Geoscape Victoria

The landscape and geological architecture, or geoscape, of southern Vancouver Island are the products of a wide variety of natural processes acting over some 370 million years. Several episodes of volcanism, erosion, sediment accumulation, and crustal movement have provided one of the world's best laboratories for the study of the effects of plate tectonics. By virtue of its position beside an actively moving ocean floor throughout the past 170 million years, Vancouver Island is an assembly of different pieces of the Earth's crust, all of which originated at different times, at different places, and under different circumstances. The fact that earthquakes are common occurrences in this region is dramatic evidence that crustal movement is continuing today.

Added to these tectonic processes are the effects of glaciation. As recently as 15 000 years ago, 1500 m of ice covered most of the island. Fiords such as Saanich and Alberni inlets, as well as the straits of Georgia and Juan de Fuca, owe their existence, in part, to the sculpting power of ice.

Kwakiutl earthquake mask
courtesy of University of British Columbia Museum of Anthropology, Vancouver, Canada.

The cumulative effect of these island-forming processes includes the beautiful scenery that surrounds us, as well as the formation of important mineral deposits and groundwater reservoirs. It is these and other natural legacies of the geological history of southern Vancouver Island that need our constant stewardship and care. Moreover, the probability that significantly large earthquakes may occur requires thoughtful attention not only to safe building design and construction, but also to other matters affecting public safety.

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Additional Reading

Muller, J.E.
1983: Geology of Victoria. Geological Survey of Canada, Map 1553A, scale 1:100 000.

Yorath, C.J. and Nasmith, H.W.
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2000: Composite relative earthquake hazard map of greater Victoria; British Columbia Ministry of Energy and Mines, Geological Survey Branch, Geoscience Map 2000-1, scale 1:25 000 (approximate).

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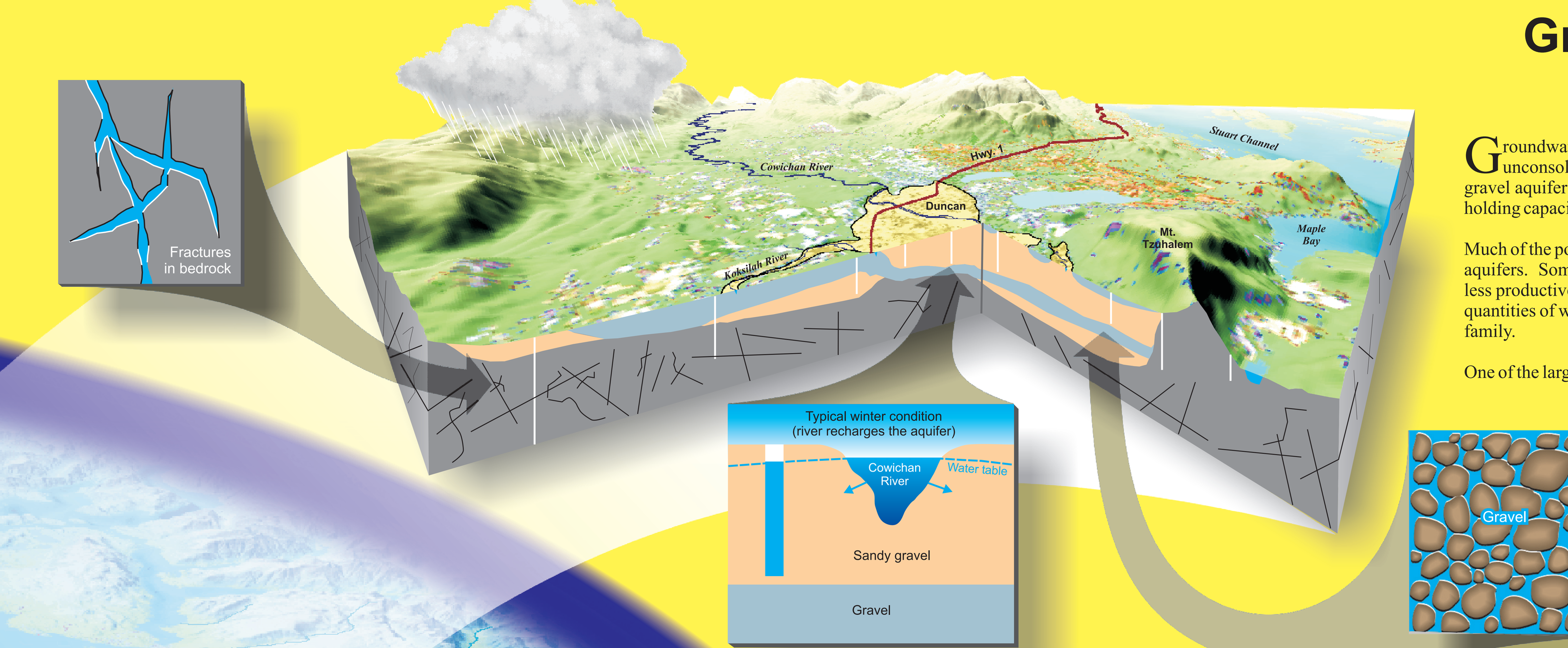
Canada

