GEOSCAPE VANCOUVER

LIVING WITH OUR GEOLOGICAL LANDSCAPE

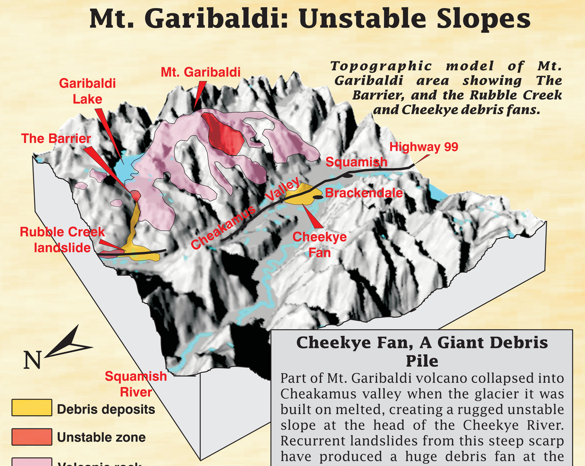
We live where the Fraser River, with the gathered waters from a vast interior watershed, breaches the coastal mountains to reach the inland sea of the Strait of Georgia. This dynamic landscape is underlain by a variety of earth materials and is continually shaped by earth processes. Its geological landscape, or geoscape, ... colliding crustal plates, earthquakes, and volcanic eruptions, processes that continue today. Glaciers and streams have carved deep valleys and deposited their sediment load in lowlands, lakes, and sea. Landslides displace rock and soil, often catastrophically. Waters dissolve, transport, and deposit metals and minerals.

The resources and land needs of our rapidly expanding population demand that we ... The liveability of the Vancouver area will, in part, depend on how well we incorporate geological knowledge into our land-use decisions.

The Population Boom
Greater Vancouver Regional District
1901 · 1971 · 1991 · 2021
1 082 000 · 1 602 000 · 2 676 000

LIVING IN THE SHADOW OF VOLCANOES

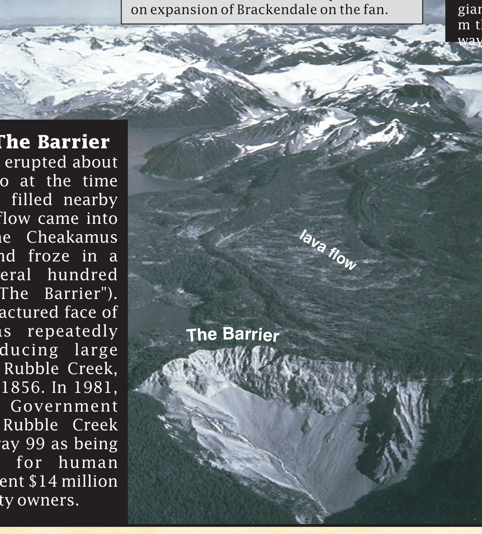
Mt. Garibaldi: Unstable Slopes



Topographic model of Mt. Garibaldi area showing The Barrier, and the Rubble Creek and Cheekye debris fans.

