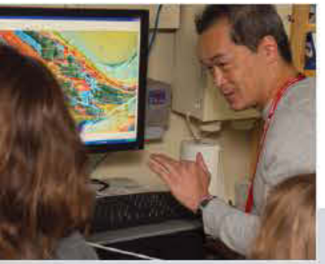
NATURAL RESOURCES CANADA
SCIENTISTS OF THE SALISH SEA

Philip Hill investigates potential hazards on and under the seafloor. Currently he studies the risk of underwater landslides in the Strait of Georgia.

Jane Wynne promotes geoscience education and outreach. She brings tsunami, earthquake and landslide science to Salish Sea schools and communities with the message "Be Prepared."

Audrey Dallimore is a marine geologist and visiting scientist. She uses information from the seafloor to study the frequency of earthquakes and tsunamis, and improve our understanding of the ocean around us.



Robert Kung is a Geographic Information Systems (GIS) specialist. His maps, used in this guidebook, provide scientists with data and detailed imagery of the seafloor.

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Salish Sea GeoTour

MARINE GEOLOGY AND GEOLOGICAL LANDSCAPES ON, UNDER AND AROUND THE SALISH SEA OF BRITISH COLUMBIA

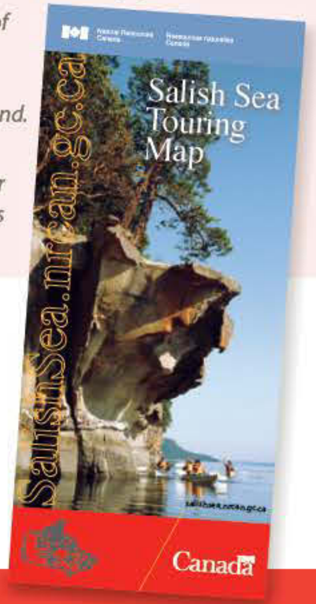
Explore the geology and landscape of the Salish Sea with your own geologist-in-your-pocket guidebook and map. Travel by water and land, over massive underwater sand dunes, ancient fault lines and disappearing islands.

Each section of the guide includes directions to stops of interest along the highways and ferry routes of the Salish Sea, an explanation of what you're looking at, and a description of the geological history of the area.

The Salish Sea includes the inland coastal waterways of southern British Columbia and Washington State, including the Strait of Georgia, Juan de Fuca Strait and Puget Sound.

In this guide:

- *Travel by ferry over a living sponge reef as big as several football fields at the entrance to Active Pass.*
- *Climb a 30-minute trail up Bodega Ridge on Galiano Island for an eagle-eye introduction to erosion by glacial ice flows.*
- *Take a close look at some of the wild and wacky netted patterns and shapes in the sandstone on Newcastle Island.*
- *Swim in 300-metre-deep Powell Lake, where the water at the bottom is 10,000 years old – and it's salty!*



Add to your experience with the Salish Sea Touring Map available from the Natural Resources Canada Bookstore: ***www.gsc.nrcan.gc.ca/bookstore.***

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.

SalishSea.nrcan.gc.ca

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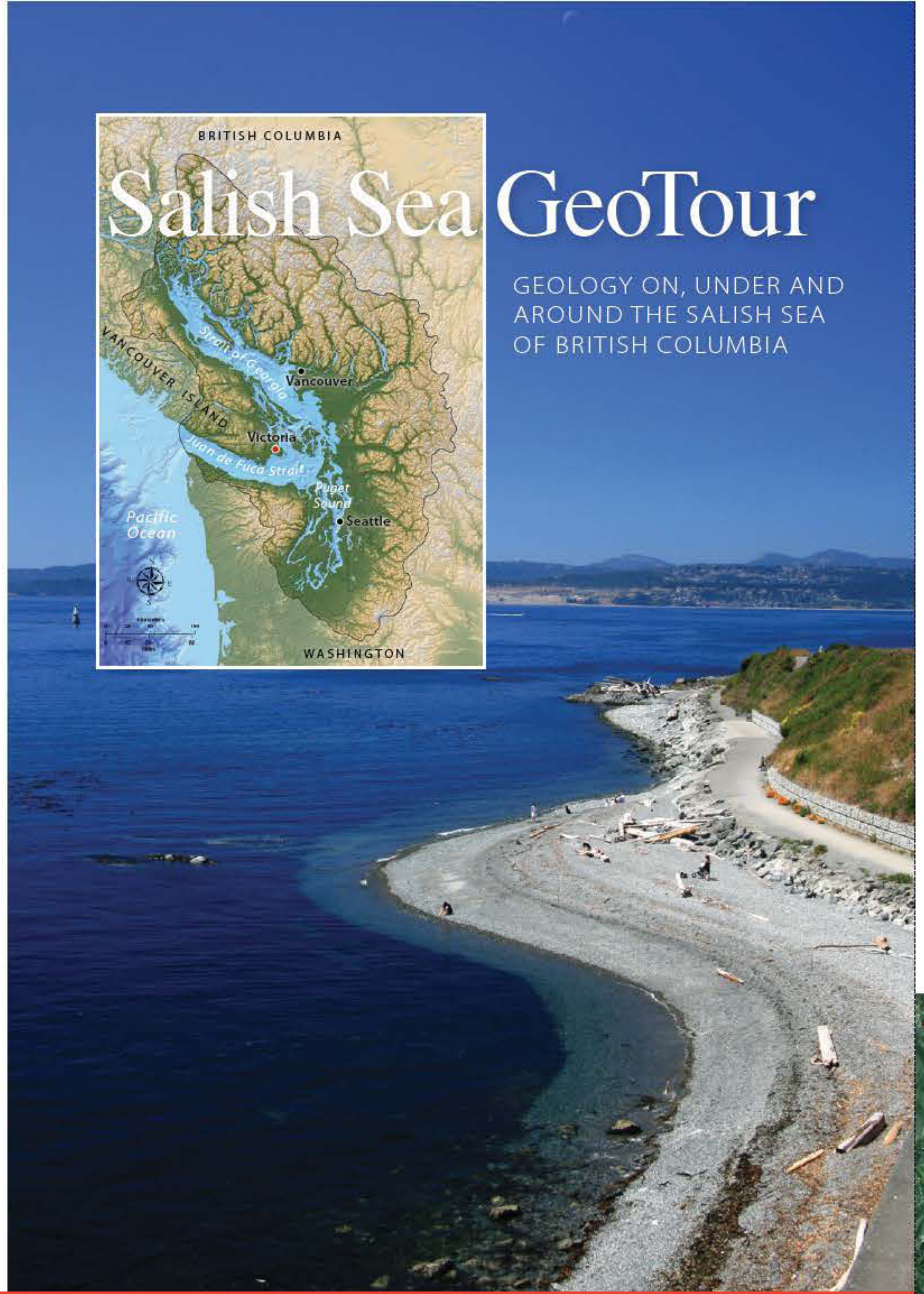
Salish Sea GeoTour: A GEOLOGY AND LANDSCAPES GUIDE

Canada



Salish Sea GeoTour

GEOLOGY ON, UNDER AND AROUND THE SALISH SEA OF BRITISH COLUMBIA

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Canada

Sea, the Final Frontier

WE KNOW MORE ABOUT OUTER SPACE THAN WE KNOW ABOUT OUR OCEANS, BUT NEW MULTI-BEAM SONAR TECHNOLOGY IS CHANGING THAT.

Bounce a tennis ball on the floor from different heights. The return times of the ball provides information on the distance between the ball and the floor. Now, bounce the tennis ball on a carpet, a cookie sheet and then on a telephone book. Note how the quality, or *energy*, of the bounce-sound changes as the surface changes. Multi-beam sonar works the same way. It sends out hundreds of beams towards the seafloor. The return times of the sound pulses from the sonar beams provide detailed information on the topography of the ocean floor - where the hills and valleys are. The returning energy of the beams tells geologists what the surface of the seafloor is made of: from loose mud, rippled sand or gravel beds, to clean, hard bedrock.

The colours on the multi-beam maps in this guidebook show the different depths of the seafloor in the Salish Sea region. The deepest parts of the seafloor are dark blue, while the increasingly shallow parts are yellow, orange and red. Scientists know a lot about the Salish Sea region above the water, but multi-beam technology is helping them explore the "final frontier." This guidebook provides a glimpse into that world.

Salish Sea GeoTour
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B TSAWWASSEN TO SWARTZ BAY
C GULF ISLANDS
D SIDNEY SPIT & JAMES ISLAND
E VICTORIA
F SAANICH INLET
G NANAIMO
H PARKSVILLE BEACHES
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Lasqueti
Sechelt
Gibsons
Parksville
Strait of Georgia
Vancouver
Nanaimo
Gabriola
Southern Gulf Islands
Fraser River
Delta
VANCOUVER ISLAND
Ladysmith
Kuper
Thetis
Galiano
Mayne
Saltspring
N&S Pender
Saturna
Duncan
Sidney
James Island
San Juan Islands USA
Victoria
Sooke
Juan de Fuca Strait
Pacific Ocean
This map shows data above and below sea level in the Salish Sea region. Land data was collected from the Canadian Digital Elevation Data web site geobase.ca/geobase/en/data/cded/index.html. Seafloor data was collected, and compiled with the land data, by the Geological Survey of Canada.
WASHINGTON
Puget Sound

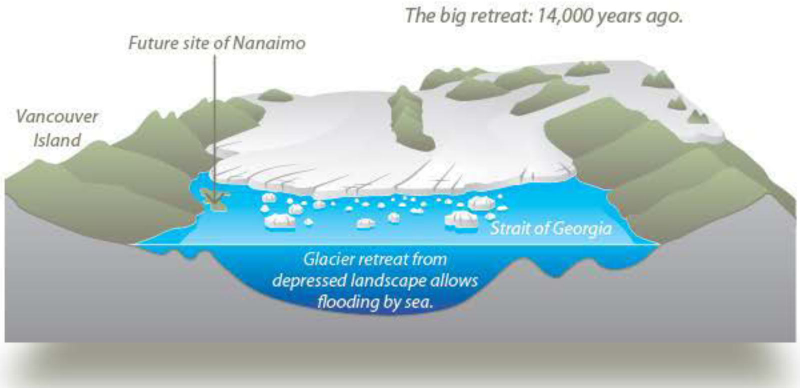
Geological Origins *of the* Salish Sea

THE SALISH SEA ENCOMPASSES THE INLAND COASTAL WATERWAYS OF SOUTHERN BRITISH COLUMBIA AND WASHINGTON STATE, INCLUDING THE STRAIT OF GEORGIA, JUAN DE FUCA STRAIT AND PUGET SOUND.

Approved by the Geographic Names Board of Canada, the British Columbia Names Office, the United States Board on Geographic Names, and the Washington State Board on Geographic Names, "Salish Sea" doesn't replace any of the existing official names, rather it's used to indicate the entire area.

The name honours the Coast Salish peoples who have lived in the Pacific Northwest for many thousands of years, and recognizes that the borders that exist between countries today do not affect flora, fauna, climate and geology.

This large ecosystem covers 18,000 square kilometres of water, and is home to seven million people, more than 200 species of fish, 20 different marine mammals, 100 types of birds, and over 3,000 invertebrate species. For visitors and residents, it's an area of great natural beauty, an important trade route, and a source of many natural resources. But, it's also an area influenced by massive and ongoing geological forces. Understanding the remarkable geology of the region, through exploration and research, is vital to the sustainability of the humans, plants, and animals that call the Salish Sea their home.



How the Basin Came to be

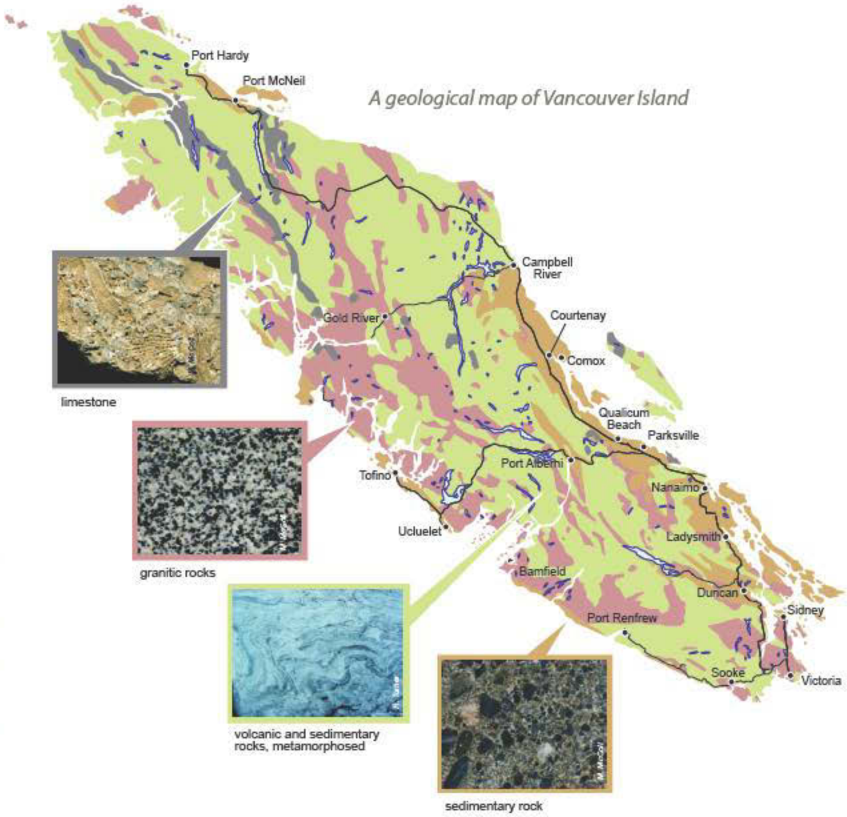
The Salish Sea Basin is a giant canoe-shaped depression created over the last 90 million years as the oceanic Juan de Fuca Plate slides under the continental North American Plate. This *subduction* process pushes up the rocks of coastal British Columbia to create the mountains on Vancouver Island, and the Coast Mountain Range on the mainland. The slow-moving subduction process continues today, changing the landscape, and creating the mountains, earthquakes and volcanoes characteristic of the region.

Many Types of Rocks

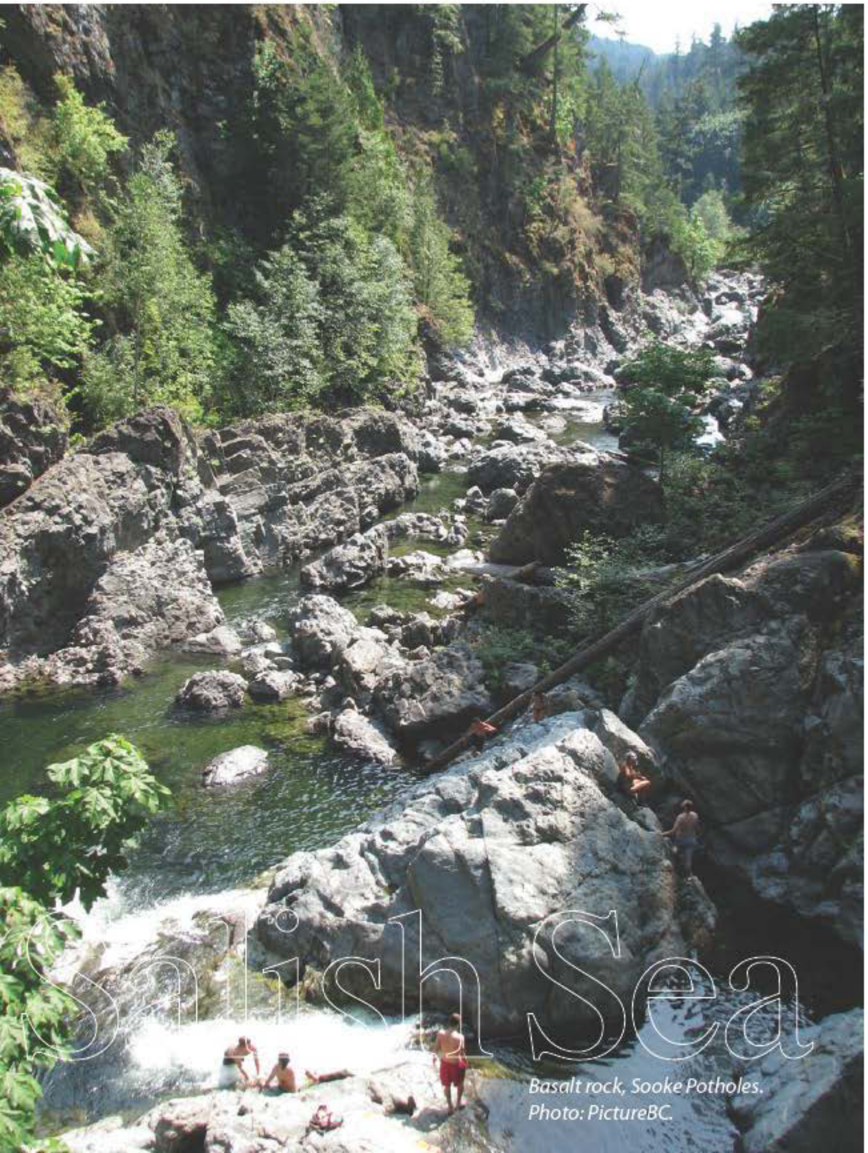
Tectonic forces are only one part of the Salish Sea story. The many types of rocks that form the mountains, lowlands and islands have played their own role in the landscape. Without having rocks to push, twist and shape, the tectonic plates and glaciers wouldn't have much of a story to tell.

The Mountains

Most of the oldest rocks in the Salish Sea area are a product of the interaction between tectonic plates. As the oceanic plate pushes under the North American Plate, ancient underground bedrock folds, faults, and is lifted to the Earth's surface, creating many of the mountains on Vancouver Island, and the Coast Mountains on the mainland.



A geological map of Vancouver Island



Basalt rock, Sooke Potholes. Photo: PictureBC.

The Lowlands

Starting about 90 million years ago, the Coast Mountains uplifted, and sand, gravel and mud eroded from the sides of the mountains, flowing downwards into the basin. Over time, this sediment compressed under its own weight and became sedimentary rock, called the *Nanaimo Group*. Geologists drilling a borehole near Tsawwassen encountered Nanaimo Group rock four kilometres below sea level. Nanaimo Group rocks, discovered on Vancouver Island, are one-and-a-half kilometres above sea level. These discoveries give geologists an idea of just how extensive the Nanaimo Group once was.

About 40 to 55 million years ago, tectonic movement tilted and folded the Nanaimo Group, creating the outcrops of rock seen around the Salish Sea today. Some of these distinctive sandstone outcrops can be seen along the TransCanada Highway, just outside of Nanaimo, and near the Duke Point ferry terminal. Today, 85 per cent of Vancouver Island's population live on Nanaimo Group rocks.

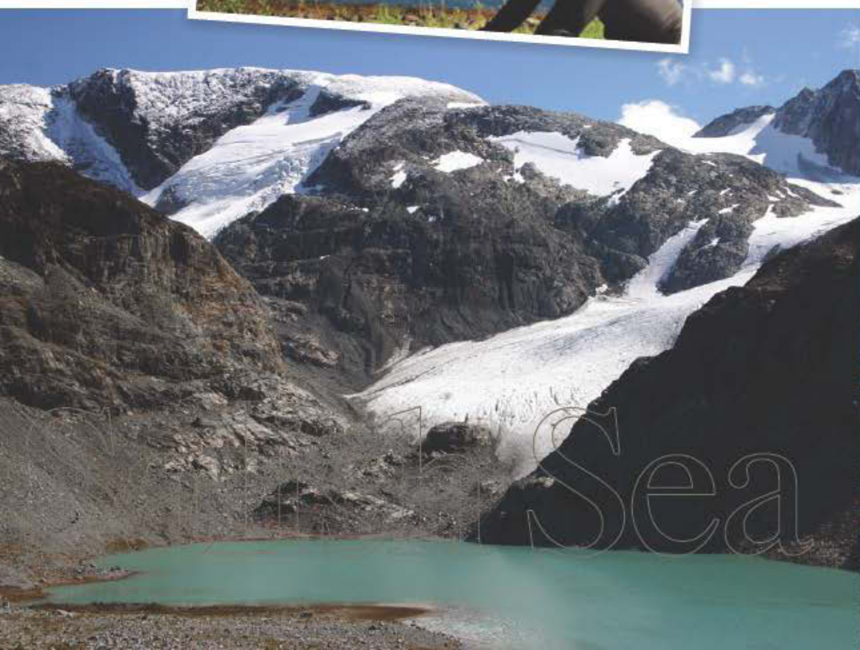
GeoTour

Glaciers

Glaciers play a significant role in the geological history of the Salish Sea. There have been at least eight ice ages in the area, going back two-and-a-half million years. The last Ice Age began about 35,000 years ago when the climate turned much colder and wetter, and glaciers began to grow in the nearby mountains. Glaciers flowing from the Coast Mountains filled the Salish Sea with almost two kilometres of ice, and buried nearly all of Vancouver Island. Looking up at the mountains, you can see just how high the ice was – for example, the peak of Mount Arrowsmith on Vancouver Island is rough and jagged because it protruded above the ice. Compare this with a lower peak, such as Mount Finlayson, which has a smooth, round summit. During *glaciation*, ice completely covered Mount Finlayson.

The amazing thing about glaciers is they can take many thousands of years to build, and only a few hundred years to melt and disappear. Throughout this guide, you'll see information on the legacy of the glaciers. They've created many of the inlets, shaped the mountains and rocks, changed the sea level, and left behind a tremendous amount of sediment.

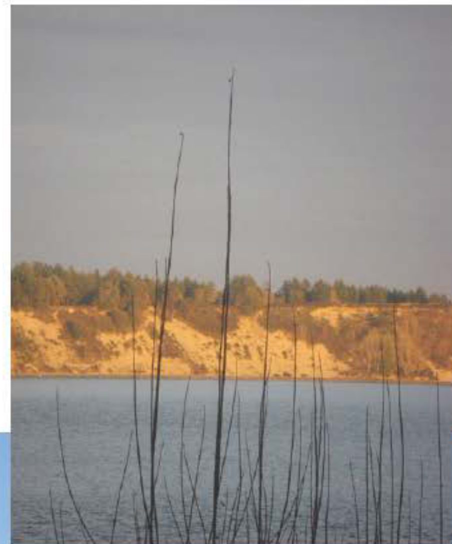
Wedgemont Glacier, near Whistler.



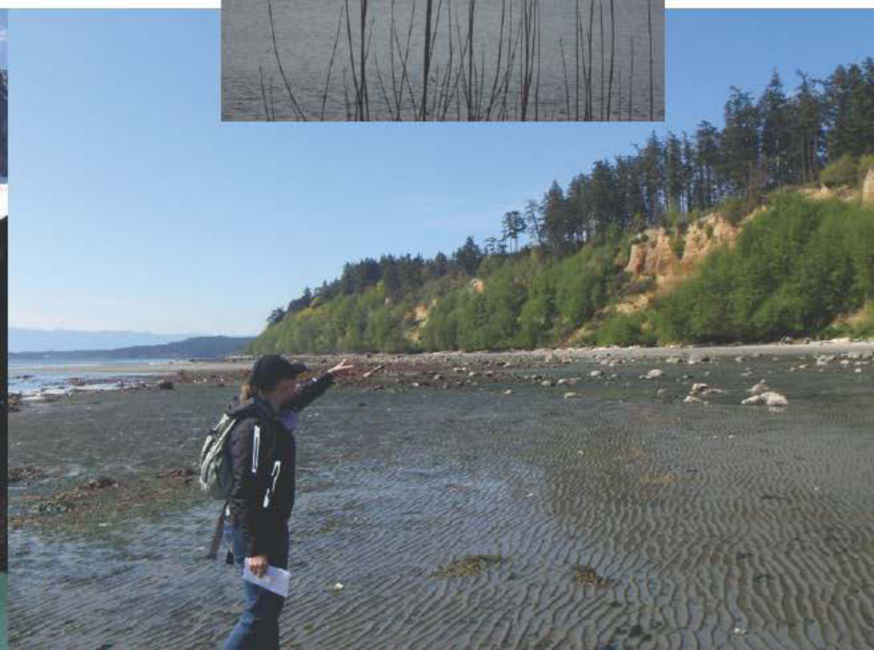
Glacial Sands

As the glaciers from the last Ice Age melted, they left behind thick sand and gravel deposits now called the *Quadra Sands* (also known as the *Quadra Formation*). Geologists have proven that this distinctive white quartz sediment came from the Coast Mountains. Pockets of the Quadra Sands are preserved in an area over 240 kilometres long, 40 kilometres wide, and up to 100 metres thick in places. Today, you can still see the Quadra Sands in the cliffs of Point Grey in Vancouver, in the Sechelt gravel pit on the Sunshine Coast, and in the sea cliffs of Quadra Island near Campbell River and James Island near Victoria.

The Quadra Formation is also a treasure trove of fossils. Mastodon teeth and bones found in the Quadra Sands tell the story of long-extinct *megafauna* that roamed the Salish Sea region before the last Ice Age.



Quadra Sands make up the cliffs of James Island (left), and Witty's Lagoon (below), near Victoria



Changing Sea Levels

When the ice in the Salish Sea Basin started to melt at the end of the last Ice Age, about 14,500 years ago, shorelines were between 60 and 120 metres higher than they are today. In areas like Parksville, gardeners will often find shells in their gardens, high above today's shoreline – proof of much higher sea levels existing thousands of years ago. A process called *glacial loading* and *rebound* highly impacted sea levels. Glacial loading and rebound is like pushing into memory foam. The weight of your hand makes an indent in the foam (loading), and it takes time for the foam to spring back in place once you've removed your hand (rebound).

It took about 25,000 years for the ice load to build up in the Salish Sea, but only about 300 to 400 years for it to melt, leaving a very large dent in the Earth's crust. Over the next few thousand years, the land slowly rebounded from the weight of the ice.

At the peak of the last Ice Age, much of the Earth's surface water was contained in the ice sheets. As the ice sheets melted, the sea level rose. However, once the land started to rebound from the weight of the ice, the sea level dropped once more, reaching today's levels about 5,000 years ago. We can see evidence of these changes in the different levels in the shoreline at Parksville and other areas on Vancouver Island and the Gulf Islands.

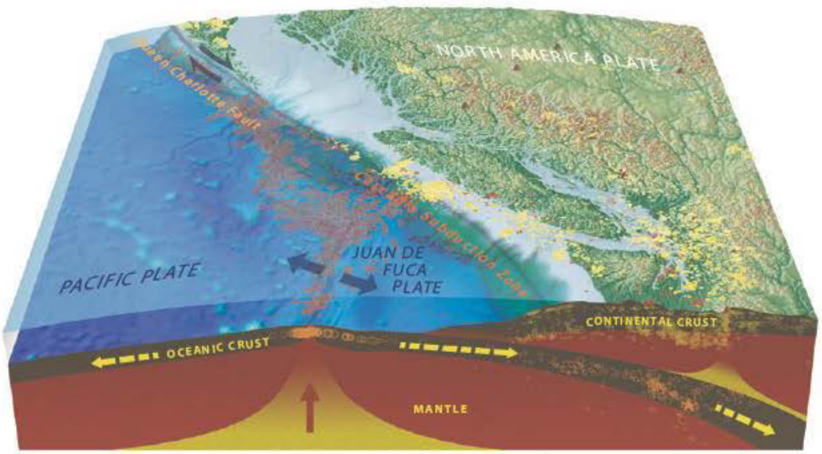
Currently, sea levels all over the world are rising because global climate change is causing the oceans to warm and expand, and polar ice caps to melt. Residents of the Salish Sea region may notice changes in sea level, especially in the Richmond area. Scientists predict Richmond's sea level could rise by half-a-metre in the next 100 years, partly because of warming water temperatures, and partly because the thick pile of sediments deposited by the Fraser River is compacting under its own weight (loading). However, communities in the northern Salish Sea region won't notice rising sea levels as much because the motion of tectonic plates under their feet is raising bedrock in the area, a few millimetres a year. Although sea level rise will vary across the Salish Sea, it's still important to plan for extreme storm events and sea surges caused by a changing climate.

A Note on Earthquakes and Other Hazards

The Salish Sea is located above the boundary between the oceanic Juan de Fuca Plate and the continental North American Plate. This boundary, the Cascadia Subduction Zone, spans 1,000 kilometres from northern Vancouver Island to northern California. The Juan de Fuca Plate is descending or *subducting* beneath southwestern British Columbia at roughly the same rate as fingernails grow – about four centimetres per year.

Approximately 400 earthquakes occur each year in the Cascadia Subduction Zone. However, only about a dozen of these earthquakes are felt by people. Earthquakes capable of causing structural damage happen every decade or so, and are typically greater than magnitude 5 (M5). However, the Salish Sea region is also due for a much larger earthquake. The last "big one" happened in the year 1700, and seismologists warn the area is due for another *megathrust* earthquake (M8 or greater).

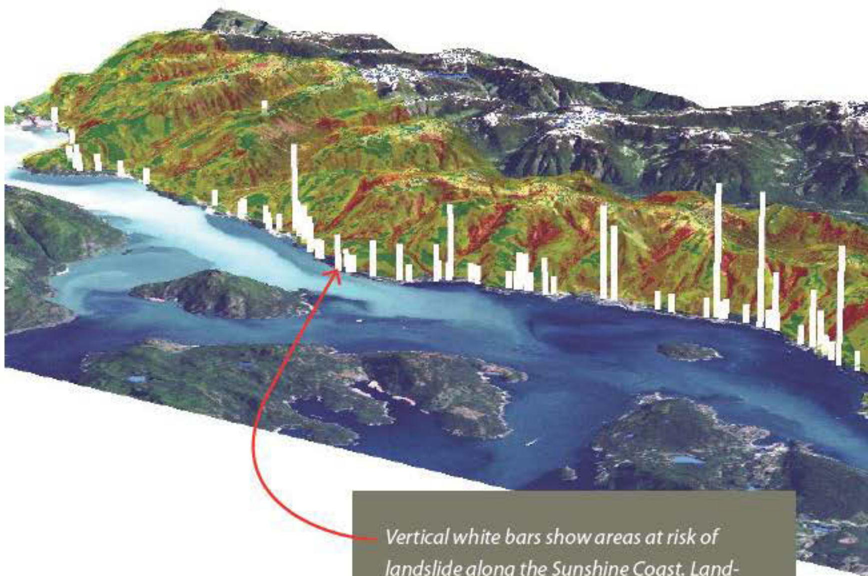
Visit **EarthquakesCanada.nrcan.gc.ca** for more information.



The yellow and orange dots show past earthquake activity in the Salish Sea Region.

When we think of tsunamis, we think of earthquakes like the devastating 2004 Indian Ocean earthquake and tsunami that killed over 230,000 people. However, large landslides can also trigger tsunamis either underwater, or from a cliff or mountain on the shoreline. When a large event like a landslide displaces water, it can cause waves to propagate away from the disturbance. You can even get a tsunami in a lake! In the Salish Sea, a local tsunami generated by a landslide is far more likely than from an earthquake.

On many of the unstable shorelines along the coast, and especially along the Sunshine Coast, a landslide could trigger a local tsunami. Another area that marine geologists watch is in front of the Fraser Delta. Sediment from the Fraser River collects on a steep, underwater slope. A submarine slide – when built-up sediment slides down the underwater slope – would also displace a large amount of water and trigger a tsunami.