Groundwater — a valuable and vulnerable resource



Groundwater is found in aquifers, which are underground formations of permeable or fractured bedrock or unconsolidated sediments that can produce useful quantities of water when tapped by a well. Sand and gravel aquifers generally yield much greater amounts of water than do bedrock aquifers because of their larger holding capacity. Water in aquifers is replenished, or recharged, from rain, snowmelt, lakes, and rivers.

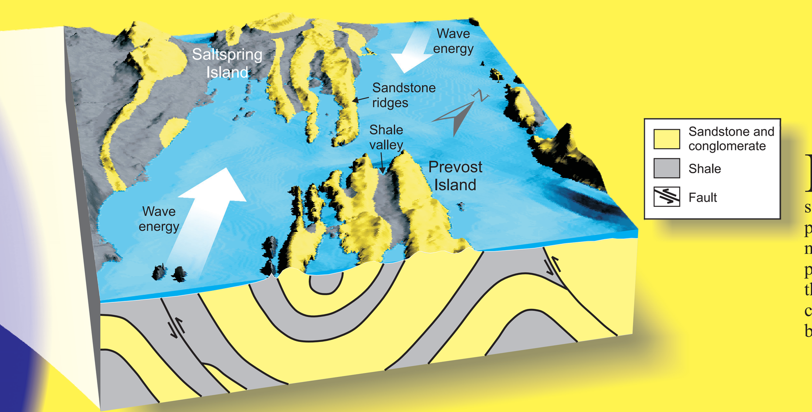
Much of the population outside of Victoria and Nanaimo obtains its water from highly productive sand and gravel aquifers. Some of the more mountainous regions and the Gulf Islands have mostly bedrock aquifers, which are less productive. Though a few wells drilled in bedrock aquifers on southern Vancouver Island supply sufficient quantities of water to irrigate farmland, most bedrock wells yield only enough water to meet the needs of a single family.

One of the largest sand and gravel reservoirs on southern Vancouver Island is in the lower Cowichan River valley. Wells drilled into this aquifer provide sufficient water for industry, fish hatcheries, pulp mills, agriculture, and between 1000 and 1600 homes.

To date, contamination of the Cowichan River has only been a minor issue; however, it is vulnerable to seepage from surface and underground storage facilities and chemical spills. Such contamination would be difficult and costly to rectify, and once affected, the aquifer might be unusable for decades.

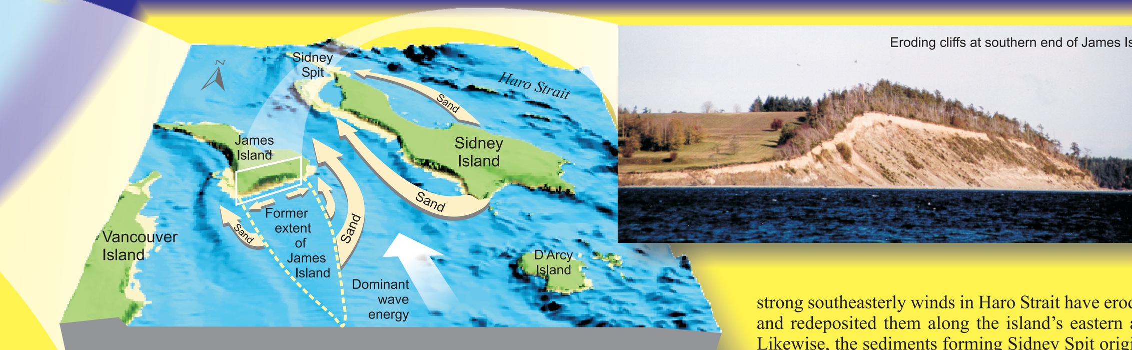
On parts of southern Vancouver Island and in the Gulf Islands, the intrusion of salt water into aquifers is becoming a problem. Pumping more fresh water than can be recharged naturally may allow seawater to invade the aquifer. Urbanization, including the construction of paved roads and parking lots, also affects groundwater aquifers by not allowing as much surface water to penetrate into the ground and recharge the aquifers.