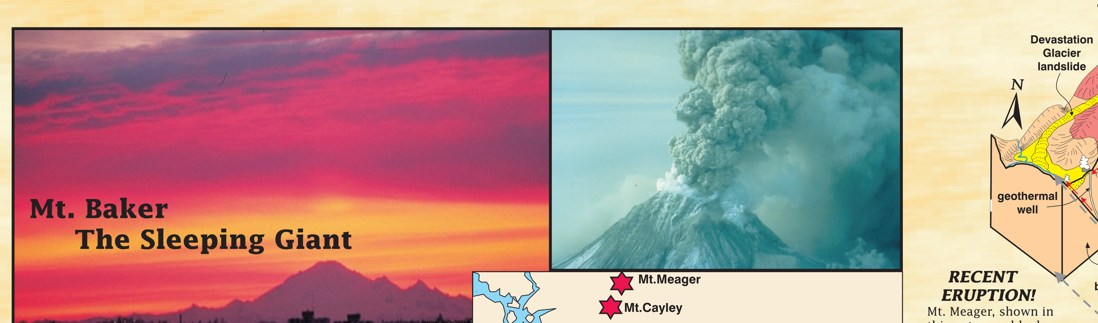
Cheekye Fan, A Giant Debris Pile

Part of Mt. Garibaldi volcano collapsed into Cheakamus valley when the glacier it was built on melted, creating a rugged unstable slope at the head of the Cheekye River. Recurrent landslides from this steep scarp have produced a huge debris fan at the mouth of Cheekye River just north of Brackendale. The possibility of a large landslide from Mt. Garibaldi places limits on expansion of Brackendale on the fan.

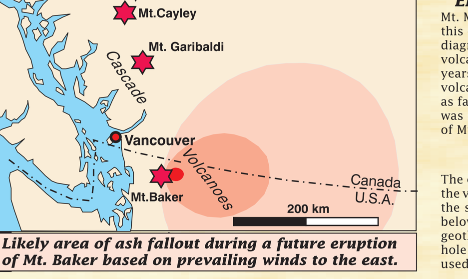


Collapse of The Barrier

Mt. Garibaldi last erupted about 13,000 years ago at the time when glacier ice filled nearby valleys. A lava flow came into contact with the Cheakamus valley glacier and froze in a steep face several hundred metres high ("The Barrier"). Since then, the fractured face of The Barrier has repeatedly collapsed, producing large landslides along Rubble Creek, most recently in 1856. In 1981, the Provincial Government designated the Rubble Creek area along Highway 99 as being too hazardous for human habitation and spent $14 million to buy out property owners.

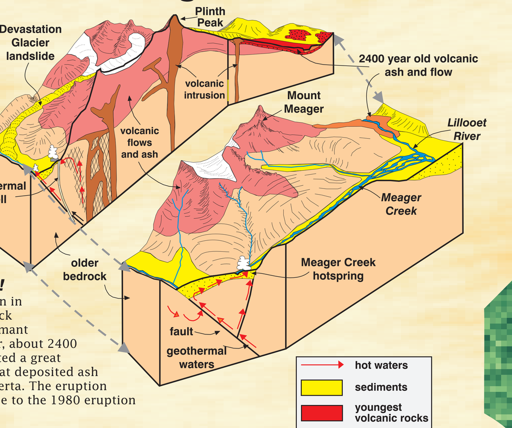


Mt. Baker looms above the Vancouver skyline. This volcano has been built by numerous eruptions over the last 30,000 years. Its conical shape reflects its status as an active volcano and distinguishes it from more eroded, dormant volcanoes like Mt. Meager, Mt. Cayley, and Mt. Garibaldi. Mt. Baker is built by several processes. Molten rock can flow quietly out onto the surface as lava. In contrast, forces can explode magma, producing a cloud that "rains" ash hundreds of kilometres down wind from the volcano. Ash can be a hazard to aircraft and can create breathing problems for humans and livestock. Avalanches of hot volcanic rock and gas mix with water melted from snow and ice to form giant debris flows. About 7000 years ago a debris flow at least 100 m thick, from Mt. Baker, flowed down the Nooksack River all the way to Puget Sound.



Likely area of ash fallout during a future eruption of Mt. Baker based on prevailing winds to the east.

Mt. Meager: STILL COOKIN' !



RECENT ERUPTION!
Mt. Meager, shown in this cut-away block diagram, is a dormant volcano. However, about 2400 years ago it erupted a great volcanic cloud that deposited ash as far east as Alberta. The eruption was similar in size to the 1980 eruption of Mt. St. Helens.

