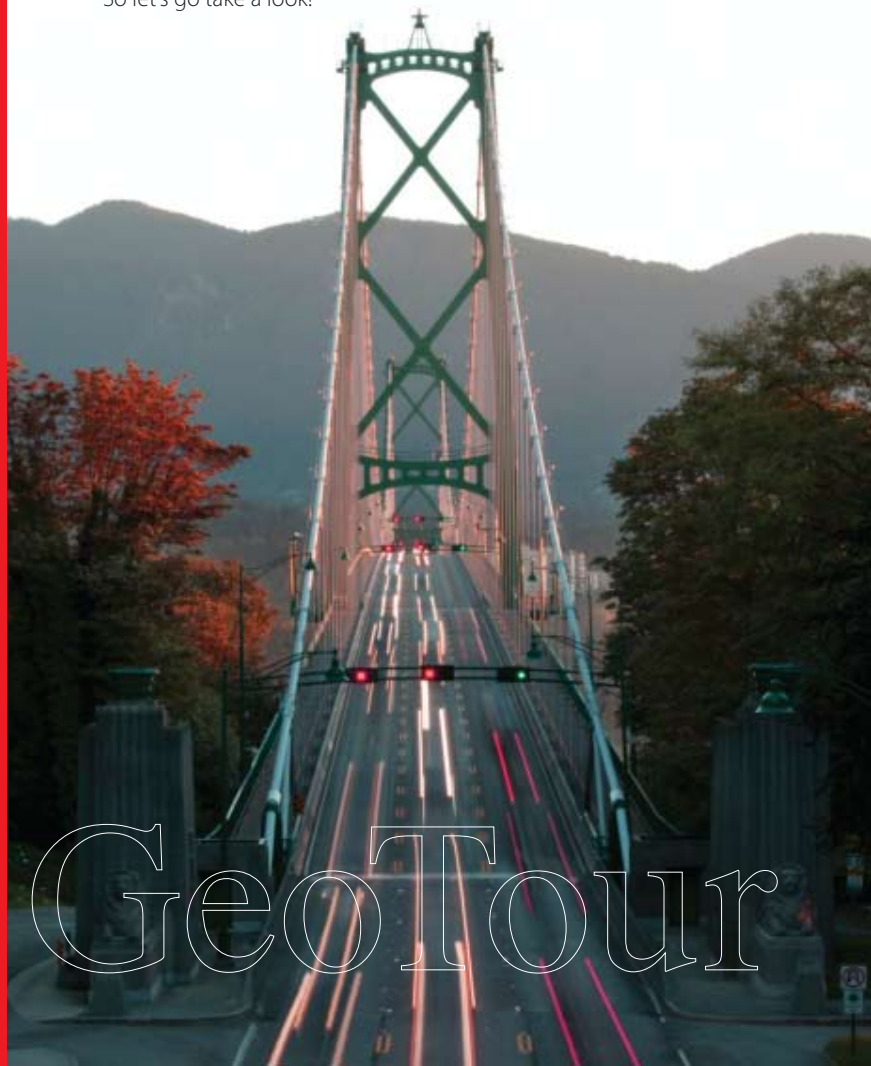
Sea to Sky GeoTour

from

Sea to Sky

HIGHWAY 99 BETWEEN VANCOUVER AND WHISTLER, BETTER KNOWN AS THE SEA TO SKY CORRIDOR, PASSES THROUGH SOME OF THE MOST BEAUTIFUL AND DIVERSE LANDSCAPE IN BRITISH COLUMBIA.

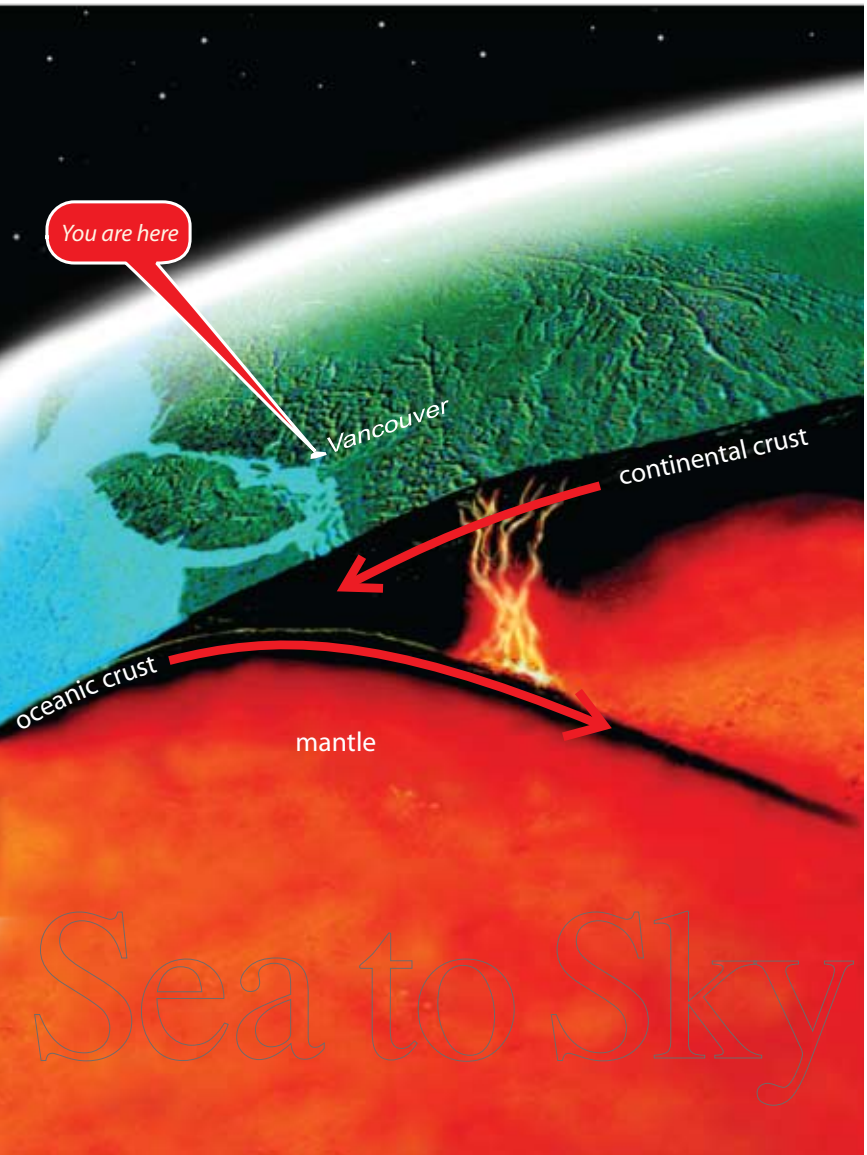
Our journey begins with Vancouver's valley and oceanside setting. It follows the sheer mountain wall of an ocean fiord, passing communities perched on steep slopes, pounding waterfalls, famous climbing cliffs and a former mine, before arriving in Squamish. North of Squamish we travel through a mountain valley bordered by craggy peaks, glaciers and volcanoes. This guide uncovers the geological stories that lie behind the stunning landscape – how the land came to be and how humans live with its hazards, resources and fragile environment. So let's go take a look!



HOW THE MOUNTAINS AND VALLEYS GOT HERE

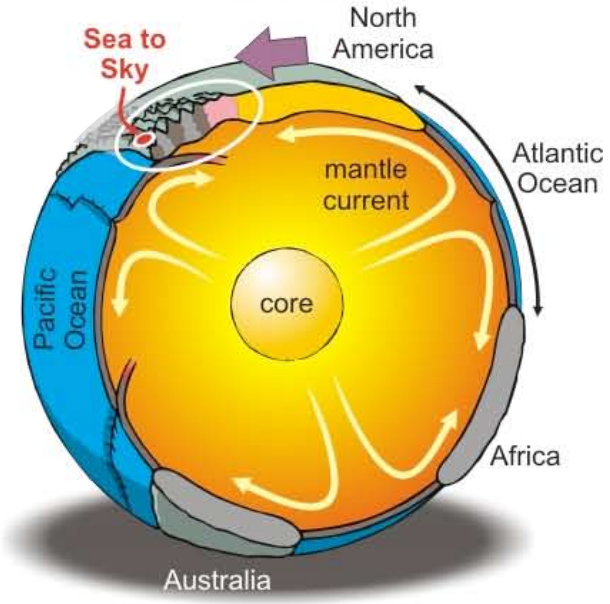
When Plates Collide

VANCOUVER AND THE SEA TO SKY CORRIDOR ARE LOCATED ON CANADA'S WEST COAST. COASTAL BRITISH COLUMBIA IS AT THE LEADING EDGE OF THE WESTWARD-MOVING NORTH AMERICAN TECTONIC PLATE. THIS IS ONE OF MANY VAST PLATES, EACH TENS OF KILOMETRES THICK, AND THOUSANDS OF KILOMETRES WIDE, THAT MAKE UP THE SEGMENTED, RIGID SKIN OF OUR PLANET.



Driven by movement from the Earth's mantle, the North American Plate, with British Columbia as part of its leading edge, overrides the oceanic plate at the fingernail-growing speed of four centimetres per year. This region is known for the slow-moving collision that continues to create the mountains, earthquakes and volcanoes.

About 70 kilometres below Vancouver, the oceanic plate is slowly moving eastward on a downward dive into the mantle. Earthquakes are the creaks and groans of this giant collision. Caught in this tectonic vise, the compressed edge of the North American landmass rises. Rivers and glaciers are relentless carvers of the landscape, cutting valleys that form our mountain ranges. Deep below the surface, the descending oceanic plate transforms under pressure, releasing liquids that melt adjacent rock. The liquid rock works its way to the surface in the form of volcanoes. Rising heat warms the North American Plate in the process, expanding the rock, which adds to the rise of mountains.

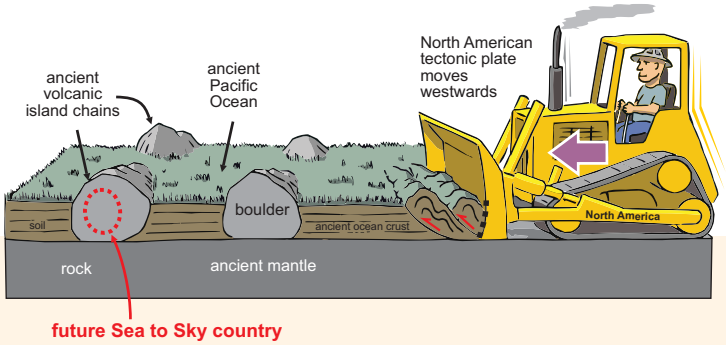


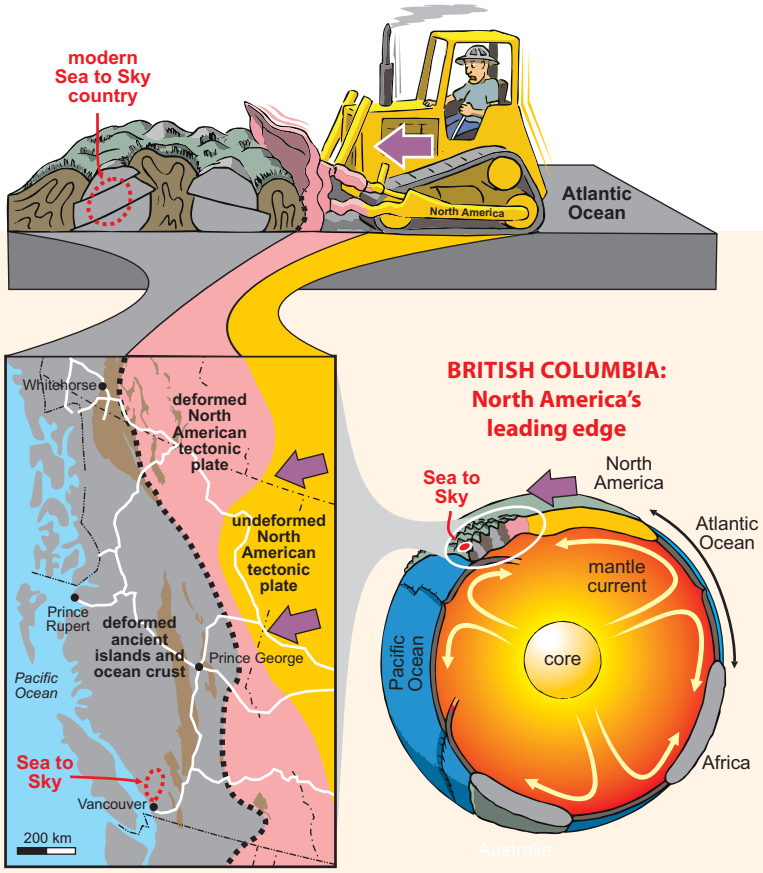
Sea to Sky GeoTour

Collision Built British Columbia

FOR THE PAST 170 MILLION YEARS, THE NORTH AMERICAN AND OCEANIC PLATES HAVE BEEN COLLIDING IN BRITISH COLUMBIA. Over this time, the North American Plate has been pushing west, driving over tens of thousands of kilometres of the thinner and denser oceanic plates. Volcanic islands, built on those oceanic plates, have collided with and become stuck to this moving front of North America. These bits of volcanic islands have added land, extending North America's landmass to the west. This 'new' land includes most of what we call British Columbia today.