Different rock types, different landforms



Different types of rocks respond to weathering and erosion in different ways. The coincidence of interlayered formations of shale and sandstone/conglomerate, their northwesterly aligned folded structure, the eroding power of southeasterly moving glacial ice, and the modern southeasterly or northwesterly directed wind-driven waves and storm patterns have resulted in the prominent northwesterly-southeasterly alignment of the Gulf Islands. Throughout these beautiful islands the prominent headlands and high ridges are formed from comparatively erosion-resistant sandstone/conglomerate, whereas the narrow bays and valleys are sculpted from softer and more easily eroded shale.

Sediments on the move

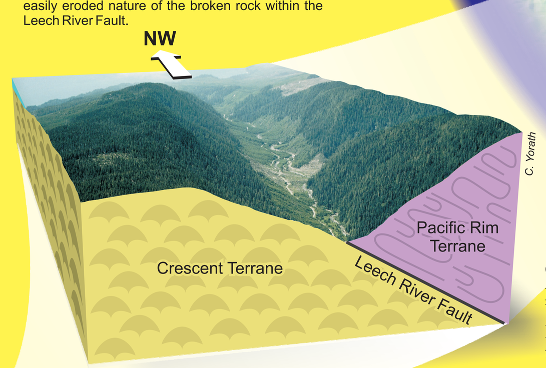


An example of modern landscape change is shown by James and Sidney islands. Extending southward from James Island is an extensive area of shallows that reflects the once greater extent of the island. Northwesterly-directed waves generated by strong southeasterly winds in Haro Strait have eroded the glacial sand and gravel of southern James Island and redeposited them along the island's eastern and western shores, as well into nearby deeper water. Likewise, the sediments forming Sidney Spit originated on southern Sidney Island from where they have been moved by longshore currents to form the spit.