TAPPING ENERGY FROM THE EARTH
The earth beneath Mt. Meager is hot. Surface waters seep under the volcano and become heated, then rise along fractures to reach the surface as hot springs. Holes have been drilled to 3000 m below the mountain to test this hot water plumbing system as a geothermal energy source. When hot water rises quickly in a drill hole it changes to steam; the force of this expanding steam can be used to generate electricity.

SEA TO SKY

Highway 99 and the B.C. Rail line follow the east shore of Howe Sound north to Squamish, and then wind their way along mountain valleys to Pemberton and beyond. Travellers pass a mine that once was the largest copper producer in the British Commonwealth, a volcano that last erupted in the Ice Ages, unstable slopes, and hazardous debris fans.

Britannia Mine: Economic Boon, Environmental Problem

The orebody within Britannia Mountain was mined from 1905 to 1974. It was a natural concentration of over 50 million tonnes of iron sulphide-rich rock containing 1% copper, 0.6% zinc, and other metals such as silver, gold, and cadmium. At its peak, the Britannia mine employed over 2000 people and produced metal that today would be worth $1.3 billion. The mine contributed to the growth and status of B.C. as an international centre for exploration and mining.

Metals on the Move

Metals from the old Britannia Mine contaminate nearby Britannia Creek and Howe Sound. Rainwater and snowmelt enter the mine through a pit at the top of Britannia Mountain. The waters react with sulphide minerals, leaching metals which are carried in solution from the tunnels to Britannia Creek and Howe Sound where they spread out as a sheet on denser seawater. The copper contents of these waters reach levels that are toxic to aquatic life. Controlling metal dispersion from Britannia will likely involve limiting the flow of water into the mine, and collecting and chemically treating escaping waters.

Treacherous Slopes

Debris flows are common in our coastal mountains because heavy rains fall on steep slopes mantled by loose sediments. Highway 99 between Horseshoe Bay and Britannia has a history of destructive debris flows.

1. Torrential rainfall swells streams along the mountain crest.
2. Sediment slumps into a raging stream, forming a slurry (debris flow) that surges down the channel.
3. The debris flow swells in volume as it picks up additional sediment and trees from the channel and canyon walls.
4. The debris flow emerges from the canyon onto a fan where it damages houses, roads, bridges, and a rail line.

Acidic metal-rich waters draining the Britannia mine precipitate iron along the stream channel.

A debris flow dam above Lions Bay

Aftermath of a debris flow that swept through Lions Bay in February 1983, killing two people.

15,000 years ago

Howe Sound area during the Ice Age.

The Ice Age sculpting the landscape

A tidewater glacier in Alaska - what the Squamish area looked like 13, 000 years ago.

A glacier 2 km thick filled Howe Sound about 15,000 years ago and was part of an ice sheet that covered most of B.C. This was one of many glaciations that occurred during the last 2 million years ("The Ice Age"). Features eroded by glaciers include fiords such as Howe Sound, U-shaped valleys, sharp-crested mountain peaks, and grooved bedrock surfaces. Material removed by glacial erosion was deposited in valleys and lowlands as thick sequences of sediment.

13,000 years ago: glacier retreat

Protecting People and Property

Debris fans are favoured sites for development because they are less steep than adjacent mountainsides. However, the fans are prone to floods and debris flows. The mining community of Britannia, for example, was devastated by a sudden flood on October 28, 1921. This flood occurred when a blocked culvert caused a railway embankment to temporarily dam Britannia Creek and then fail, releasing a catastrophic flood. A series of debris flows in the 1980s swept across debris fans north of Horseshoe Bay, destroying bridges and homes and claiming 11 lives. Zoning regulations now restrict development on hazardous fans. Where existing development is threatened, it can be protected by dams or deflection barriers, and by deepening and lining stream channels. Over $15 million was spent on protective works along Highway 99 following the disasters of the 1980s.

Britannia before and after catastrophic flood of 1921. Thirty-seven people were killed and about half the 170 houses in the town were destroyed.