Vertical white bars show areas at risk of landslide along the Sunshine Coast. Landslides are common in the Coast Mountains because of the combination of loose glacial sediments, steep slopes and heavy rainfalls.

FRASER DELTA: A LAND OF SAND

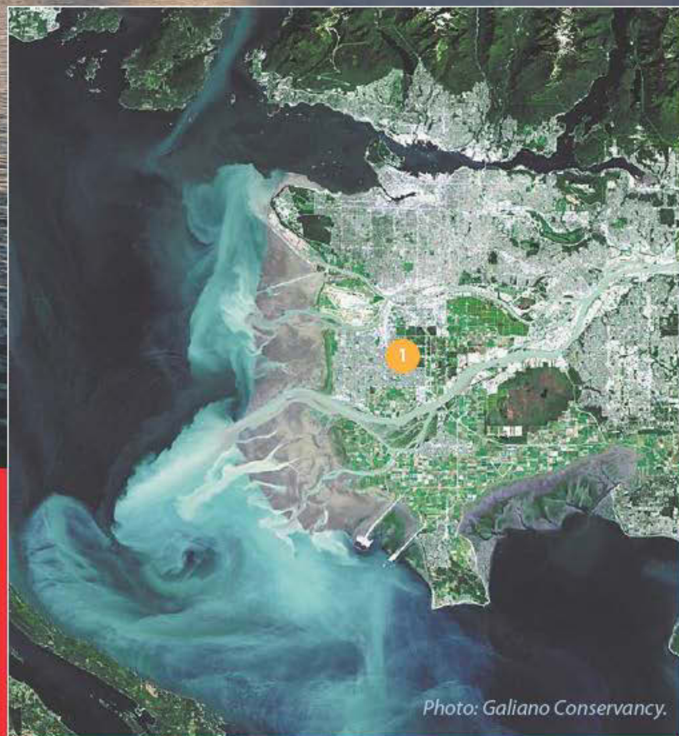


Photo: Galiano Conservancy.

Geology of the Salish Sea is a complicated story, and there are still many things to discover, especially beneath the sea. Take your time as you travel, and enjoy your tour. It's an area rich in geological history, and the evidence of the glaciers, earthquakes and sea level changes are all around you in the rocks, fiords and fossils.

Salish Sea GeoTour

A Land of Sand

A Land-building River

OVER 1,300 KILOMETRES LONG, THE FRASER RIVER TAKES IN WATER FROM A QUARTER OF BRITISH COLUMBIA'S LANDMASS, AND ACCOUNTS FOR ABOUT TWO-THIRDS OF THE FRESH WATER ENTERING THE SALISH SEA. Among other things, the river is used for transportation, recreation and fishing. It's a source of water for farming and power (on tributaries), and supports five species of salmon and 65 other species of fish, including steelhead and giant sturgeon.

This massive river gathers eroded rock and soil from across British Columbia and carries it south to the sea. The river has built over a hundred square kilometres of new floodplain land, including the entire city of Richmond, since the end of the last Ice Age.

The Delta Forms

The Fraser River Delta began to form about 10,000 years ago. Before that, the area now known as New Westminster was oceanfront property. Today's locations of Richmond, Coquitlam, Langley and Delta did not exist.

As the glacial ice retreated from the Salish Sea region, the Fraser River began to drop water-suspended debris at the point where the river met the ocean. The constant addition of sand, mud, rock and clay to the land's edge pushed the shoreline further out to the Pacific Ocean, and up toward what is now Pitt Lake, resulting in the landscape that we recognize today.

Valuable Plains

The Fraser River Delta is the largest delta in western Canada and its wide, flat plains are extremely valuable. Deposits of silt and clay from the river create fertile agricultural land, while a growing population increases the demand on the area for urban and industrial development.

The delta provides habitat for many wetland species including plants, insects, breeding waterfowl, reptiles, amphibians and mammals. It's recognized as a globally significant estuary, and is part of the Pacific Flyway, hosting large numbers of migratory birds as they travel north and south each season.


Photo: Seadoc Society


Photo: Seadoc Society


Photo: Picture BC.

To see the Fraser Delta habitat in action, visit the Reifel Island Migratory Bird Sanctuary, just west of Ladner. Some 230 species of birds use these grounds. A network of trails and blinds allow you a glimpse into the importance of the estuary to wildlife.

Contact the BC Waterfowl Society at 604-946-6980 for more information.

The Delta in Retreat

If it weren't for human intervention, the delta would look very different. Today, large ships drag machinery along the river bottom to remove accumulated debris. Dredging helps maintain shipping channels, while numerous dykes prevent the river from overflowing, and infrastructure like bridges and shipping docks change the natural flow of the river. Because sediment is no longer added, parts of the delta front are slowly eroding.

If you're driving from Vancouver to Tsawwassen, take the time to stop at Deas Island Regional Park, off Highway 99. Five kilometres of trails run beside the Fraser River and Deas Slough. You can almost touch the massive container ships as they travel up the Fraser River, giving you a good idea of the importance of the river to the Lower Mainland economy. You may also see the dredging ships at work as they try to keep sediment from building up at the river mouth.

Photo: Picture BC.

About two-and-a-half million cubic metres of sand are dredged from the Fraser River's shipping channel each year (below).

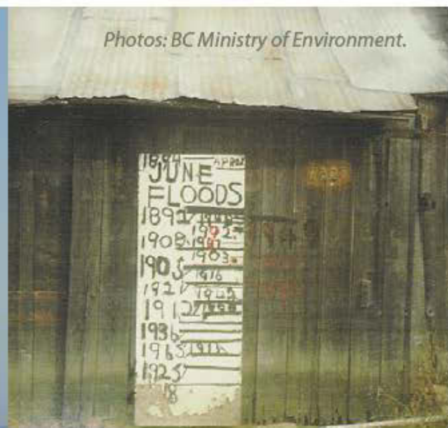
Flood!

The Fraser River used to flood regularly. In 1894, a massive flood, caused by rapid snowmelt, destroyed early settlements across the Lower Mainland and the Fraser River Delta. Fortunately, the Fraser's largest recorded flood did little damage due to sparse settlement in the area. However, residents of the Lower Mainland and Fraser Delta weren't as lucky in 1948. Seven metres of floodwater covered nearly one-third of the Fraser Delta! The floodwaters damaged rail lines and the Trans-Canada Highway, damaged or destroyed 2,300 homes, and left the entire floodplain covered in silt, driftwood and debris. The damage to the area totalled approximately $20 million ($210 million 2011 dollars).

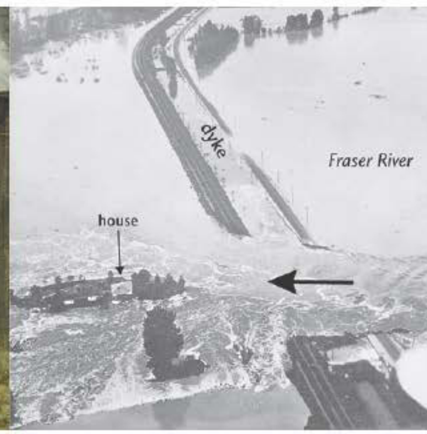
Today, 600 kilometres of dikes, 400 floodboxes, and 100 pump stations protect communities in the Lower Mainland. However, flood control remains an ongoing challenge, particularly for those communities built across the low-lying mud and sand that makes up the delta.

Since many of the dikes also function as walking and cycling trails across the Fraser Delta, you can get close enough to see how they work for yourself. They're also a good way to see the geology of the delta at work. Access Boundary Bay Regional Park from several parking spots in Delta and Ladner, and take the dike trail. Note how the dike skirts the mudflats. At one time, the mudflats extended much further inland – evidence of delta building. You'll also see plenty of birds, plants and other animals that depend on the delta.

Photos: BC Ministry of Environment.



Flood levels on a barn door, Fraser Valley.



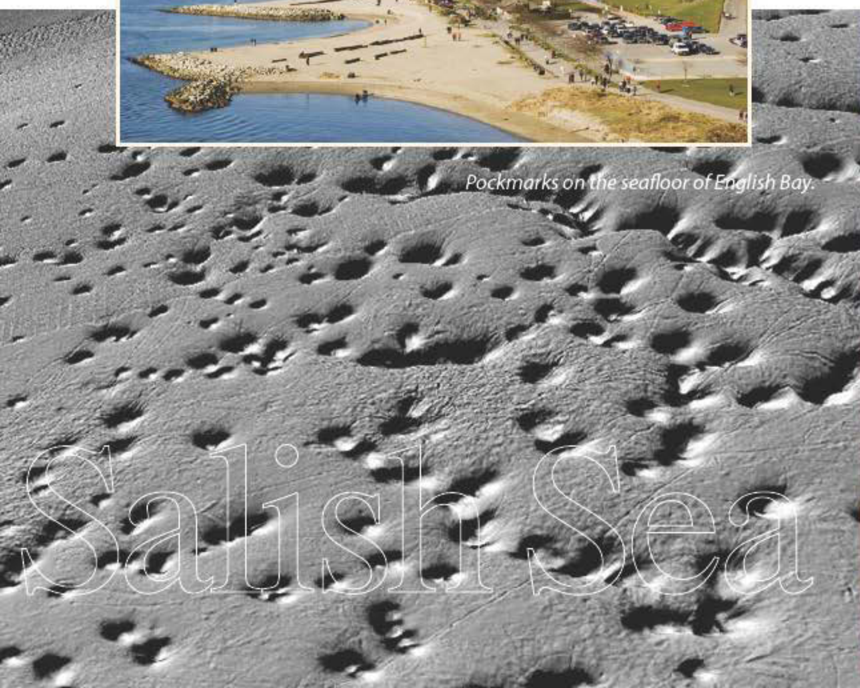
Flood waters breach a dyke near Mission, 1948.

Pockmarks are Craters on the Seafloor

If you could stand on Kitsilano Beach, and look through a telescope underwater to the bottom of English Bay in downtown Vancouver, you would see hundreds of craters dimpling the seafloor. Today, scientists use multi-beam imagery to do just that. Called *pockmarks*, these craters range in diameter from five to 100 metres wide, and are up to 15 metres deep. Their existence is also linked to the story of the Fraser River.

The Fraser Plume carries fine sediment from the river mouth to several distant locations, including English Bay at the mouth of Vancouver Harbour. The sediment has large quantities of organic matter in the form of wood and leaf debris. Once deposited, bacteria rapidly attack the organic matter, removing all the oxygen and generating methane gas. Sometimes this gas escapes from the sediments, and forms craters on the seafloor. The pockmarks at English Bay are located only 16 to 65 metres below the surface, so they can potentially pose a challenge to shipping lanes if they suddenly release fluid or gas.

English Bay. Photo: Picture BC.



Pockmarks on the seafloor of English Bay.

VENUS - the Seafloor Seer

The ocean is as difficult as outer space to study. Traditionally scientists work from ships, send down instruments to the seafloor, and bring them back up to recover the data. But, technology is providing a new way to study the oceans, and the Salish Sea is the proving ground. The Victoria Experimental Network Under the Sea (VENUS) is a cabled seafloor observatory that monitors the Fraser Delta, the Strait of Georgia and Saanich Inlet. Instruments sit on the seafloor and send data to the VENUS facilities via fibre optic cable. The most exciting part about the VENUS network is that the videos, images and readings are available online in real time! So, any ocean explorer, including you, can access this rich bank of information. By accessing information recorded around the clock, scientists gain a better understanding of the underwater processes, hazards and ecology of the Salish Sea.

Photos: VENUS.

For more information on VENUS visit **www.venus.uvic.ca**

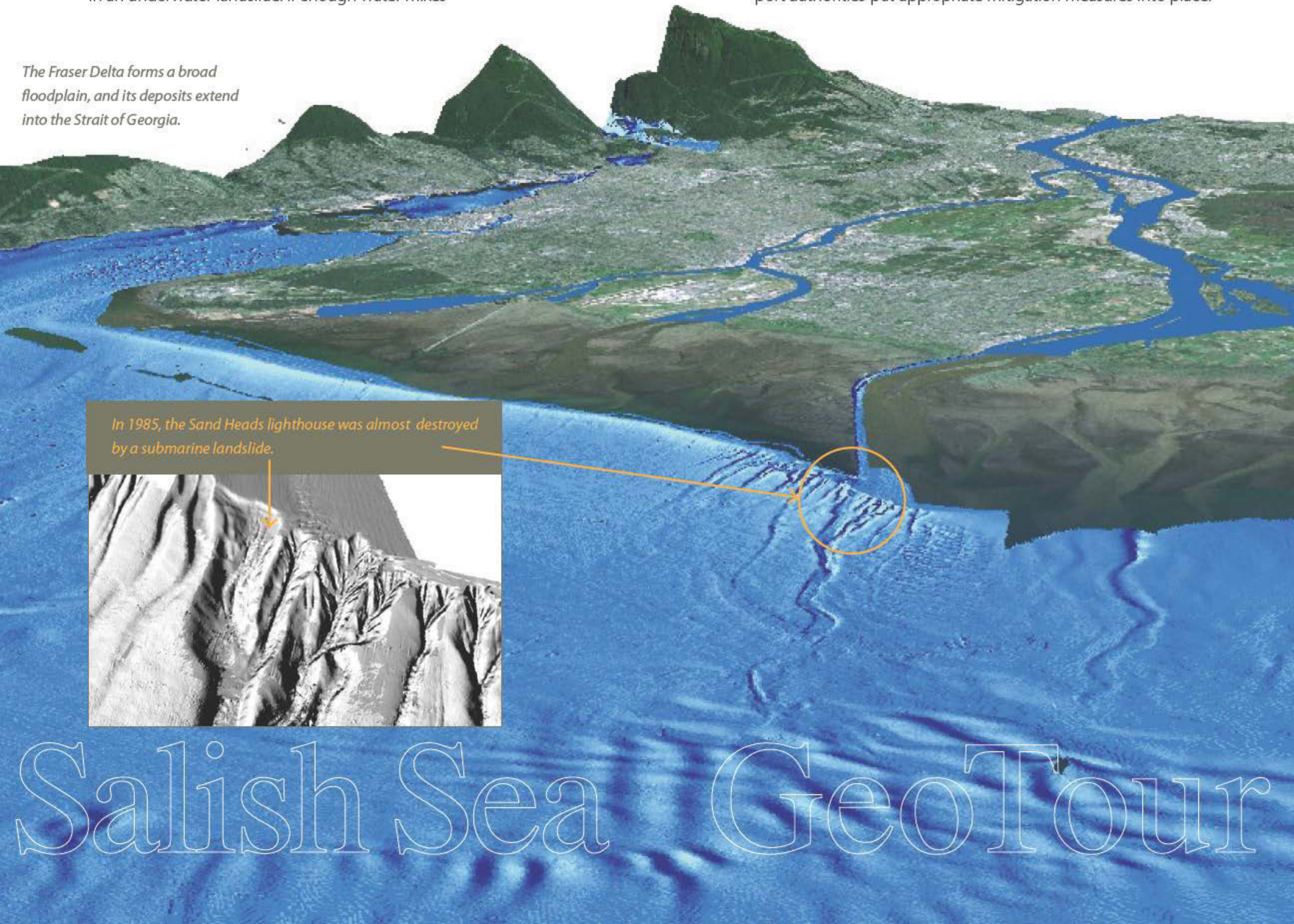
Under the Surface, a Landslide

In front of the Fraser Delta, VENUS instruments measure how sediment travels underwater. The Fraser River deposits approximately 18 million cubic metres of sediment to the delta and edge of the Salish Sea every year. If all that sediment was mud, it would be enough to cover downtown Vancouver with six metres of mud every year!

When the fresh river water enters the Strait of Georgia at the mouth of the river, the sediment quickly sinks. This creates an underwater pile of sediment, which gets steeper and steeper until eventually, it becomes unstable and a portion breaks off in an underwater landslide. If enough water mixes into the landslide, it transforms into a fast-moving, powerful flow of sediment and water called a *turbidity current*. Driven by gravity, the turbidity current flows down the underwater pile of debris, and creates deep channels along its path. Some of these *submarine channels* are over 25 metres deep.

Scientists are concerned that this pile of sediment may fail and result in an underwater landslide. This could also trigger a tsunami. As part of the VENUS project, Natural Resources Canada tracks where new sediment is deposited, and what causes landslides on the delta slope. Being able to predict a *submarine slide* will help port authorities put appropriate mitigation measures into place.

The Fraser Delta forms a broad floodplain, and its deposits extend into the Strait of Georgia.



In 1985, the Sand Heads lighthouse was almost destroyed by a submarine landslide.

GETTING THERE:

To reach Deas Island Regional Park, take Highway 99 towards Delta. At the Highway 17 junction, take 62B Street, which becomes River Road. The entrance is well marked.

To visit the Reifel Migratory Bird Sanctuary, take Ladner Trunk Road (Highway 10) west to 47A Ave. and onto River Road. Drive three kilometres and cross the bridge to Westham Island, following the road to the large black gates. The driveway to the left leads to the sanctuary parking lot.

Boundary Bay Regional Trail is accessible from several locations. If you're near Tsawwassen, take Highway 17 south to Tsawwassen. Turn left on 56th Street, turn left again on 12th Street, and right on Boundary Road. The park entrance is on your left.

TSAWWASSEN TO SWARTZ BAY

Salish Sea GeoTour

Travelling the Tides to Victoria

Tsawwassen Ferry Terminal

IF YOU'RE COMING FROM VANCOUVER ON HIGHWAY 99, TAKE THE EXIT TO HIGHWAY 17 TOWARDS TSAWWASSEN. SIGNS FOR THE FERRY TERMINAL ARE WELL MARKED.

The Tsawwassen Ferry Terminal is located at the edge of the shallow tidal flats that surround the Fraser Delta shorelines. As you get close to the ferry terminal, you'll notice a large number of vehicles and campers parked on the rocky beach on the south side of the causeway. The shallow depths in the bay, which cause bigger boats navigational grief, are perfect for angling and many other water activities. While you wait for the ferry, look towards the large port facility next door. It is both a container terminal and a coal-shipping terminal – the largest coal export facility in Canada.

The seafloor is dredged to allow deep-draught ships (like ferries and container ships) to access these waters. For more information on why dredging is necessary, see the Fraser Delta section in this guidebook.

In front of the port facility, strong tidal currents rip along the steep submarine slopes that mark the point where the shallow underwater plains of the delta give way to the deep seafloor of the Strait of Georgia. If you could stand on the seafloor, you'd see how the strong currents have created a number of underwater sand dunes. In some areas of the Salish Sea, where tidal currents are very strong, these sand dunes can be many metres high.

A Trip through the Plume

Photo: VENUS.

AS THE FERRY LEAVES TSAWWASSEN, YOU'LL SEE AN AREA OF LIGHTER, BROWN-COLOURED WATER AS THE BOAT MAKES ITS WAY TOWARDS VANCOUVER ISLAND. YOU'RE TRAVELLING THROUGH THE FRASER PLUME.

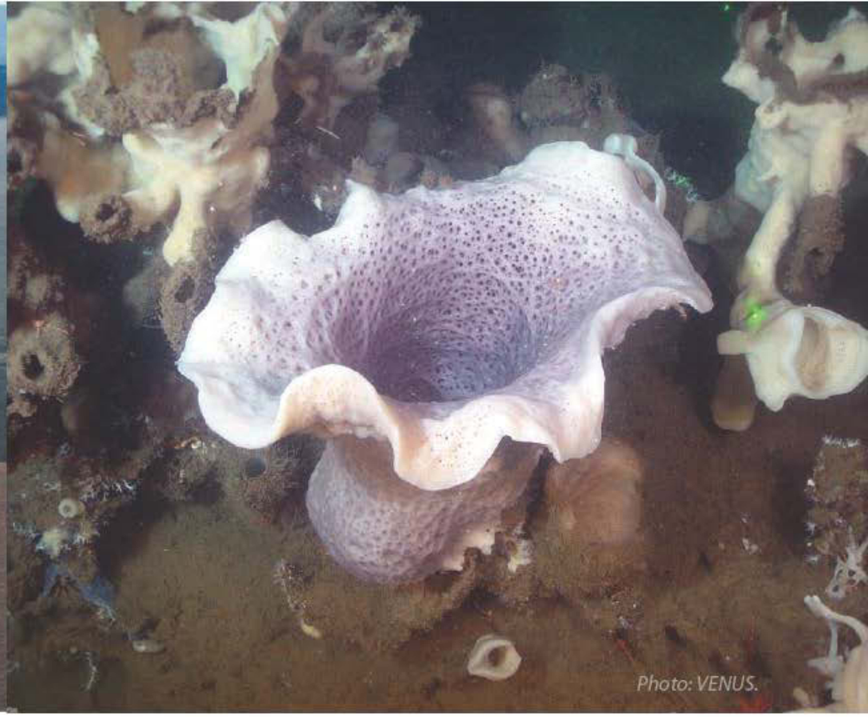


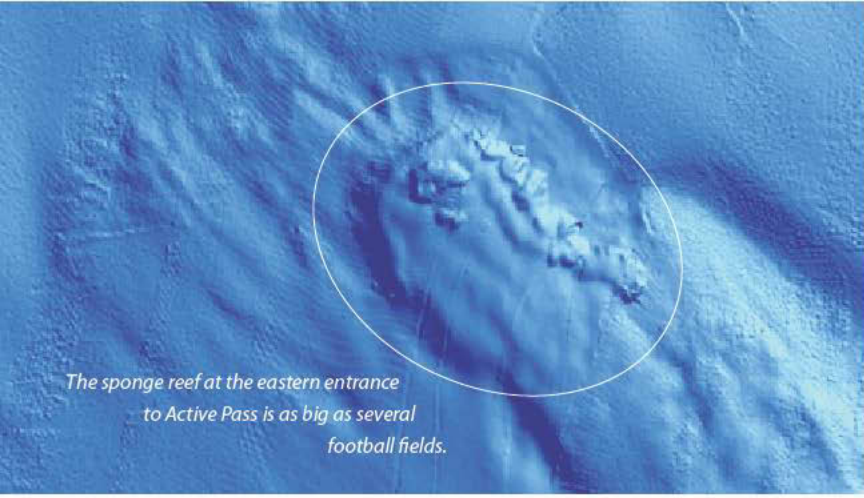
Photo: VENUS.

When the flow of the Fraser River is particularly strong, especially in the spring, the river carries a large load of sediment. When the river reaches the Strait of Georgia, the sediment suspended in the river water is propelled into the ocean, forming a noticeable plume. The large area covered by the plume gives us a good idea of the enormous amount of sediment and fresh water that enters the Strait from the river every day. And, because the dispersion of the river water depends on tidal and wind-driven currents, the shape of the plume is constantly changing, making for spectacular photos from the air.

Unique Sponge Reefs

Sponges are found worldwide in deep water, but the only known place sponges form reefs is on the continental shelf of British Columbia. The restricted geographic distribution of these reefs is partly due to the type of material found on the floor of the Salish Sea – the reefs grow where the seafloor is made of bedrock or coarse gravel, but will not grow on mud or sand.

Sponge reefs provide habitat for a range of ocean creatures, including this squat lobster.



The sponge reef at the eastern entrance to Active Pass is as big as several football fields.

Travelling over Top of a Reef

New multi-beam technology is helping scientists detect the presence of these delicate and important underwater reefs. Surveys have located several reef patches in the Salish Sea, and to the north, along the British Columbia coast in Queen Charlotte Sound, and in Hecate Strait, east of Haida Gwaii. The reefs support a complex ecosystem, which is quite different from that of the surrounding ocean floor; and, are valuable nursery habitats for juvenile rockfish – which can live to be more than 100 years old – as well as many other species of fish and invertebrates.

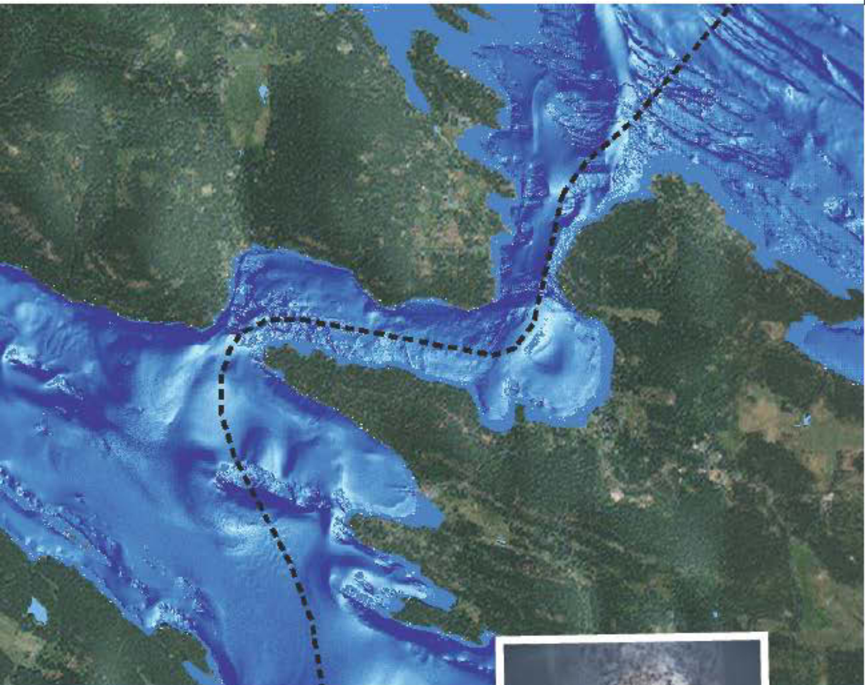
A healthy sponge reef lives at the eastern entrance to Active Pass, part of the main ferry route between Vancouver and Victoria. It is as big as several football fields, with individual sponge mounds as tall as four metres high. Scientists estimate that the reef is several centuries old! A second reef nearby, just south of Active Pass, is largely dead, with many broken pieces. Groundfish trawling likely damaged the reef before scientists even knew of the existence of a reef in this location.

Since 2006, other areas in British Columbia, with similar reef structures, are closed to groundfish trawling. Some of these reefs cover 1,000 square kilometres, grow up to 25 metres tall, and are about 9,000 years old. Their existence leads scientists to believe there are still many other underwater discoveries to make.

Sponge reefs in British Columbia waters.

Active Pass – A Tight Squeeze

To reach Swartz Bay, just north of Victoria, the ferry has to navigate Active Pass, a narrow passage between Galiano and Mayne islands. Plotting a course through the pass is extremely difficult, not only because it is so small for such a large ship, but also because the tidal currents are very strong. As the ferry goes through the passage, you may feel the ship roll, and you'll see the swirling waters that demonstrate the great force of the tidal currents ebbing and flowing through their daily cycle. The strong currents prevent sediment building up on the seafloor, so there is exposed bedrock throughout the pass.



This multi-beam image, along the ferry route through Active Pass, shows the bedrock bottom stripped of all sediments by powerful currents.

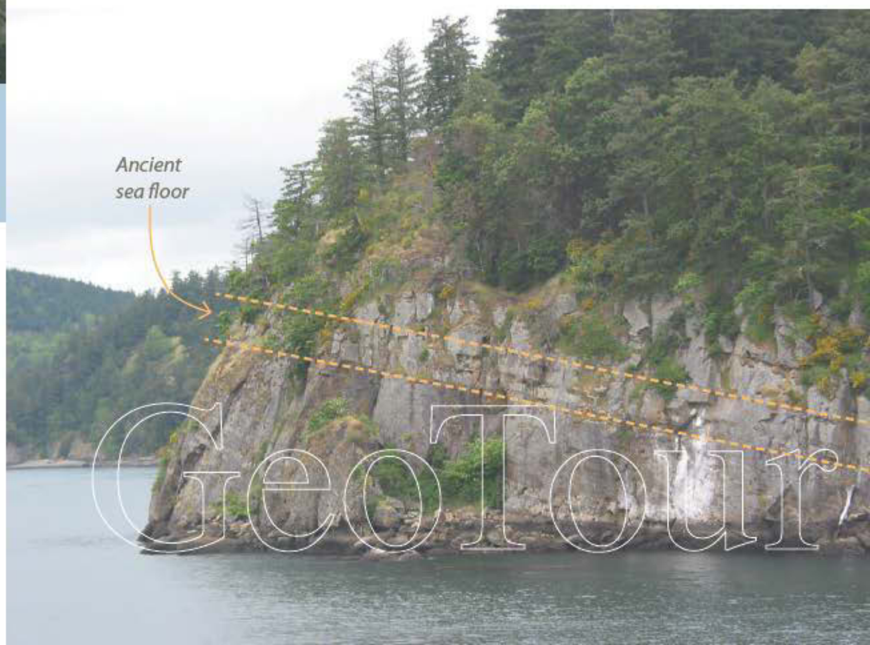
Note the interesting shapes caused by the tidal currents on the cliffs of Galiano Island as you go by. If you could peer underwater, you'd see that these same currents have created underwater moats around some of the Gulf Islands.

Salish Sea

Seeing the Sea Floor in Active Pass

Before you turn your attention away from the water – did you know that you're travelling over more underwater dunes? These dunes are bigger than the dunes in front of the Tsawwassen Ferry Terminal and are made of pea gravel. If you're lucky enough to be on the ferry when it occasionally reroutes through Boundary Pass, you will travel over some of the largest underwater dunes in the world – dunes up to 26 metres high.

Now look at some of the cliffs in Active Pass before the ferry leaves the passage. You'll see layers of rock, one on top of the other. Some of these layers are ancient sea floors, when sea levels were 60 to 80 metres higher than they are today. Read more about rock layers in the Gulf Islands section of this guide.



GeoTour

Swartz Bay: Welcome to Victoria

To get to the Swartz Bay Ferry Terminal, the ferry has to navigate between numerous islands and sandbars. Look for the red and green buoys in the water that help guide the ferries through the more difficult sections. Once you reach Swartz Bay, you have two choices: travel west along West Saanich Road to see beautiful Saanich Inlet, or travel south on the Pat Bay Highway to Victoria. Don't forget to stop at Island View Beach to stretch your legs and see disappearing James Island.

Enjoy the spectacular trip – you may see eagles and seals, as well as a large range of recreational and commercial boats navigating their way through the churning waters. If you're lucky, you'll see some killer whales, or orcas, a true West Coast icon.

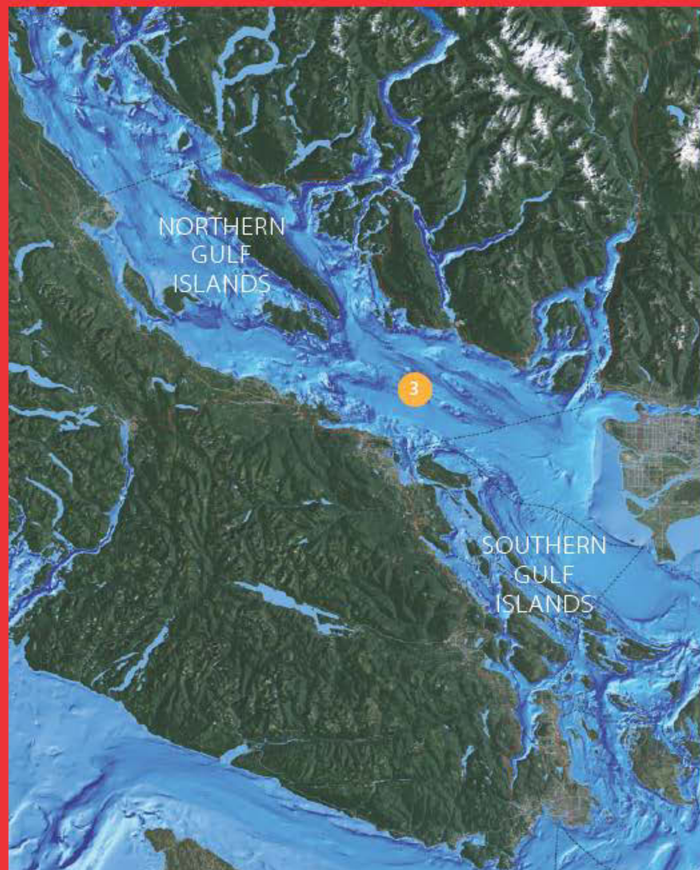
GETTING THERE:

You can take your car, or travel as a walk-on passenger, on the ferry from Tsawwassen to Swartz Bay, Victoria. You'll cross the Strait of Georgia, travel the currents of Active Pass, and see spectacular scenery.