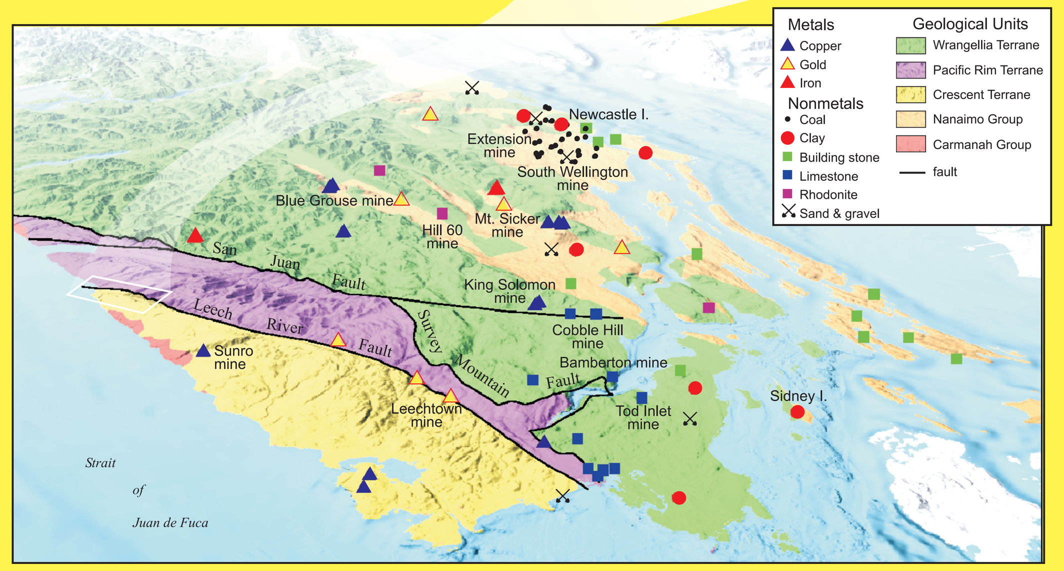
A tectonic collage

Vancouver Island is made up of three distinctly different fragments of the Earth's crust, called terranes. The largest of these, Wrangellia, consists of igneous and sedimentary rocks that formed far from their present position. Through the motions of the Earth's tectonic plates, Wrangellia collided with the ancient edge of North America about 100 million years ago. Following that collision, coal-bearing sedimentary rocks of the Nanaimo Group accumulated along the east coast of the Island and beneath that much later became the Strait of Georgia. A second collision occurred about 54 million years ago when sedimentary and volcanic rocks of the Pacific Rim Terrane were rammed beneath the southern and western edges of Wrangellia along the San Juan and Survey Mountain faults. A third collision occurred about 42 million years ago when a volcanic island, perhaps similar to modern Iceland, and belonging to the Crescent Terrane, was emplaced beside and beneath the Pacific Rim Terrane along the Leech River Fault. Associated seafloor volcanic rocks form the Olympic Mountains across the Strait of Juan de Fuca. Following these two later collisions, sedimentary rocks of the Carmanah Group accumulated upon the Crescent and Pacific Rim terranes.

View northwest toward Sombrio Point along Loss Creek Valley. The origin of the valley relates to the easily eroded nature of the broken rock within the Leech River Fault.



One of the most prominent faults on Vancouver Island is the Leech River Fault. Its surface trace, or faultline, is coincident with a narrow, steep-sided valley extending from Sombrio Point on the Strait of Juan de Fuca to Esquimalt Lagoon. The surface, or plane, of the fault is inclined to the north and separates the Pacific Rim Terrane from the Crescent Terrane. Another less prominent, but important, fault is the San Juan Fault extending from near Port Renfrew to beyond Cobble Hill. For much of its length it separates the Pacific Rim Terrane from Wrangellia.

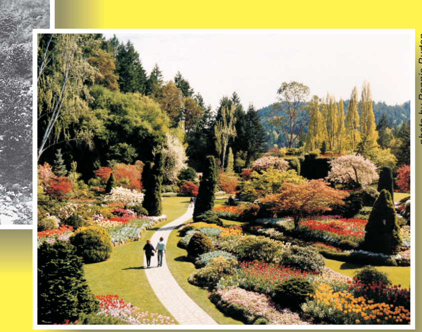


Map showing distribution of geological terranes and important mineral deposits.

Mineral resources have been important to the economic development of southern Vancouver Island. Its volcanic rocks have yielded copper from mines on Mount Sicker, near Duncan, and gold from several veins there and elsewhere. Gold has also been recovered from stream placer deposits at Leechtown. Sedimentary rocks in the Nanaimo area contain coal seams that were mined from 1852 until 1967, during which time 72 million tonnes were extracted. Nonmetallic mineral products including sand and gravel (aggregate) for concrete and road construction, limestone for cement, and clay for bricks have been and remain of major importance to the local economy. In many instances, abandoned mines and quarries have been reclaimed for other purposes, the most well known being the conversion of an old limestone quarry into the world-famous Butchart Gardens.

The Sunken Garden and Cement Plant circa 1924.

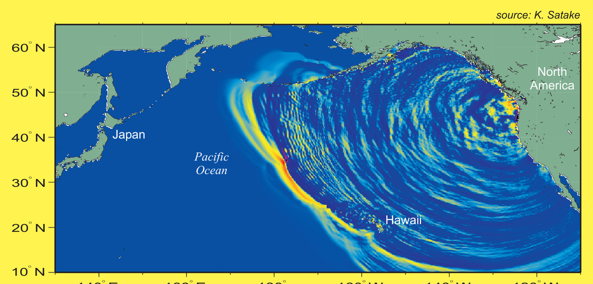
The world-famous Butchart Gardens are an example of mine reclamation.



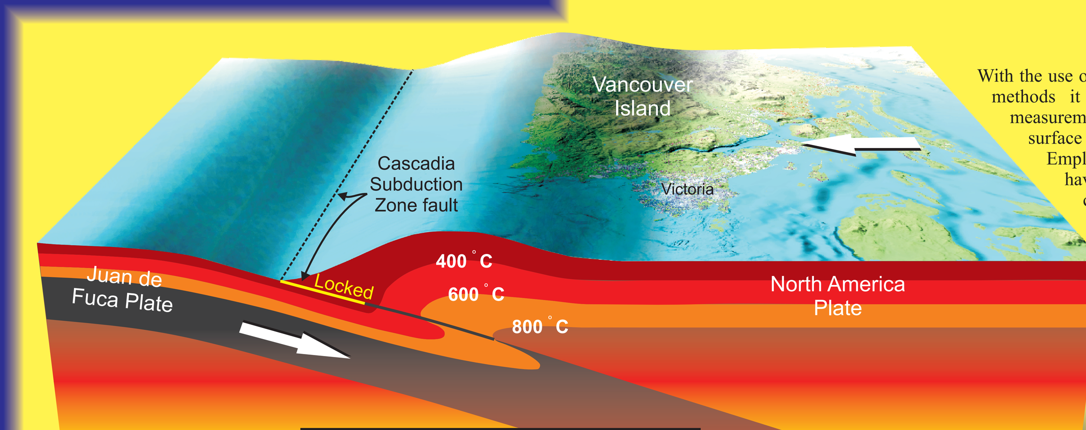
The current Sunken Garden.
courtesy of The Butchart Gardens Ltd. Victoria, B.C.