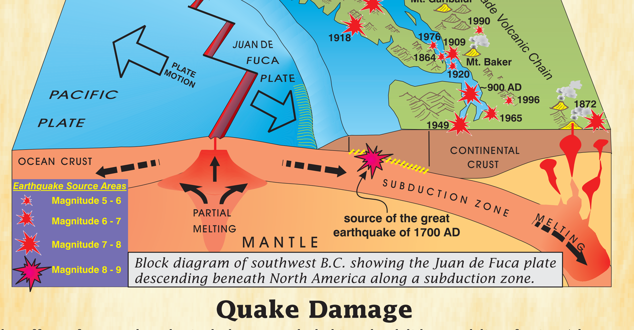
EARTHQUAKE !! ON SHAKY GROUND

Plates & Quakes

An earthquake is the result of a sudden release of energy when rocks under stress slide abruptly past one another along a break in the Earth's crust (fault). Most earthquakes occur where the large rigid plates that make up the outer shell of the Earth are in contact with one another.

Where Earthquakes Happen

There is an average of one earthquake in southwest B.C. every day. Nearly all are too small to be felt, but a damaging earthquake occurs somewhere in the region about once every 20 years. The largest earthquake in this century was a magnitude 7.3 event in 1946, centred beneath central Vancouver Island. Were this earthquake to occur today under Vancouver, damage would be in the billions of dollars. Recently, scientists have recognized a history of infrequent, but great (magnitude 8 to 9) earthquakes on the fault separating the subducting Juan de Fuca and North America plates. The last great earthquake in 1700 AD affected the entire coast from northern California to southern B.C.



Block diagram of southwest B.C. showing the Juan de Fuca plate descending beneath North America along a subduction zone.

Quake Damage

The effect of an earthquake includes ground shaking, landslides, and liquefaction (change of sediment from a solid to a quicksand-like liquid state). Earthquakes are most destructive when they are centered near cities, but the damage can differ considerably from site to site because of local geological conditions. For example, shaking on loose sediment is likely to be greater than shaking on bedrock. Some earthquakes trigger destructive sea waves (tsunamis) that can surge hundreds of metres inland, have heights of 10 m or more, and cause loss of life and severe property damage. In southwest B.C., the tsunami threat is greatest on the outer coast of Vancouver Island.

Earthquakes cannot be prevented. However, the damage they cause can be reduced through geological and geophysical studies that contribute to proper design of buildings and other structures, emergency planning, and public education. Geological mapping can identify areas of possible severe ground shaking, liquefaction, or landslides.

Earthquakes Felt In Vancouver

~1700 AD, west of Vancouver Island, magnitude 8+ (great earthquake; native villages destroyed)
Dec. 15, 1872, north-central Washington, magnitude 7.4 (felt strongly on the Lower Mainland)
Jan. 11, 1909, San Juan Islands, magnitude 6 (felt strongly in Lower Mainland)
Dec. 6, 1918, Vancouver Island., magnitude 7 (damage on west coast of Vancouver Isl.)
Jan. 24, 1920, San Juan Islands, magnitude 5.5 (felt strongly in the Lower Mainland)
June 23, 1946, Vancouver Island, magnitude 7.3 (much damage on central Vancouver Isl.)
April 13, 1949, Puget Lowland, magnitude 7 (much damage in Seattle and Tacoma)
April 29, 1965, Puget Lowland, magnitude 6.5 (much damage in Seattle)
Nov. 30, 1975, Strait of Georgia, magnitude 4.9 (many aftershocks)
May 16, 1976, southern Gulf Islands, magnitude 5.4
April 14, 1990, Fraser Lowland, magnitude 4.9 (many aftershocks)
May 3, 1996, east of Seattle, magnitude 5.5 (felt in the Lower Mainland)

NEED MORE INFO?