Let's say a tractor is plowing a field with big, scattered boulders. The tractor represents the North American Plate, the soil is ocean floor and the boulders are volcanic islands. As the tractor moves forward, its blade pushes soil and boulders together, deforming the soil and breaking the boulders. The tractor blade also becomes damaged in the process. Modern British Columbia represents the combination of broken boulders, deformed soil, damaged blade and tractor.





HOW BRITISH COLUMBIA WAS BUILT AND SEA TO SKY COUNTRY CAME TO BE: an analogy

170 million years ago (above) *As the Atlantic Ocean began to spread, North America moved westwards and collided with nearby ocean floor and volcanic islands.*

Today (right) *British Columbia's landmass is a collision zone of deformed volcanic islands, sea floor and North American continental margin.*

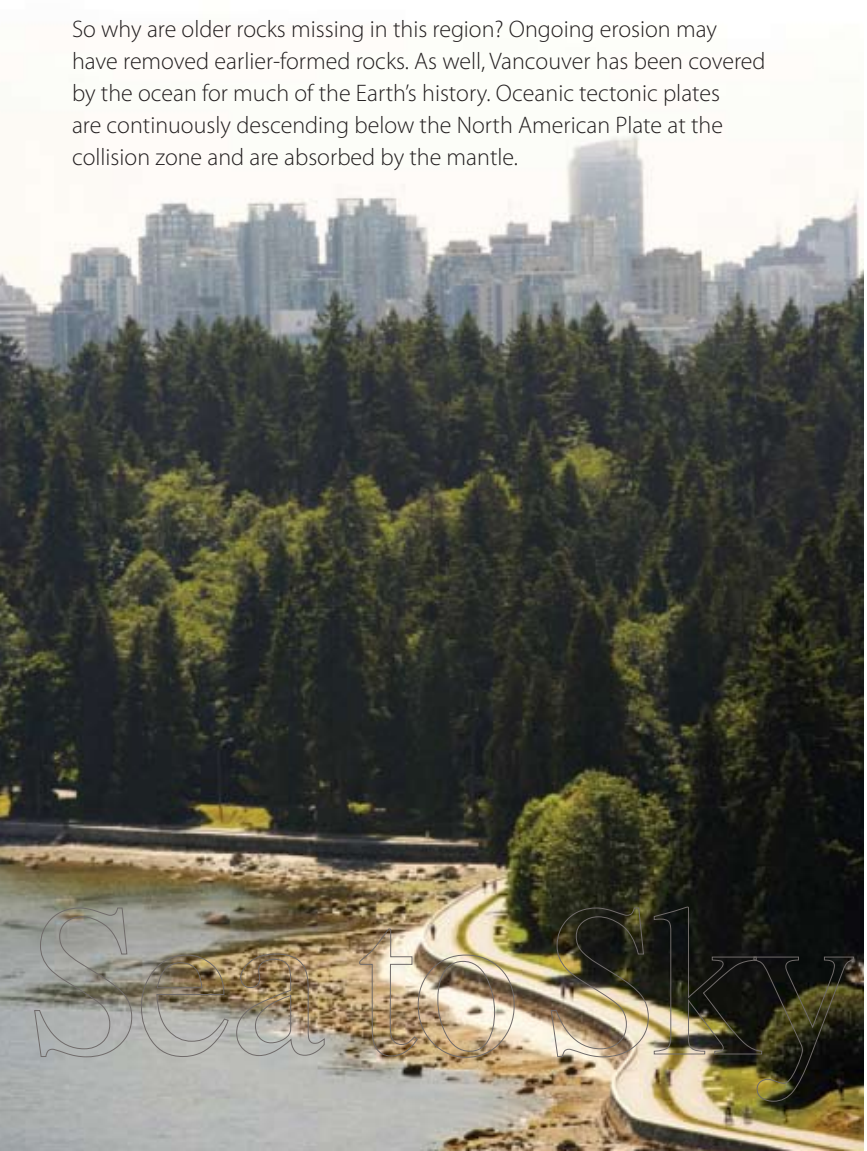
Sea to Sky GeoTour

The Earth is Very Old – Vancouver is Very *Young*

IF THE 4.5 BILLION YEAR HISTORY OF THE EARTH IS REPRESENTED BY A SINGLE CALENDAR YEAR, THE ENTIRE HISTORY OF THE HUMAN SPECIES SPANS ONLY THE LAST FOUR HOURS OF DECEMBER 31ST. The history of humans in the Vancouver region is represented by the last minute of the last day of the year.

The rocks underlying the Vancouver area – sandstones in Stanley Park, granites and volcanic rocks in the mountains to the north – are all less than 200 million years old. In our calendar year, they were all formed in just the last two weeks of December.

So why are older rocks missing in this region? Ongoing erosion may have removed earlier-formed rocks. As well, Vancouver has been covered by the ocean for much of the Earth's history. Oceanic tectonic plates are continuously descending below the North American Plate at the collision zone and are absorbed by the mantle.

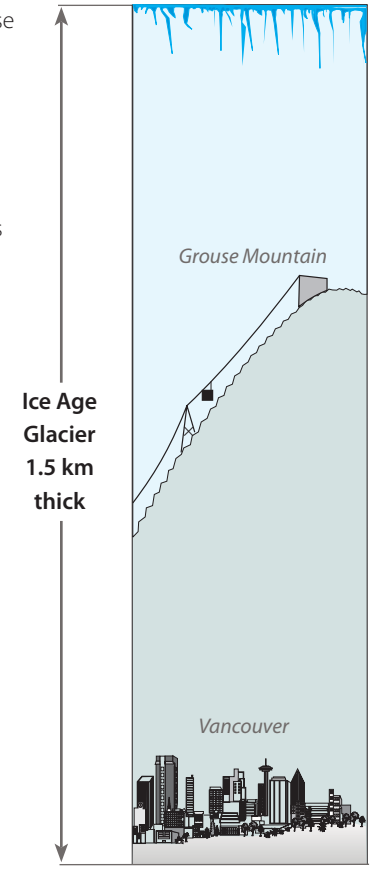


Vancouver is Constantly Changing

IF YOU WERE TO TRAVEL BACK IN TIME AND VISIT THE VANCOUVER REGION 15,000 YEARS AGO (OR 750 GENERATIONS AGO), YOU WOULDN'T RECOGNIZE IT! The land was in an ice age. Only the highest peaks poked above vast ice fields and the region looked like modern day coastal Greenland. The site of downtown Vancouver lay under more than a kilometre of glacial ice.

The last Ice Age had a dramatic effect on the Vancouver region. Flowing glaciers scoured valleys, steepened valley sides and rounded lower ridges. Today, remnants of these glaciers remain only in the highest mountains. The remaining glaciers are melting rapidly. The land is in motion.

So, with these thoughts in mind, let's head out and take a look at the Sea to Sky country.



Sea to Sky GeoTour

SITE 1: CYPRESS LOOKOUT

Cypress Lookout – The Big Picture of Vancouver

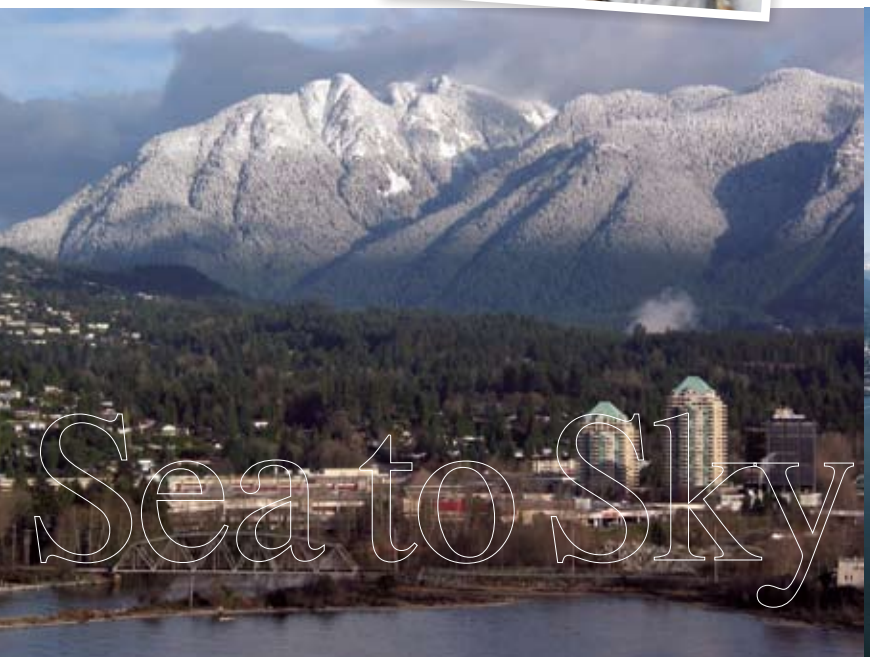
A Big Valley and Inland Sea

VANCOUVER IS FAMOUS FOR ITS MOUNTAINS, BUT FROM THE CYPRESS LOOKOUT, YOU MAY BE SURPRISED BY HOW FEW MOUNTAINS YOU SEE.

In front of you is a vast panorama of lowlands and ocean. The Fraser Valley extends to the south and east, to the far off wall of the Cascade Mountains. To the west, you can see the inland sea known as the Strait of Georgia. It is also known as the Salish Sea in tribute to the First Nations people who have inhabited the area since the last Ice Age. Further to the west is Vancouver Island.

Ski areas in the North Shore Mountains provide commanding views of Vancouver and its geography. This lookout, along the access road to Cypress Bowl Ski Area, is just a short drive, or a challenging bike ride, from Highway 1 in West Vancouver. It is well worth a visit.

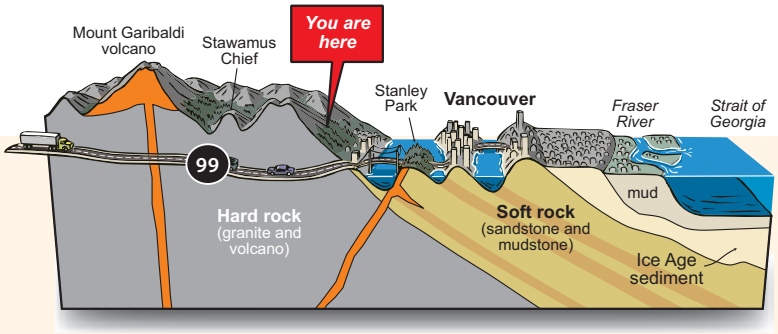
Mountains may make Vancouver famous, but the Fraser Valley made Vancouver possible. These lowlands provide the land base for a major metropolitan centre, rich agricultural lands, an excellent harbour and a site along British Columbia's largest river. It is not a coincidence that British Columbia's largest city lies within its largest coastal valley.



Sea to Sky GeoTour

A Giant Pocket Carved in Soft Rock

So why is the Fraser Valley so big? The simple answer is that it is a depression carved in a pocket of soft rock, surrounded by harder rock. Soft sandstone and shale in the valley have been scoured deeply over geologic time by rivers and glaciers. The mountains that surround the valley and inland sea – the Coast Mountains, the Cascade Mountains and Vancouver Island Ranges – are all composed of much harder granite and volcanic rock that have resisted erosion and remain as high-standing mountainous areas.



A cross section illustrating the rock foundations of the Sea to Sky corridor.

Is That Mountain aVolcano?