*Find ferry schedules and information at **bcferries.com***

Salish Sea

GULF ISLANDS



GeoTour

Sediment Layers and Groundwater

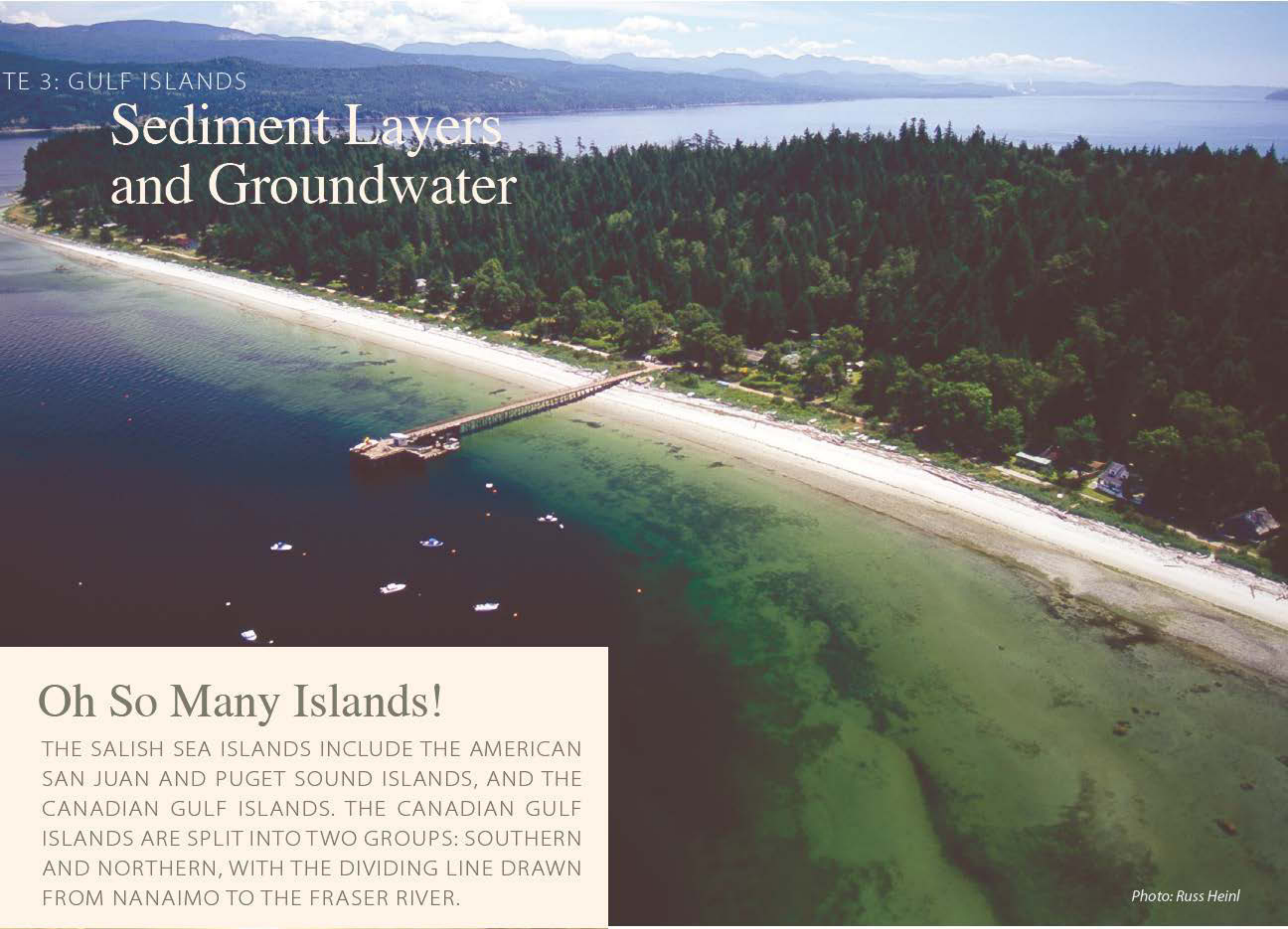


Photo: Russ Heinl

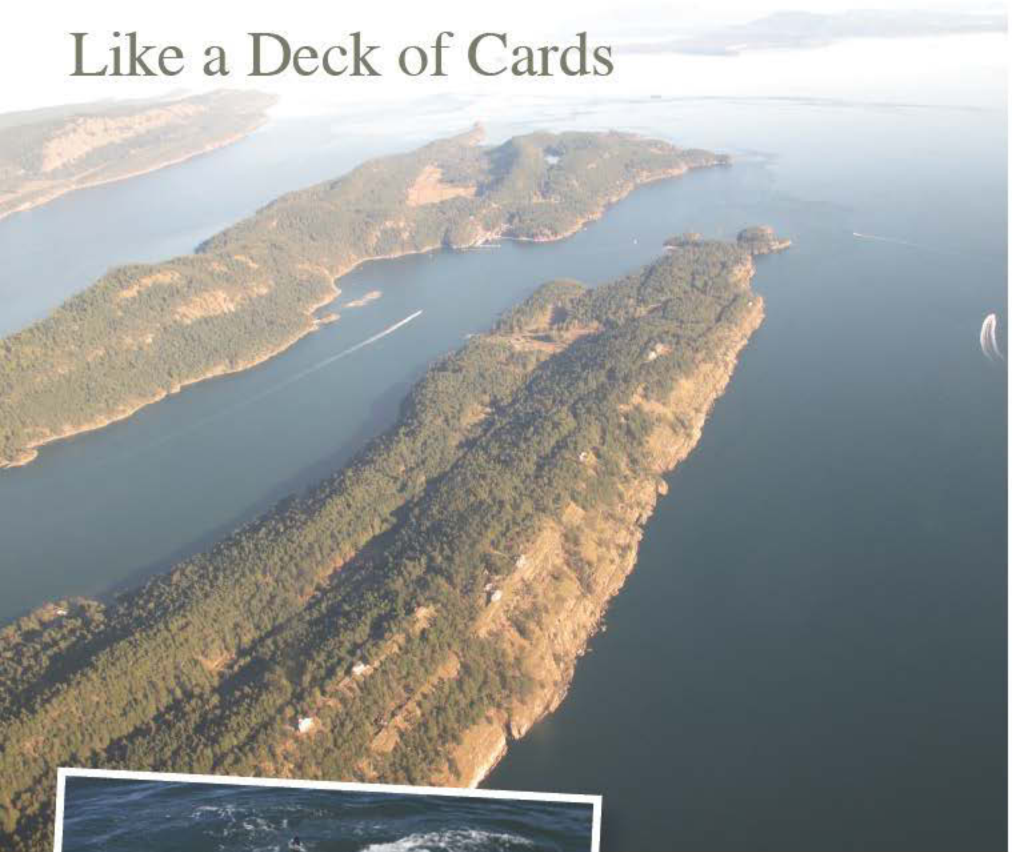
Oh So Many Islands!

THE SALISH SEA ISLANDS INCLUDE THE AMERICAN SAN JUAN AND PUGET SOUND ISLANDS, AND THE CANADIAN GULF ISLANDS. THE CANADIAN GULF ISLANDS ARE SPLIT INTO TWO GROUPS: SOUTHERN AND NORTHERN, WITH THE DIVIDING LINE DRAWN FROM NANAIMO TO THE FRASER RIVER.

There are hundreds of islands and thousands of islets in the Salish Sea region. The islands lie in the rain-shadow between Vancouver Island and the Olympic Peninsula in the south, and the Coast Mountains in the north. Winters are mild, and summers are warm and dry, attracting visitors year-round. Only the largest islands, like Saltspring and Hornby islands are accessible by ferry. To reach many of the smaller, less populated islands you'll need to travel by private boat, water taxi or kayak. Some of the islands, like Lasqueti Island, don't have electricity, but each island is unique and it is worth spending some time exploring by land and by water.

GeoTour

Like a Deck of Cards



Hundreds of millions of years ago, rivers carrying rocky debris deposited their load along the edge of British Columbia, just as the Fraser River does today. After millions of years of this conveyer-belt type activity, the sediments compressed - under their own weight - into hard layers of sandstone, and softer layers of silt and clay. Dissolved ocean minerals acted like glue, cementing the sediments together. Repeated many times, this process led to the formation of the Nanaimo Group, the sedimentary rock that forms much of eastern Vancouver Island and the Gulf Islands. In some places, these layers of sandstone are 16 kilometres thick!

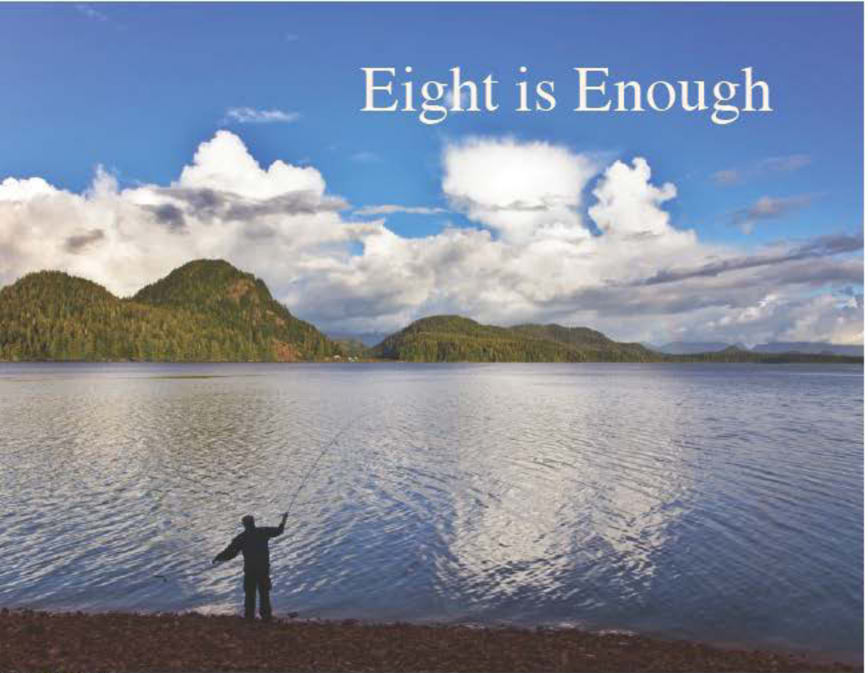
However, the geological process is never over. About 40 million years ago, motion from the tectonic plates that make up the Earth's crust, warped and folded the formerly neat layers of rock over themselves. If you're travelling through the Gulf Islands, you'll notice that many of the islands have ridges and valleys that appear almost terraced. Where once these layers were stacked flat, one on top of another, folding action has tilted them like a deck of cards. You can see evidence of sediment layering on most of the islands. If you're taking the Tsawwassen-Victoria ferry through Active Pass, you'll see some of this layering in the cliffs.

Aerial view of Nanaimo Group rock on North and South Pender islands.

A chance encounter with an Orca pod in the Gulf Islands.

The picturesque Southern Gulf Island ferry routes take you past unique waterfront homes and perfect vantage points to view the layers of sedimentary rock that make up the Nanaimo Group, like the South Pender Island cliff below.

Eight is Enough



Eight ice ages, over the past two-and-a-half million years, have advanced and retreated, scouring the land. The grinding movement of the enormous ice flows was enough to erode the soft rock layers, but not the harder ones, leaving a pattern of hills and valleys on the landscape. When the deepest valleys filled with water from melting ice, the results were the Gulf Islands of the Salish Sea.

Because of a warmer climate in the southern Salish Sea region, parts of the Gulf Islands and Vancouver Island were the last areas to be covered with ice and the quickest to melt.

As the giant ice sheets of the last Ice Age began to retreat about 12,000 years ago, herds of giant bison and mastodons roamed the grasslands of the Gulf Islands.

Views of the hills and valleys from Mount Maxwell on Saltspring Island

Kayakers view the spectacular rock formations on Galiano Island.
Photo: Pacific Northwest Expeditions Ltd. seakayakbc.com

Salish Sea

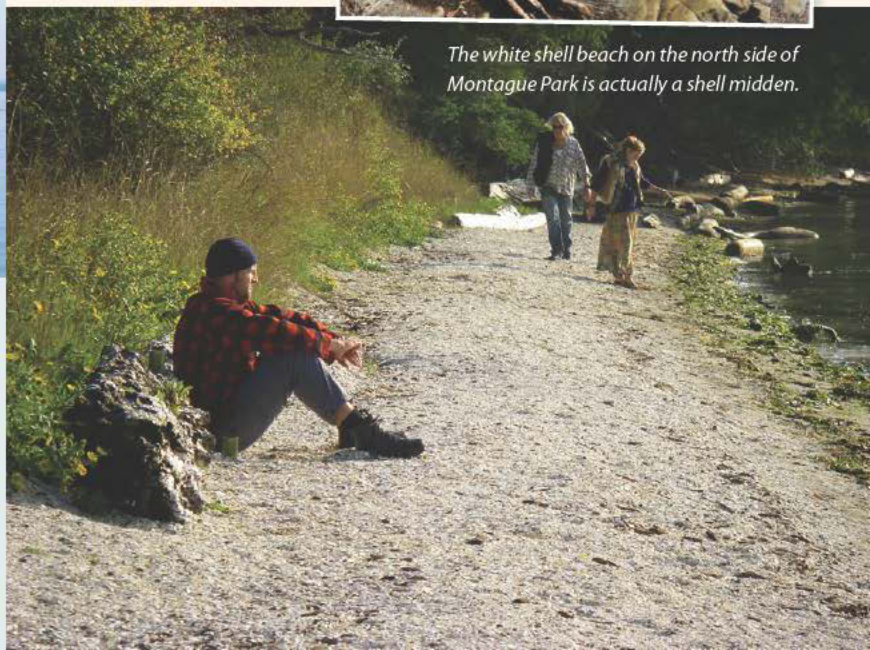
A Trip to Galiano

Accessible by ferry from Vancouver and Victoria, Galiano Island is a long narrow wedge, 27.5 kilometres long, but only six kilometres wide. It's an island visited by more birds than humans, but it's also a great place to get a taste of Gulf Island geology.

On arrival, disembark from the ferry in Sturdies Bay and head for popular Montague Park. Once you get there, you'll immediately notice a white shell beach on the north side of the park. This is one of several shell middens on Galiano Island, evidence of First Nations people living on the island more than 3,000 years ago. Over time, the middens – piles of castaway shells leftover from many years of harvesting shellfish in the area – were eroded by waves, crushed, and re-deposited on the beach at Montague Harbour.

From the harbour, take the trail past the lagoon, and around Gray Peninsula. In addition to beautiful views of the other Gulf Islands, birds and marine life, you'll come across an amazing rock ledge near the boat launch on the northwest edge of the peninsula. The layers of titled sedimentary rock were exposed by movement of the ice sheet during the last Ice Age.

These sedimentary rocks, beside the boat launch at Montague Park, were exposed and polished by ice during the last Ice Age.



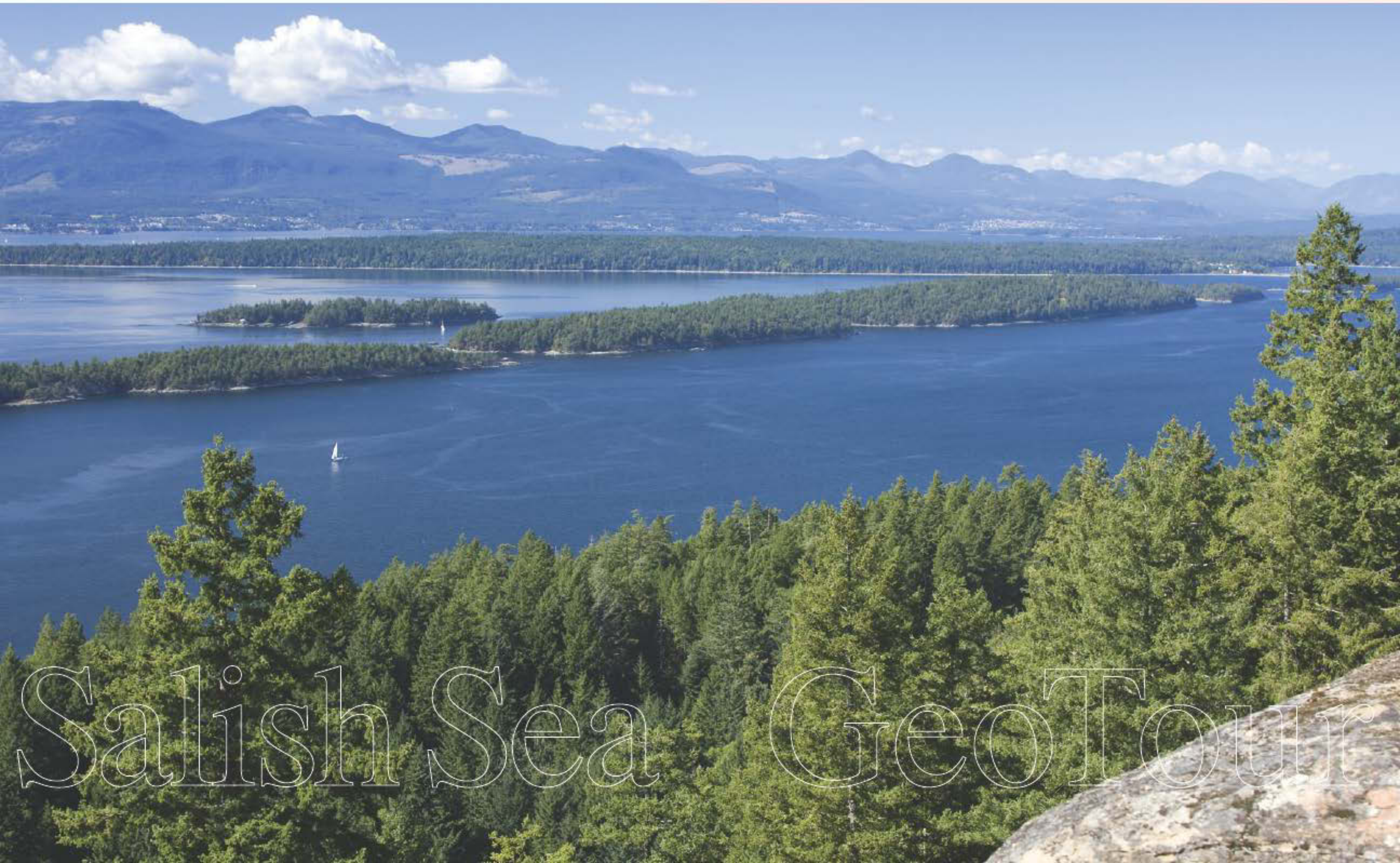
The white shell beach on the north side of Montague Park is actually a shell midden.

Aligned like Peas in a Pod

Continue your visit on Galiano along Porlier Pass Road to Cottage Way, and the entrance to the trail to Bodega Ridge. The trail is a steep 30-minute climb to the top of the ridge, 328 metres above sea level. It's worth the climb to see many of the southern Gulf Islands and islets stretching out in front of you. Take a close look at the islands and notice how they all align northwest to southeast. Erosion of the folded rocks by glacial ice flows, and modern wind-driven waves, have resulted in the almost uniform alignment of the Southern Gulf Islands.

Bodega Ridge is also shaped by erosion. During the last Ice Age, ice and water eroded the softer sandstone and shale on the Gulf Islands, creating the valleys and bays. The harder, erosion resistant sandstone remained, creating headlands, and ridges like the one you're standing on. These ridges are easy to see all over the Gulf Islands.

Two of Galiano's most popular hikes - to the top of Mount Galiano (above), and along Bodega Ridge (below) - provide a birds-eye view of how the Southern Gulf Islands were shaped by the last Ice Age.



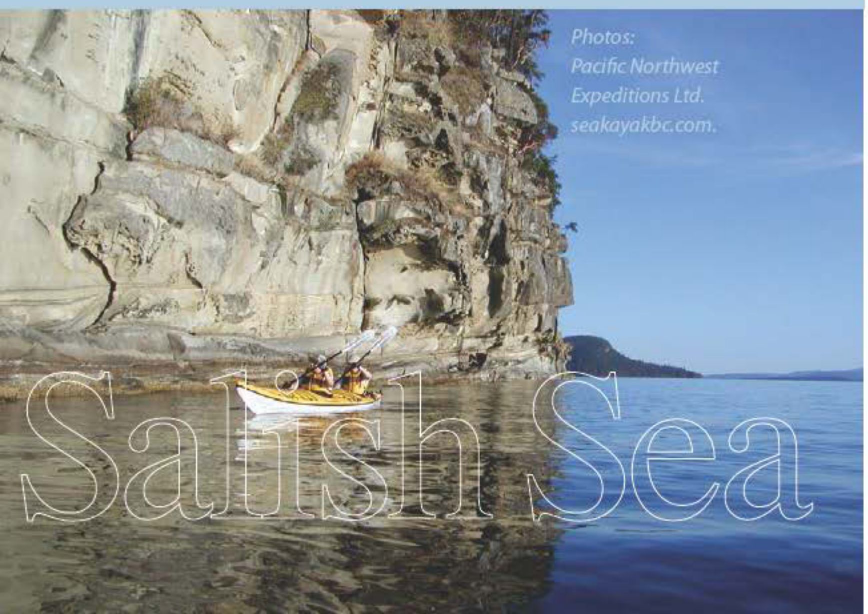
Get Your Paddle Out

It's worth travelling by boat or kayak to the bottom of Bodega Ridge too. Many of Galiano's geological features are best seen by water. At the bottom of Bodega Ridge, unique sandstone shapes provide a backdrop for wildflowers, eagles, falcons and turkey vultures. Below you, the ocean floor is an important area for rockfish, lingcod, crabs, urchins, shrimp, starfish and sponges.

Continue by water to Dionisio Point Provincial Park, on Porlier Pass at the northern tip of Galiano Island. More middens remind us of the First Nations history in the area; and intricately sculpted sandstone shelves are examples of *honeycomb weathering*, a phenomenon found all over the Gulf Islands.

Another great spot to see honeycomb weathering is only a short drive, cycle or walk from Sturdies Bay. Take Cain Road, then turn left onto Whaler Bay Road. There's a small public dock and plenty of honeycomb weathering along the shore. For more information on honeycomb weathering, see the Nanaimo section of this guide.

A mix of salt, water and permeable rock creates the unusual shapes and patterns in the sandstone on Galiano Island.

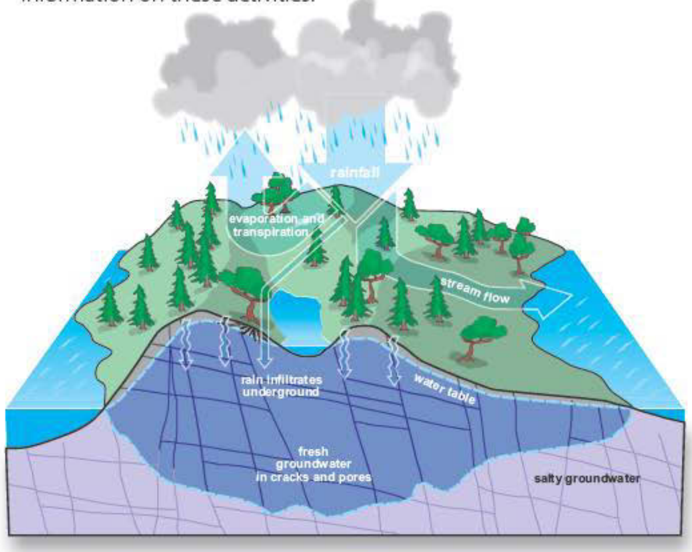


Groundwater: Water from Rain

In the Gulf Islands, water supplies are an ongoing issue. Most homes on the islands depend on wells that tap into groundwater. As the population on the islands increases, more water is used, and the winter rains that provide the groundwater can't keep up, causing wells to run dry in the summer months. To compound the problem, in some areas close to the coast, when too much fresh water is used, salt water from the ocean can encroach into the groundwater supply, and the well water becomes unusable.

To have water, there must be a place to store it. While there is plenty of rain, the islands don't have high mountains with winter snow to store water into the summer months. There aren't many lakes on the islands, so that only leaves limited areas of fractured rock to store water. And, even if there was more storage available, not much of the winter rain would get stored in lakes, cisterns or in the ground. Most of the rainwater evaporates, is absorbed by plants and forests, or flows into streams and out to the ocean. Scientists predict that the Gulf Islands will have warmer, drier summers in the future, so island communities are working hard to implement water conservation measures, and protect the land around sources of groundwater.

Visit the Islands Trust web site at ***islandstrust.bc.ca*** for more information on these activities.



Water supplies on the Gulf Islands comes from rainfall. Much of the water evaporates, is absorbed by plants, or flows to the ocean. Only a small amount is stored in fractured rock under the island.

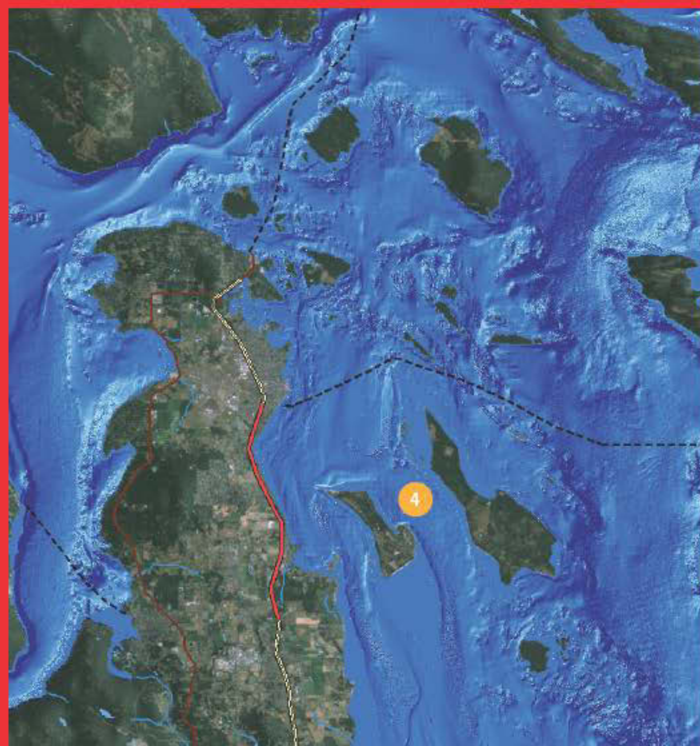
GETTING THERE:

*Many of the larger Gulf Islands are easily accessible by ferry from Victoria, Vancouver and Nanaimo. Contact BC Ferries by phone at 1-888-BC FERRY, or visit their web site (**bcferries.com**) for more information.*

To get to Galiano Island, take a 55-minute ferry from Tsawassen. Galiano is also a scenic ferry trip from Swartz Bay in Victoria, which sometimes includes stops at Mayne and Pender islands before reaching Galiano.

If you'd like to visit some of the smaller islands, private companies offer a variety of options including boat rentals, kayak/canoeing trips, and water taxis.

SIDNEY SPIT & JAMES ISLAND



GeoTour

Shifting the Sands of Time

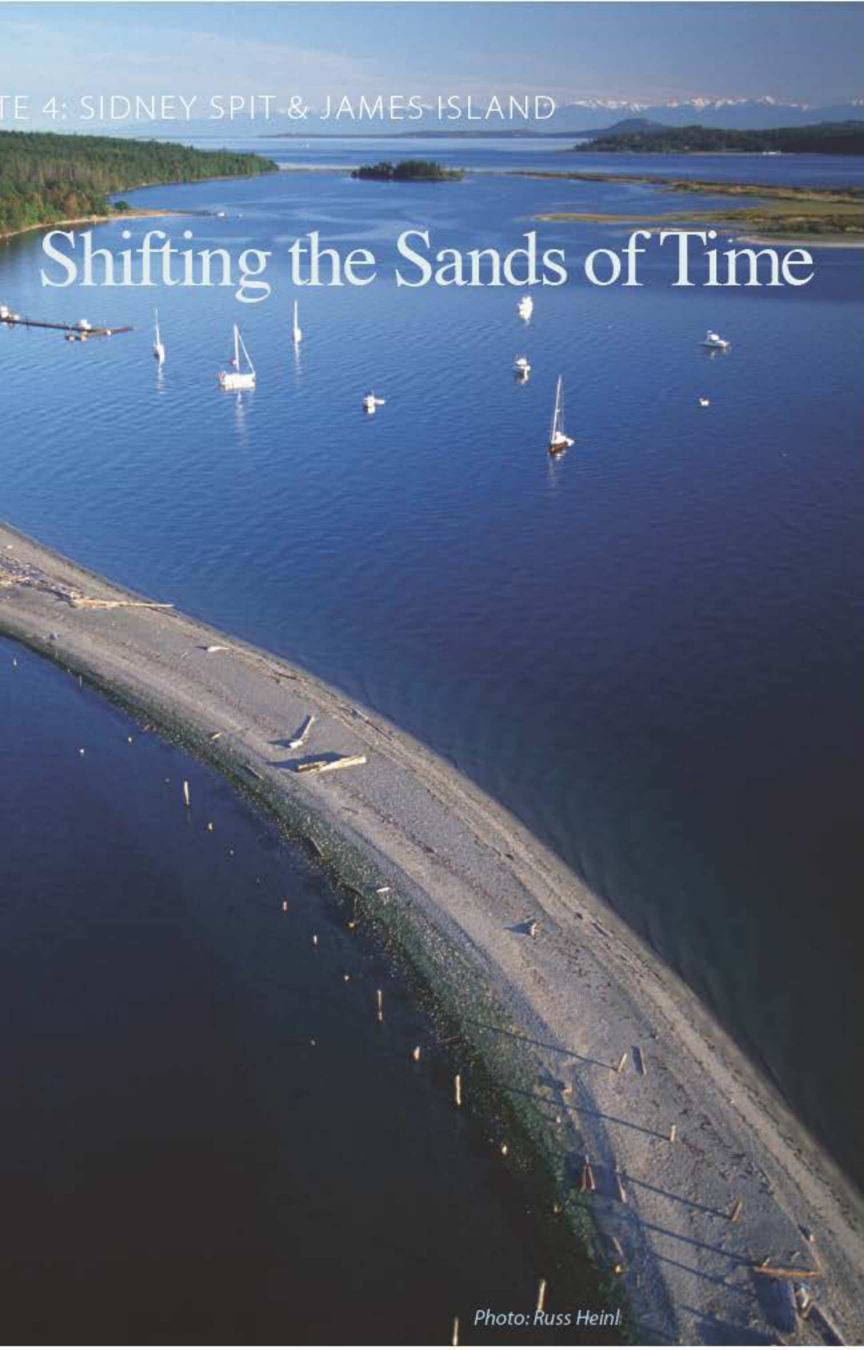
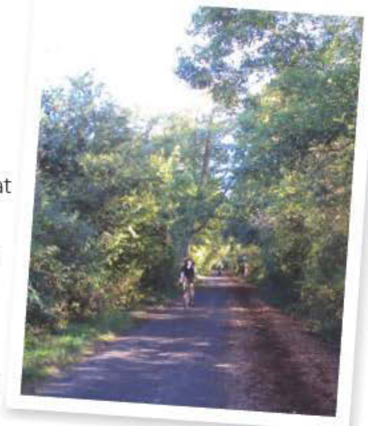


Photo: Russ Heinl

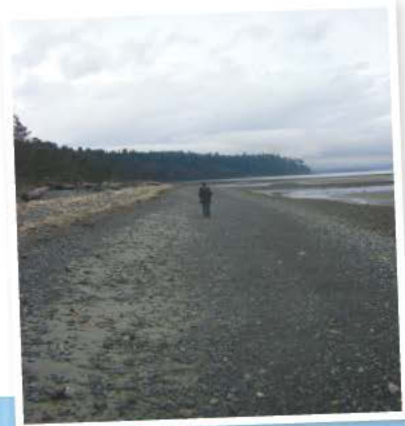
SIDNEY SPIT AND JAMES ISLAND ARE GOOD EXAMPLES OF HOW THE LANDSCAPE AROUND US CONTINUES TO CHANGE. IF YOU WERE ABLE TO TRAVEL IN TIME, EVEN A THOUSAND YEARS AHEAD, THESE TWO PLACES WOULD BE SIGNIFICANTLY DIFFERENT.