Geology, glaciation, volcanoes, landslides, groundwater, geochemistry

Geological Survey of Canada
Natural Resources Canada
605 Robson Street
Vancouver, B.C. V6B 5J3
Maps & Publications: (604) 666-0271
Library: (604) 666-3812
Enquiries: (604) 666-0529
http://www.nrcan.gc.ca/gsc/gschp.html

British Columbia Geological Survey
Ministry of Employment and Investment
1810 Blanshard Street
Victoria, B.C. V8V 1X4
Enquiries: (604) 952-0429
http://natural.gov.bc.ca

Emergency Preparedness

Emergency Preparedness Canada
P.O. Box 10000
Victoria, B.C. V8W 3A5
Enquiries: (604) 363-3621

Provincial Emergency Program (PEP)
605 1200 W. 73rd Ave.
Vancouver, B.C. V6P 6G5
Enquiries: (604) 660-3723

Mining

British Columbia and Yukon Chamber of Mines
840 West Hastings St.
Vancouver, B.C. V6C 1C8
Enquiries: (604) 681-5328
http://www.bc-mining-house.com/chamber

Mining Association of British Columbia
840 West Hastings Street
Vancouver, B.C. V6C 1C8
Enquiries: (604) 681-4321

Floods & Groundwater

B. C. Ministry of Environment,
Water Management Division
10334 - 152A Street
Surrey, B.C. V3R 7P8
Enquiries: 1-800-665-7027

Earthquakes

Pacific Geoscience Centre
Geological Survey of Canada
Natural Resources Canada
P.O. Box 6000
Sidney, B.C. V8L 4B2
Enquiries: (604) 363-6500
http://www.nrcan.gc.ca/gsc/gschp.html

Additional Reading

Geology and geological hazards of the Vancouver region, southwestern British Columbia. Edited by J.W.H. Monger. 1994, Geological Survey of Canada Bulletin 481

Vancouver and its region. Edited by G. Wynn and T. Oke. 1992, UBC Press

Vancouver geology. J.E. Armstrong. 1990, Geological Association of Canada, Cordilleran Section

Landslides in British Columbia. Information Circular 1993-7. B.C. Ministry of Employment and Investment, Geological Survey Branch

Earthquakes in British Columbia. Information Circular 1991-6. B.C. Ministry of Employment and Investment, Geological Survey Branch

Web and Internet Info

Earth science information on the World Wide Web and Internet can be found by referring to the following news groups:
sci.geo.geology
sci.geo.hydrology
sci.geo.oceanography
comp.infosystems.gis