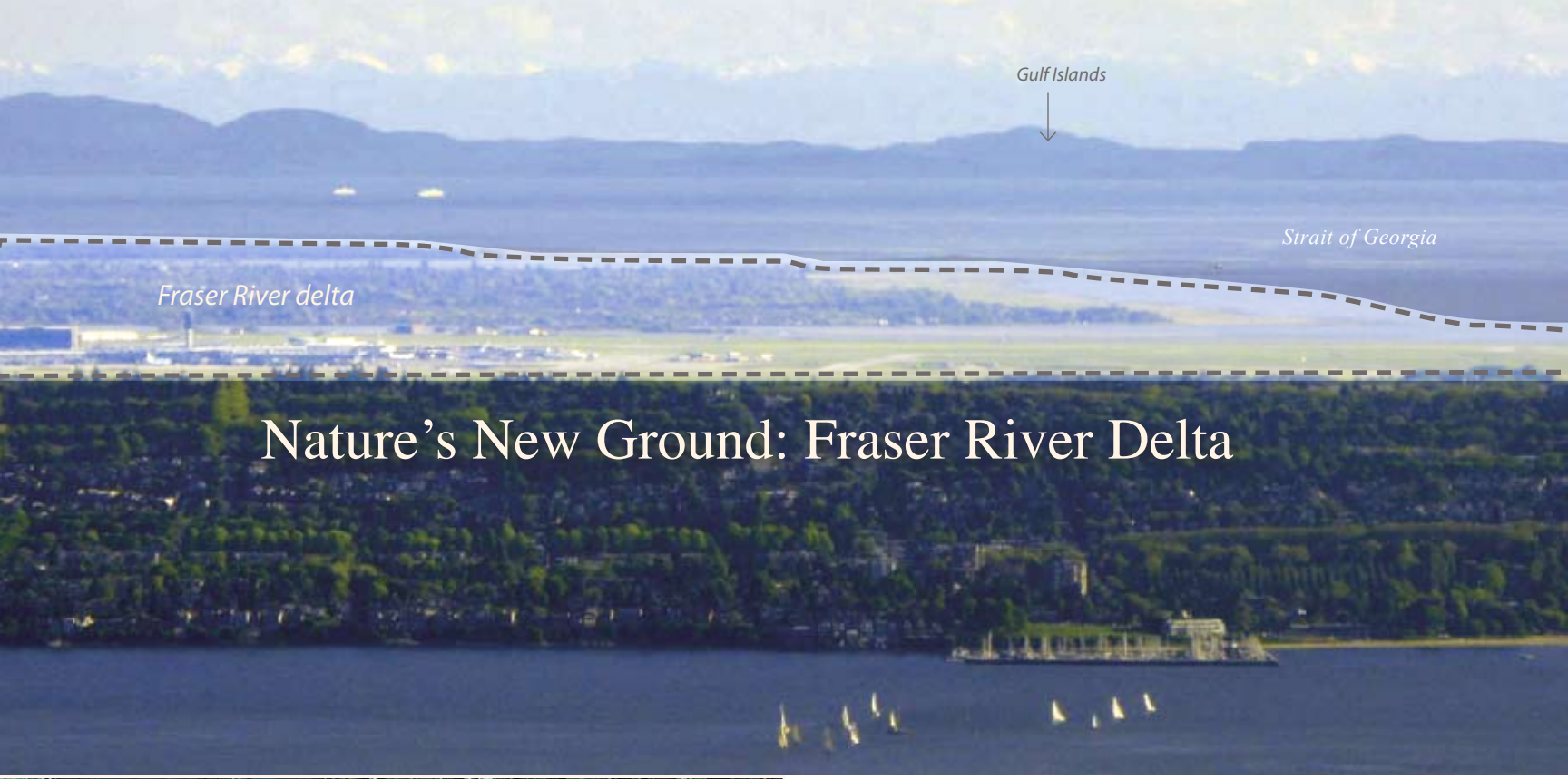
The cone shape of Mount Baker, rising high on the southeastern horizon, looks like a volcano. It is: in the 1880s, small eruptions on its summit created fireworks visible in Victoria. Mount Baker is a reminder that Vancouver sits above a vast, slow-moving tectonic engine that melts rock. Every so often that melted rock works its way to the surface. One day Mount Baker will erupt again.

About 70 kilometres beneath your feet, the oceanic plate is slowly moving east. The rocks you're standing on are under stress. Every day there are tiny earthquakes. We know that bigger earthquakes are coming; we just don't know when. So, engineers in the Vancouver region design buildings to withstand very large earthquakes.

At Cypress Lookout, you stand at the boundary between hard and soft rock. Behind you are hard-rock mountains. In front of you, soft rock underlies the valley. This soft sandstone rock is largely hidden below soil, sediment and water, but along the shores of Stanley Park some of these soft sandstone rocks are exposed.

Glaciers have ground away at the soft bedrock in the region, creating the deep trough filled with an inland sea, known as the Strait of Georgia. The Fraser River dumps its sediment load into the strait. This sediment builds up and over time, the river converts sea to land.

Sea to Sky GeoTour



Nature's New Ground: Fraser River Delta

To the southwest of Vancouver is an expanse of very flat coastal land. This is the Fraser delta (above), new land created by the Fraser River over the millennia as it dropped its load of sand and silt at the ocean's edge. The Fraser River, over 1,300 kilometres long, takes in water from a quarter of British Columbia's landmass. It also gathers eroded bits of rock and soil from that same vast landscape and carries them south to where the energy of the river wanes as it meets the sea. Over a hundred square kilometres of new floodplain land, including the entire city of Richmond, has been built by the river since the end of the last Ice Age 10,000 years ago.

This satellite image of the Vancouver region shows the Fraser River flowing in from the east. Its mud-rich waters divide into channels that cross the delta floodplain of farm (green), city (grey) and mud flat (brown) before entering the sea. Image courtesy of Galiano Conservancy Association.

GETTING THERE:

Take Highway 1 west through West Vancouver to the Cypress Provincial Park exit (exit eight). The Cypress Lookout parking lot is several kilometres up the hill.

Sea to Sky GeoTour

SITE 2: HORSESHOE BAY

Coastal Mountains and an Ice Age Fiord

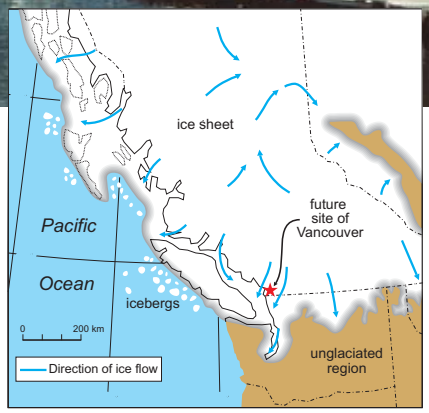
A Village on the Sound

Just west of Cypress Lookout, the highway turns abruptly to the north and follows the steep shoreline of a coastal inlet, Howe Sound. Horseshoe Bay, a village at the mouth of Howe Sound, is a major terminal for ferries bound for Vancouver Island, the Sunshine Coast and Bowen Island.

A Route Through the Mountain Wall

Image D-00436 courtesy of Royal BC Museum, BC Archives.

The view from Horseshoe Bay is dramatically different from that at the Cypress Lookout. Here we look towards the mountains – at Cypress Lookout, we looked away. Peaks crowd Howe Sound; this is the southern end of a chain of coastal mountains that extend from Vancouver to Alaska. Howe Sound is a valley carved into this mountain chain, flooded by the sea. North of Squamish, the valley floor emerges and the Sea to Sky Highway follows this mountain valley to Whistler.



A Tale of Two Coastlines

If you look at a map of western North America, you will see a striking difference between the coastline of the northwestern United States and the coastline of British Columbia. The former is relatively straight with few inlets; the British Columbia coast is highly irregular with many deep inlets.

The difference between the two coastlines relates to how glaciers covered the region during the last Ice Age. Before this Ice Age, the British Columbia coast was similar to the coast further south. But during the Ice Age, glaciers wore deep valleys in the rock, and when the glaciers melted, the sea flooded the long finger-like inlets left behind. These glacier-carved inlets are referred to as fiords and Howe Sound is the southernmost fiord on the British Columbia coast.

The height of the Ice Age glaciers that once flowed down Howe Sound can be interpreted from the shape of the local mountains.

Seeing the Ice Age in the High Peaks

As you look north from Horseshoe Bay, you may notice something peculiar. The lower hills, such as the islands in the Sound, are smooth and rounded. The higher ridges and peaks are still rounded, but less so. The highest peaks, such as the Tantalus Range on the skyline to the north, are craggy. What's going on?

You are looking at the grinding effect of ice age glaciers. As glaciers flowed down Howe Sound, they ground harder where they were thicker, smoothing out the rock and creating the rounded hills you see today. The lower limit of the craggy peaks lies at about a two-kilometre elevation. This shows us the thickness of the ice age glaciers. As you stand at Horseshoe Bay, imagine two kilometres of slow-moving ice over your head! Only the highest peaks that stood above the glacier were spared.

Steep mountain slopes rise above Highway 99, north of Horseshoe Bay.

A Challenging Highway Route

From Horseshoe Bay, you can see part of the route of the Sea to Sky Highway as it hugs the shores of Howe Sound. Because the valley bottom is flooded by an inland sea, engineers had to build the highway on steep slopes, using extensive rock cuts, cantilevered roadways and bridges – all very expensive solutions.

GETTING THERE:

Take exit two off Highway 1/99 and wind down to Horseshoe Bay village to find parking near the ferry terminal. Horseshoe Bay has a pleasant waterfront park with interesting views from its busy bay toward the backdrop of Howe Sound and the Coast Mountains.

Sea to Sky GeoTour

SITE 3: LIONS BAY VILLAGE

The Challenge of Steep Slopes

The Highway 99 wooden trestle bridge over M Creek shortly after its destruction by a debris flow in October 1981. Trestle bridges were used during construction of Highway 99 in the 1950s and designed to withstand floods. At the time, highway engineers did not know that steep mountain streams were prone to debris flows. Photo courtesy of Oldrich Hungr.

Village on the Side of a Mountain

Lions Bay is perched on a steep mountain slope above Highway 99. The village, with its spectacular views across Howe Sound, is a good example of the challenges of living on a steep slope. Lions Bay has suffered from deadly mudslides. Engineered structures now protect the village.

Tragedy is Our Teacher

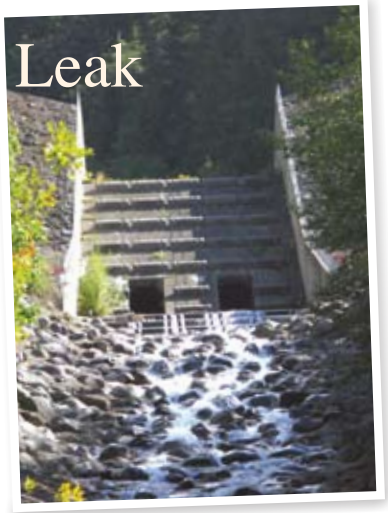
Steep slopes are inherently unstable. Tragedies related to landslides, floods and debris flows, along the Sea to Sky Highway over the last century, have taught us much about how mountains work. In 1915 at the Britannia Mine, a landslide slammed into a mine bunkhouse, killing 56 people.

Six years later, in 1921, a flood on Britannia Creek destroyed the village of Britannia Beach, killing 37 people. When Highway 99 was constructed along Howe Sound in the late 1950s and settlement of Lions Bay began in the 1960s, engineers had yet to understand the danger posed by debris flows. Highway bridges were designed to withstand floods but not a flow of rocks, mud and tree debris. On a stormy night in the winter of 1981, a debris flow destroyed a highway bridge just north of Lions Bay leading to several fatal car crashes.

Rock falls have closed the highway many times over the years.

A Dam Built to Leak

Just off the highway, a bridge spans Harvey Creek. Harvey Creek drains the steep mountain slope above Lions Bay. Looking upstream you will see a dam. The unusual feature of the dam is that Harvey Creek flows right through two tunnels at the base. Why build a dam that allows water to pass through?



Sea to Sky GeoTour

Damage in Lions Bay shortly after the debris flow in February 1983. Photo courtesy of the Vancouver Sun.

Tragedy from a Flow of Debris

The answer lies in the history of Lions Bay. On a late February night in 1983 during an intense rainstorm, a torrent of mud, rock and tree debris roared down nearby Alberta Creek. This debris flow destroyed bridges and houses in Lions Bay, and at a bend in the creek, spilled out of the channel, destroying a house and killing two boys. In the aftermath of the tragedy, engineers had to look for new solutions to protect the community.

The dam on Harvey Creek is designed to stop and store any debris flow that comes downstream. Above the dam, is a storage basin that sits empty. Thus, regular stream flow is allowed to pass through the dam unimpeded.

The Coastal Mountains rise steeply above Lions Bay beside Harvey Creek.

A different engineering solution is employed on nearby Alberta Creek. The stream channel has been converted into a concrete chute, large and straight to ensure any debris flow stays in the channel and passes safely through the village to the sea below.

GETTING THERE:

Lions Bay is about 12 kilometres north of Horseshoe Bay on Highway 99. Take the Lions Bay exit (Oceanview Road). Turn uphill onto Oceanview Road, then left at Crosscreek Road and park just beyond the bridge. At the bridge, a path follows the creek upstream to the base of the dam. To return to Highway 99, continue on Crosscreek Road, turn left at the stop sign and follow the road to the highway.

SITE 4:
PORTEAU COVE PROVINCIAL PARK

Highway Hazards and an Undersea Story

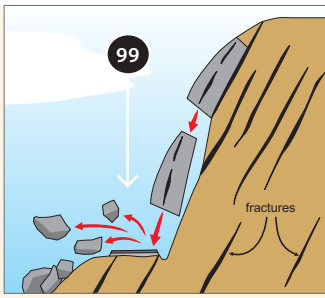
A Shallow Fiord

Heading north from Lions Bay, Highway 99 hugs the lower slopes of the mountain wall, with views across Howe Sound and towards the Coast Mountains. Much of the highway route is either cut into rock slope, or built on bridges cantilevered out from the slope, across creeks or valleys. The highway is a testimonial to engineering ingenuity. At Porteau Cove Provincial Park, the highway route descends from the slopes to take advantage of the rare low-lying shoreline. Howe Sound narrows dramatically from a broad, island-studded sound, to a narrow steep-walled inlet, becoming a true fiord. Views in all directions can be seen from a large parking area on the flats. An emergency ferry terminal provides an alternative to the highway should it be blocked by a landslide. South of the parking lot, a quieter shore is marked by logs and boulders where you'll find a provincial campground. It is a picturesque place to spend some time.

Porteau Cove slide July 30, 2008. Photo courtesy of The Canadian Press/ Jonathan Hayward.