Take the turn-off from the Pat Bay Highway to Island View Beach, or take the Galloping Goose regional cycling trail from either Sidney or Victoria. Turn east, towards the ocean at Michell's Farm.



A Ridge to Nowhere

As you head towards the ocean, note the steep ridge in front of you. This ridge runs parallel to the coast from Cowichan Head (just north of Cordova Bay) to Saanichton Bay. Similar ridges exist on the rest of the peninsula, including one that runs from Cordova Bay, past Elk and Beaver Lake, to Keating Cross Road. You'll have driven right by it if you came from Victoria. Or, if you rode your bike along the Galloping Goose to get to Island View Beach, you might have noticed the gravel pit on Cordova Bay Road. This pit - and other gravel pits along Keating Cross Road - hint at the materials that make up the ridges in the area.

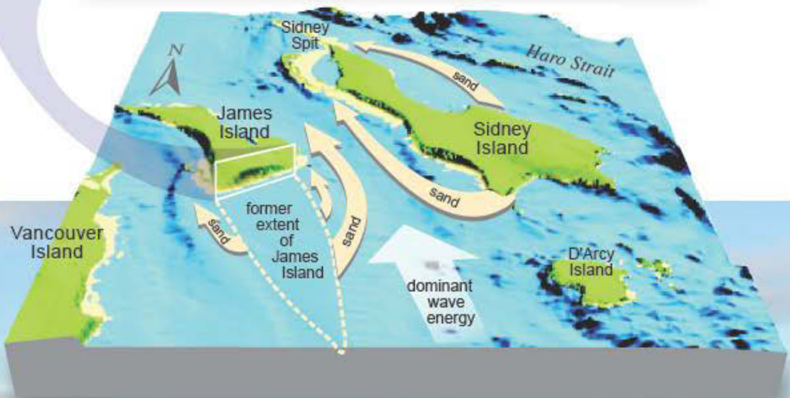


These ridges are evidence of the glaciers that used to cover the land during the ice ages. All that's left are piles of gravel and sand, left behind when the glaciers melted. To learn more about this process, see the Sechelt section in this guidebook.

The ridge at Island View Beach.

A Disappearing Island

Once you reach Island View Beach, park in the picnic area and walk towards the ocean. Directly across from you is James Island – or at least the half that is still above water. The southern end of James Island is now just a shallow part of the seafloor. Strong winds and northwesterly waves have eroded the glacial sands and gravels, re-depositing them on both sides of the island and into deeper water. This process is ongoing and one day, in the far future, the island will completely disappear.



The Cliff-side Story

While you're at Island View, walk over to the cliffs that overhang the southern end of the beach. The cliffs are made of layers of sediment, and tell the story of the glacial and interglacial periods in the area. At the top, you'll see a two-metre-thick layer of clay. This clay indicates the height of the sea level about 13,000 years ago, when the local glaciers began to melt. The next layer down is about 30 metres thick and is part of the Quadra Formation – as glaciers advanced during the last Ice Age, they brought eroded sands and gravels down from the Coast Mountains on the mainland.

Below the Quadra Formation layer, you'll see increasingly older layers. The next layer is a dark band of silt and sand, deposited by streams as sea levels dropped. The rusty brown layer below it is even older, and comes from sediment suspended in a marsh-like environment. These two layers are about 58,000 to 29,000 old. The layer at current sea level – visible at low tide – is about 62,000 years old and linked to an older ice age.

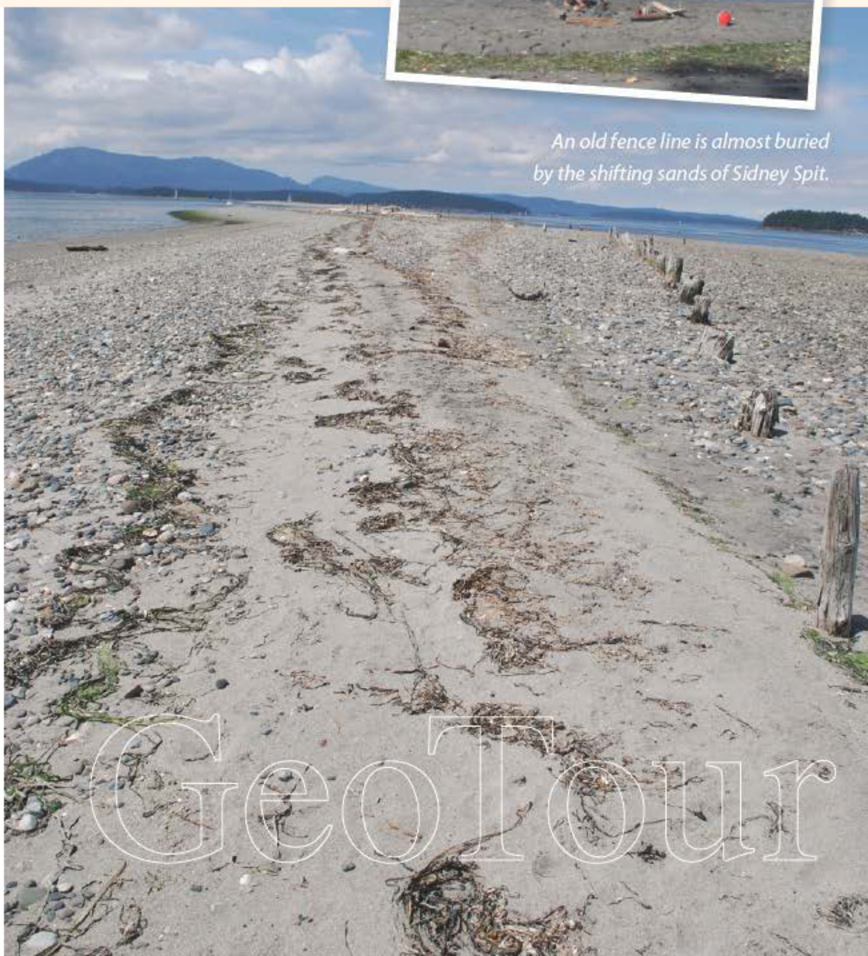
During the summer, the passenger ferry to Sidney Spit and Island departs daily from the Sidney Pier.

This image shows the shallow sediment flats around Sidney and James Islands.

Sidney Spit

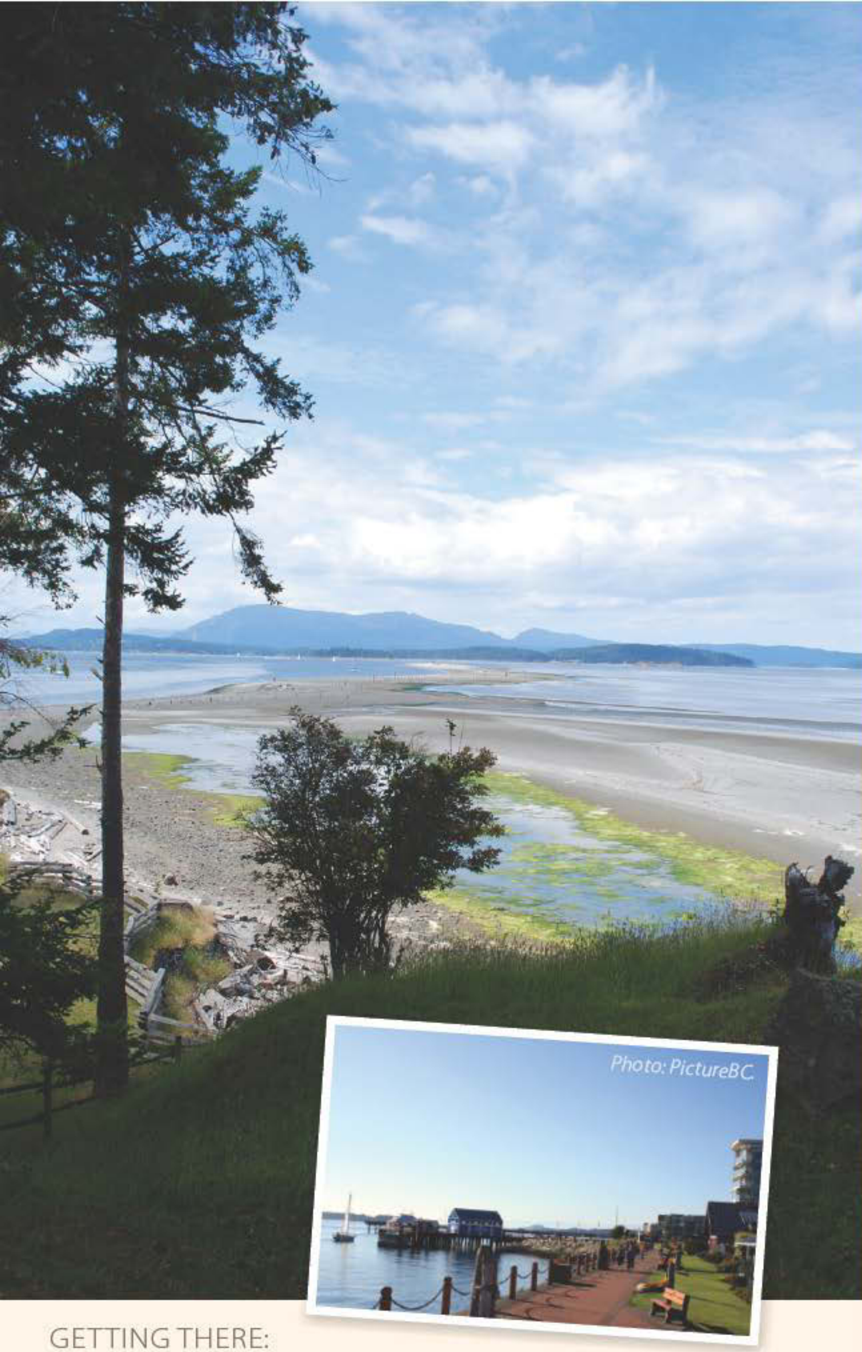
The best way to see Sidney Island and Sidney Spit Marine Park is to stop in the small town of Sidney, just south of the BC Ferry terminal at Swartz Bay, or half an hour north of Victoria. Walk through the town of Sidney and on to the public wharf. To your right you'll see the golden sand of Sidney Spit and Island. If you'd like a closer look, a seasonal foot-passenger ferry leaves the wharf several times a day.

Sidney Spit is really two spits extending from the north end of Sidney Island. The sediments that make up the spits came from the cliffs at the other end of the island. Over many years the cliffs have been eroded, and powerful waves and currents slowly shifted the liberated sand and gravel northward around the edge of the island in a process called longshore drift. The two spits have each extended more than one-and-a-half kilometres offshore, and turned the area in between, into a sheltered bay.



An old fence line is almost buried by the shifting sands of Sidney Spit.

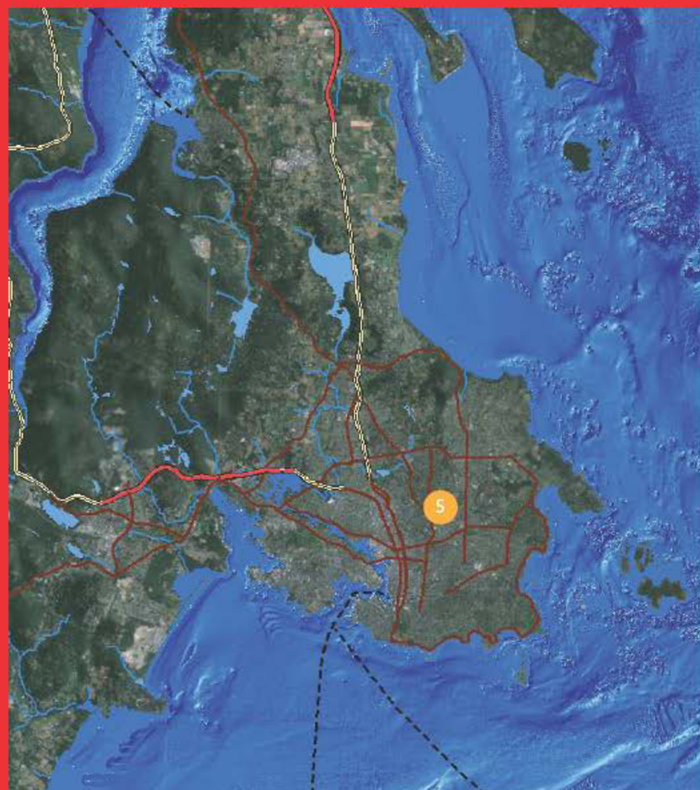
Salish Sea GeoTour

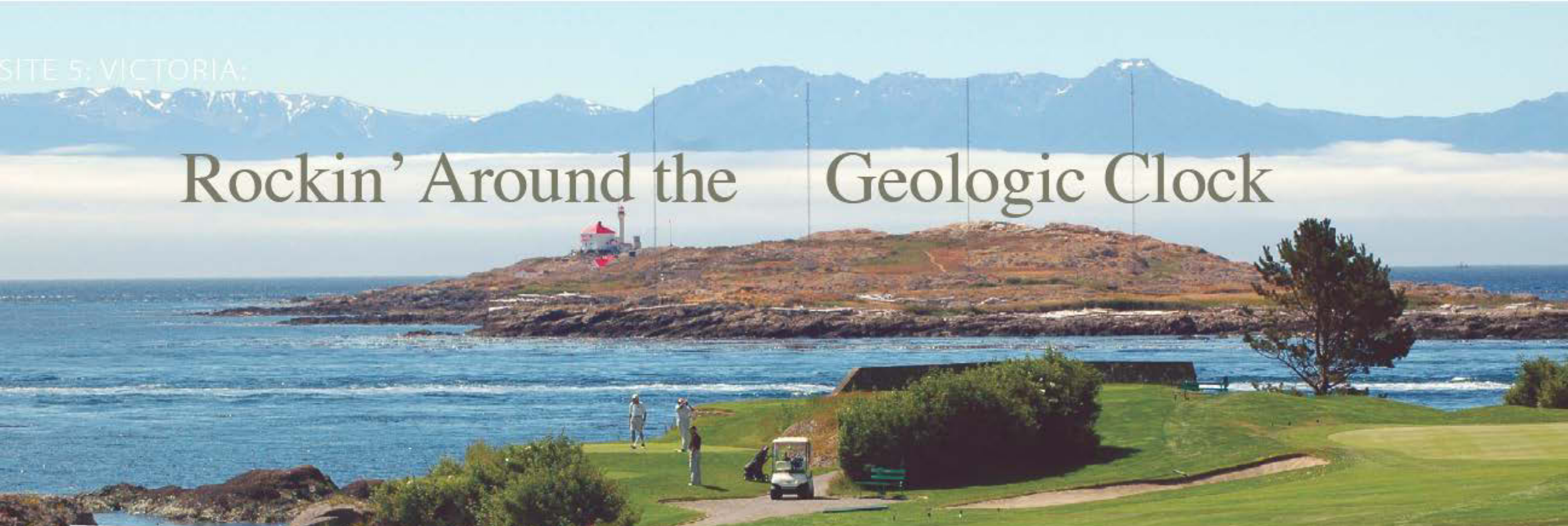


GETTING THERE:

Unless you've got a very strong front crawl, you'll need a boat to reach these islands. James Island is privately owned, but it's possible to hike and camp on Sidney Island. You can rent a boat near the Sidney Marina, or take the 25-minute passenger ferry to Sidney Spit that runs from late May to early September.

VICTORIA





Rockin' Around the Geologic Clock

Victoria

TO TRULY EXPERIENCE VICTORIA, YOU'LL NEED TO SPEND A FEW DAYS EXPLORING THE "CITY OF GARDENS."

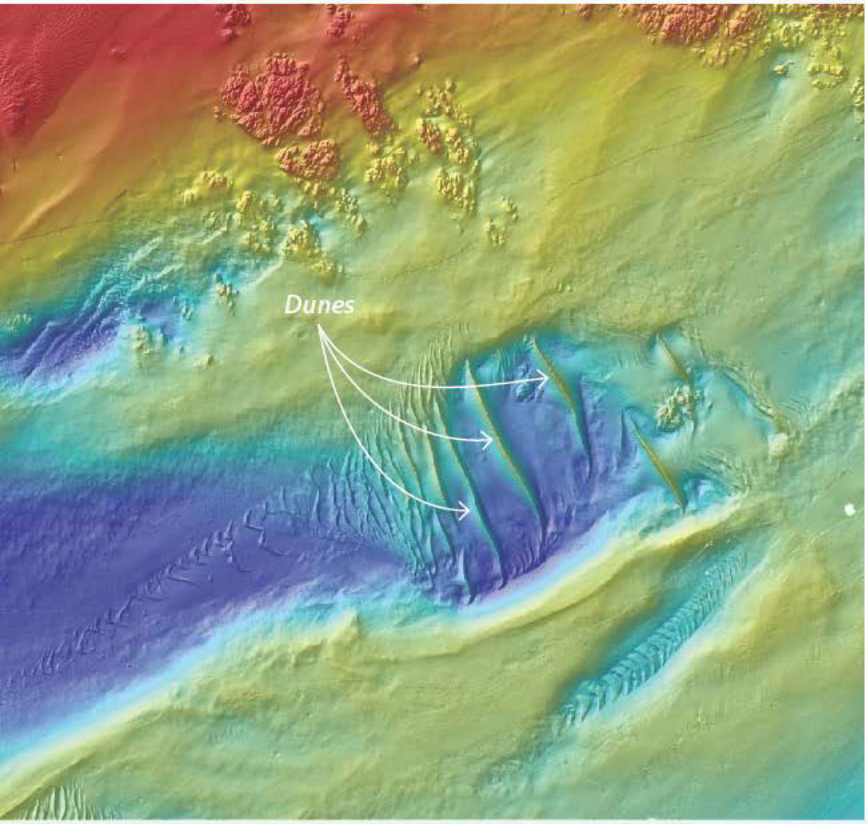
Victoria is the capital of British Columbia, and has the largest urban population on Vancouver Island. Much of the area is built on rock that used to be 20 kilometres below the Earth's surface, but Sooke and Metchosin are actually sitting on rocks that were once part of an ancient seafloor. If you're travelling to or from the Vancouver ferry on the Pat Bay Highway, you'll pass Mount Newton to the west of the highway, and be driving over 170 million-year-old magma from an ancient volcanic eruption. On a clear day, you'll also see the classic volcano-cone shape of Mount Baker in Washington State to the east.

Closer to town, golfers at the Victoria Golf Club at Gonzales Point are playing on sedimentary rocks that were pushed up from deep parts of the ocean by faults that run across Vancouver Island. If you visit nearby Gonzales Beach at the end of Foul Bay Road, or hike up Gonzales Hill off Beach Drive, you will have spectacular views of the strong currents of the Juan de Fuca Strait, with the Olympic Mountains of Washington State in the background. These strong tidal currents give us some of the amazing underwater geological features around Victoria, like the giant underwater sand dunes off Oak Bay.

Mount Baker

Salish Sea GeoTour

Dunes the Size of a Ten-Story Apartment Building



This multi-beam image of the seafloor off Oak Bay shows a large underwater dune field. Blue represents the deepest water, red the shallowest.

Just off the beach at Oak Bay, giant underwater sand dunes dominate the seafloor. They've been measured as tall as 26 metres high, 300 metres long, and 1,200 metres wide! This makes them some of the largest seafloor dunes in the world.

Strong tidal currents, moving in and out of the Salish Sea, create these massive dunes. In the same way that wind transports sand to form sand dunes in the desert, strong tidal currents move sediment to create underwater dunes. Because of the currents, these giant dunes are constantly moving. Some dunes travel as much as the length of a football field in a single year. The ever-changing seafloor makes designing and engineering seafloor cables and pipelines extremely challenging. To help community planners and engineers, marine scientists study underwater features - like the giant dunes - to learn about sediment deposits and erosion, and the stability of the seafloor.

View the tranquil waters of Oak Bay from Gonzales Hill (above).

Photo: Picture BC.

A Trip to the Inner Harbour

The Inner Harbour of Victoria is usually a lively place: people stroll the sidewalks, take tea at the Empress Hotel, and photograph the Parliament Buildings.

Our tour of the Inner Harbour geology starts at the corner of Government and Belleville streets near the Empress. Walk past the Parliament Buildings, on your left, to the corner of Menzies and Belleville streets. At Confederation Garden Park, walk over to the smooth, polished bedrock you can see protruding from the ground. About 14,000 years ago, this piece of rock was under one kilometre of glacial ice. Look at the very top of the Parliament Buildings next door. From the base to the very top of the highest dome, that's 50 metres. Now imagine just how high the ice was!

Look back to the rocks. Note the scratches in the rock, particularly the *flutes* – broad troughs carved into the rock. These scratches and flutes, caused by rocks and sand encased in the ice, show the direction the glacier was travelling. You'll also see some pale discs of rock encased in darker rock. Both types of rocks were melted deep underground, then uplifted when the tectonic plates collided and began the mountain building process on the island, between 54 and 42 million years ago.

That Hotel is Sinking!

Victoria is built on a number of basins. As the glaciers of the last Ice Age melted and retreated, marine clay and mud washed down to the centre of the basins, leaving the basins' floors covered with unstable sediment. The area where the Empress now sits is one of these basin floors. The Lekwungen People, ancestors of today's Esquimalt and Songhees First Nations, called this site "whu-sei-kim," or "place of mud," and the tidal mudflats of the Inner Harbour were some of the best clam beds on the coast. When the Empress was built, engineers "reclaimed" part of the mudflats by building a seawall across the bay, creating the Inner Harbour causeway.

Walk over to the causeway and look across the street towards the Empress. Does one side of the building look higher than the other? If it does, there's a good reason for that.

The north wing of the Empress sits on gravel and bedrock, but the south wing rests on marine clay, which compresses under heavy weights. Hotel foundations were laid in 1904-05, and the central wing opened in January 1908. Within six months, the foundations in the south wing had sunk by nine centimetres. During construction of the south wing between 1912 and 1915, engineers had to re-level the wing every month, and then every year after that. In 1971, engineers calculated the south end of the Empress had sunk 73 centimetres, although much of the sinking occurred within the first five years.

Salish Sea GeoTour

At One Time, Not an Island at All

Geology plays a big role in Victoria, and much of the geologic history of the city lies in the history of Vancouver Island. Vancouver Island is a good example of how the Earth is constantly changing around us. At one time Vancouver Island wasn't an island at all! Over the past 375 million years, the area of Vancouver Island has been part of a vast underwater plateau, part of a chain of volcanoes and then covered by glaciers. It has been fused to North America, been through many periods of mountain building, and eventually became an island.

An Ancient Collision

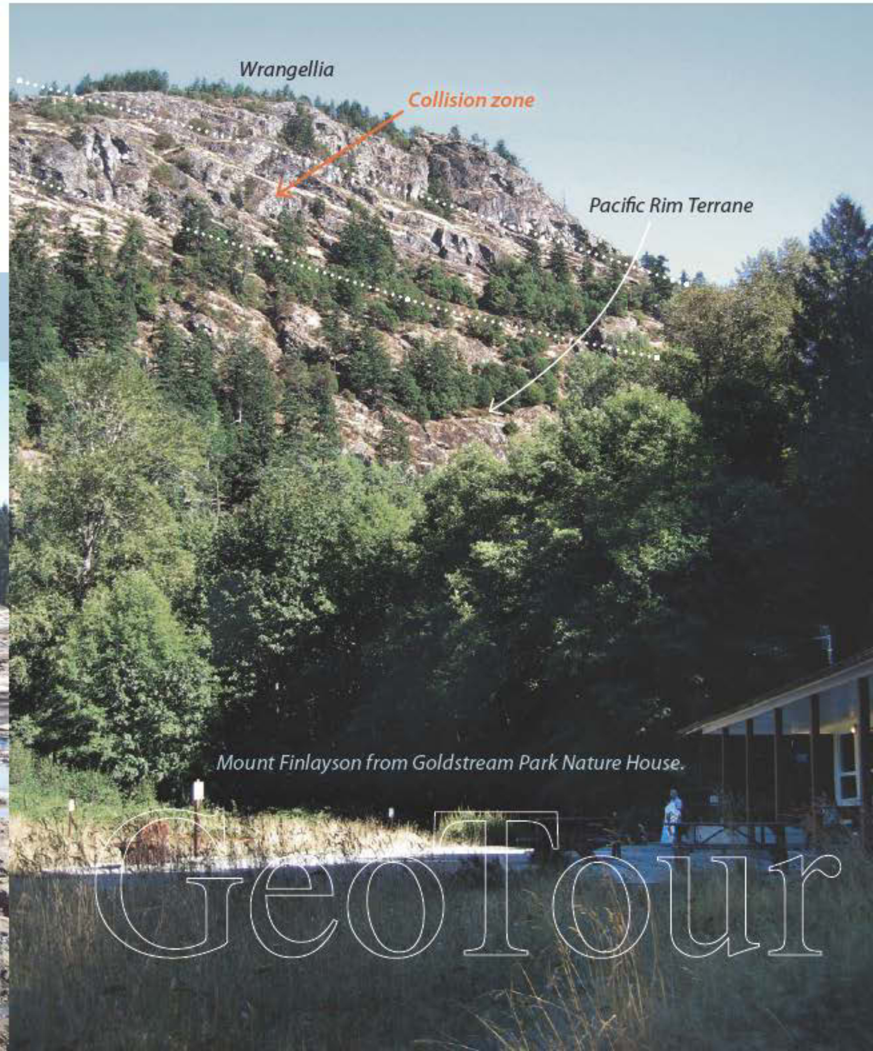
Vancouver Island is formed from three different pieces of the Earth's crust, called *terranes*. The largest of these, *Wrangellia*, collided with the ancient edge of North America about 100 million years ago. Following that collision, coal-bearing sedimentary rocks accumulated along the east coast of Vancouver Island and beneath what much later became the Strait of Georgia. A second collision occurred about 54 million years ago when the *Pacific Rim Terrane* rammed sedimentary and volcanic rocks beneath Wrangellia; and a third collision occurred about 42 million years ago, shoving a volcanic island, belonging to the *Crescent Terrane,* next to and under the Pacific Rim Terrane. The areas where these terranes collided created a number of faults that we can see evidence of today.

Rocks of the Pacific Rim Terrane exposed at Botanical Beach. Weathering of the rocks creates the famous tide pools, with colourful marine life easily observed at low tide.

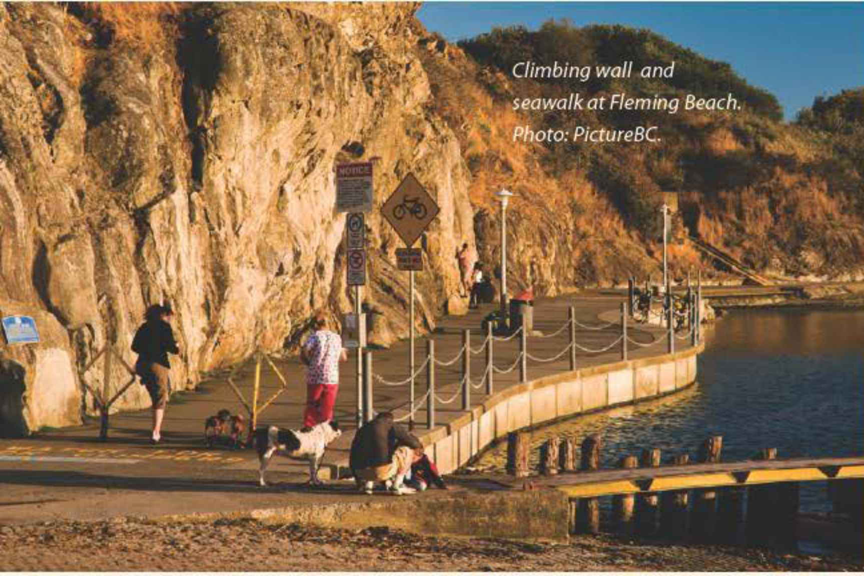
Finding Faults: A Detective Story

If you're driving north from Victoria, or south from Nanaimo, pull over at Goldstream Park and take a half-kilometre stroll through the forest to the Visitor's Centre. Look across the stream to Mount Finlayson. What you're looking at is the Survey Mountain fault where Wrangellia and the Pacific Rim Terrane collided.

The lower half of the cliff is the Pacific Rim Terrane while the upper half is Wrangellia. The crumpled-looking area in the middle marks the collision zone. When geologists find a site like Mount Finlayson, where older rock is on top of younger rock, it's a sign that a fault in the Earth's crust exists in that area. It's the first important clue in a long detective story of mapping and studying to determine when the fault was last active. The Survey Mountain fault is one of many ancient, inactive faults under and around Victoria.



Mount Finlayson from Goldstream Park Nature House.

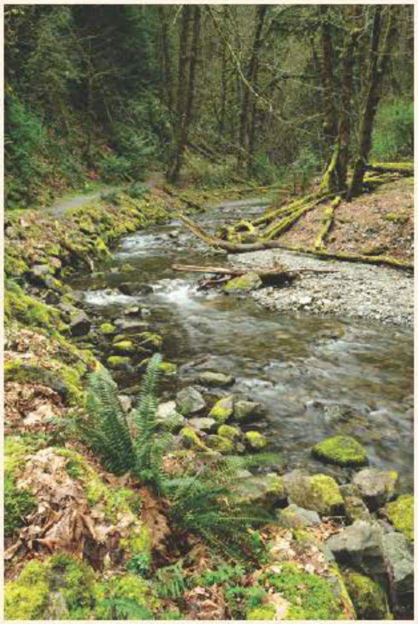


Climbing wall and seawalk at Fleming Beach. Photo: PictureBC.