Waiting for "The Big One"

Giant earthquakes have occurred along the Cascadia Subduction Zone throughout the past several million years. The last one, on January 26, 1700, caused a tsunami that produced large waves on Vancouver Island and waves which crossed the Pacific Ocean bringing damage to coastal Japan. Geological evidence of this earthquake and earlier large earthquakes is well preserved along the coasts of British Columbia and northwestern United States where buried salt-marsh peat deposits attest to sudden sinking of coastal areas during the earthquakes.

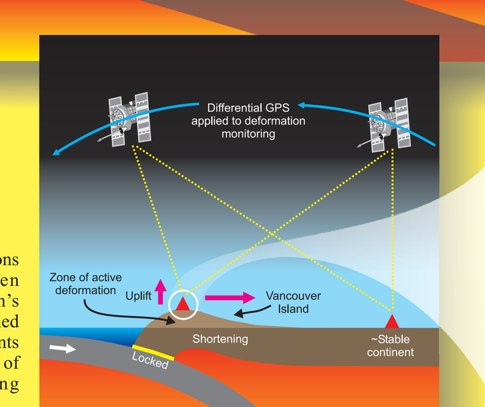


This mathematical simulation shows the tsunami created by the Cascadia Subduction Zone earthquake on January 26, 1700, as it reaches Hawaii on its way across the Pacific Ocean.



With the use of GPS satellite technology and other geodetic methods it is possible to make extremely accurate measurements of distances between points on the Earth's surface and to detect changes in their elevations. Employing these and other techniques, scientists have concluded that the Juan de Fuca Plate is currently locked to the North America Plate along the Cascadia Subduction Zone fault beneath the edge of the continent. Where the fault is locked, the temperature is estimated to be less than 350°C. Whereas at temperatures less than 350°C, rocks behave in a brittle fashion and are thus susceptible to earthquakes, those at higher temperatures tend to flow while under stress, with no earthquakes occurring. Due to locking, the western part of Vancouver Island is being flexed upward (shown here as greatly exaggerated) and compressed horizontally as the North America and Juan de Fuca plates converge upon one another. Eventually the locked zone must release, causing a giant earthquake (magnitude 8 to 9) to occur at any time within the next few hundred years. At that time, areas along Vancouver Island's west coast will suddenly drop by as much as 1 m or more.

Changes in the elevations and distances between positions on the Earth's surface can be determined from precise measurements obtained from satellites of the global positioning system (GPS).



GPS tracking station.
M. Schmidt

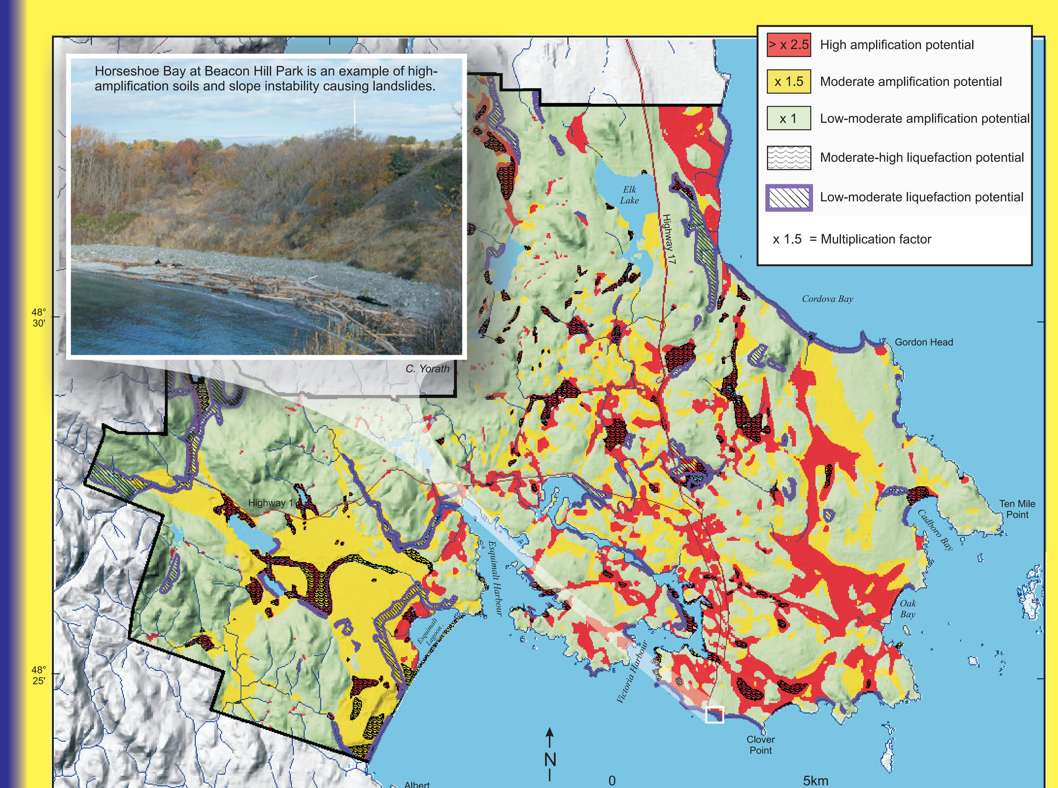
For additional information: http://www.pgc.nrcan.gc.ca/geodyn/geodyn.htm