Highway Hazards

From Porteau Cove, the view of Highway 99 gives us an idea of the challenges faced by highway engineers. Stand in the parking area and look across the bay to the north. The highway hugs the shore, skirting a rock bluff. Notice the series of seaward sloping fractures that cut the granitic rock. It is like a deck of cards, with the sloping sheets of rock separated by cracks. Construction of the highway undercut this cracked rock, removing a buttress and destabilizing it. To compensate, loose rock has been removed and long steel bolts have been used to pin the remaining sheets of rock together. Drill holes allow water to drain from the cracks. This reduces the water pressure that can build up during rainstorms. Otherwise, the water would lubricate the cracks and allow the rock to slip. Despite the best engineering efforts, a rockfall in July 2008 blocked the highway for several days.



The granite bluff along Highway 99 just north of Porteau Cove is cut by a series of cracks that have challenged highway engineers.

Sea to Sky GeoTour

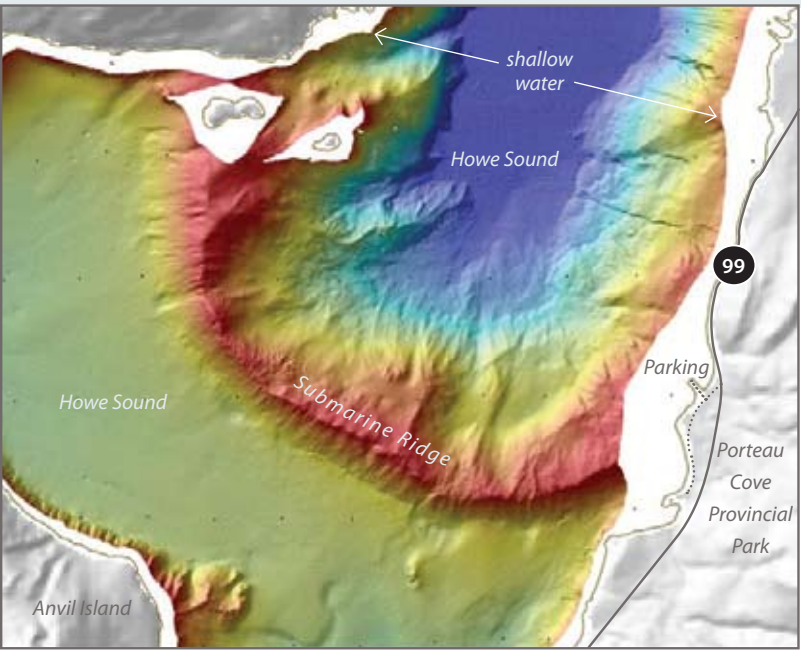
The seafloor ridge extends below Howe Sound from Porteau Cove to the far shore.

An Underwater Ridge of Glacial Debris

Visit Porteau Cove on a summer weekend and you will see a hive of activity as scuba divers come and go from the water. This popular diving spot has a number of artificial reefs established just off shore to enhance sea life. Porteau Cove is also popular with divers because of the shallow depths of the sea floor, a rarity in steep-walled Howe Sound.

Hidden below the surface, a giant submarine ridge of boulders, gravel and sand stretches from Porteau Cove, across the fiord, to the far shore. This ridge rises 250 metres from the sea floor to within 30 metres of the surface. The ridge marks the forefront of a glacier that was present 10,000 years ago. A glacier acts like a conveyor belt, slowly carrying rock forward and releasing it at the snout as a pile of debris. Today at Porteau Cove, the glacier is long gone, but the ridge of debris remains underwater.

If we drained Howe Sound: *From Porteau Cove, the submarine ridge extends across Howe Sound to the far shore. The deepest seafloor is coloured dark blue. Increasingly shallow seafloor is coloured yellow and red. Very shallow water is coloured white.*



GETTING THERE:

About 25 kilometres north of Horseshoe Bay, turn west at Porteau Cove Provincial Park, where you'll find a large parking lot along the beach. Enjoy the views at the ferry dock and spend time at the nearby picnic area, equipped with restrooms.

Sea to Sky GeoTour

SITE 5: BRITANNIA MINE

Managing the Environmental Legacy

The concentrator building of the former Britannia Mine dominates the site of the BC Museum of Mining at Britannia Beach along Highway 99.

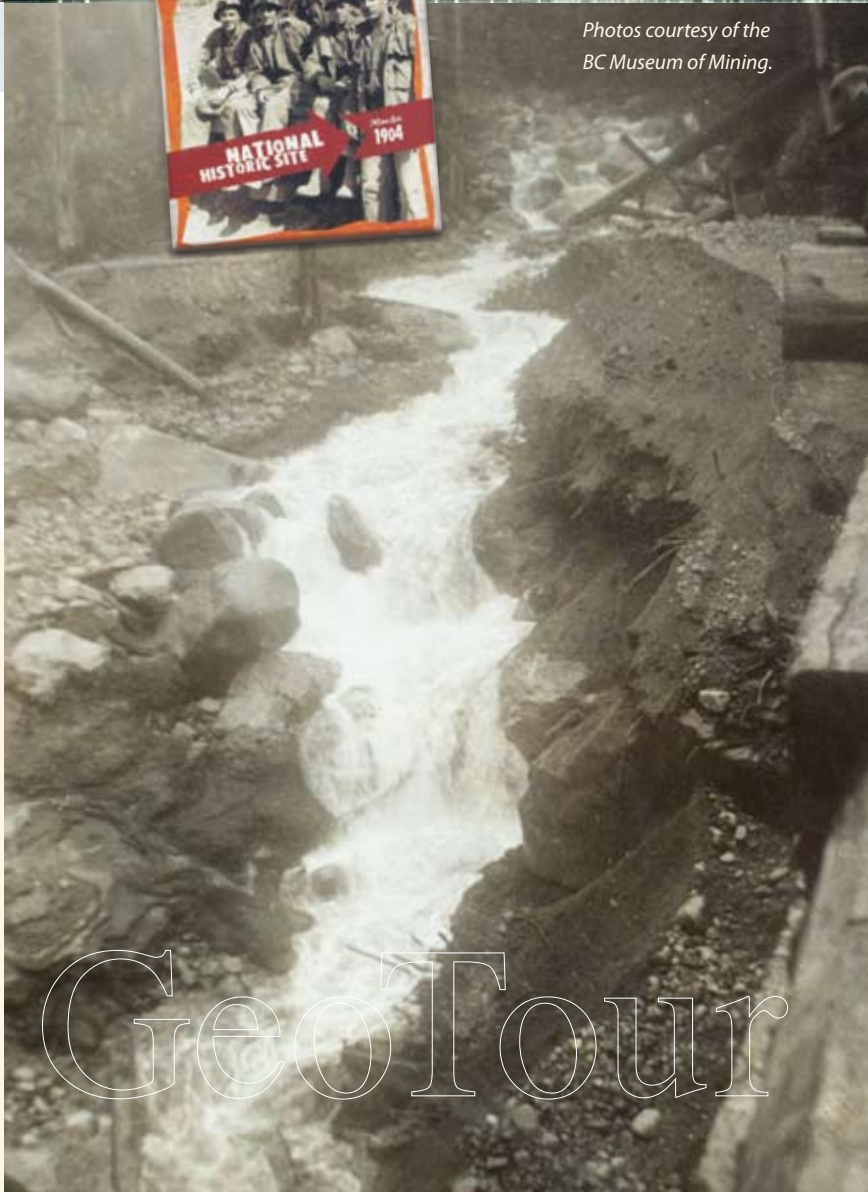
Photos courtesy of the BC Museum of Mining.

A Place Filled with Stories

Britannia Beach has a long and proud history as a coastal community. It has thrived on its mineral wealth, but endured tragedies from landslides and floods, and environmental damage. Britannia has many stories to tell, so make the time to stop and explore. Visit the museum, pan for gold and follow a guide through a tour of old mine tunnels.

A Rich Mining History

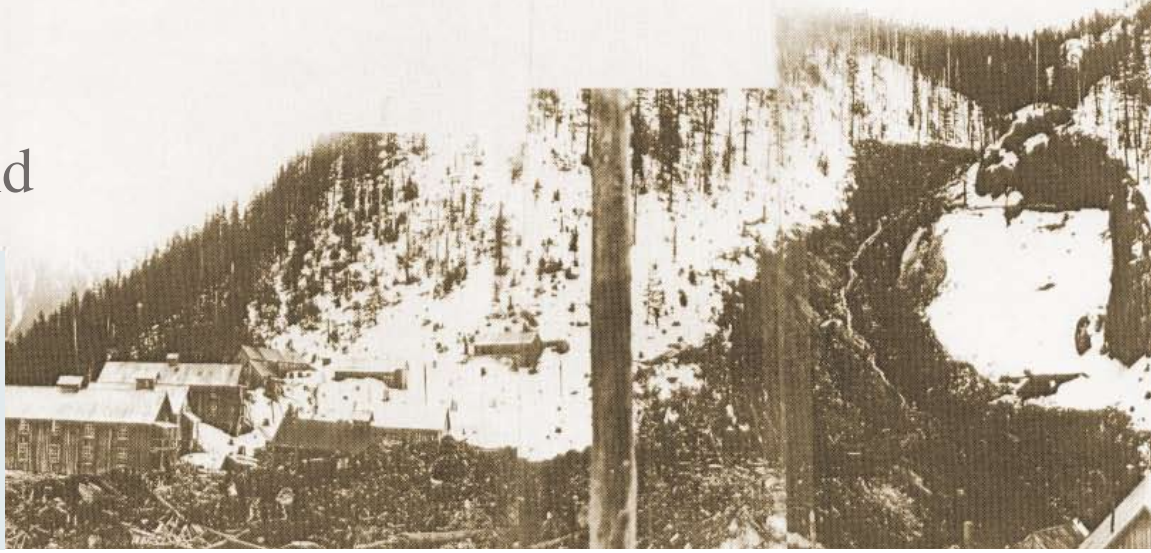
Britannia Beach sits where Britannia Creek, flowing from the mountains, has built broad gravel flats along the shores of Howe Sound. The historic mine mill, built in staircase fashion against the hillside, dominates the community. The mountain is a warren of mine tunnels that once fed ore to the mill. Over its 70-year history, the mine processed ore and shipped the metal concentrate to smelters elsewhere. Finely ground waste rock from the mill was used as landfill to extend the shoreline and carried by pipeline to the shallow offshore waters for disposal.



Sea to Sky GeoTour

Finding Safe Ground

A BIG CHALLENGE IN MOUNTAIN COUNTRY IS FINDING LAND THAT IS SAFE FOR DEVELOPMENT. NOWHERE ELSE IN BRITISH COLUMBIA HAS EXPERIENCED SUCH A FRUSTRATING SEARCH FOR SAFE GROUND AS BRITANNIA.



A landslide in 1915 killed 56 people at a mountain-top camp for the Britannia Mine. This event ranks as the second most deadly landslide in Canadian history. Photo is courtesy of the Vancouver Public Library.

After the discovery of copper ore on Britannia Mountain, a mining camp was built in a high basin. One night in 1915, a landslide swept into a bunkhouse, killing 56 people.

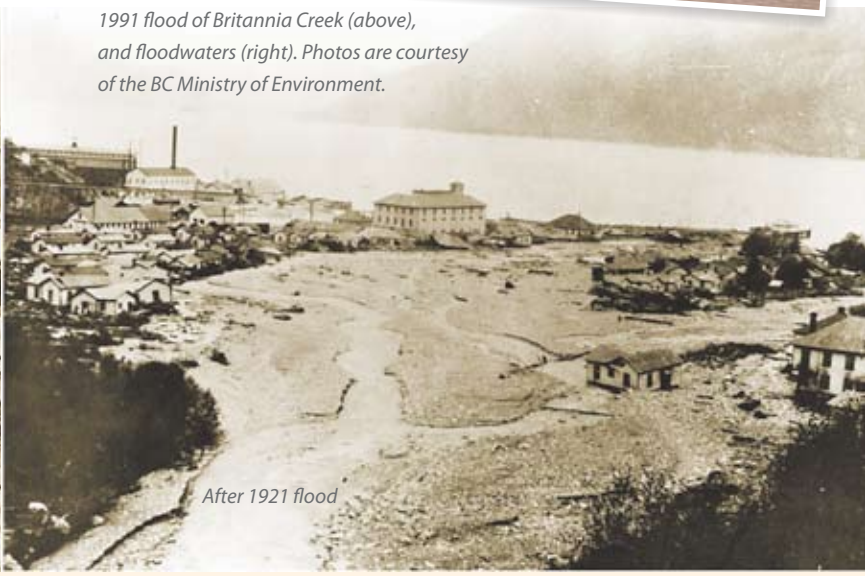
Looking for safer ground, the mine quarters were moved 600 metres down to Britannia Beach, on the shoreline flats by Britannia Creek. But in 1921, a flood engulfed the town during a winter storm, killing 37 people and sweeping many houses out to sea. The village was moved again, this time halfway up the mountain, where it proved to be a safer location.

But, just as a reminder, Britannia Creek flooded again during a summer rainstorm in 1991, submerging the flats and burying large areas under a blanket of thick gravel. Today, rock dykes line the stream to help prevent future floods.