GETTING THERE:

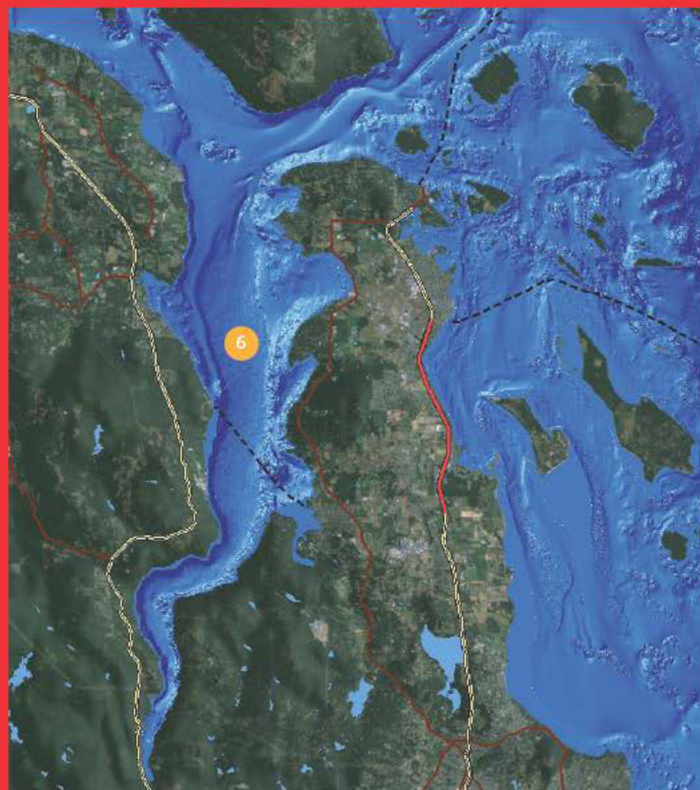
Take an hour-and-a-half ferry ride from Tsawwassen in Vancouver to Swartz Bay. Victoria is a half-hour drive south, along the Pat Bay Highway.

Or, drive an hour-and-a-half south from Nanaimo (also accessed by ferry from Vancouver). Going this way, you'll travel along the Malahat Highway, so make sure to stop and see the fault at Goldstream Park. If you're there in the fall, you may also see thousands of Chum, Chinook and Coho salmon returning to spawn, along with hundreds of bald eagles who are doing a little fishing of their own.



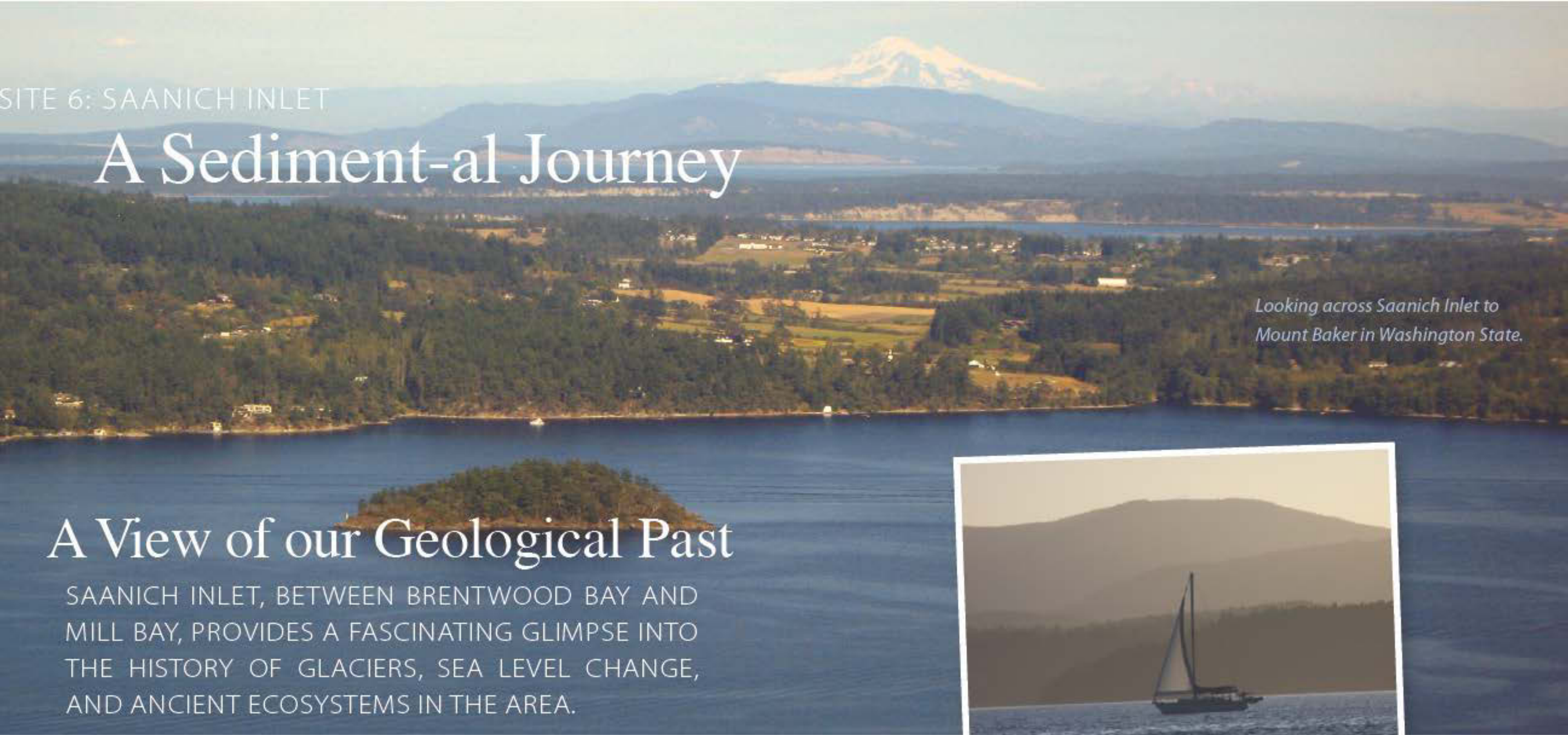
Once you're in Victoria, hundreds of kilometres of trails make for fun and easy days of walking or cycling to see some of the fascinating geological sights of the area.

SAANICH INLET



Salish Sea GeoTour

A Sediment-al Journey



Looking across Saanich Inlet to Mount Baker in Washington State.

A View of our Geological Past

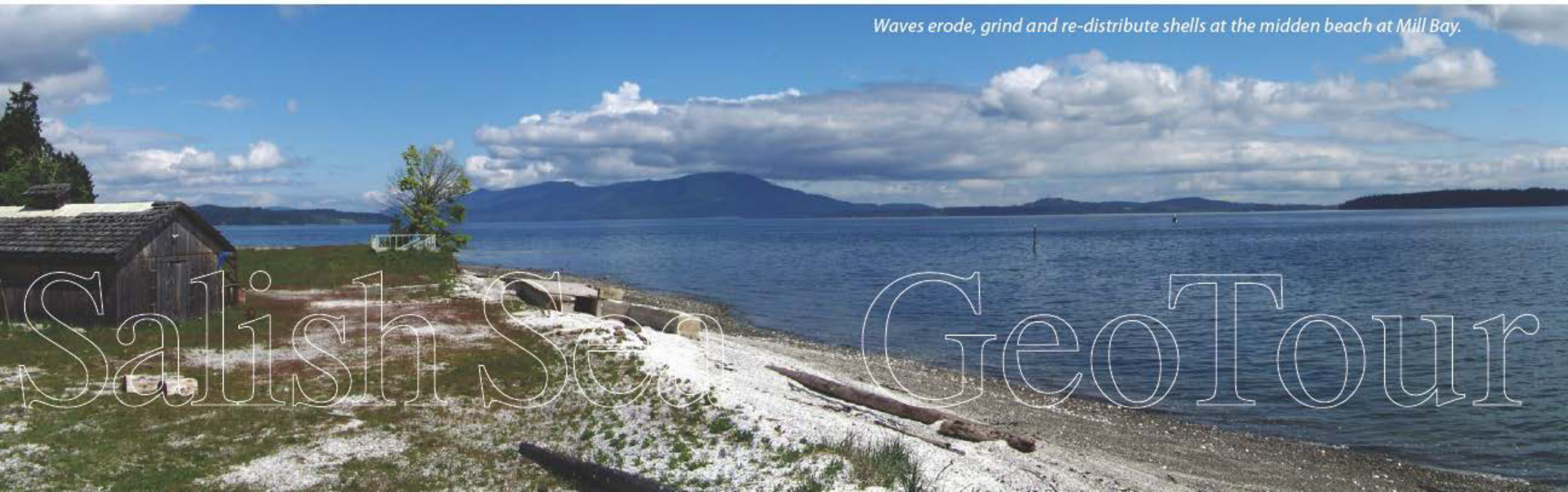
SAANICH INLET, BETWEEN BRENTWOOD BAY AND MILL BAY, PROVIDES A FASCINATING GLIMPSE INTO THE HISTORY OF GLACIERS, SEA LEVEL CHANGE, AND ANCIENT ECOSYSTEMS IN THE AREA.

For a bird's-eye-view of the inlet, take Highway 1 north over the Malahat, and stop at the summit. You'll see directly across Saanich Inlet towards Mount Tolmie and Mount Douglas. These two mountains are the exposed bedrock roots of ancient mountains, revealed by millions of years of erosion, then scoured by glacial ice. Stop at the next lookout and, on a clear day, you'll see all the way to the Gulf Islands, and across the Salish Sea to Mount Baker in Washington State. Mount Baker is an active volcano!

For a much closer look of Saanich Inlet, take the ferry from either Brentwood Bay or Mill Bay, and you'll travel right across this glacially-carved fiord.

At Mill Bay, take a good look at the spectacular white shell beach. It's not actually a natural beach – it's a midden beach, which means humans made it over thousands of years. Generations of First Nations peoples shelled their daily food here, and the shells collected and broke down, eventually forming the beach cover.

If you're arriving or leaving by ferry by way of Brentwood Bay, you may want to take the time to travel West Saanich Road north, to the Institute of Ocean Sciences. Both Natural Resources Canada and the Department of Fisheries and Oceans have displays on marine science. Natural Resources Canada occasionally offers tours, but please call ahead with your request: 250-363-6500. The Institute of Ocean Sciences is also where research vessels are based.

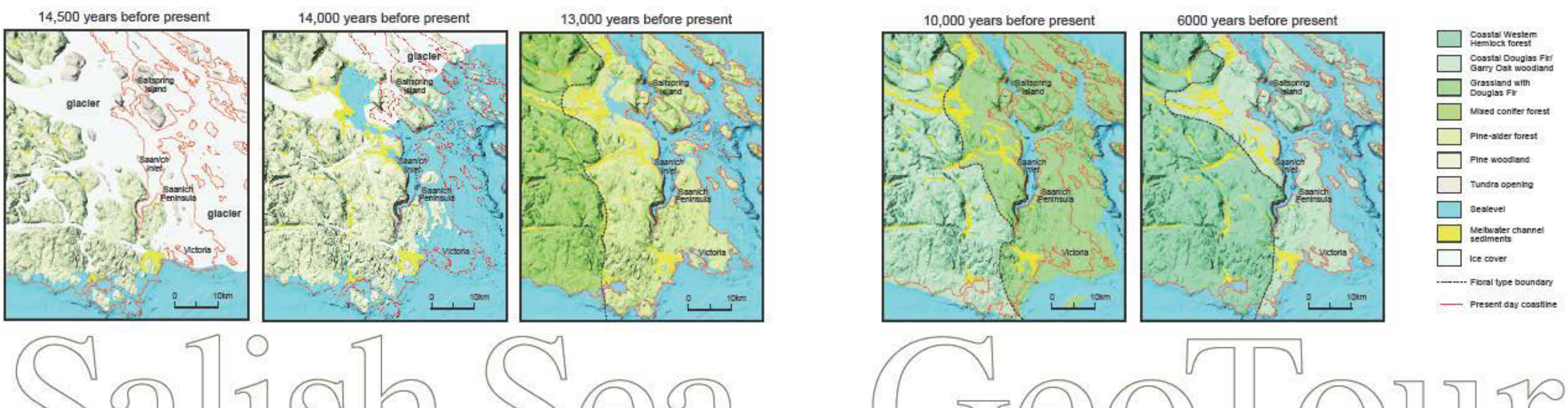


Waves erode, grind and re-distribute shells at the midden beach at Mill Bay.

Changing Sea Levels

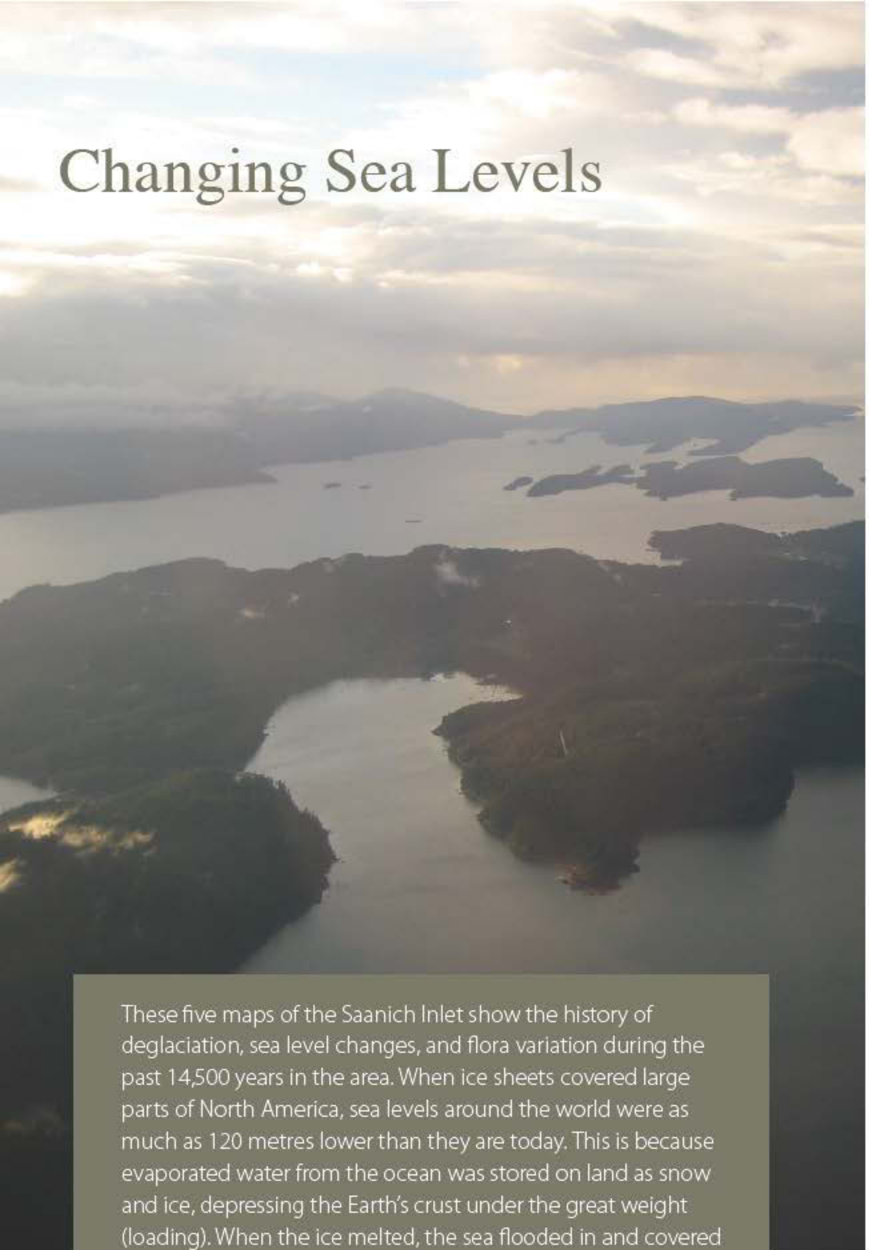
These five maps of the Saanich Inlet show the history of deglaciation, sea level changes, and flora variation during the past 14,500 years in the area. When ice sheets covered large parts of North America, sea levels around the world were as much as 120 metres lower than they are today. This is because evaporated water from the ocean was stored on land as snow and ice, depressing the Earth's crust under the great weight (loading). When the ice melted, the sea flooded in and covered areas that are now land. Marine shells found on high sandy cliffs, like those on James Island and along Island View Beach, are evidence that the sea level was once much higher.

Between 14,500 and 10,000 years ago, the local sea level dropped as the Earth's crust rebounded from its glacial weight. Since then, the sea level has risen gradually until reaching today's level about 5,000 years ago. Sea level is now starting to rise again due to the effects of climate change.



Salish Sea GeoTour

Changing Sea Levels



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14,500 years before present

14,000 years before present

13,000 years before present

10,000 years before present

6000 years before present

Salish Sea GeoTour

A Sediment Library

Once the sea level in Saanich Inlet stabilized, layers of very unique sediments built up on the bottom of the inlet. Seventy metres underwater, at the mouth of the inlet, is a ridge, or *sill*, that blocks the free passage of incoming ocean waters. This means that the bottom waters of the inlet are mostly stagnant and without oxygen. Bottom dwelling creatures can't survive there, so sediment accumulates in annual layers, or *varves*, for thousands of years, undisturbed by creatures burrowing on the seafloor.

These annual sediment layers provide a whole library of information. They tell us what the environmental conditions were like thousands of years ago: the climate, fish populations, ocean conditions and the frequency of earthquakes.

Traditionally, geologists use long tubes (piston cores) to sample a cross-section of the many sediment layers in an inlet. However, the top layers of sediment in Saanich Inlet are far too delicate for this method. Instead, geologists freeze the sediments to the outside of an ice-filled barrel. These *freeze core* sediments give us a record of the past thousand years or so. Scientists commonly use *core samples* to study how drastically ocean and climate conditions have changed in the past 300 years since the Industrial Revolution, when humans began altering the amount of greenhouse gases in the environment.

A close-up of a sediment core sample from the Saanich Inlet. One dark layer and one light layer is a year's accumulation of sediment. Layers of fish bones are also visible.

Core samples are taken from specially equipped ships.

Evidence of Earthquakes

Because earthquakes rock the ocean floor, they cause an unusual layer of disturbance in the marine sediments, which date to a specific period. Layers of disturbed marine sediments in Saanich Inlet, and other inlets along British Columbia's coast, date to a giant earthquake in AD 1700. First Nations oral history, and a documented tsunami that hit Japan, record the same catastrophic event.

Marine sediments tell us that we can expect a very large earthquake in the Salish Sea region about once every 500 years - and many smaller earthquakes in the years between. This information helps communities plan for the "big one" by designing safer buildings and infrastructure, and putting emergency plans into place.

Not a Great Fish Story

At the bottom of Saanich Inlet, and a few other very unique inlets in British Columbia with shallow sills, no oxygen is present. Where these *anoxic* bottom waters exist, rapid influxes of dense oxygenated ocean waters – brought in over the sills during storms – creep along the bottom, pushing the waters without oxygen upwards. This can occasionally cause mass suffocation of fish and other marine organisms. Fish skeletons make up many of the layers within the sediment cores taken from Saanich Inlet, a testament to these sudden, nature-driven fish kills in the inlet.

The anoxic bottom of the Saanich Inlet is in direct contrast to the abundant life on the seafloor outside of the inlet.

Photo: VENUS.

What Sediments Tell Us

The sediment layers taken from Saanich Inlet also contain phytoplankton called *Diatoms*. These single celled creatures "bloom" in summer, and make up the lighter coloured sediment layer seen in core samples.

Using a powerful microscope, marine geologists can identify which of the 4,000 known species are in the Saanich Inlet sediment layers. From this, they can learn much about the cycles of sunlight and nutrients in the coastal waters, going back many thousands of years. This is important because fish populations depend on the nutrients in the coastal ocean waters, and ocean ecosystems change in cycles. Some cycles of change are decades long, some cycles are centuries long, and some are thousands of years long.

In the summer, phytoplankton (Diatoms) are so numerous in the ocean their "blooms" can be seen from space.

Some cycles relate to the moon and the sun. For example, high and low tides, caused by the phases of the moon, mix the layers of nutrients in the ocean. Bigger tides increase nutrient availability. The amount of sunlight (seasons) also impacts the amount of nutrients in the water (photosynthesis), and how those nutrients are absorbed.

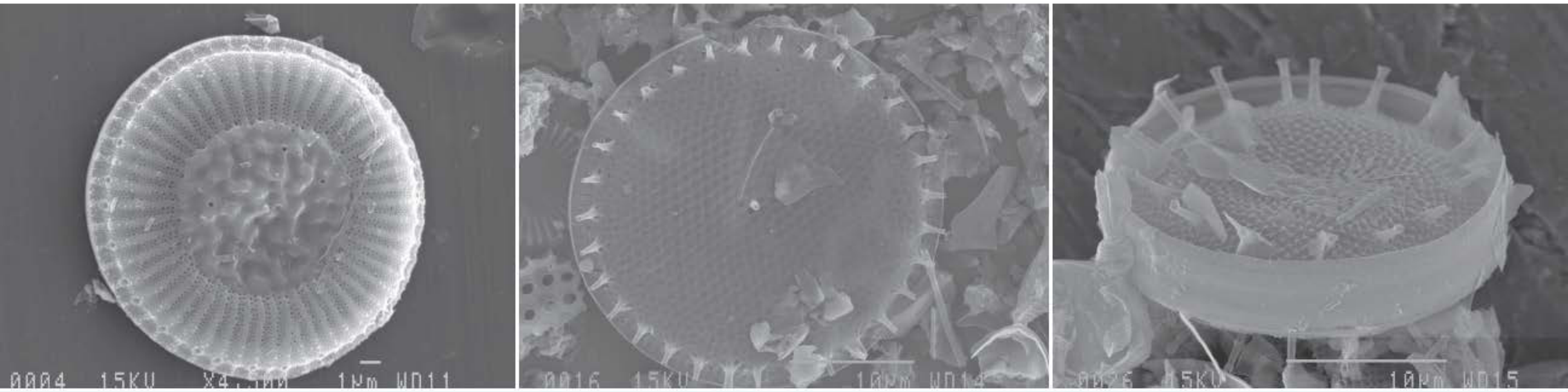
However, the causes of many of the cycles in the ocean and atmosphere are still mysterious. With all these cycles interacting with each other, it's not so easy to predict how our oceans, atmosphere and marine ecosystems work today, let alone how they will work in the future as climate changes. There is so much more for the ocean scientists of the future to discover!

VENUS

The Victoria Experimental Network Under the Sea (VENUS) is a seafloor laboratory that uses a network of underwater fibre optic cables to monitor the Saanich Inlet, Fraser Delta and Strait of Georgia.

In the Saanich Inlet, the VENUS network measures the unique geochemical environment, including ancient seafloor bacteria preserved by the low levels of oxygen in the inlet. The network also monitors the many marine species that must adapt to the differing levels of oxygen that occur in the inlet, at the mouth of the inlet, and outside the inlet.

For more information on the VENUS project, visit ***venus.uvic.ca***



Over 4,000 identified species of Diatoms are found in the Saanich Inlet
Left: Cyclotella Sp. *Center:*Thalassiosira pacifica
*Top right:*Thalassiosira nordenskioeldii.

VENUS equipment is lowered to the seafloor in the Saanich Inlet.

GETTING THERE:

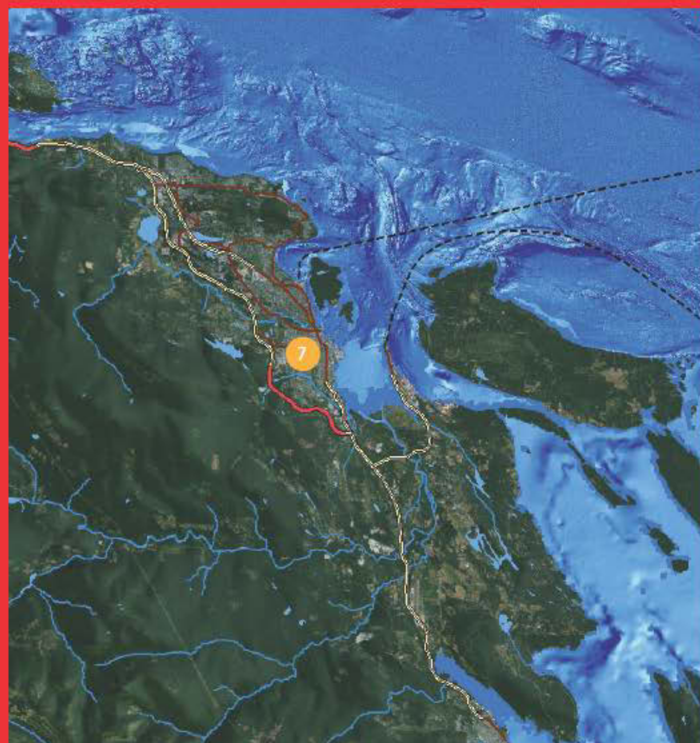
To get to the Malahat Lookout from Victoria, travel north along Highway 1 towards Duncan. Pass the rest area at the summit, and turn into the following rest area - a small cut-away hill between the road and viewpoint - for a spectacular vista of Saanich Inlet below.

To reach the ferry from Brentwood Bay, take the Pat Bay Highway and turn left at Keating Cross Road. At West Saanich Road (Highway 17A), turn right and travel through Brentwood Bay's roundabout, turning left on Verdier Avenue and down the hill to the ferry terminal.

If you're coming from Duncan, turn left on Deloume Road at Mill Bay, then take a right on Mill Bay Road. The Mill Bay ferry terminal is at the end of the road.

If you'd like to visit Natural Resources Canada at the Institute of Ocean Sciences, continue from Brentwood Bay, along rural West Saanich Road, for approximately twenty minutes to Pat Bay. The building will be on your left hand side.

NANAIMO



Salish Sea GeoTour

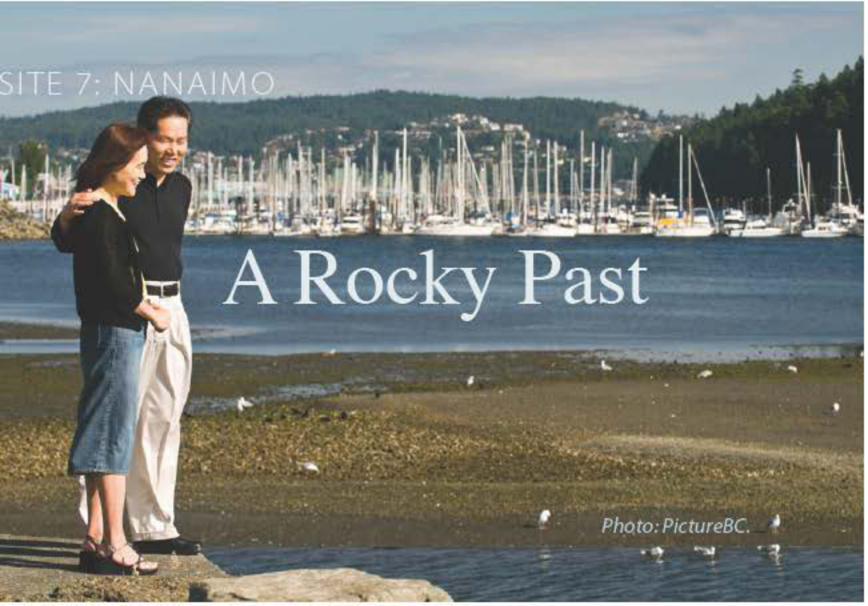


Photo: PictureBC.

All Aboard!

TWO SCENIC FERRY ROUTES CONNECT NANAIMO AND VANCOUVER, ACROSS THE FREQUENTLY CHOPPY, TIDAL CURRENTS OF THE STRAIT OF GEORGIA.

Or, if you're coming from Victoria, Nanaimo is an hour and a half drive north through the smaller communities of Mill Bay, Duncan and Ladysmith. Whichever way you come, you're travelling into a landscape that's been covered in ice, trampled by dinosaurs, warmed by a tropical climate, and mined for coal.

Departure Bay ferry terminal, with Newcastle Island in the background (below).

The Oldest Rock

Because we see, touch, and walk on them every day, we don't usually think much about the rocks below our feet. However, rocks shape everything we do: where we live, how we get our water, and the resources we take from the earth.

The oldest rocks below Vancouver Island are nearly 400 million years old. They belong to the *Wrangellia Terrane,* the ancient piece of the Earth's crust that forms most of the island and much of the coast of southern Alaska. These rocks include limestone and volcanic rocks that formed below the ocean, and at great depths were injected with molten granite, later cooling and solidifying. The folding and faulting caused by movement of the tectonic plates gradually brought these rocks to the Earth's surface. For more information on terranes, see the Salish Sea Mountains section of this guide.

The Nanaimo Group – a Rocky Past

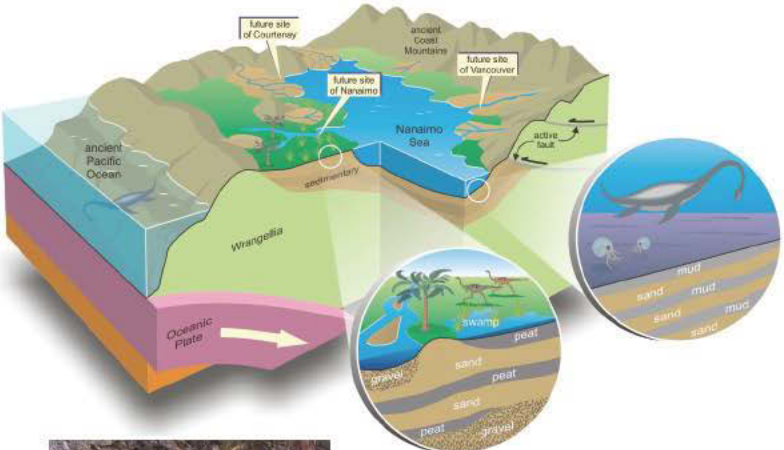
From about 90 to 65 million years ago, sand, gravel and mud eroded from the Coast Mountains, and accumulated on the shorelines and seafloor of a broad sedimentary basin covering much of the Wrangellia Terrane in the modern Salish Sea area. As the weight of the sediment build-up increased, it compressed the sand, gravel and mud into layers of sedimentary rock called the *Nanaimo Group.* The Nanaimo Group makes up most of eastern Vancouver Island and contains coal, fossils and some of the local water supply.