When the ground moves

The effects of an earthquake of any given magnitude vary according to the distance from the epicentre as well as local geological and topographic conditions. Ground shaking can be increased (amplified) or reduced (attenuated) by soils overlying bedrock. The map below shows the estimated variation in ground motion due to differences in soils for an earthquake that produces moderate shaking. For this situation, the most common to be expected in the Greater Victoria area, amplification potential is greatest (red) in areas underlain by thick deposits of soft clay, particularly where they are capped by peat and organic soils, and lowest (green) where bedrock is exposed. For very strong shaking caused by a nearby earthquake, the pattern would be very different. For a full discussion of this subject the reader is referred to the reference listed in "Additional Reading". Water-saturated loose sands are susceptible to liquefaction during prolonged strong shaking. When soils liquefy they lose their strength and cannot support structures built upon them. In the Victoria area, the liquefaction potential is greatest in geologically young beach sands and artificial fills. Many sandy shoreline deposits along the east coast of Vancouver Island liquefied during the 1946 Vancouver Island earthquake.

Earthquake-induced shaking can cause slope instability (landslides). In Greater Victoria, the slope-instability hazard is greatest along sea cliffs such as those bordering Cordova Bay, and some cliffs facing the Strait of Juan de Fuca, as well as in valleys cut into soft glacial sediments. Most rock slopes appear to be relatively stable, although some areas of less-stable bedrock occur in the Mount Finlayson–Malahat–Goldstream River region.

For additional information: http://www.em.gov.bc.ca/geology



A relative earthquake hazard map of Greater Victoria (for moderate shaking).
NOTE: This map should not be used for potential hazard evaluation of specific properties.

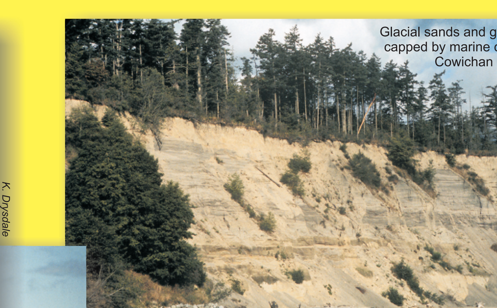
The legacy of ice

The effects of glaciation on southern Vancouver Island are conspicuous. Bedrock exposures commonly are striated and grooved, dramatically showing the erosive effects of ice-entrained debris during the last glaciation, between 30 000 and 10 000 years ago. Boulders, or erratics, of various sizes, which were carried by the ice and left behind when it melted, can be seen in most areas of the island. Glacial deposits of sand and gravel form James and Sidney islands, Cowichan Head and many other areas. The large gravel pit along Metchosin Road formed as the delta of a river draining from ice in Saanich Inlet and the Goldstream watershed about 14 500 years ago.

Scratches and grooves cut by glacial ice at Finlayson Point.

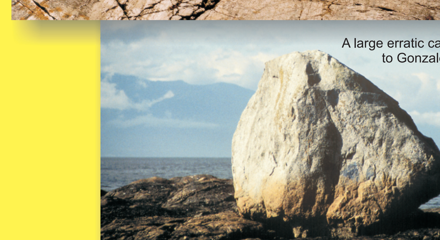
K. Drysdale

Glacial sands and gravels capped by marine clay at Cowichan Head.