Truck buried by gravel after the 1991 flood of Britannia Creek (above), and floodwaters (right). Photos are courtesy of the BC Ministry of Environment.

Photos courtesy of the BC Museum of Mining.

Before 1921 flood

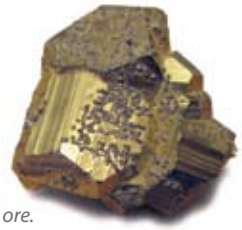


After 1921 flood

Billion Dollar Bonanza from a Freak of Nature?

The ores at Britannia are full of copper. They also contain iron, zinc, arsenic and other metals. Over the mine's life, it produced metals worth about $1.3 billion in today's dollars. How did these rich ores come to be?

Metals are generally found in trace concentrations in all rocks. The creation of a concentrated ore body required some very special circumstances in the history of the Earth. Such circumstances are so rare that an ore body might be considered a freak of nature. The Britannia Mine ores provide a good example of one such 'freak of nature'.



Iron ore.

Copper-rich ore.

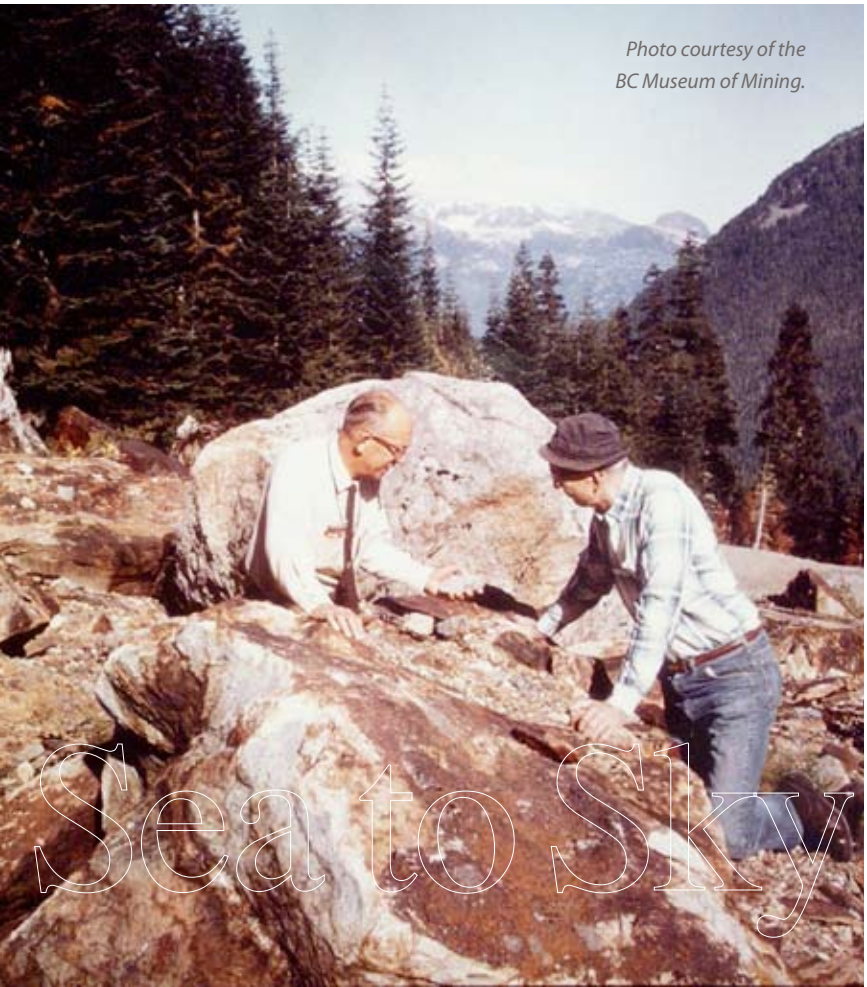
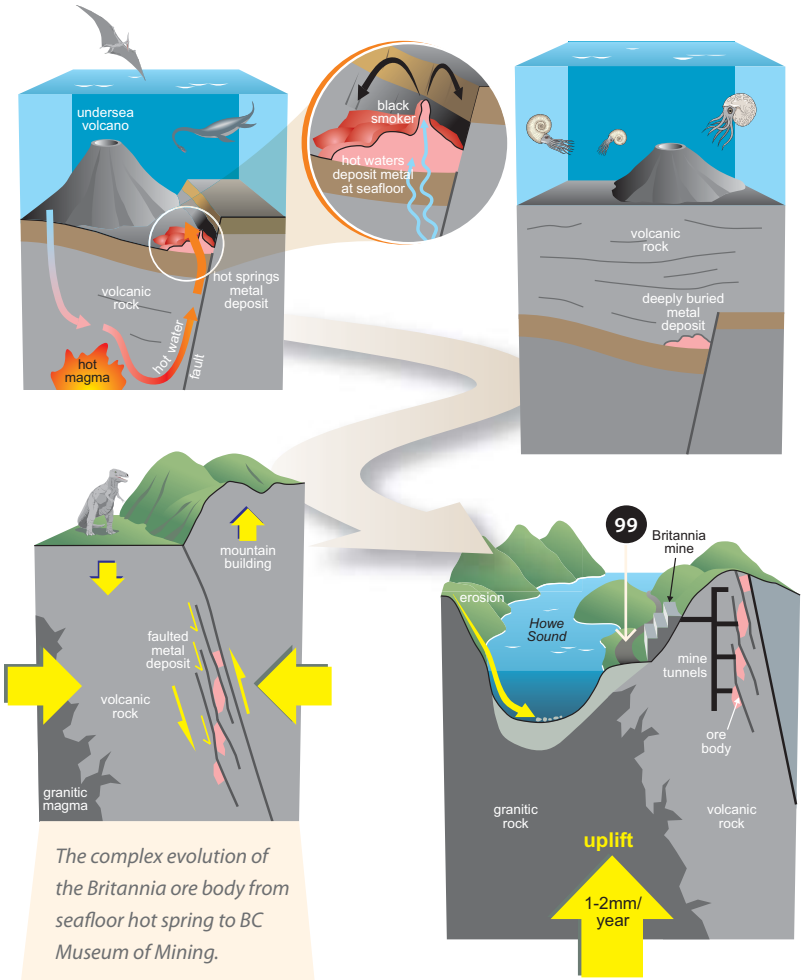


Photo courtesy of the BC Museum of Mining.

Geologists believe the Britannia Mine ores formed a hundred million years ago when a hot spring deposited metals on the volcanic seafloor. Heated seawater, circulating deep through volcanic rocks, leached metals from the rocks. The metals were carried to the seafloor, where they accumulated as a large deposit. Seafloor mud and lava from nearby volcanoes covered the metals, protecting the deposit from dissolving back into the seawater. Much later, the ores were faulted and folded during several periods of uplift and mountain building. Erosion from rivers and glaciers then carved mountains, exposing part of the ores to alert prospectors and the rest is history.

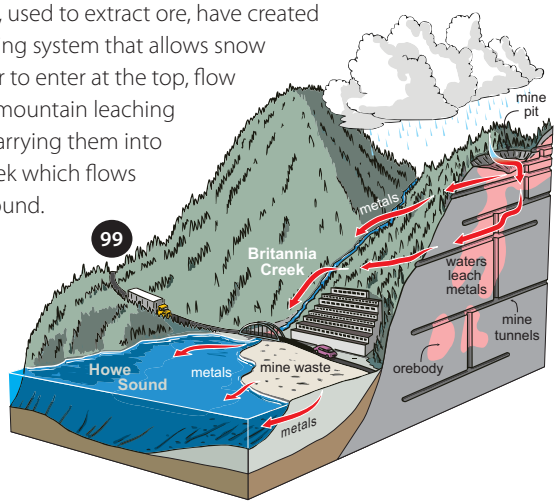


The complex evolution of the Britannia ore body from seafloor hot spring to BC Museum of Mining.

Sea to Sky GeoTour

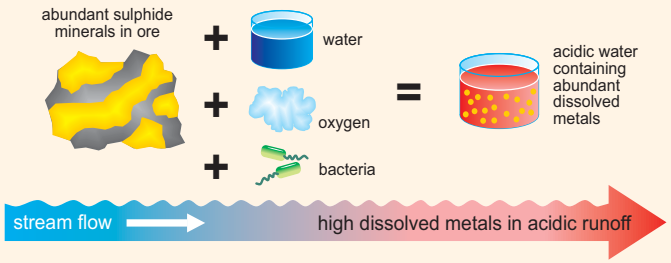
The Problem: Metals that Move

The challenge at Britannia Mine has been to stop the metals, including copper, from leaching out of the remaining ore and tailings. Copper ores occur throughout Britannia Mountain. Mine tunnels, used to extract ore, have created a vast plumbing system that allows snow and rainwater to enter at the top, flow through the mountain leaching metals and carrying them into Britannia Creek which flows into Howe Sound.



Acid Rock Drainage

How do metals dissolve in water? When some metal ores come into contact with air and water, they dissolve. This chemical reaction creates both sulphuric acid and dissolved metals. Any ore exposed to air and water, such as in mine tunnel walls or buried in waste piles, can generate acid and dissolved metals which can then be transported by flowing waters. Acid rock drainage is a significant challenge many mining operators must address today.



Acid rock drainage results from the reaction of ores rich in iron sulphides with water, oxygen, and bacteria to form acidic waters capable of dissolving and transporting metals.

The Solution: Capture and Treat

The solution at Britannia Mine has been to capture and treat metal-bearing water. Mine water now runs through a treatment plant that removes copper and other metals. Lime is added to neutralize the acid. It captures the metals as sludge and the sludge is put back in the mine.

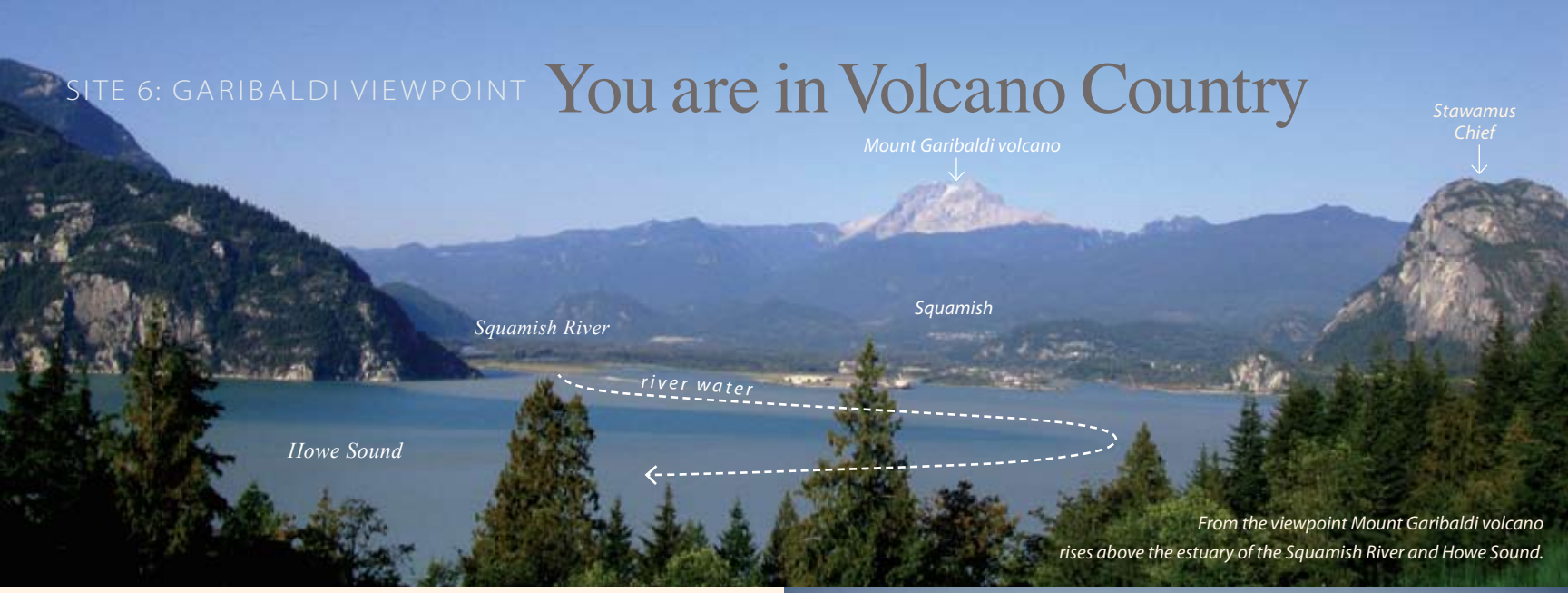
GETTING THERE:

Britannia Beach sits on the shores of Howe Sound and Highway 99, about 33 kilometres north of Horseshoe Bay. The BC Museum of Mining is housed on the property of the former Britannia Mine, once the largest copper mine in the British Empire.