Salish Sea GeoTour

Tropical Nanaimo

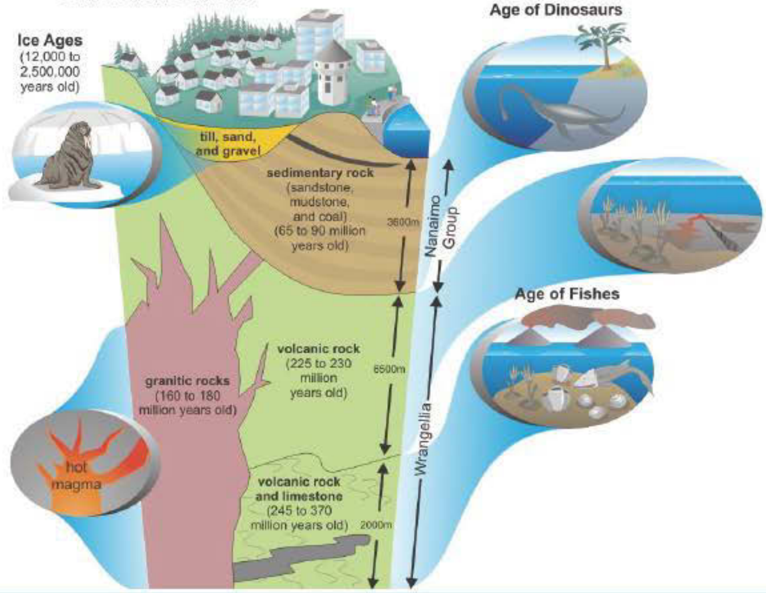
The Nanaimo Group sediments deposited on top of the Wrangellia rocks give us a snapshot of a vastly different environment than the one that exists today.

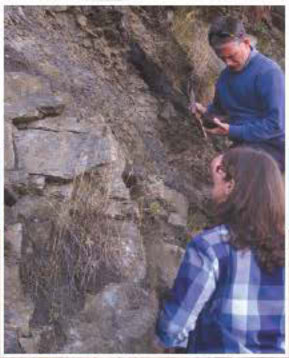
Eighty million years ago, Nanaimo was tropical. At the edges of the basin, swamps filled with decaying vegetation, eventually transforming into coal. The fossilized leaves, nuts, flowers, crabs, turtles and even sharks – and the fossils of extinct animals like ammonites, mosasaurs and elasmosaurs – are evidence of Nanaimo's tropical climate.



Ice Age Nanaimo

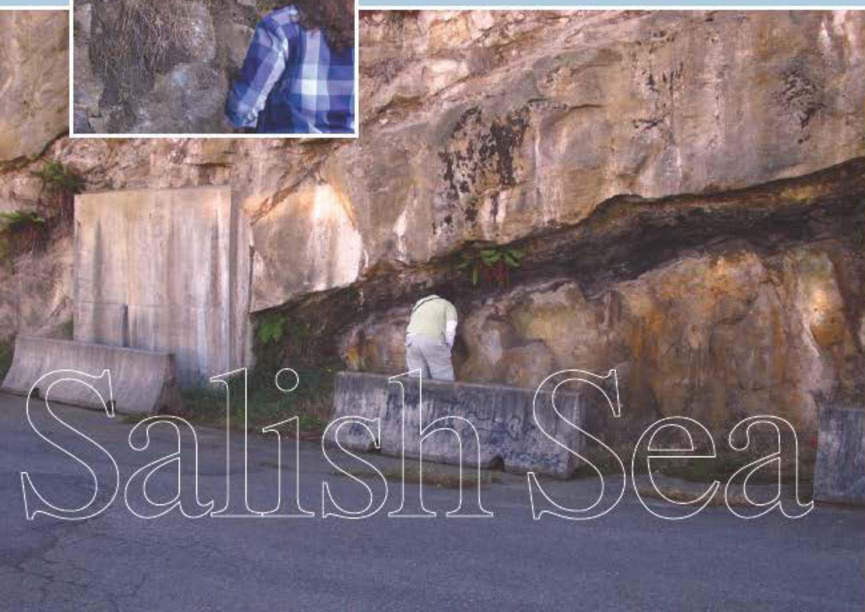
Fast forward to the more recent past – in geological terms at least. The most recent period of glaciation began about 35,000 years ago. The climate turned colder and wetter, and almost all of Vancouver Island was covered by at least one-and-a-half kilometres of ice. The ice sheet began to retreat 14,500 years ago, melting rapidly and leaving most of Nanaimo under water. Ancient clam shell fossils, found far above present sea levels, prove that Nanaimo was on the ocean floor 15,000 years ago. As the land rebounded from the weight of the glaciers, Nanaimo – and the clam shells – were above sea level once more.





Geologists study Nanaimo Group rock near the Duke Point Terminal. Photos: R.G. Anderson.

A mastodon, like this one in the Natural History Museum of New York, once roamed the area around Nanimo.



Nanaimo Coal

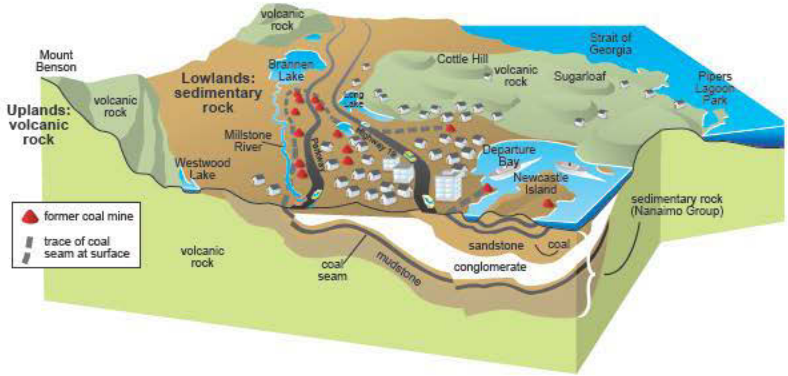
In 1849, the local Che-wech-kan people of Nanymo Bay brought Newcastle Island coal to the attention of the Hudson's Bay Company in Fort Victoria. The discovery of this ancient resource – dating back to the formation of the Nanaimo Group rocks – heralded the start of mining in the Nanaimo coalfield.

Working in the mines was difficult and dangerous, claiming the lives of nearly 700 men. Most of the Nanaimo mines closed when the demand for coal dropped in the 1970s. The only mine still open in the region is the Quinsam mine near Campbell River. However, excavators are exploring the possibilities for mining coal to generate methane, just north of Nanaimo.

For more information on Nanaimo's history of coal, a visit to the Nanaimo District Museum is well worth your time. The "Coal Mine Experience" lets visitors experience what life was like underground, and recreates a working mine shaft and equipment.

Photo: Picture BC.

A Trip to Newcastle Island



Originally occupied by the Coast Salish peoples, Newcastle Island, a ten-minute ferry ride from downtown Nanaimo, is a wonderful spot to walk the history of coal and geology of Nanaimo. The island enjoys a colourful past: coal mining between 1849 and 1883; sandstone quarrying from 1869 to 1932; and the operation of several Japanese-owned herring salteries – until World War II and the internment of the Japanese in British Columbia's interior. However, since 1931, people enjoyed the island first as a resort, and today as a publicly owned marine park.

Take the one-and-a-half kilometre Kanaka Bay trail from the day-use area. You'll walk through towering Douglas-fir, past a marsh, to a ventilation shaft, part of the old coal mine on the island. The shaft is 119 metres deep and over 100 years old. People find many of these shafts around Nanaimo. Fortunately, most of them are now covered over or filled in.

After the Wrangellia Terrane collided with the edge of North America, coal bearing rock accumulated on the east side of Vancouver Island, creating coal seams like this one in Nanaimo. Photo: R.G. Anderson.

Salish Sea GeoTour

Photos: PictureBC.

If you're still feeling energetic, take the Channel Trail once you return to the day-use area. You'll walk through Douglas-fir, arbutus, and Garry oak, and along the water to an old sandstone quarry. Sandstone from the Nanaimo Group was quarried extensively on the island because of its strength and high quartz content. Newcastle sandstone was used to build the Nanaimo Post Office, Nanaimo Court House, and a number of buildings around the world, including the San Francisco Mint. From 1923 to 1932, the sandstone was also quarried into metre-sized discs that were used to grind wood-chips into pulp. Circular holes where the discs were quarried, and some imperfect pulp-stones, are preserved in the park.

Honeycomb Weathering

The sandstone at Newcastle Island also offers you a chance to see some unusual shapes in the stone as you wander the beaches and trails of the island. Take a closer look at some of the weird netted patterns in the sandstone. Geologists call this *honeycomb weathering.*

Honeycomb weathering requires a mix of permeable rock, a source of soluble salt - like ocean water, and repeated episodes of wetting and drying - like ocean spray from tides and waves. At Newcastle Island, waves deposit saltwater onto the porous sandstone. As the water dries, the salt crystallizes and causes the minerals in the sandstone to break apart and become loose. Over time, wind and waves erode the loose minerals. A type of algae, growing on the sandstone in some places, creates a protective barrier between the sandstone and saltwater, preserving walls between the cavities, and creating the weird and wonderful netted patterns.

So why isn't all the sandstone on Newcastle Island honeycombed? Some sandstone is simply more resistant to erosion, and forms ridges, lips and concretions – cannonball shaped rocks within the sandstone layers.

The erosion of the Nanaimo sandstone is an active and ongoing process. If you want to see more, take a short 20-minute ferry ride from Nanaimo to Gabriola Island. The Malaspina Galleries are a series of spectacularly eroded sandstone caverns and overhangs at Taylor Bay in Gabriola Sands Provincial Park. You can see the galleries at low tide from the beach, but the best viewing is done from a kayak.

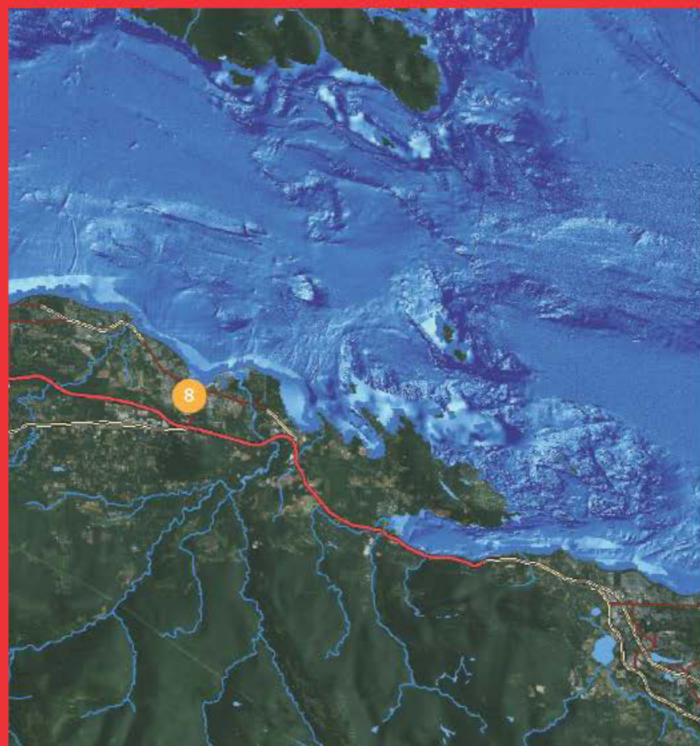
Photo: Pacific Northwest Expeditions Ltd. seakayakbc.com

GETTING THERE:

The scenic two-hour ferry ride from Tsawwassen to Duke Point takes you from Vancouver to just south of Nanaimo on Vancouver Island. The terminal is located approximately 30 minutes south of downtown Vancouver along Highway 99. Alternatively, take the equally scenic Horseshoe Bay ferry from West Vancouver. You'll arrive close to downtown Nanaimo in an hour-and-a-half. If you're travelling by car from Victoria, take the TransCanada Highway (Highway 1), and follow the signs to turn off on Old Island Highway (Highway 19A) to Nanaimo.

To reach the Newcastle Island ferry terminal, take Highway 19A to downtown Nanaimo, and turn at Comox Road, heading towards the water. Parking is available at Comox and Cliff streets, and the terminal in Maffeo Sutton Park is a short walk along the waterfront

PARKSVILLE



Salish Sea GeoTour

A Lesson in Beachside Geology

Photos: PictureBC.

Rathtrevor Beach: Geology in Action

THE AREA OF OCEANSIDE – PARKSVILLE AND QUALICUM BEACH – IS WELL KNOWN AS A BEAUTIFUL AND GEOGRAPHICALLY DIVERSE REGION. IT'S ALSO WELL KNOWN FOR ITS BEACHES.

At the south end of Parksville, as you come into town, you'll pass the most popular camping spot in British Columbia, Rathtrevor Provincial Park. Rathtrevor Beach is the reason; almost a kilometre of white sand stretches towards the Gulf Islands and Coast Mountains at low tide.

Rathtrevor Beach is also a great example of geology in action. In winter, storms move the sand on the beach offshore, leaving pebbles and cobbles fronting a narrow-looking beach. The smaller waves and calmer winds of summer bring the sand back again, and create a wider and smoother beach.

Sand Sculpture

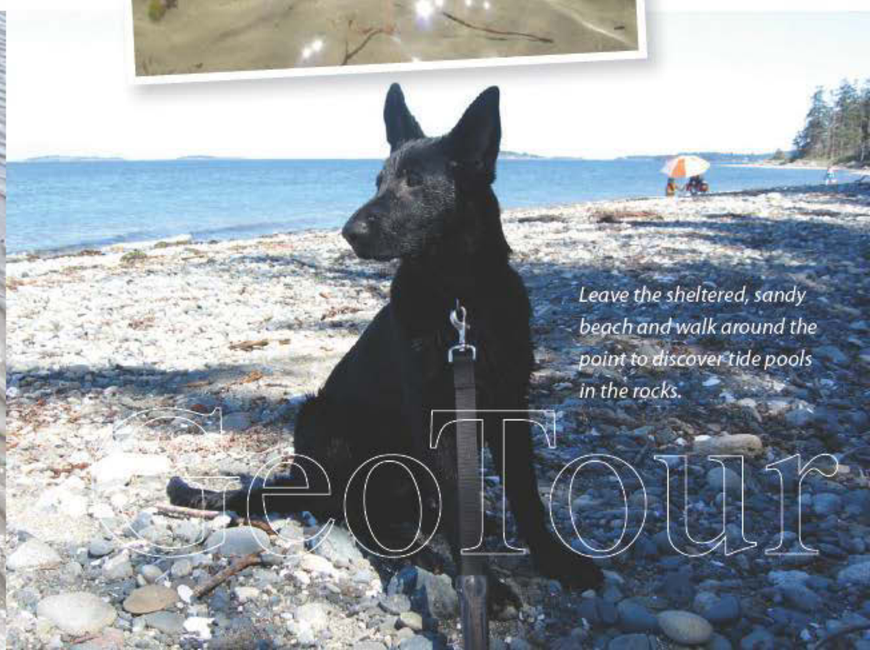
As you walk along Rathtrevor Beach, you'll notice the many sand ripples and ridges, both above the tide line and in the water. When a storm blows through the area, it creates a *storm ridge,* with lots of logs and debris. The action of tides and waves form most of the ripples in the sand, but where the sand is very dry, the wind can also blow it around to form small ripples and dunes.

Chasing the Tides

Unless you live by the beach and see the changes from season to season, the most obvious change to most beachgoers is the tide coming in and out. If you set up your towel too far down the beach, the rising tide will chase you back up. There is such a strong tidal range at Rathtrevor, and the beach is so wide, that you can actually see each wave creeping a little farther up the beach as the tide comes in.

Visitors of all ages enjoy the beaches of Rathtrevor year round.

The *intertidal zone* – where the water covers and uncovers the sand as the tides change - is home to a wide range of specialized creatures. At low tide, you will see many crabs scurrying across the beach and numerous holes in the sand, the tops of burrows made by clams and worms. The large stretch of sand and changing tides also create one of the warmest swimming beaches in British Columbia. The tide comes in over the hot sand, heating the water.



Leave the sheltered, sandy beach and walk around the point to discover tide pools in the rocks.

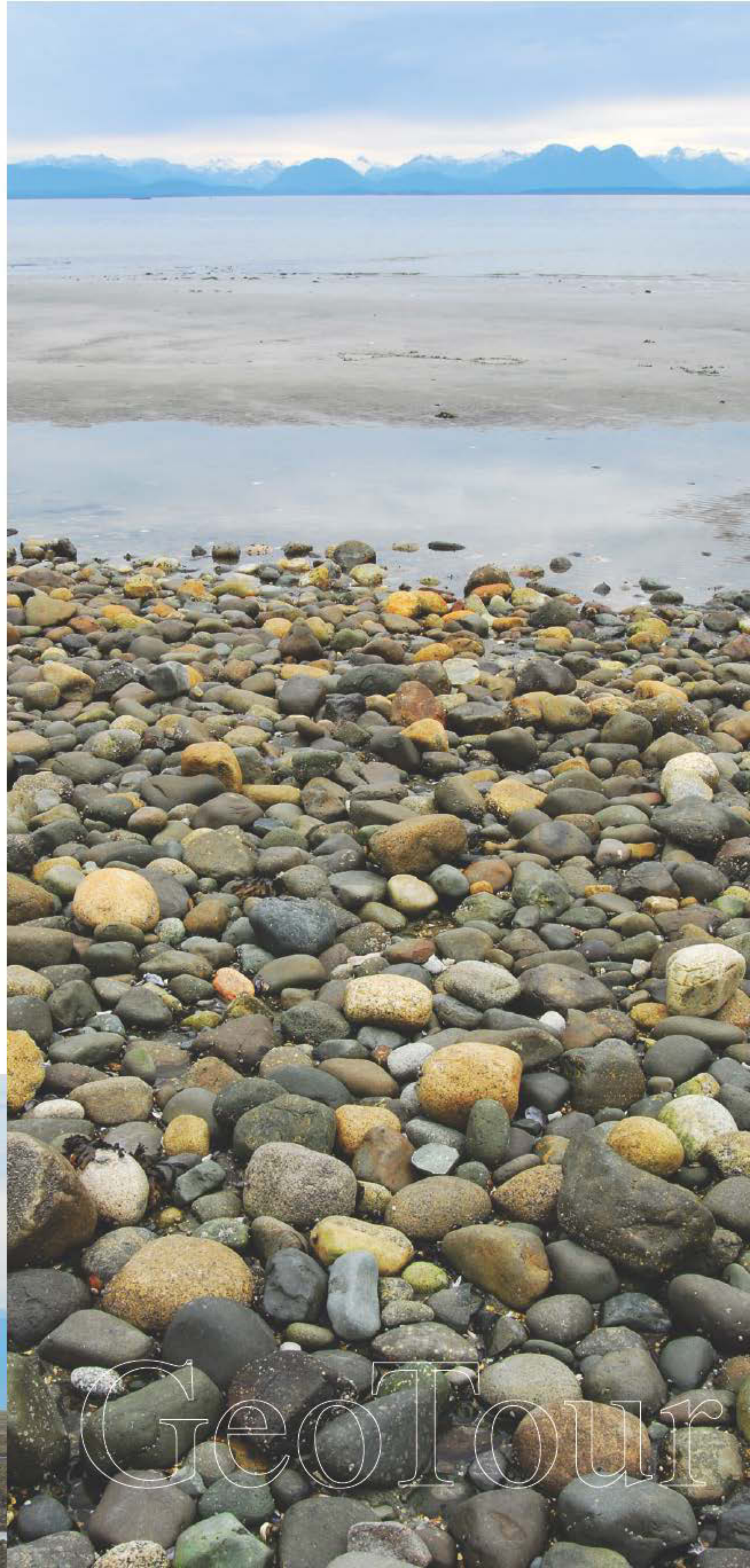
Recipe for a Beach

Continue along the highway to Parksville, turning right on Corfield Street to get to Parksville Community Beach. Note the great expanses of sand, especially at low tide. After taking a quick dip in the warm water, continue north along the West Island Highway to Qualicum Beach. The highway takes you directly to the beach, so find a spot to stop and walk the along the promenade that parallels the beach. You'll notice how different the shoreline is, although you've travelled only a few kilometres. At high tide, Qualicum Beach is mostly pebbles and cobbles.

Photo: PictureBC.

The recipe for making a Salish Sea beach depends on the mix of ingredients, including the amount of glacial deposits in the local area, the energy and direction of the prevailing winds, waves, currents and tides, and the type and availability of rock or sediment on nearby shores. Parksville Beach is open to different wind and tidal patterns than Qualicum, but the differences between the two beaches are more likely due to the availability of sand. The sediment (sand) deposited on Parksville beach comes from an abundant source: adjacent sand bluffs laid down by ancient glacier-fed rivers. Known as the Quadra Formation, these sand bluffs are found throughout the Salish Sea Basin. Because of its location, Qualicum Beach has only a limited source of sediment – from the erosion of a rocky shore. For more information on the sand bluffs and Quadra Formation, see the Introduction in this guide.

The sheltered position of Qualicum Beach provides summertime water temperatures of up to 21ºC - a nice change from the average 12ºC temperatures of the Salish Sea.



GETTING THERE:

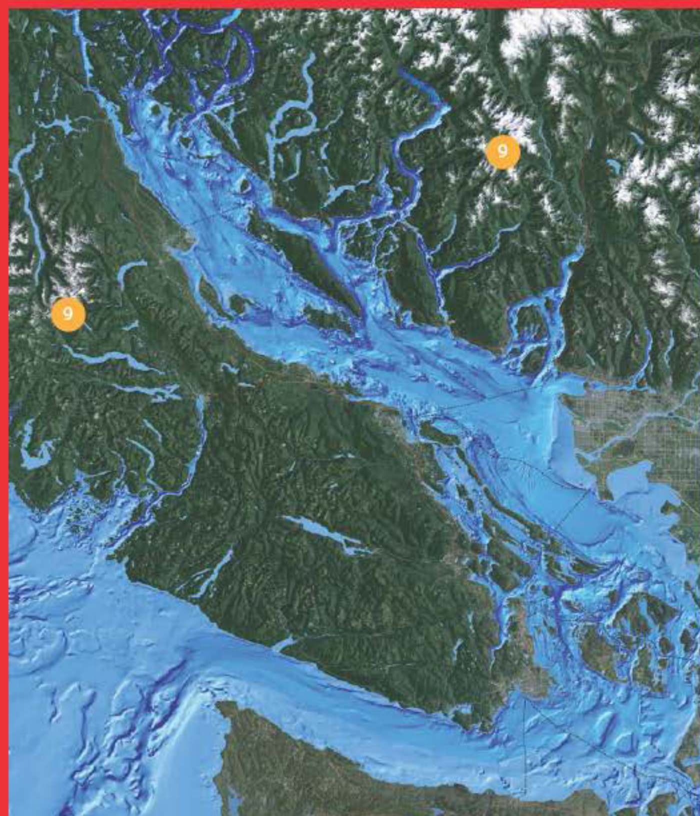
Parksville is a 30-minute drive north of Nanaimo along the Island Highway (Highway 19). To see the amazing sands of Rathtrevor Beach, turn off of Highway 19 at exit 51. Rathtrevor Beach is well sign posted on your right-hand side.

Parksville Community Beach is adjacent to downtown along Highway 19, and has great picnic and playground facilities.

If you continue north along the West Island Highway (Highway 19A), you will reach the community of Qualicum Beach. Turn up Memorial Avenue from the beach to see the town.

Salish Sea

SALISH SEA MOUNTAINS



GeoTour

9: SALISH SEA MOUNTAINS

A Sea Surrounded

The Coast Mountains provide a stunning backdrop to Vancouver.

Mountains on Every Side

WHETHER YOU TRAVEL THE SALISH SEA REGION BY BOAT, PLANE, BIKE OR CAR, MOUNTAINS SURROUND YOU.

On British Columbia's mainland, the Coast Mountain Range dominates the Vancouver skyline, while on Vancouver Island, the mountain ranges provide the spiny backbone of the island's geology. The Salish Sea mountains, like British Columbia's other mountain ranges, are a result of massive tectonic forces deep below the Earth's surface.

Looking towards Mount Arrowsmith on Vancouver Island.

The Salish Sea, and most of southwest British Columbia down to northern California, sits on the edge of where two of the Earth's tectonic plates meet: the oceanic Juan de Fuca Plate, and the much larger continental North American Plate. The smaller Juan de Fuca Plate is slowly sliding or subducting underneath the North American Plate. During the collision, the subduction process pushes up ancient rock from below the Earth's surface to create the mountain ranges in the region. Subduction is a process that still goes on today.

Rocks and a String of Old Volcanoes

If you flew into Vancouver, drove through the Lower Mainland, or came from Vancouver Island, you'll have seen the Coast Mountains looming over Vancouver. You're looking at granitic bedrock that was once far below the Earth's surface but was pushed upwards between 45 to 175 million years ago.

Over tens of millions of years, erosion stripped away the rock on the surface, exposing the ancient granitic rock you see today. Geologists believe the granitic rocks of the Coast Mountains were once the molten roots of deeply eroded volcanoes. Most of today's Coast Mountains aren't volcanoes – they're just made of ancient rock that melted and then crystallized deep within the Earth's crust. However, in some places younger volcanoes built up over these old volcanic roots, creating successive chains of volcanoes. Only the very youngest volcanoes - less than three-million years old - have survived erosion and remain today, including Mount Baker and Mount Garibaldi.

Dramatic Mount Garabadi forms part of the Coast Mountain Range.

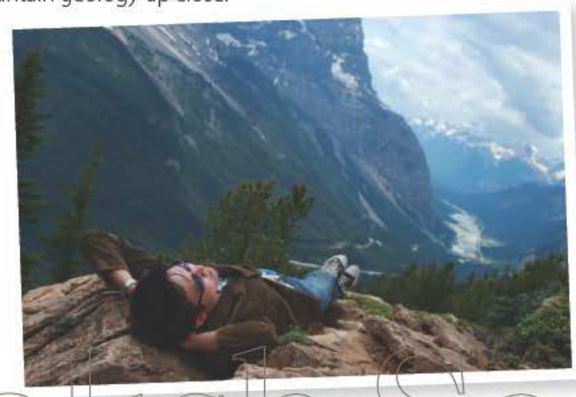
Salish Sea GeoTour

Shaping Mountains with Sandpaper

Views of Howe Sound and the Sea to Sky Highway from Stawamus Chief.

The subduction process created the Coast Mountains, but what we see today also owes much to erosion by water and ice. As the glaciers grew and then retreated over eight ice ages, ice and rivers carved U-shaped valleys which then filled with layers of sediment when the glaciers retreated. Advancing glaciers formed deep, ocean fiords too – read more about the Salish Sea fiords in the Powell River section of this guide.

As well as forming the valleys, glaciers also shaped the mountains - literally. At various times over the ice ages, sheets of ice covered mountain slopes below 1,500 metres elevation. As the glaciers advanced and retreated, the sand and gravel trapped in the ice acted like sandpaper, smoothing and rounding the peaks. The Coast Mountain peaks that appear rough and jagged remained above the ice. If you have the time, use the *Sea to Sky Geotour Guidebook* ***(bcgeotours.nrcan.gc.ca)*** to take a trip from Vancouver to Whistler along the Sea to Sky Highway and see some of this mountain geology up close.



Mountains on an Island

Many people don't know that there are magnificent mountain ranges on Vancouver Island. The tallest peaks lie in the middle of the island, with a graduated band of lowlands extending north and south from the centre, and down to the seafloor past Port Hardy, the most northerly point on the island you can reach by driving, and Victoria in the south. Many of these peaks remain snow-capped well into summer, and some have permanent ice fields, easily visible from the shores of the Salish Sea near Parksville.

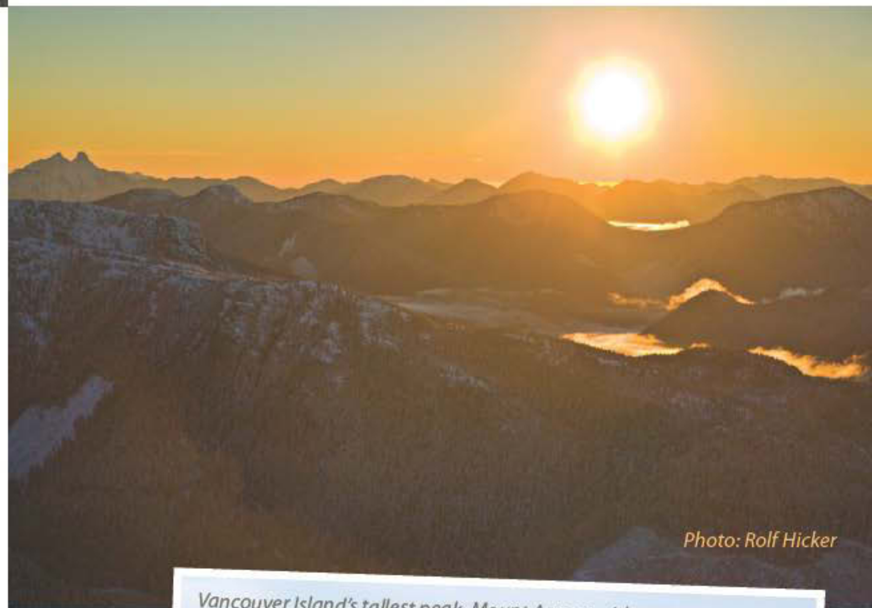
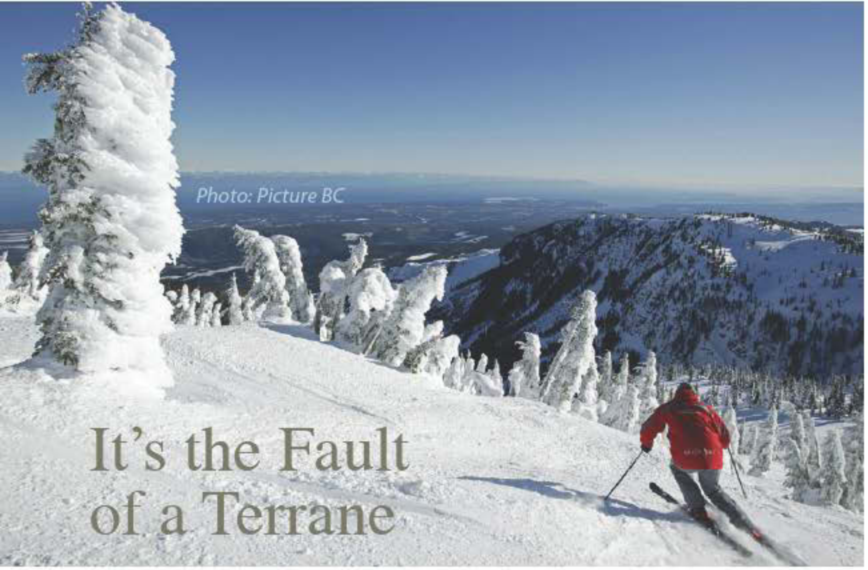


Photo: Rolf Hicker

Vancouver Island's tallest peak, Mount Arrowsmith, looms in the background at Parksville beach.