C. Yorath

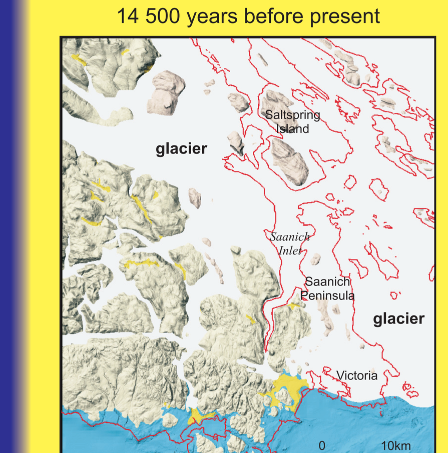
A large erratic carried by glacial ice to Gonzales Bay (Foul Bay).



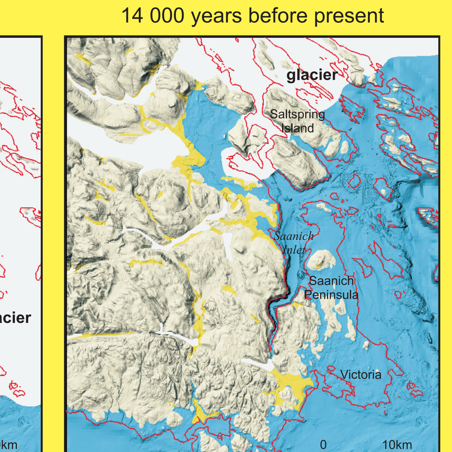
C. Yorath

These five maps (below) show the history of deglaciation, sea-level changes and flora variation during the past 14 500 years in the area surrounding Saanich Inlet. During glaciation the crust was depressed beneath the weight of the ice, and sea level was lowered because water was removed from the oceans to form glaciers. As the ice melted, the depressed crust and lowered sea levels regained their former elevations, resulting in marked changes to shorelines in the area as well as the distribution and types of forest cover. Modern sea level was reached about 5000 years ago and since then has changed very little.