Sea to Sky GeoTour

SITE 6: GARIBALDI VIEWPOINT

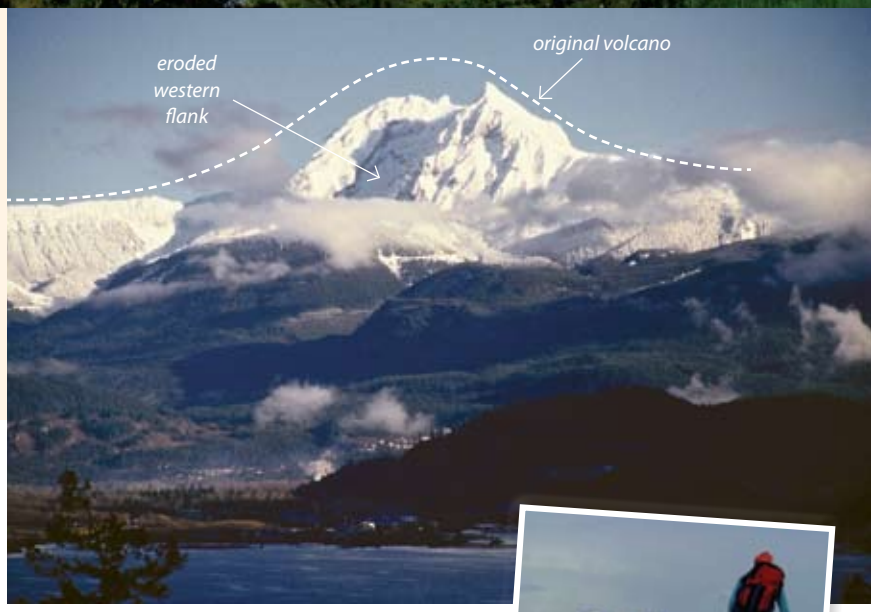
You are in Volcano Country



From the viewpoint Mount Garibaldi volcano rises above the estuary of the Squamish River and Howe Sound.

A Volcanic Chain

DISGUISED BY EROSION AND COLLAPSE, MOUNT GARIBALDI IS A MAJOR VOLCANO, PART OF A CHAIN ALONG THE COAST OF THE PACIFIC NORTHWEST THAT INCLUDES MOUNT BAKER NEAR VANCOUVER AND MOUNT ST. HELENS NEAR PORTLAND IN OREGON. YOU ARE IN VOLCANO COUNTRY!



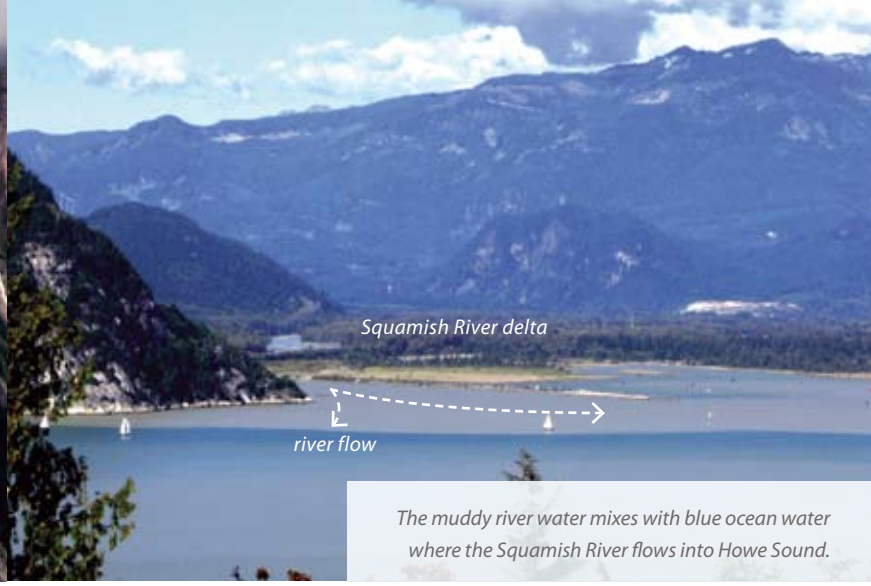
Mount Garibaldi: Only Half a Volcano

Mount Garibaldi doesn't look like a volcano. It lacks the cone-like shape of classic volcanoes like Mount Fuji in Japan or Mount Baker in Washington State. Erosion has had the upper hand over Garibaldi's conical construction from eruptions. In fact, only half of the original volcano still stands. This is because of the volcano's curious history combining both fire and ice.

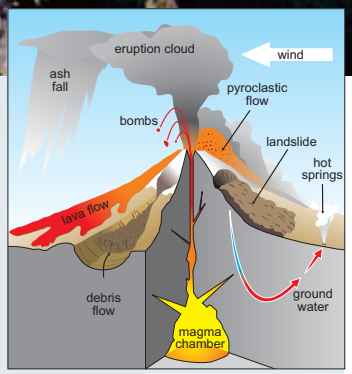
Mount Garibaldi erupted and built a large cone during the waning stages of the last Ice Age, about 13,000 years ago. At that time, the Squamish Valley was filled by a massive glacier.

The eruptions, which were explosive and fiery, built a cone of volcanic rubble and ash. On one side, the cone was built on a rock foundation, but to the west, the cone formed on top of the glacier. As the ice melted, the western part of the mountain collapsed in a series of giant landslides. Today, the remains of that half of the volcano lie as a giant fan of debris spread across the Squamish Valley north of Squamish.

Volcanoes: Poorly Built Mountains



The muddy river water mixes with blue ocean water where the Squamish River flows into Howe Sound.



A volcano can pose many dangers, most commonly landslides and debris flows.

Most mountains are made of rock uplifted from great depths during mountain building and then sculpted by erosion into mountains. Because the mountain rock was once buried deep within the Earth's crust, it has been 'pressure treated' and is strong and resistant to erosion. Volcanoes on the other hand, have never been buried. Instead they grow upward by successive volcanic eruptions. From an engineer's point of view, this is substandard construction: a mix of layers of lava, loose ash and volcanic rubble. As a consequence, volcanoes erode much faster than other mountains. Landslides, debris flows and rock falls are more frequent. This makes volcanoes more dangerous than other mountains.

Will Garibaldi Erupt Again?

Geologists don't know if Mount Garibaldi will erupt again. However, they do know that volcanoes can be dormant for tens of thousands of years or more and suddenly erupt again. Fortunately, eruptions are commonly preceded by days, months, or even years of warnings. Rising magma creates small earthquakes that are easily detected at seismograph stations in the region. Other warnings include change in the shape of the ground and release of steam and volcanic gases. So, we are unlikely to be surprised by an eruption.

Throughout British Columbia, we have many geologically "young" volcanoes. The occurrence of small earthquakes beneath some of these volcanoes over the past 25 years and the presence of warm or hot springs, tells us that the Sea to Sky corridor and other regions in British Columbia are still volcanically active.

Filling of the Fiord

The head of Howe Sound is a flat plain, covered by forest and marsh to the west, and the town and port of Squamish to the east. This plain is a delta built of sand and silt deposited by the Squamish River as it meets the ocean and loses its energy. The muddy-grey river water is distinct from the blue waters of Howe Sound. Measurements show that the river delta is advancing about four metres each year. Since the first Europeans visited the area in the 1700s, the delta has advanced about a kilometre, transforming ocean to new land.

GETTING THERE:

About four kilometres north of Britannia Beach, along Highway 99, there is a broad view of the end of Howe Sound. A pullout on the oceanside of the highway allows you to stop and enjoy the view. To the north is the solitary Mount Garibaldi rising almost three kilometres above Howe Sound.

SITE 7: SHANNON FALLS PROVINCIAL PARK

An Ice Age Hanging Valley

Shannon Falls cascades down pale coloured cliffs of granite.

Forest and Falls

Shannon Falls Provincial Park provides a short but lovely walk through a rain forest to a spectacular waterfall.

Why is there a Waterfall?

Viewed from across the highway, Shannon Falls flows from a valley high above craggy cliffs. Over the past ten thousand years, the small creek has barely made a dent into the hard rock it flows over. Before the last Ice Age, this high valley was once connected to the Howe Sound Valley by a downward slope. But the glacier steepened and deepened Howe Sound Valley, disconnecting it from little tributary valleys like Shannon Creek. The small side valleys which flowed into Howe Sound Valley were left hanging upon cliffs above the main valley floor. Such 'hanging valleys' are a common feature of glaciated mountains, as are the waterfalls that they create.

Photos this page by BC Parks.

GETTING THERE:

The access road to Shannon Falls Provincial Park is at traffic lights 40 kilometres north of Horseshoe Bay and four kilometres south of Squamish.

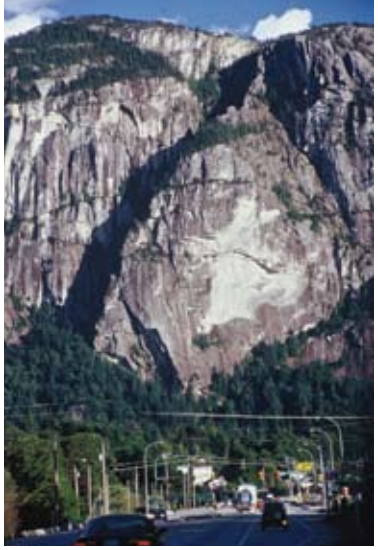
Spectacular ridges and grooves have been carved into granite along Highway 99 by the flow of ice age glaciers.

SITE 8: STAWAMUS CHIEF PROVINCIAL PARK

Granite Wall, Climbers' Mecca and Ice Age Sculpture

A Protruding Peak

Stawamus Chief, just south of Squamish, is perhaps the most famous geological landmark along the Sea to Sky Highway. On its western side, 700 metre high cliffs of granite, popular with rock climbers, rise above the highway. At its base, granite has been sculpted and striated by flowing glacial ice. A trail to the top ascends its gentler eastern slopes and provides an astonishing view of Howe Sound, the Squamish Valley and Mount Garibaldi.



Glacial Grooves: Tracks of the Ice Age

As you look up at the Chief, imagine two kilometres of glacier above you. Imagine enough ice to cover the top of the Chief, at 700 metres, and then add another 1,300 metres of ice. Imagine how that creeping glacier, armed with grit and stones stuck in its base, was able to carve and polish the rock it flowed across. Then look at the polished, scratched and sculpted rock beside the parking area and pedestrian overpass on both sides of the highway. The rock is sculpted into smooth ridges that look like the backs of whales. Look closely. The polished surface is marked by parallel scratches.

Making of the Chief

Several factors have created this incredibly steep, remarkable cliff. There has been little change to the tough granite that makes up the cliff since the last Ice Age. Large vertical cracks run parallel to the cliff. These cracks make the Chief behave like a deck of cards, sitting on end. Geologists believe that the last great Ice Age glacier, flowing down the valley, sheared away great slabs of granite from the mountain along these cracks, creating the cliffs we see today.

Coast Mountains are Granite Country

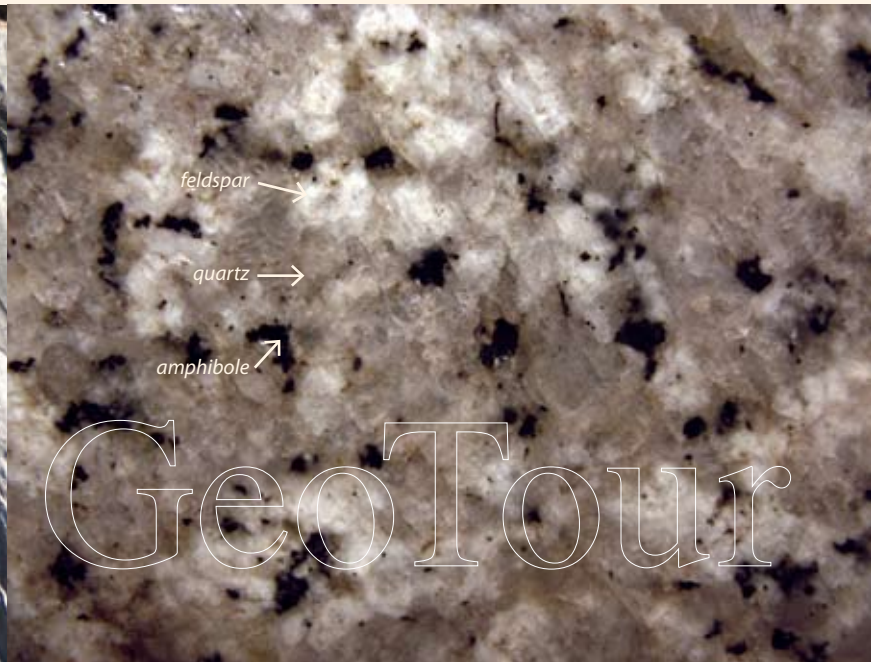
Granitic rocks are easy to spot. They have a salt and pepper appearance and texture made up of dark minerals and lighter coloured crystals of feldspar and quartz. We can think of granite as 'failed lava.' Granite is liquid rock that never made it to the Earth's surface, but rather cooled and crystallized deep underground.

The Chief is a portion of a former underground chamber of molten rock, now solidified and raised to the surface by mountain-building. The Coastal Mountains from Vancouver to Alaska form a great ridge of granite – the largest area of granite outcroppings in North America.