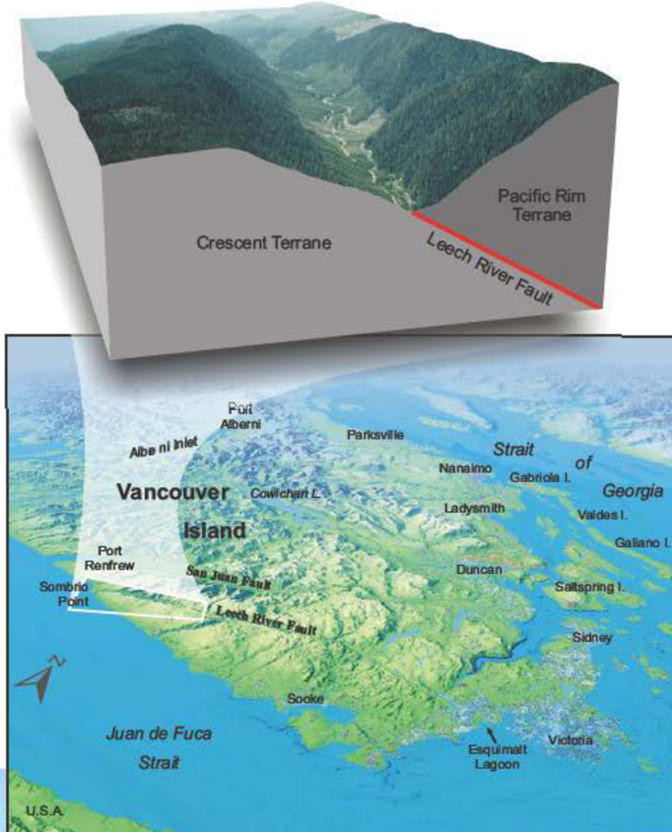


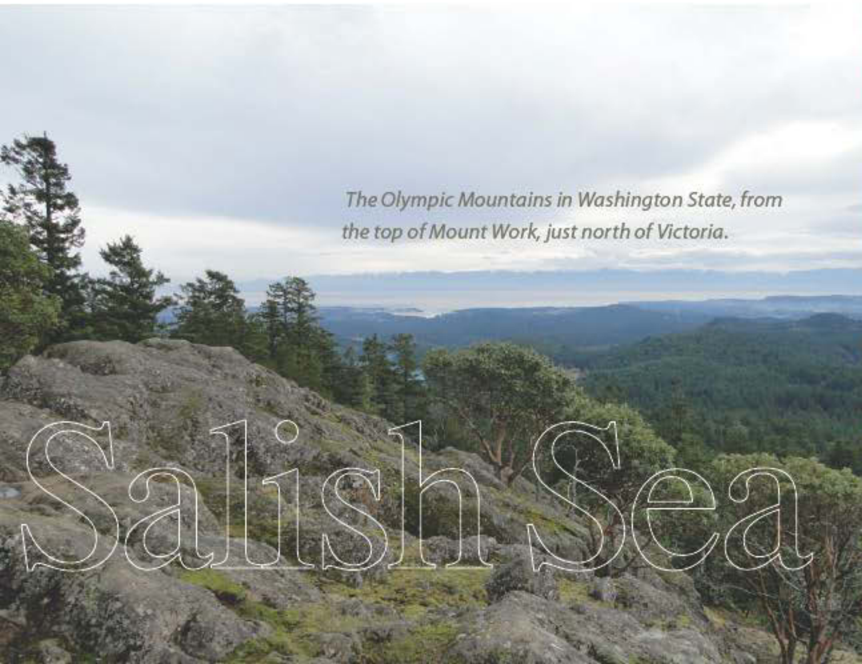
It's the Fault of a Terrane

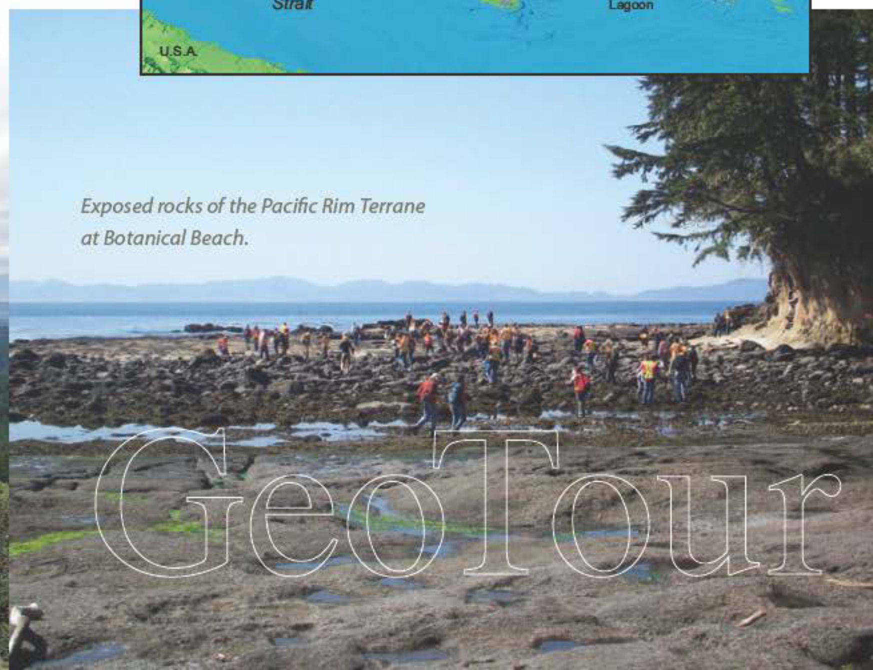
The mountains of Vancouver Island owe their existence to the subduction process too, but have a slightly different story than the Coast Mountains. As the ancient oceanic plate collided with the North American Plate, underwater volcanoes, mud, and ancient islands were crushed together and added to the edge of the North American Plate. These pieces of the Earth's crust are called *terranes*. The Salish Sea is made up of many of these terranes, and each one is unique. Some of the rocks that make up the terranes have come from thousands of kilometres away! The boundaries between the terranes are called *faults* and you can clearly see some of these faults, like the Leech River and San Juan faults near Victoria, as long linear valleys on a map.

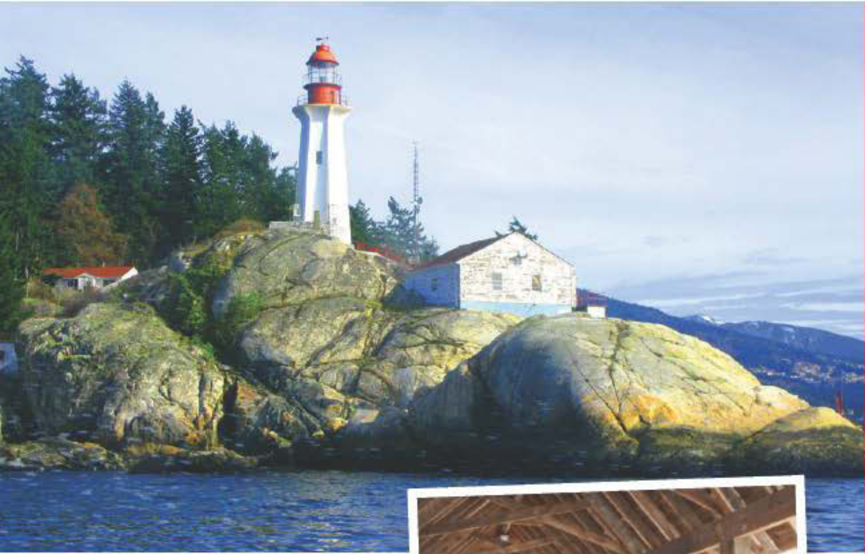
So how exactly were the mountains on Vancouver Island created? Between 45 and 52 million years ago two terranes, the Crescent and the Pacific Rim, crashed into the piece of crust Vancouver Island was sitting on (the *Wrangellia Terrane*). This massive crash thrust ancient rock skyward, creating the mountain ranges.

However, as with the Coast Mountain Range, the mountains we see on Vancouver Island today are quite different from the mountains that were thrust skyward millions of years ago. Geologists estimate that up to ten kilometres of rock has already been eroded from the mountains on Vancouver Island since they were formed.




The Olympic Mountains in Washington State, from the top of Mount Work, just north of Victoria.


Exposed rocks of the Pacific Rim Terrane at Botanical Beach.



GETTING THERE:

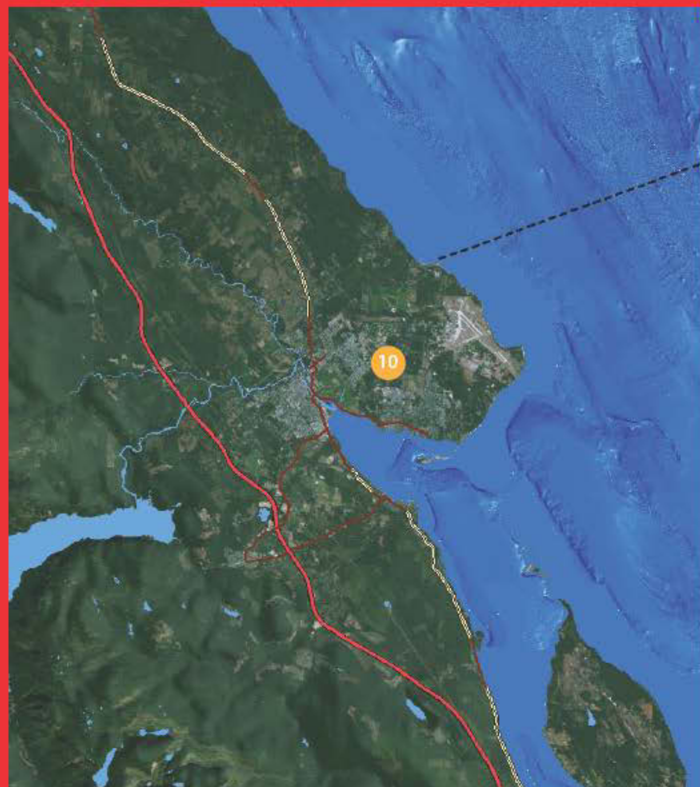
*The best way to see the Coast Mountains is to take a drive along the Sea to Sky Highway (Highway 99) from Vancouver to Whistler. There are gorgeous parks, waterfalls, and lookout points up and down the highway. The Sea to Sky GeoTour **(bcgeotours.nrcan.gc.ca)** provides a guided geological tour of that area. You'll also see some of the range as you travel the Sunshine Coast to Sechelt and Powell River.*

To get a closer look at Vancouver Island's mountains, head towards the Parksville area. From many of the beaches and roads surrounding Parksville and Qualicum Beach you'll see snow-capped Mount Arrowsmith at 1,818 metres high. Or take a day trip to Mount Washington near Courtenay.

In the winter, seven metres of snow isn't unusual, making for incredible skiing, and in the summer, hundreds of kilometres of mountain biking and hiking trails will get you up close and personal with the ancient rock.

Salish Sea

COURTENAY-COMOX

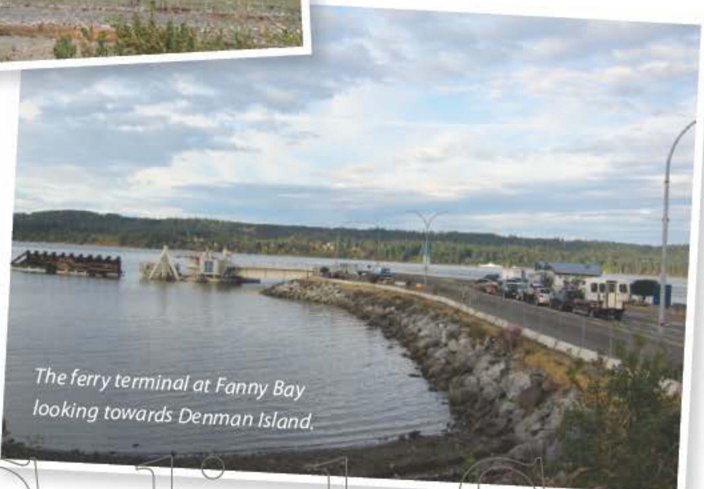


GeoTour

Coal, Sand and an Ancient Reptile

Denman Island

Take Highway 19A, the West Island Highway, from Parksville for a leisurely and scenic view of mid-Vancouver Island. As you pass Fanny Bay, you'll see Denman Island across a short stretch of water. After the last Ice Age, the sea level in the Comox area was about six metres lower than it is today. A long sandbar once connected Denman Island to Vancouver Island, and a large intertidal beach stretched all the way from the northern cliffs of Denman Island to Comox. Today however, you'll have to take a ferry to reach the island, as the large beach is now seafloor.



The ferry terminal at Fanny Bay looking towards Denman Island.

Comox Coalfield

Comox and the communities of Courtenay and Cumberland owe much of their early history to the vast Comox coalfield. The field covers 2000 square kilometres, extending from Fanny Bay to Campbell River. Between 1888 and 1953, the field produced 19 million tons of coal. The mines brought the railway, development of the harbours, and immigrants from China and Japan to the area. Today, a single mine operating west of Campbell River is all that remains.

Cumberland Photos: Picture BC.

Just before you reach Courtney, turn left on Royston Road, and take a side trip to Cumberland. Royston Road will cross the Island Highway and become Dunsmuir Avenue. Stop at the Cumberland Museum at the corner of Dunsmuir and First for a guided tour of coal mining in the area. Tours and displays explain how coal is formed, and tell the story of the dangers, the miners and the impacts of coal mining on the Comox Valley.

Aerial view of Comox. Photo: Picture BC.

Salish Sea GeoTour

The Sand Science of Goose Spit

Goose Spit is a large sand formation that juts off the southeast tip of Comox and extends offshore into Comox Bay. Head down Hawkins Road and drive out onto the spit through a narrow entrance. On one side of the spit, you'll find the sandy beaches and shallow protected waters of Comox Bay. The other side of the beach is more gravelly and open to the strong currents of the Strait of Georgia.

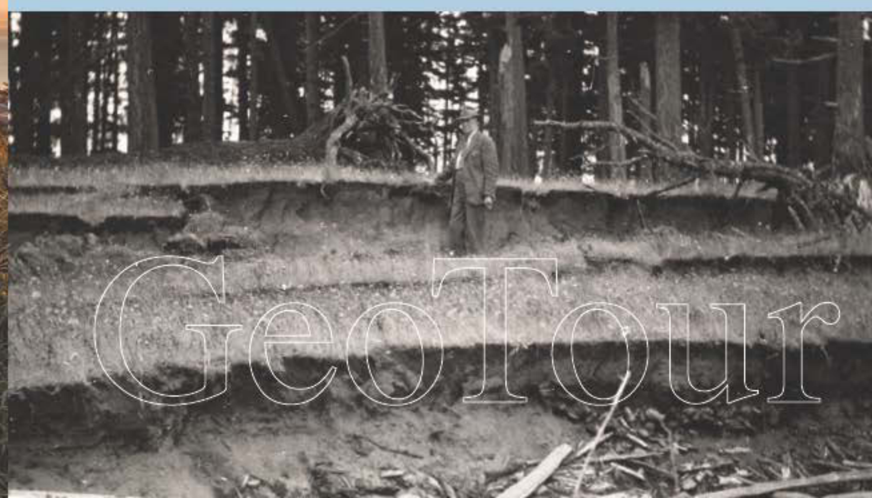
A spit is created by waves that hit the land at an angle, gradually extending the beach laterally from a point of land. At Goose Spit, the waves hit the seaward side of the spit, and carry the sand around the end, giving the spit its hook-like shape. The area inside the spit is sheltered, an ideal habitat for rare plant species and perfect for anchoring a boat and bird watching.

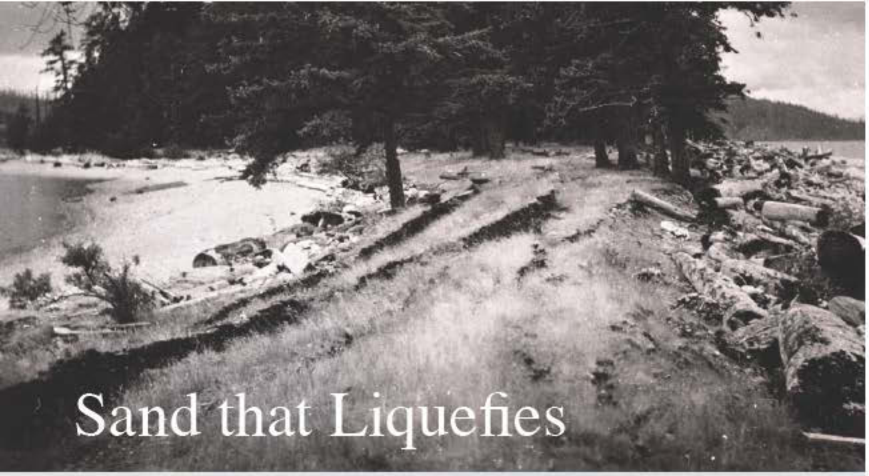
Goose Spit
Photo: Picture BC.

Slip-sliding Away

One of the largest earthquakes on record in the Salish Sea region, a magnitude 7.3, occurred on June 23, 1946. Its epicentre was 30 kilometres below the town of Courtney. Records show damage to buildings and roads throughout the region, and people reported many strange observations, including cracks and trenches, geysers of mud and *sand boils* – liquefied sand that looks like it's boiling out of the ground. Reports tell of a trench the length of a football field at the west end of Goose Spit, and in places, sections of the beach completely disappeared. A modern survey of the seabed offshore of the spit shows that an underwater *submarine landslide*, triggered by the earthquake, was a probable cause of these features.

Impacts of the 1946 eathquake: the submarine landslide off Goose Spit (above), and dramatic land movement on shore near Courtenay (below).





Sand that Liquefies

In all, seventeen similar cases of submarine beach failures occurred in the region due to the 1946 earthquake. Sand formations like Goose Spit seem to be quite susceptible to a process called *liquefaction*. Have you ever stomped on a sandy beach until the sand turns into a slurry of sand and water? When sand grains are shaken up, they pack themselves tightly together and expel the water, filling the spaces between them and creating the slurry. The shaking caused by an earthquake has a similar effect on the water-filled sediments below the beach. In the resulting slurry, the sediments lose all their strength and just flow or slide down the relatively steep underwater slope the sand spit has created.

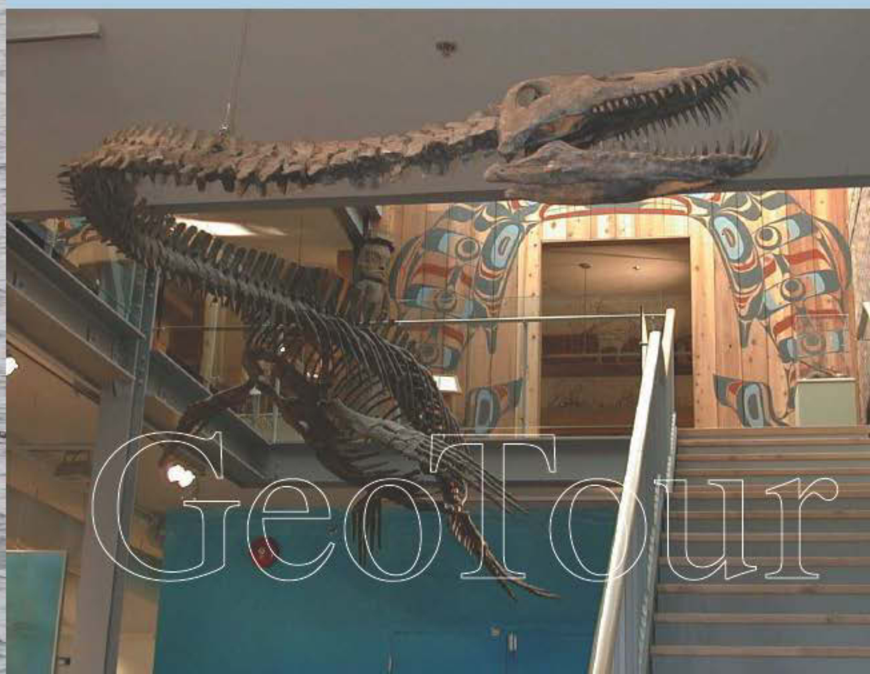
Photo: Picture BC.

Discovering Dinosaurs

In 1988, two amateur palaeontologists – a man and his daughter – discovered a cluster of fossils on the banks of the Puntledge River, west of Comox. Months of studying and testing revealed that the great beast was an Elasmosaur – the first found in British Columbia. Over ten metres (35 feet) long, the Elasmosaur is an 80-million-year-old long-necked marine reptile. Since then, other discoveries include two Mosasaurs (sea lizards), a second Elasmosaur, and a tooth from a Theropod dinosaur. Visit the Courtenay Museum to see these amazing creatures. The museum's palaeontology department also runs field trips to the excavation sites where you might discover your own dinosaur!

Photo: Picture BC.

Elasmosaurs were about 14 metres long and weighed over 2,000 kilograms. They were sea dwellers, and ate mainly fish. In addition to the Putledge River Elasmosaur displayed at the Courtenay and District Museum (photo), other specimens have been found at Trent and Englishman Rivers.



Salish Sea GeoTour

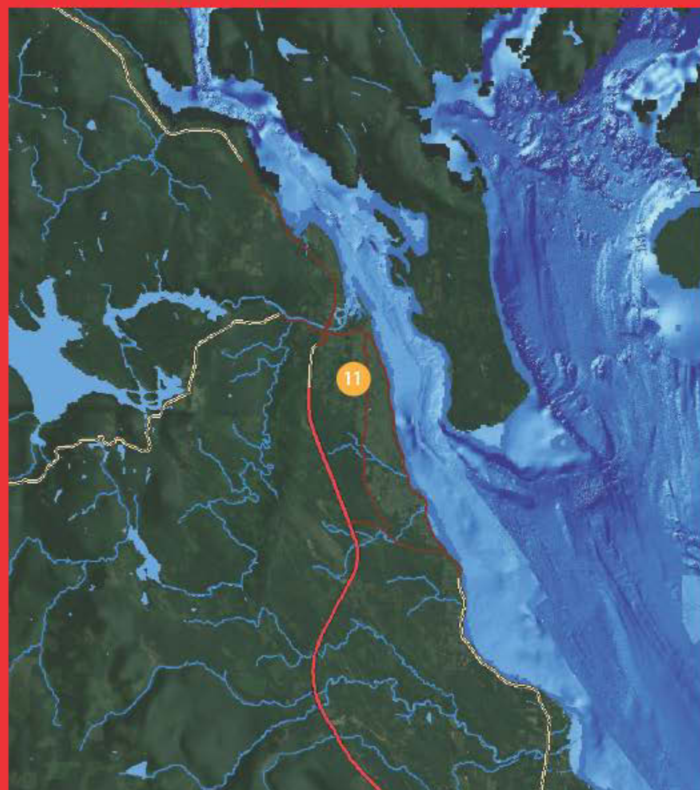
Photo: Picture BC.

GETTING THERE:

Comox is about three hours north of Victoria, or an hour from Nanaimo along the TransCanada Highway (Highway 1). From Parksville, take the scenic West Island Highway, or the faster Island Highway (Highway 19). You can also get to Comox via an hour-and-a-half ferry ride across the Strait of Georgia from Powell River.

To reach Goose Spit, head south of Comox on Comox Road. Turn left on Pritchard Road, then right on Balmoral Road. Balmoral Road becomes Hawkins Road, leading to the spit.

CAMPBELL RIVER



Salish Sea GeoTour

A Narrow Tale

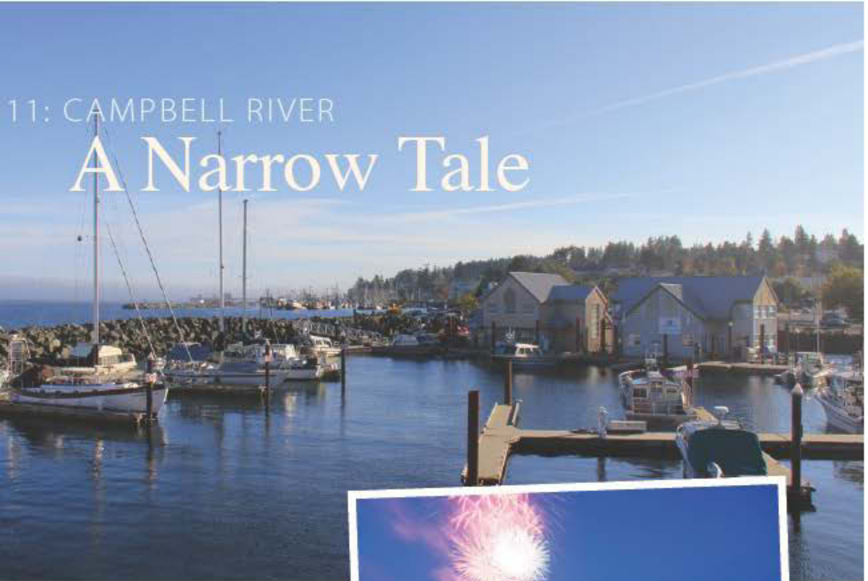


Photo: Picture BC.

A Small Town with a Big Bang

Located an hour-and-a-half drive north of Parksville, Campbell River is the salmon capital of Canada. It's an interesting town to spend some time in, take a fishing charter and reel in a few salmon, or go whale watching to see Orca, seals and many waterbirds.

If you're lucky enough to be on a boat, your captain might take you through treacherous Seymour Narrows in Discovery Passage. If ocean travel isn't for you, drive 11 kilometres north of Campbell River on Highway 19 to the Ripple Rock Rest Area. Or, stop at the well-marked parking lot, six kilometres past the rest area, for a four-kilometre hike through first and second growth forest to a viewpoint of the Narrows. However you get there, you're looking at the site of a National Historical Event – a massive explosion that had much to do with geology.

Ripple Rock

Ripple Rock is an underwater mountain located in the middle of Seymour Narrows. For many years, it had a notorious reputation: its twin peaks were less than three metres below the surface of the water at low tide. Captain George Vancouver called it "one of the vilest stretches of water in the world." Over the years, Ripple Rock damaged or sunk 119 ships, and more than 100 lives were lost. In 1958, 1,270 tons of explosives blew the mountain up. The blast displaced 635,000 metric tons of rock and water, throwing debris 300 metres in the air and onto the land on either side of the Narrows. Captured by television, it was one of Canada's first nationwide broadcasts. Today, the remainder of the twin peaks sit 14 metres below the waterline at low tide – a much safer distance for most boats.

Even though the peaks of the mountain are gone, Seymour Narrows, with its furious tide changes, remains a dangerous stretch of water. If you're viewing the Narrows by land, try to time your visit with the changing of the tides. You'll see large ships and fishing boats battle steep waves, in some cases going just as much backward as they are forward. Only the largest boats travel this stretch of water when the tides change, and even today, the duelling tidal currents occasionally catch mariners unaware.

If you're lucky, you'll see a cruise ship go by. Because the passage is so narrow, it feels like you can reach out and touch the ship as it passes. If you're visiting at slack tide, you'll see smaller boats making the trip through the passage, a safer time to travel.

Photo courtesy of the Campbell River Museum.

Using the Tides for Power

Seymour Narrows is one of the top 50 potential sites for tidal power generation in Canada. This is because large volumes of water are forced through the small passages of the Narrows. Because of strong tidal currents, several other sites around the Gulf Islands in the Salish Sea offer excellent potential for tidal power too. In the future, this type of technology may provide power to local communities.

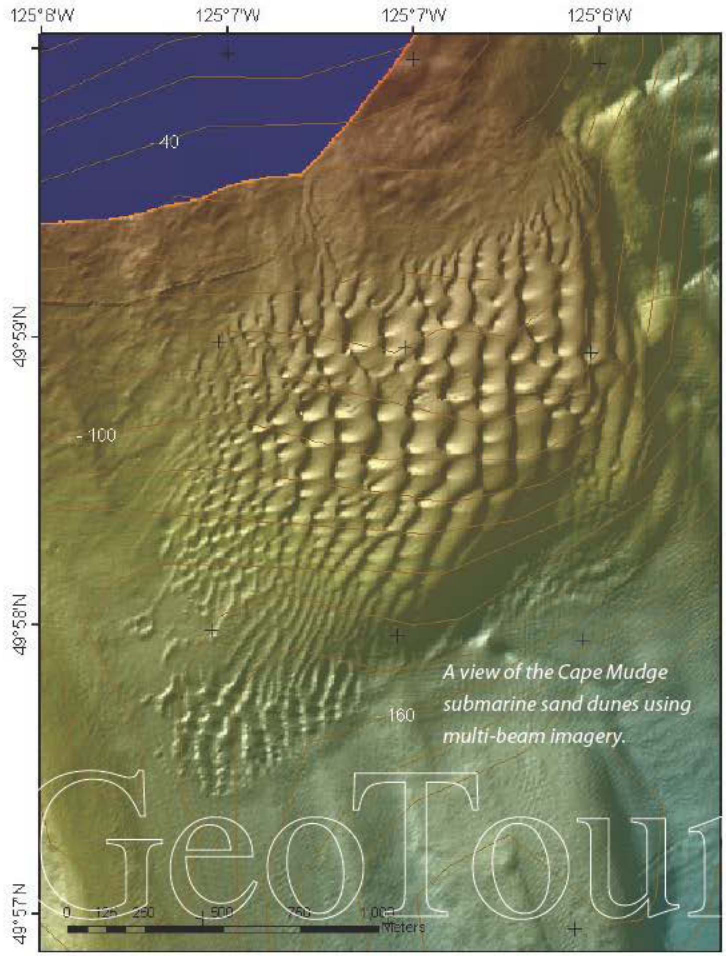
Tidal turbine installation at Race Rocks on Southern Vancouver Island.

The Power to Move Sand

The same strong tidal currents that are dangerous to mariners have the power to move mud, sand and even gravel-sized sediment along the bottom of the seafloor. When the conditions are just right, sand and gravel can be sculpted into impressive underwater dunes. An example of these underwater dunes is found off the We Wai Kai First Nation village at Cape Mudge on Quadra Island. These dunes are up to nine metres high and more than 100 metres in length.

The sandy bottom of the Cape provides the perfect habitat for the sand lance (also known as the needlefish), a long, eel-like fish that burrows into the sand. Sand lances are important forage fish for cutthroat trout and humpback whales.

Face of a Pacific Sand Lance. Credit: Collin Smith, United States Geological Survey.



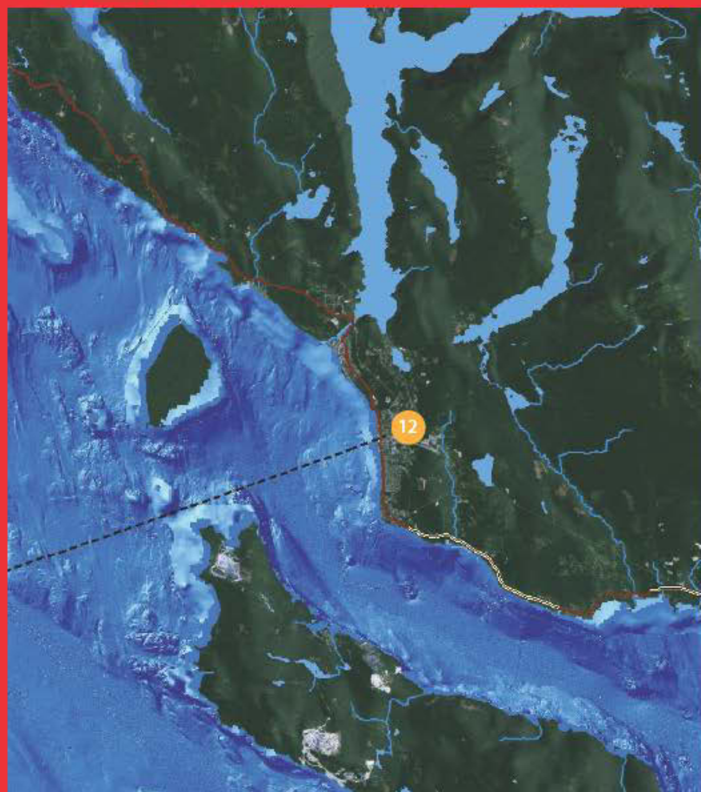
A view of the Cape Mudge submarine sand dunes using multi-beam imagery.