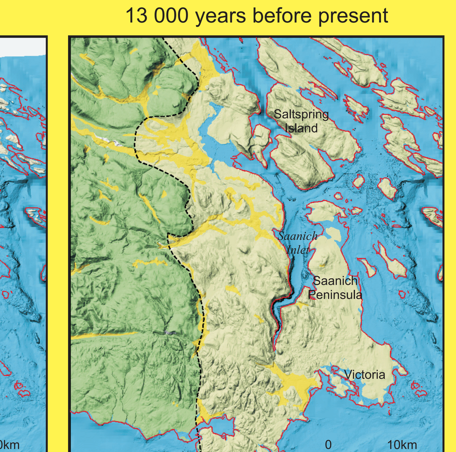
14 500 years before present



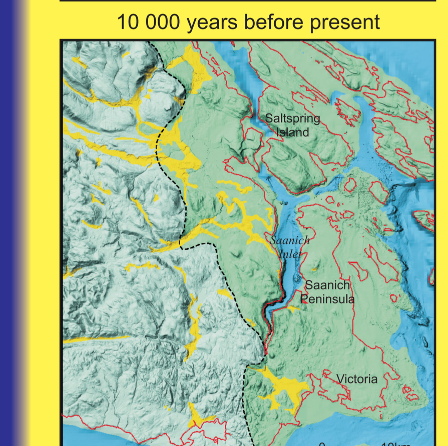
14 000 years before present



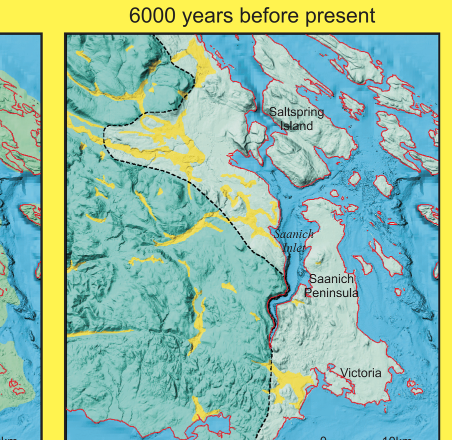
13 000 years before present



10 000 years before present

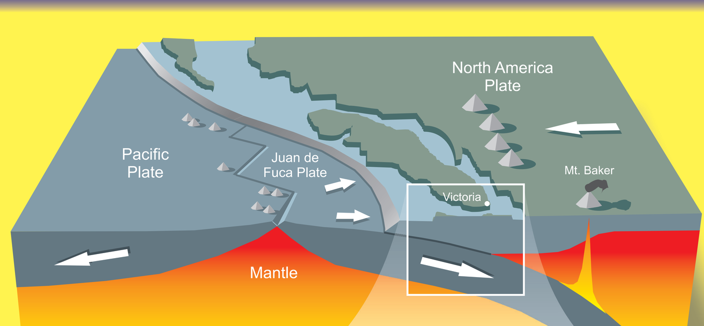


6000 years before present



- Coastal Western Hemlock forest
- Coastal Douglas fir/ Garry oak woodland
- Grassland with Douglas fir
- Mixed conifer forest
- Pine-alder forest
- Pine woodland
- Tundra opening
- Sea level
- Meltwater-channel sediments
- Ice cover
- Floral type boundary
- Present-day coastline

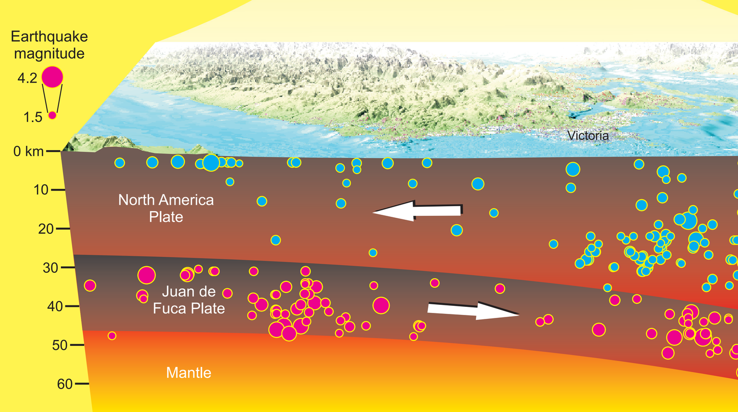
Living with earthquakes



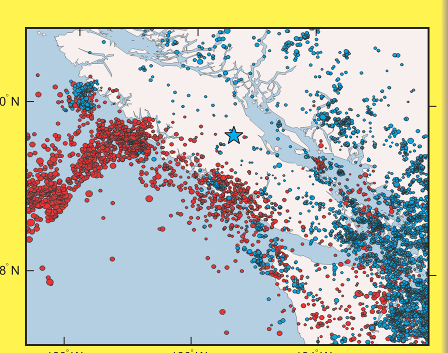
During an earthquake, energy is released when rocks under stress slide past one another along a fault, or fracture, in the Earth's crust. These situations most commonly occur at, or close to, the boundaries of moving tectonic plates that make up the outer shell of our planet. Southern Vancouver Island is situated above the boundary separating the oceanic Juan de Fuca Plate and the continental North America Plate. Beneath the boundary, or Cascadia Subduction Zone, the eastward-moving oceanic plate is descending, or being subducted, beneath the westward-drifting continent.

The magnitude scale (sometimes called the Richter Scale) is used to measure the size, or energy release, of an earthquake. The scale is logarithmic, meaning that a magnitude 7 earthquake produces a ground displacement 10 times greater than a magnitude 6 event and 100 times greater than one of magnitude 5, and so on. The amount of energy released in an earthquake increases by about 32 times with each unit increase in magnitude.

More than 200 small earthquakes are recorded each year in this region, several of which are felt. Those large enough to cause damage occur roughly once each decade, whereas very large subduction zone earthquakes happen centuries apart.



On southern Vancouver Island, earthquakes occur within the subducting Juan de Fuca Plate (red dots) and in the overlying North America Plate (blue dots). The figure on the left shows the locations and depths of those earthquakes above magnitude 1.5 recorded between 1985 and 2000 within 10 km on either side of the vertical face of the diagram. The vertical, east-west face passes just south of the city of Victoria, as shown on the figure on the right. The largest earthquake recorded to date on Vancouver Island was a magnitude 7.3 event in 1946, located within the North America Plate beneath the central part of the Island (blue star).



Distribution of epicentres (increasing size of dots indicates magnitudes of 1 to 6) for earthquakes within the Juan de Fuca Plate (red) and the North America Plate (blue) for the period 1985 to 2000.

For additional information: http://www.pgc.nrcan.gc.ca/seismo/table.htm

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