View of vertical and parallel cracks in the granite cliffs of Stawamus Chief. The sunlit parts of the cliff show where cracks – and slabs of rocks – used to be. In the shadows, thin slabs of broken granite lie between cracks in the rock, forming steps in the cliff surface.

A close-up of parallel scratches carved by stones embedded in the base of the Ice Age glacier (left).

A close up view of intergrown crystals in granite.



Sea to Sky GeoTour

A Steep Climb for a Stunning View

The climb up the backside of Stawamus Chief is steep and strenuous, but very rewarding. The trail climbs steadily, in part by staircase, to the rounded granite dome of First Peak. From there, the entire setting of Squamish – the town and the mouth of Squamish River - is revealed. Howe Sound and its surrounding mountains spread to the south. Enjoy the view!

The Squamish River enters Howe Sound directly below the viewpoint of First Peak on Stawamus Chief. The river dumps its load of sand and silt at the ocean, causing the delta front to advance seaward. The river has filled over 25 kilometres of ocean inlet since the last Ice Age, creating the Squamish Valley. The flat valley floor below you was all once ocean!

The granite top of First Peak of Stawamus Chief, over 500 metres above the ocean, has been rounded and scratched by a flowing glacier. At the peak of the last Ice Age, Stawamus Chief was covered by over a kilometre of flowing glacier.

GETTING THERE:

There are pullouts on both sides of Highway 99 (eight kilometres north of Britannia Beach and three kilometres south of downtown Squamish) that access the park. A pedestrian overpass connects the two sides.

Sea to Sky GeoTour

SITE 9: TANTALUS VIEWPOINT

Welcome to Glacier Country

The view of the rugged and rising peaks of the Tantalus Range. Ice age glaciers have flowed across and rounded all but the highest peaks.

A steep glacier cracks and breaks as it creeps down a steep valley carved into the north side of the Tantalus Range.

NORTH OF SQUAMISH, HIGHWAY 99 CLIMBS FROM THE SQUAMISH RIVER FLOODPLAIN, CROSSES THE STEADY SLOPE OF THE DEBRIS FAN BELOW MOUNT GARIBALDI AND THEN WINDS ITS WAY THROUGH ROCK HILLS ABOVE THE CHEAKAMUS RIVER CANYON. The Tantalus viewpoint offers a dramatic panorama of the glaciated peaks of the Tantalus Range and introduces us to the story of rising mountains and retreating glaciers.

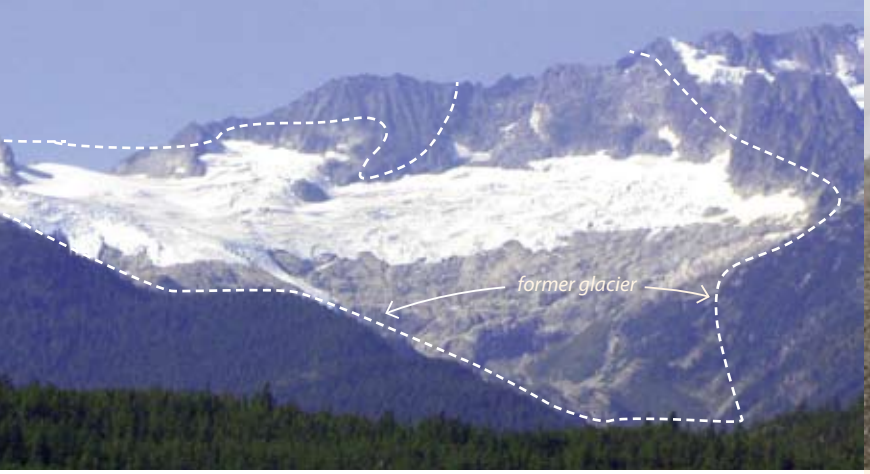
Mountains on the Rise

Rugged mountain landscapes are often rising landscapes, where uplift is outpacing erosion. Geologists believe the nearby Coast Mountains have risen about 2,000 metres in the last 10 million years and that uplift continues today at a rate of 1-4 millimetres per year. The land you see is in motion!

North Slopes and Icefields

The last Ice Age lives on in the high peaks north of Squamish. Glaciers in the Tantalus Range lie within steep rock basins on the north-facing side of the range. There they are partly shielded from direct sunlight and so have survived while glaciers on the south-facing, sunny slopes have melted much faster and are much less extensive today.

The largest glaciers in the Sea to Sky area are icefields that form great glacier-covered domes or uplands within broad mountain ranges. The Pemberton Icefield covers 300 square kilometres of mountainous area west of Whistler and glaciers flowing from the icefield are visible from Whistler Mountain. Local glaciers are fed by very high snowfall accumulations in the area. Moist air masses move eastward off the Pacific Ocean and are forced to rise up and over the Coast Mountain barrier where they then drop large amounts of precipitation.



Melting Mountains

Glaciers are in retreat around the world, including along the Sea to Sky corridor due to a warming global climate. The glacier in the photo above has retreated from its former position in the 1800s, evident by the large area of bare, grey-coloured rock. Geologists believe the glacier has lost about 50 per cent of its mass over the last 200 years. The rapid ice melt has increased the summer flow of local rivers, but this will decrease in the future if smaller glaciers disappear completely.

GETTING THERE:

There are two viewpoints, one on each side of the highway. The northbound viewpoint is about 16 kilometres north of downtown Squamish and is high above the highway. The southbound viewpoint is a roadside pullout with an additional view down the valley to Squamish and Howe Sound. Both viewpoints provide a panorama of the Tantalus Range.

These photos chronicle the retreat of the Wedgemont glacier near Whistler between 1979 (below) and 1998 (right). Photos courtesy of Steve Irwin.

Sea to Sky GeoTour

SITE 10: BRANDYWINE FALLS

Lavas and a Canyon-cutting Waterfall

A viewing platform provides great views of Brandywine Falls and canyon.

Lava Landscape

Travelling towards Whistler along Highway 99, you'll see a series of dark rocks with very distinctive column-like fractures. These are lavas that have erupted and flowed across the floor of the valley. You are in volcano country, and these lavas are part of that story. The turn off to Brandywine Falls Provincial Park lies within these lava outcrops and provides an opportunity to take a closer look at this lava landscape.

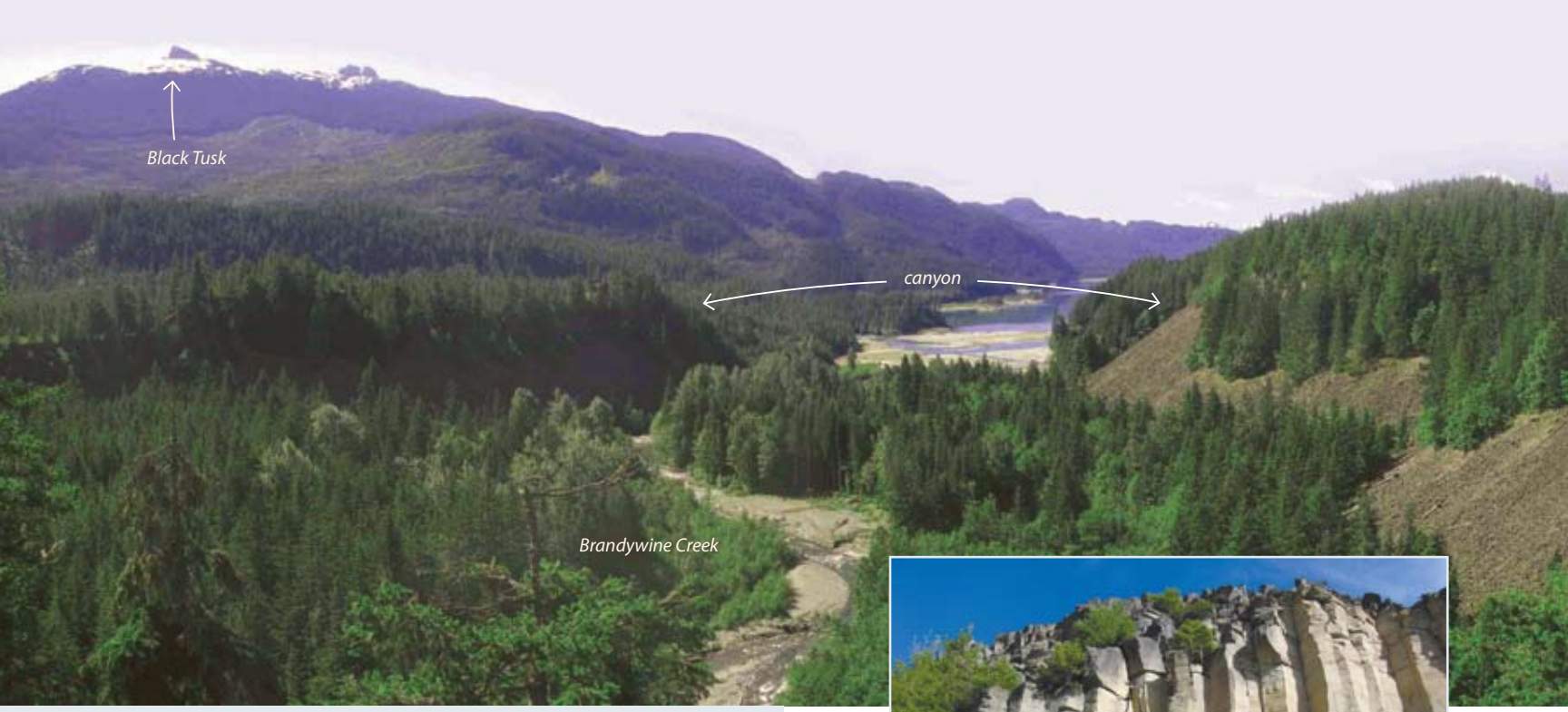
The park is well worth a visit. Walk a quiet trail over a stream and through the forest, to a viewing platform of spectacular Brandywine Falls and a deep canyon cut through the layers of lava rock.

A Canyon-cutting Waterfall

Near the parking lot, the trail crosses Brandywine Creek as it flows in a shallow notch cut into the valley floor. At the falls, this quiet stream suddenly cascades 70 metres into a canyon. From there, the creek travels down the canyon for half a kilometre to join the Cheakamus River.

Take a close look at the waterfall and canyon cliffs. The canyon wall exposes a series of lava layers that fill the valley. The uppermost lava layer overhangs other layers, suggesting it is more resistant to erosion. The lip of the waterfall flows from a shallow notch cut into the upper lava layer and cascades to a large pool. Behind the falls and pool is a shallow cavern. Erosion is active here, perhaps due to a combination of surging waves, abrasion, shock waves from the impact of falling water, continual wetting and ice wedging of rock cracks during winter. Rock erosion behind the falls undercuts the cliff, leading to the eventual collapse of the lip of the falls. This ongoing erosion slowly moves the position of Brandywine Falls upstream and leaves behind a half-kilometre long canyon in its wake. The waterfall and canyon will someday advance upstream to the parking lot area. The waterfall is indeed, a "canyon-cutter."

Sea to Sky GeoTour



A second viewpoint lies beyond the falls and looks across the lower canyon of Brandywine Creek to the well known volcanic spire of Black Tusk (site 11).

Lava Layers and Columns

Lava rock layers along the highway contain striking and regular cracks that divide the rock into columns. In the Brandywine Falls parking lot, lava columns removed during highway construction are used as decorative rock. At the first viewpoint you can see several layers of lava, each fractured into rough columns. Lava columns form as the erupted liquid lava cools from over 1000°C, all in a matter of minutes, hours or days. During this rapid cooling, the crystallized rock shrinks, causing regular fractures that form six- or seven-sided columns. These columns, along with many small holes caused by gas bubbles frozen in the rock during cooling, are sure indicators that you are looking at former lava.

Columns of lava rock along Highway 99.

Up close, lava rock often displays the casts of gas bubbles that were preserved as the lava quickly cooled and crystallized to rock.

Lava columns are used as landscape decorations in the park as well as in nearby Squamish and Whistler.

GETTING THERE:

The well-marked turnoff to Brandywine Falls Provincial Park is about 40 kilometres north of downtown Squamish and 10 kilometres south of Whistler.

Sea to Sky GeoTour

SITE 11: WHISTLER MOUNTAIN

Bringing it all Together at the Top of the World

A gondola provides easy access to the top of Whistler Mountain and a large viewing area with the ultimate panorama of peaks.

GETTING THERE:

Turn off Highway 99 in Whistler at the Village Gate Boulevard exit. Turn left at Blackcomb Way, then immediately right to enter the parking area. In the village you will find the Whistler Village gondola. There is a charge for the ride up the mountain.

From the Roundhouse Lodge at the top of the gondola ride from Whistler Village, take the chair or trail to the very top of Whistler Mountain, or the Peak 2 Peak gondola to Blackcomb Mountain. But first, walk through the lodge to the patio deck on the north side of the building. There is a 180-degree view across Whistler Village, the valley north towards Pemberton and the surrounding peaks, many with glaciers.

Whistler is an all-season resort and eco-tourism destination, drawing adventurers of all types to its peaks and valleys.