GETTING THERE:

Campbell River is a three-and-a-half hour drive from Victoria, or a two-hour drive from Nanaimo. Take the TransCanada Highway (Highway 1), then at Parksville take either the Island Highway (Highway 19) for a quick trip, or enjoy the many towns and waterfront scenes by following the Old Island Highway (Highway 19A). Quadra Island is a ten-minute ferry ride from downtown Campbell River.

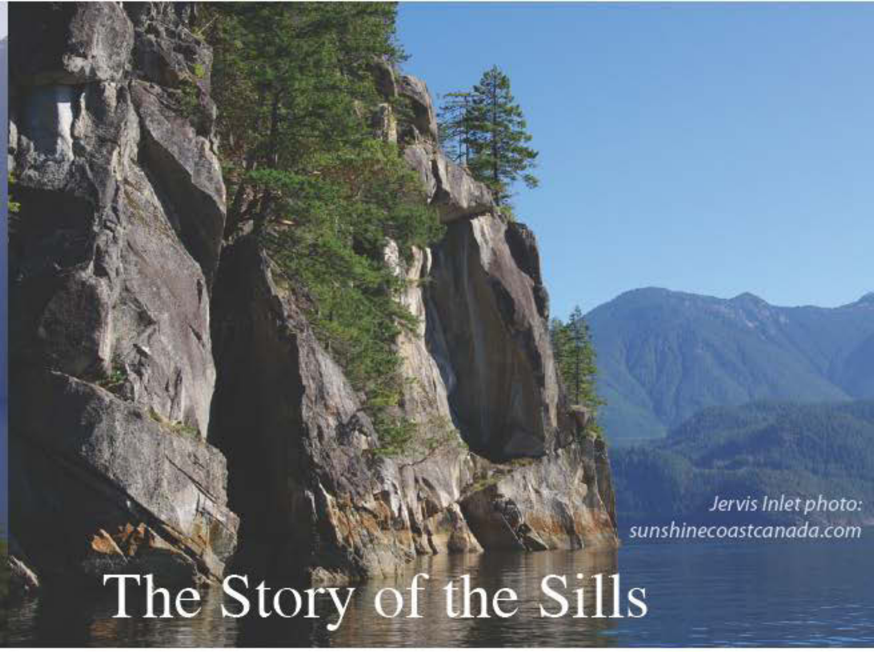
On the docks and along the seawalk at Campbell River. Photos: PicturesBC.

POWELL RIVER



A Sill-y Story

Jervis Inlet. Photo courtesy of Paul McIntosh



Jervis Inlet photo: sunshinecoastcanada.com

The Story of the Sills

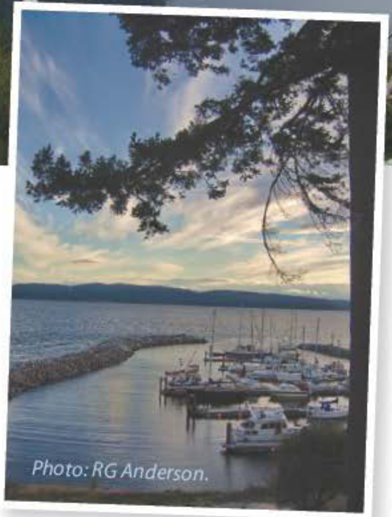
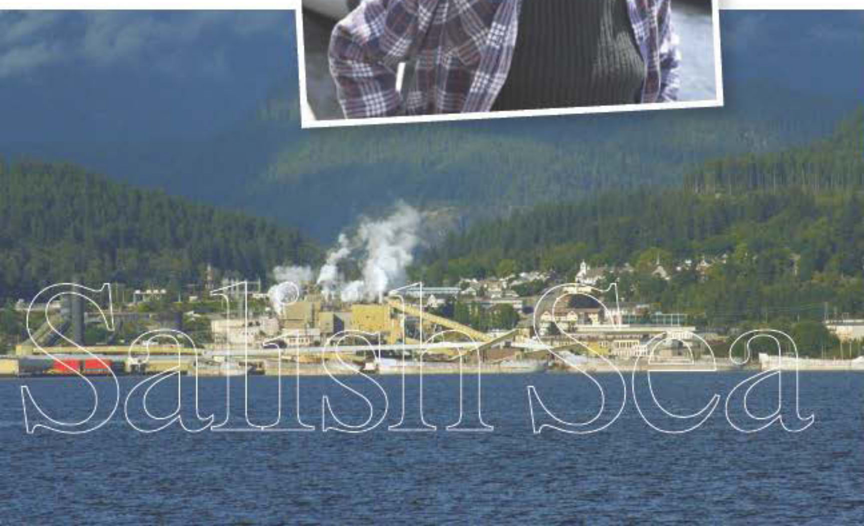


Photo: RG Anderson.

Powell River by Water

At one time home to the world's largest pulp and paper mill, Powell River owes its history to water: a salty lake, changing ocean depths and melting ice. Although Powell River is on the mainland of British Columbia, it's only accessible by water. Take a ferry from Comox on Vancouver Island, or travel the Sunshine Coast from North Vancouver, taking a second ferry from Earls Cove to Saltery Bay (south of Powell River).

The pulp and paper mill at Powell River.



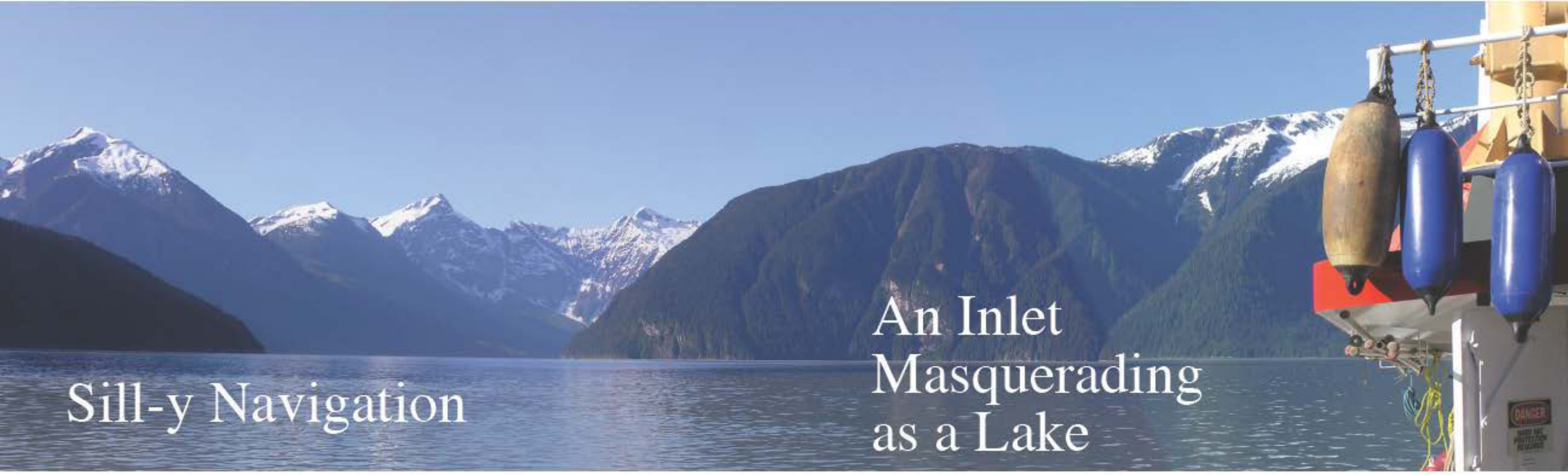
Travelling by ferry from the Sunshine Coast is an excellent way to see the sheer cliffs of Jervis Inlet, a 77-kilometre long fiord cut into British Columbia's mainland by the massive forces of ancient glaciers. At 780 metres deep, Jervis Inlet is also the deepest fiord on the coast.

As the boat enters Jervis Inlet, you're crossing directly over a sill. Sills are piles of crushed rock and silt that once-moving glaciers deposited at their front, or *snout*. As the glaciers travelled down British Columbia's inlets, scouring out the deep fiords we have today, they acted like conveyer belts, bringing huge amounts of rock and silt to the head of the inlet. When the glaciers retreated, they left behind piles of rubble. This rubble formed giant ridges – or *sills* – at the head of the inlets.

Photo: sunshinecoastcanada.com

Saint Vincent Peak, Jervis Inlet.

Salish Sea GeoTour

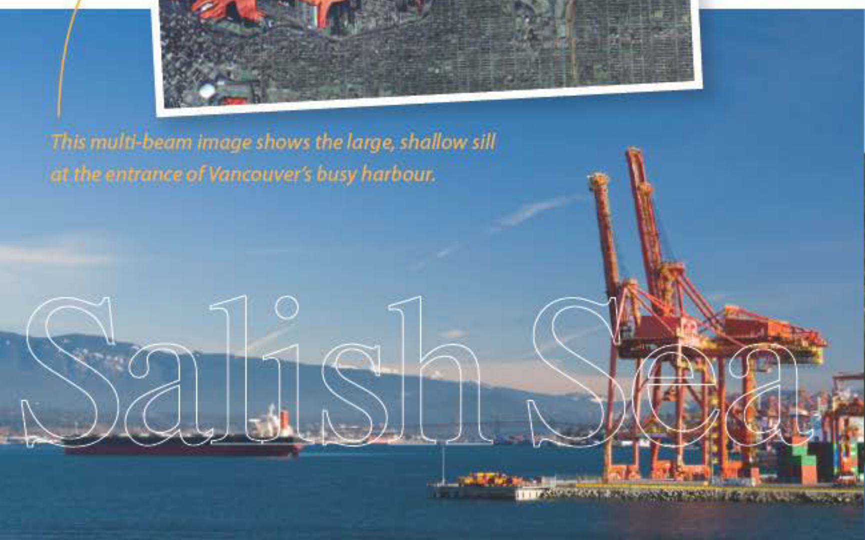


Sill-y Navigation

The change in water depth can be dramatic from one side of the sill to the other, going from tens of metres on the ocean side, to hundreds of metres on the landward side. In Jervis Inlet, the depth going over the sill is 380 metres, and the depth once you're in the fiord is 780 metres. Four hundred metres is quite a difference! That's because glaciers scoured out a deep hole in the bedrock of the inlet, but built a large rubble pile at the entrance, creating a shallow ridge.

In Knight Inlet, north of Powell River, the sill is 60 metres deep while the inlet is 540 metres deep. And, in Burrard Inlet, the *entrance* to Vancouver harbour, the sill is 15 kilometres long and only 15 metres deep at low tide. This creates a huge headache for the captains of the cargo ships and tankers that must enter the harbour to load and unload.

This multi-beam image shows the large, shallow sill at the entrance of Vancouver's busy harbour.



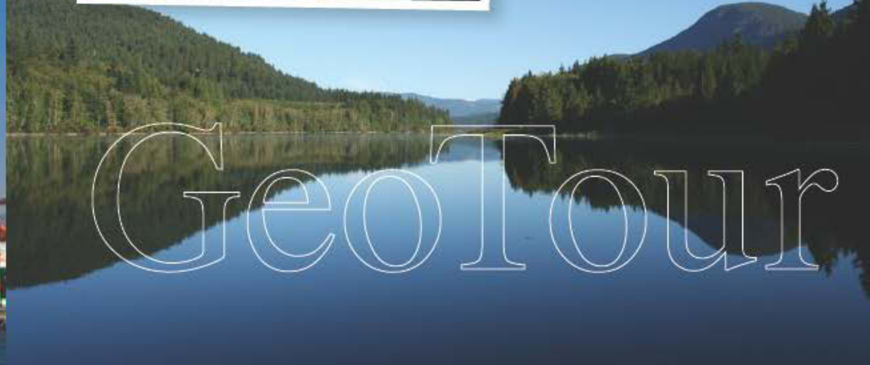
An Inlet Masquerading as a Lake

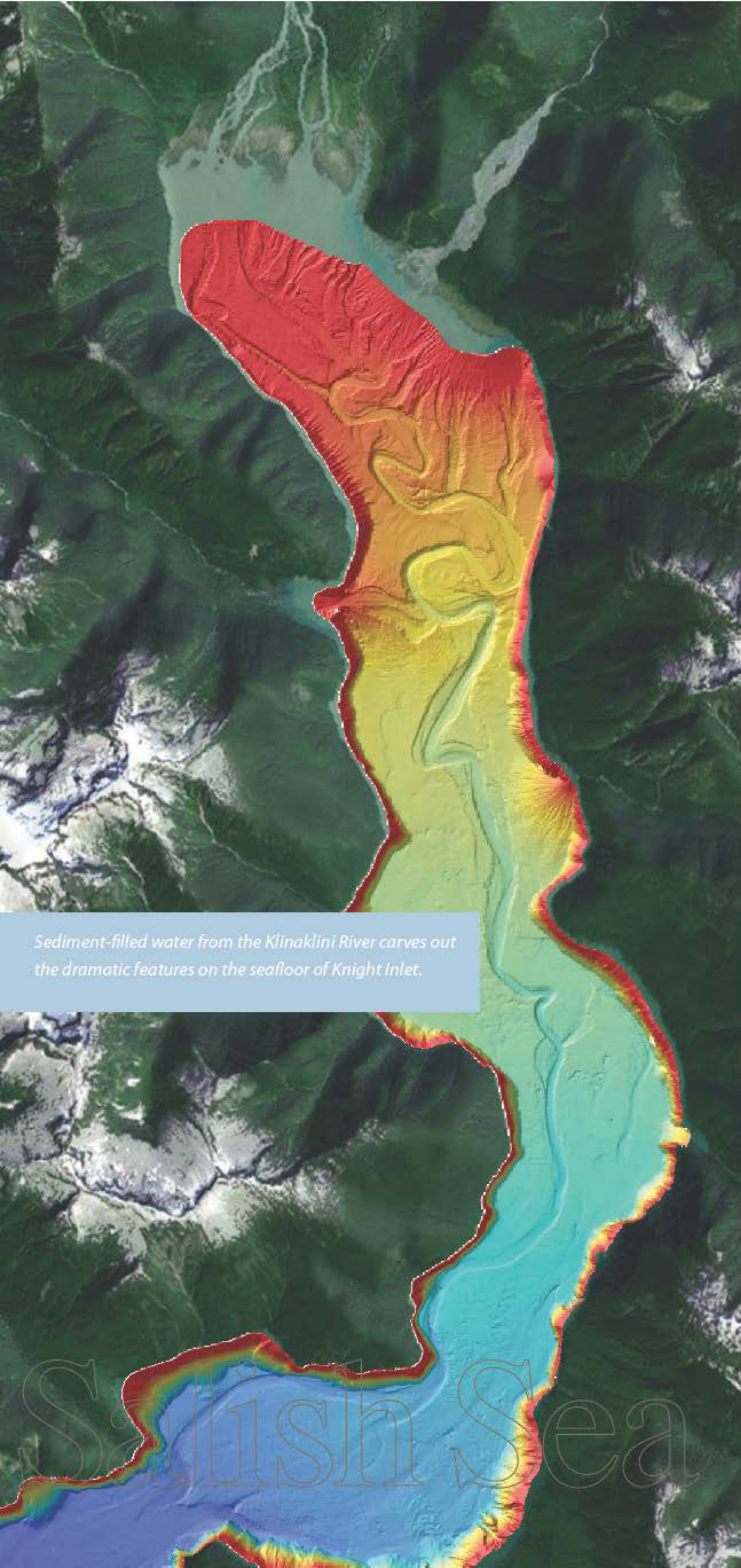
Once the weight of the glaciers was gone, the Earth's crust "bounced back," or *rebounded*, in some places leaving sills high above sea level, and creating rocky *isthmuses.*

From Powell River, drive or cycle a few minutes north to Powell Lake. The lake, with its many beaches, is a great place to take a swim, kayak, camp, or see a rocky isthmus. The "lake" is actually a 300-metre-deep land-locked former inlet, cut off from the sea by the isthmus. This ancient piece of the Salish Sea became land locked sometime between 7,000 and 11,000 years ago.

As you swim, you'll notice that the water is fresh, not salty. That's because several rivers drain into the lake, providing a surface layer of fresh water. So how do we know Powell Lake is an inlet? In 1962, geologists took samples 121 metres below the surface and discovered salt water. In samples from deeper levels, they found water that contained no oxygen or marine life, and had a rotten egg smell, indicating methane gas and hydrogen sulphide from ancient decomposition. Geologists think the water at the bottom of the lake is 10,000 years old!

Six kilometres from Powell River, Powell Lake has 450 kilometres of shoreline.





Sediment-filled water from the Klinaklini River carves out the dramatic features on the seafloor of Knight Inlet.

Underwater "Rivers" in Knight Inlet

There's more than stinky smells or ancient water at the bottom of the fiords in British Columbia. If you put your multi-beam glasses on, you might see channels under the water, running along the seafloor of some fiords.

A channel originates from a powerful river that has built a delta at the head of a fiord. In Knight Inlet, that river is the Klinaklini, which drains some of western Canada's largest ice fields. The Klinaklini River, loaded with glacial sediment, has formed a delta with a steep slope that fails frequently. Slope failures trigger *submarine* (underwater) *landslides*. As the landslide moves down the slope, water mixes into the sediments, forming a dense slurry that accelerates down the slope in a flow called a *turbidity current*. Reaching speeds up to four-metres-per-second (eight knots), these currents erode the seafloor of the fiord, and form channels that look like river channels. They even have tributaries that join and meander across the bottom of the fiord, just like rivers on land.

Melting ice and snow from the ice fields make up 50% of the Klinaklini River flow in the spring, and 25% in the summer.


Photo: PictureBC.

GETTING THERE:

From Sechelt, take the Sunshine Coast Highway (Highway 101), north to Earls Cove. It's a 50-minute ferry ride to Saltery Bay. From there, drive another half-an-hour west and then north along the highway to Powell River.

Regularly scheduled ferries serve Powell River from the Little River ferry terminal in Comox on Vancouver Island.

To get to Powell Lake, it's best to ask for directions locally as the lake area has more than 450 kilometres of scenic shoreline.

Salish Sea

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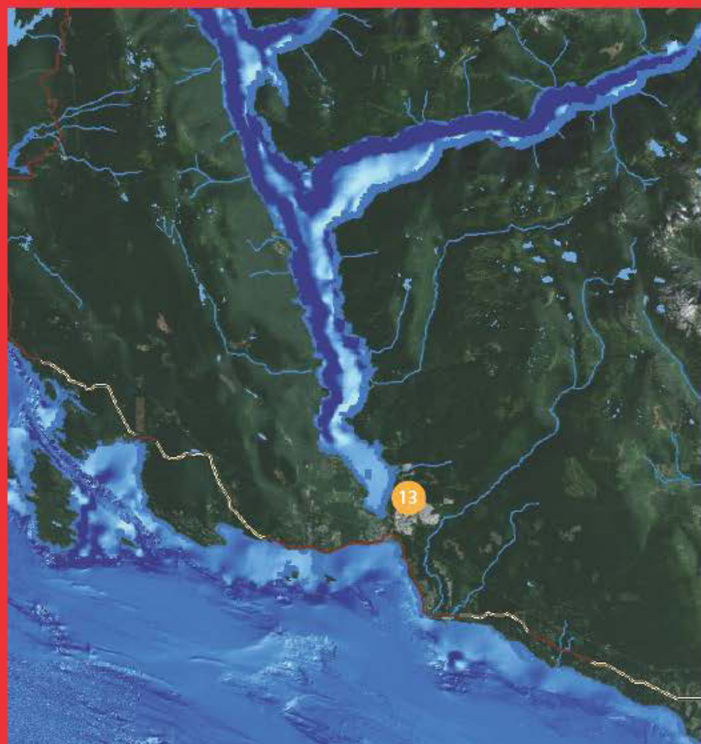

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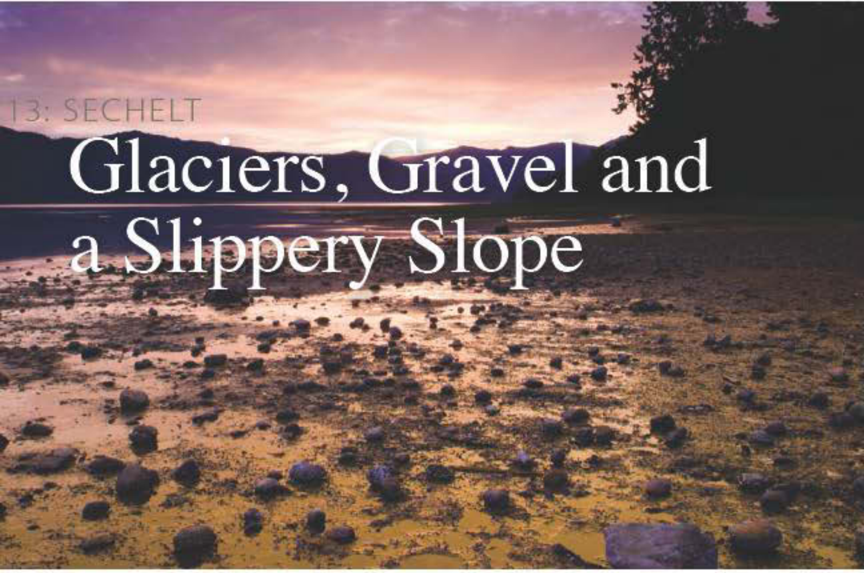
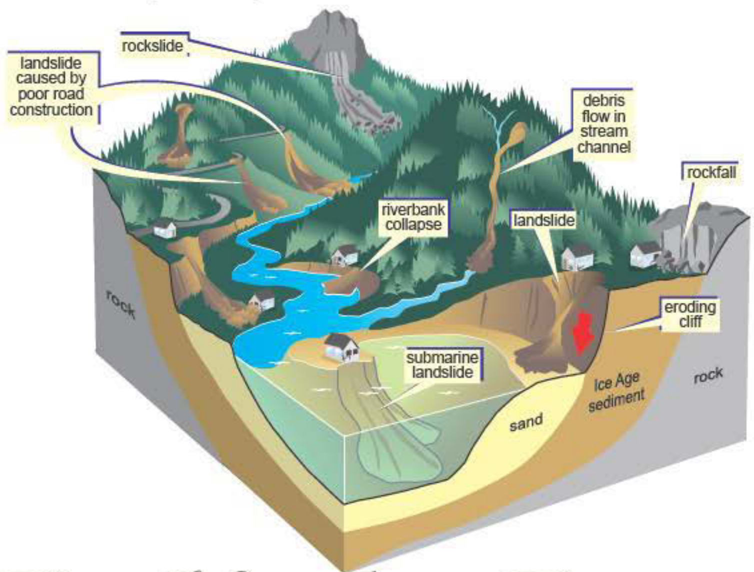


Glaciers, Gravel and a Slippery Slope

The science of landslides is all about slope. Slope affects drainage – the greater the slope, the quicker water and debris drain into the ocean. Slope also impacts the stability of the land – the steeper the slope, the higher the likelihood of a landslide. Landslides come in many shapes and sizes – big, small, fast, and slow – but almost all landslides require a slope and a trigger like a heavy rainfall or an earthquake. In the Coast Mountain Range and the Sunshine Coast, rock falls and rockslides make up a large proportion of all landslides, but fast-moving, water-soaked debris flows that travel down streambeds are also common.

Landslides, a Sloping Story

IF YOU'RE TRAVELLING TO OR FROM THE SUNSHINE COAST AND SECHELT, YOU'LL NEED TO TAKE A FERRY BETWEEN LANGDALE AND HORSESHOE BAY IN NORTH VANCOUVER. If you're leaving from Horseshoe Bay, look right, towards Howe Sound. Spectacular scenery surrounds Howe Sound and the Sunshine Coast communities; sandy beaches, sheer cliffs in numerous ocean fiords, coastal rainforests, and the towering Coast Mountains rising sharply in the background. However, while these natural features bring so much beauty to the area, they also bring the risk of landslides.



Landslide at Howe Sound

Following intense rains on February 11, 1983, a debris flow carrying sediment and a tangle of logs and boulders the size of cars, raced down Alberta Creek towards the community of Lions Bay on Howe Sound. The debris flow caused significant property damage and killed two people. This tragedy is one of many examples of debris flows in areas where roads, rail lines and logging activities have altered drainage patterns. Recent upgrades to the Sea to Sky Highway incorporate protective structures based on what the engineers learned from the events at Lions Bay.

As you travel throughout the Sunshine Coast and Howe Sound areas, notice the ways in which engineers have attempted to reduce the risk of landslides. You'll see wire nets, concrete barriers and specially designed dams that moderate the flow of debris in the event of a large rainfall into a stream system.

Gravel Pit of Glacial Leftovers

Once the ferry docks at Langdale, follow the Sunshine Coast Highway (Highway 101) towards Sechelt. From Sechelt you can see North America's largest open pit sand and gravel mine. In operation for the past 20 years, the mine will likely keep on producing material for the next 30 years. The sand and gravel extracted from the mine goes into construction, concrete production and roads.

So, where did all this sand and gravel come from? During the last Ice Age, glaciers covered the area, bringing not only ice, but also large amounts of crushed rock and other deposits encased in the ice. As the glaciers began to melt and retreat, they left the rock and sand behind. Rivers and streams, formed by melting ice, carried the sediment to the ocean, leaving large deposits of sand and gravel in the form of submarine (underwater) deltas along the shores of the Sunshine Coast. For a few hundred years after the glaciers retreated, the Sunshine Coast region remained depressed from the enormous weight of the Ice Age glaciers that sat on top of it. Sechelt's sea level was about 200 metres higher than it is today. When the land rebounded from the stress of the ice load, these large deposits of sand and gravel became land instead of submarine deltas, giving us deposits like the Sechelt gravel pit.

Gravel exports are an important part of the Sunshine Coast economy.

When they retreat, glaciers leave behind piles of crushed rock and sand. But, we don't often see these ridges – they're under our houses, parks and places of work.

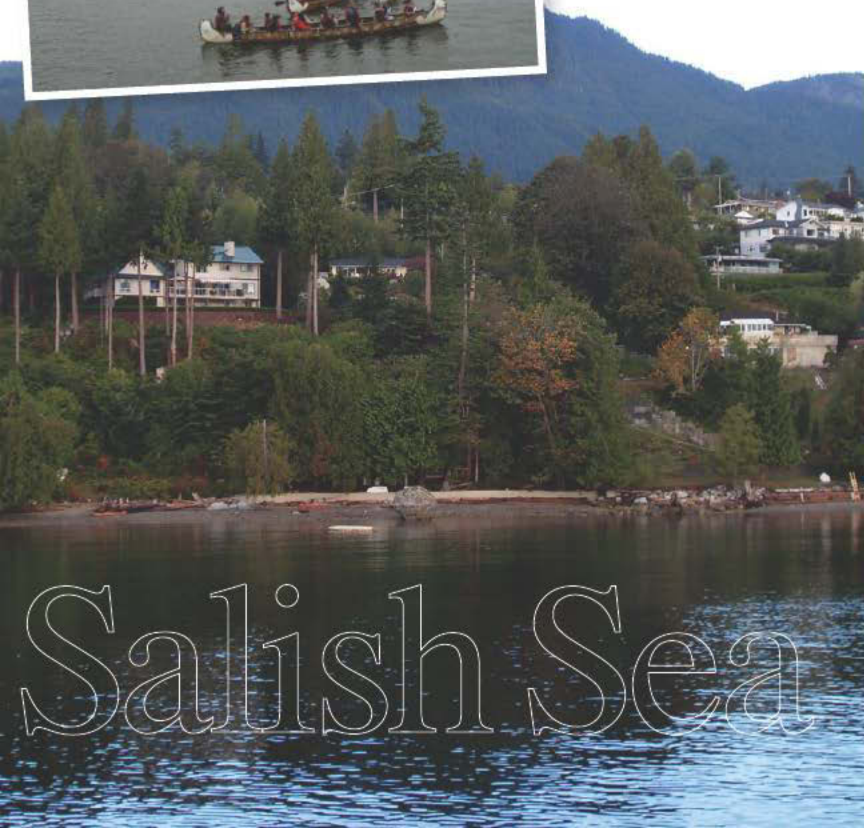
Not at Glacial Speeds After All

Curiously, the glaciers in the Salish Sea area took tens of thousands of years to build up and remain frozen, but only a few hundred years to melt. By dating deposits left by retreating glaciers – like pieces of wood and shells – geologists discovered that the age of the deposits in Sechelt and the surrounding area only span a few hundred years. This tells us that our planet can change slowly or very rapidly, based on forces we don't yet fully comprehend. Information - like how long it took for the Earth to become ice-free after the last glaciation - helps scientists to understand how rapidly our Earth and atmosphere can respond to global climate change.

Glacier in the Tantalus Range, near Whistler

Land between Two Waters

Fifteen kilometres north of Langdale, you'll reach the community of Sechelt. The name *Sechelt,* meaning, "land between two waters," refers to the original First Nations inhabitants, the Shishalh, who have occupied the area for thousands of years.



Take a walk to one of the town's beaches. It won't be too far: the main part of the town is perched on a sandbar, which divides the Sechelt Inlet from the Strait of Georgia. Without this sandbar, Sechelt would be on an island. Sediments deposited during the last Ice Age created the sandbar. After the ice melted, ocean tides and currents built up the sand bar, creating an *isthmus* that's less than four blocks wide.

Whitecaps and Whirlpools

Before you leave the area, travel north of Sechelt to visit the incredible tidal rapids at Skookumchuck Narrows Provincial Park. An easy four-kilometre walk will take you to some of the fastest moving tidal rapids in North America. Each day 200 billion gallons of sea water (on a three-metre tide) rushes over a bedrock lip, or *sill,* between Jervis Inlet and Sechelt Inlet. The difference in sea level on each side of the sill can sometimes exceed two metres, pushing the water through at 30 kilometres (16 knots) an hour. This makes for some spectacular whitecaps and whirlpools, with standing waves reaching up to a metre and a half. Sills are a common feature of glacial fiords and inlets in the Salish Sea region.

For more information on sills, see the Powell River section of this guidebook.

Surfing the rapids at Skookumchuch Narrows.

GETTING THERE:

Located on the edge of extremely steep and rough mountain terrain, no roads connect the Sunshine Coast to the rest of the province. If you want to experience Sechelt's stunning beaches, take the 45-minute ride on the Langdale ferry from Horseshoe Bay, North Vancouver. From Langdale, Sechelt is 15 kilometres north along the Sunshine Coast Highway, (Highway 101).

Or, travel by ferry via Comox on Vancouver Island to Powell River, then across Jervis Inlet to Saltery Bay – a slightly round-about way, but a great introduction to the geology and scenery of the area. Or, take a floatplane to Sechelt for a great bird's eye view of the area.

Photos: PictureBC.

To visit Skookumchuck Narrows Provincial Park, take Highway 101 past Sechelt and Madeira Park. Turn on Egmont Road and drive about six kilometres to the parking lot. The trail to the rapids is four kilometres – about an hour's walk on flat ground.

Salish Sea

ACKNOWLEDGEMENTS

GeoTour

ON THE WEB

BC GeoTours: download the Salish Sea and Sea to Sky Geotour guidebooks for free: ***bcgeotours.nrcan.gc.ca***

Climate Change Impacts and Adaptation: ***adaptation.nrcan.gc.ca***

Natural Resources Canada: ***nrcan.gc.ca***

Sea level rise in British Columbia:
env.gov.bc.ca/cas/adaptation/sea_level.html

ACKNOWLEDGEMENTS

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