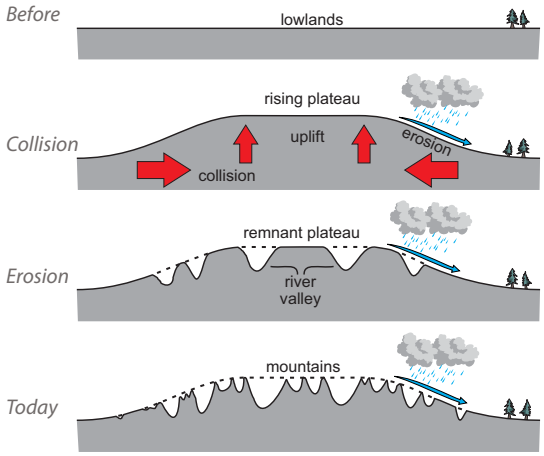
Mountaintop Wonders

No better views exist of the Coast Mountain Range than from the peaks of the Whistler-Blackcomb Resort. Go there and gaze in awe! Gondolas, chair lifts, mountaintop restaurants and numerous trails provide many options for exploring the alpine landscape of rock and meadow.

View of Whistler Village from the Roundhouse Lodge on Whistler Mountain. The tops of the highest peaks have a remarkably similar elevation which suggests they are carved from a former plateau.

The Surprising Flatness of Mountains

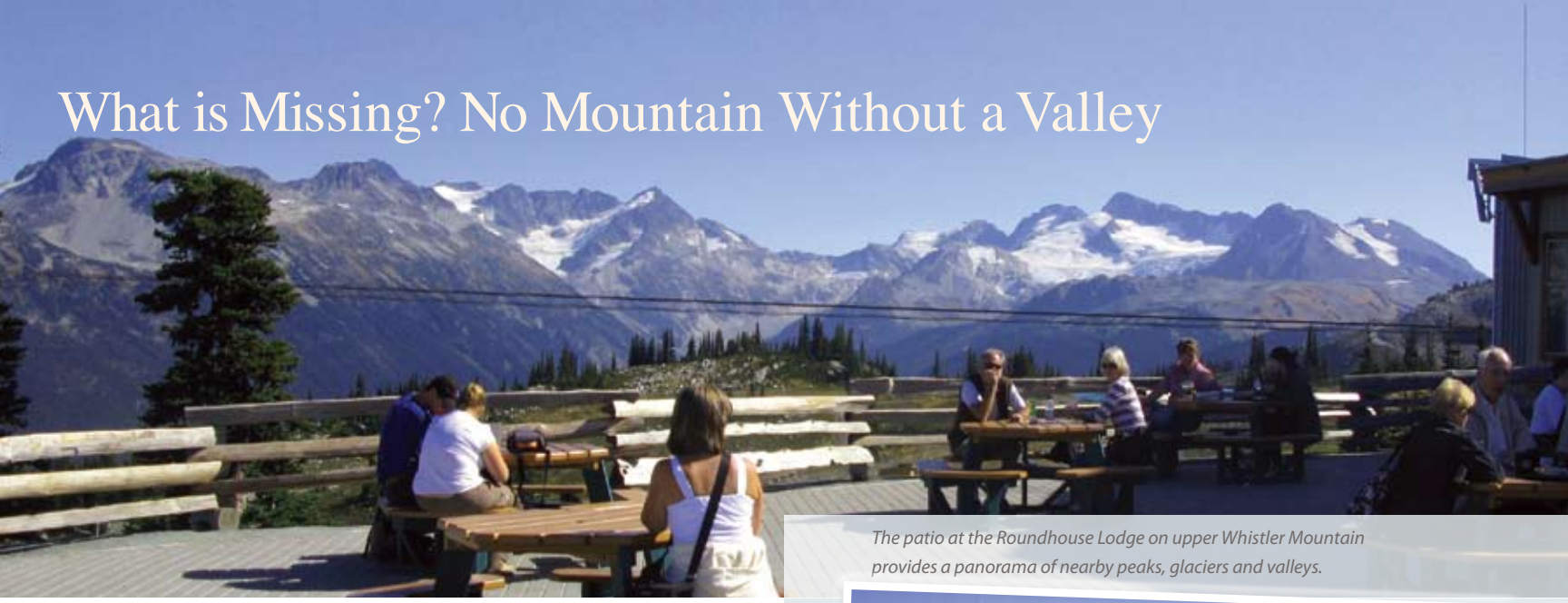
After you've taken in the stunning view, you might be surprised by the 'flatness' of the sea of peaks around you. Imagine a flat line or surface that roughly connects the tops of the peaks. Why do these steep, towering mountains seem so flat?



From Plateau to Mountains

When a collision of tectonic plates occurs, the land in the collision zone is compressed, heated and forced to rise, creating a broad upland. This high plateau may be rather flat, like the famous Altiplano of the Andes Mountains in South America. While faults can break the plateau into ridges, more commonly rivers cut a network of valleys into the plateau, creating ridges and peaks. Eventually, the original flat surface of the plateau is lost and only mountains remain. But for a period of geologic time, the tops of the highest peaks may sketch the approximate elevation of the original plateau surface. That is what we see today from Whistler Mountain – an indication of the original plateau that preceded the mountains.

What is Missing? No Mountain Without a Valley



The patio at the Roundhouse Lodge on upper Whistler Mountain provides a panorama of nearby peaks, glaciers and valleys.

WE TEND TO FOCUS ON MOUNTAINS AND THEIR PEAKS, BUT WITHOUT THE VALLEYS BETWEEN, MOUNTAINS WOULD NOT EXIST. If mountain peaks were once connected as a giant plateau of rock uplands, a tremendous amount of rock – removed from valleys – is missing. Looking at it from this point of view, the space between the peaks is quite remarkable. It's 'missing rock'.

To truly experience the space within a valley, take the Peak 2 Peak gondola from the Roundhouse Lodge. The cable for this gondola stretches across Fitzsimmons Creek Valley from Whistler Mountain to Blackcomb Mountain, a span of over four kilometres. At its highest point, the gondola is over 400 metres above the creek.

View of Whistler Village from the Peak 2 Peak gondola. The valley that Whistler lies within is the legacy of stream and glacier erosion that has removed vast amounts of rock debris and transported it to the ocean as sand, silt and gravel.

Rugged mountains rise above the Peak 2 Peak gondola that crosses the valley between Whistler and Blackcomb mountains. The empty space now traversed by the gondola was once solid rock lying below a plateau.

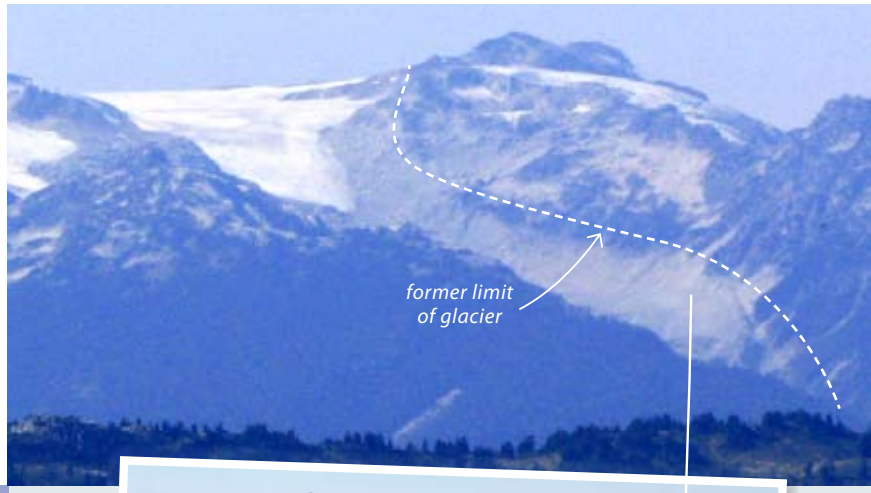
On the gondola, you hang in space high above the valley floor and far below the adjacent peaks. This space was once all rock. Looking downstream, the Fitzsimmons Creek Valley merges with the large valley that houses the town of Whistler. More missing rock! Where did it all go? Over millions of years, it has been broken and carried, bit by bit, by rock fall and landslide into streams. In turn, the streams carried the debris to rivers, and the rivers then flowed to the ocean. Ultimately, mountains end up in the oceans, accumulating as piles of silt, sand and pebbles on the seafloor. The ongoing advance of the Fraser River and the Squamish River deltas reflect the ongoing transport of bits of mountains to the sea on the 'conveyor belt' of rivers.

Glaciers, Icefields, Volcanoes and Valleys

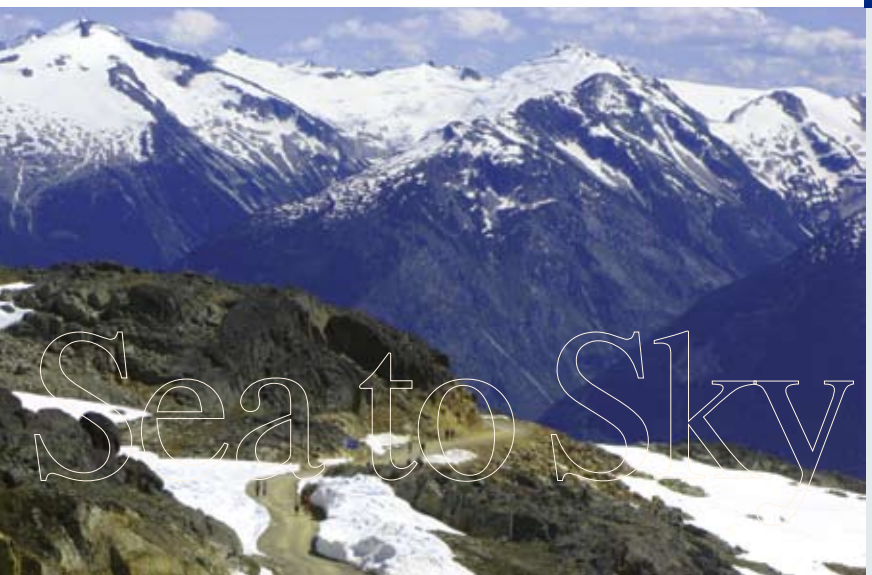
Back on Whistler Mountain, take the chair lift to the top of the peak. Here you will really feel on top of the world. In all directions there are peaks and valleys. There are a variety of trails to explore. But first, let's take a look at our surroundings.

Far to the west, on the skyline, a rock ridge is capped in part by a smooth glacier. Tongues of this glacier extend down into the valleys.

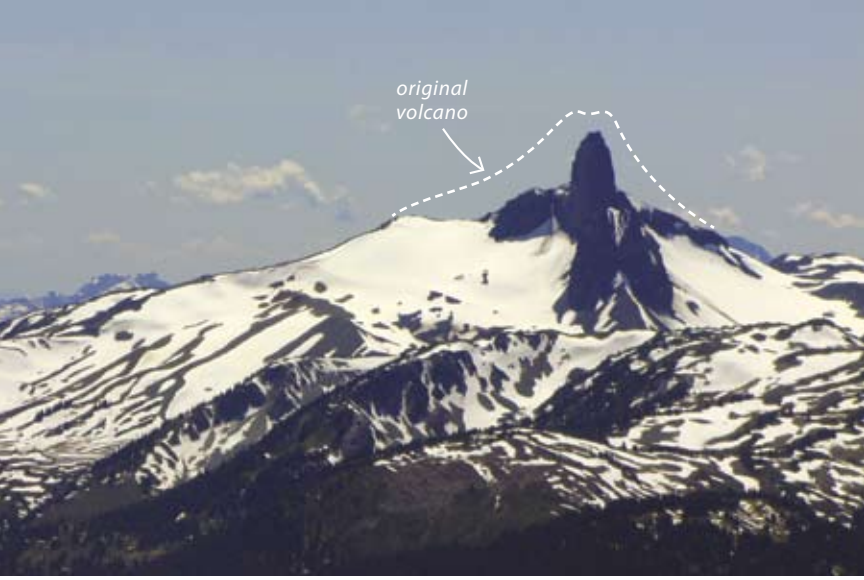
You are looking at the edge of the Pemberton Icefield, a vast glacial plateau that spills down side valleys. This Icefield is truly a remnant of the last Ice Age, now making its last stand in this high mountain region. Like other glaciers in the region, this Icefield is melting quickly and is in rapid retreat.



A view to the west from Whistler Mountain to the Pemberton Icefield.



Sea to Sky GeoTour



Black Tusk: Roots of a Former Volcano

Directly south and across a valley from Whistler Peak is a distinctive black spire rising from a gentle ridge. This is Black Tusk, the most distinctive feature on the skyline. Black Tusk lies within Garibaldi Provincial Park. The park protects a volcanic highlands famous for its glaciers, lakes and mountain wildflowers.

This region has many small volcanoes, in various states of erosion. Black Tusk is the most famous and is a popular hike and climb. The black spire is the remainder of a small cinder volcano and the spire was the conduit for rising lava. Fiery eruptions caused a cone of volcanic rubble to accumulate around this vent. Erosion has removed most of this volcanic cone, leaving the harder conduit as a volcanic spire.

So, we will leave you here, at the top of the mountain, hopefully with the time to take a walk and soak in this remarkable Sea to Sky landscape that shapes how we work and play. Incredible nature is all around you. Enjoy!

Sea to Sky