GEOSCAPE VANCOUVER

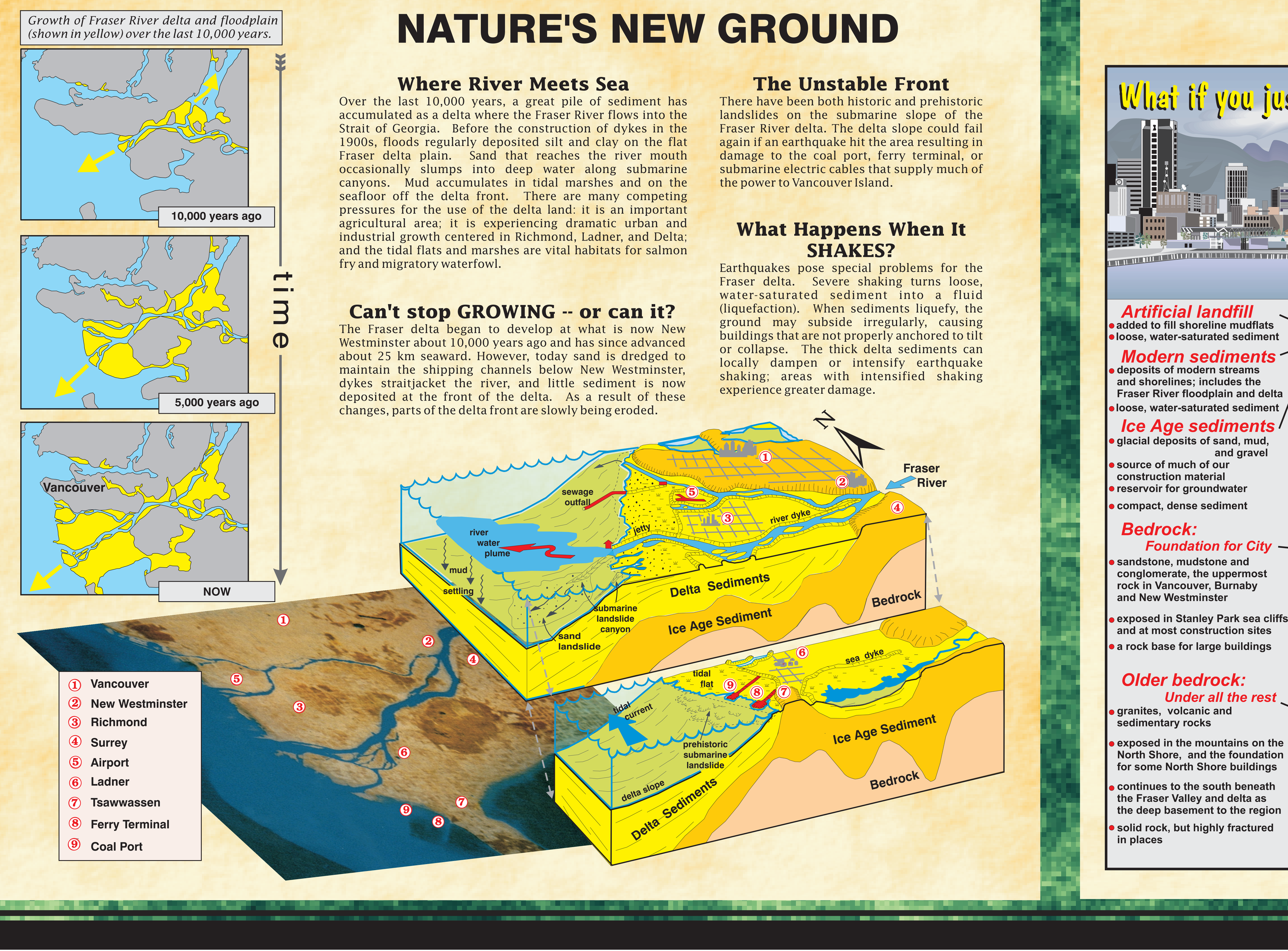
Geological Survey of Canada Open File 3309, 1998

Produced by: Robert J.W. Turner, John J. Clague, Bertrand J. Groulx

Contributors
Natural Resources Canada, Geological Survey of Canada; J.J. Clague, S.G. Evans, B.J. Groulx, C.J. Hickson, L.E. Jackson, Jr., J.M. Journeay, J.L. Luternauer, P. Metcalfe, D.C. Mosher, B.D. Ricketts, G.C. Rogers, R.J.W. Turner, G.J. Woodsworth
B.C. Ministry of Employment and Investment, Geological ...

THE FRASER RIVER DELTA

NATURE'S NEW GROUND



Growth of Fraser River delta and floodplain (shown in yellow) over the last 10,000 years.

Where River Meets Sea

Over the last 10,000 years, a great pile of sediment has accumulated as a delta where the Fraser River flows into the Strait of Georgia. Before the construction of dykes in the 1900s, floods regularly deposited silt and clay on the flat Fraser delta plain. Sand that reaches the river mouth occasionally slumps into deep water along submarine canyons. Mud accumulates in tidal marshes and on the seafloor off the delta front. There are many competing pressures for the use of the delta land: it is an important agricultural area; it is experiencing dramatic urban and industrial growth centered in Richmond, Ladner, and Delta; and the tidal flats and marshes are vital habitats for salmon fry and migratory waterfowl.

Can't stop GROWING -- or can it?

The Fraser delta began to develop at what is now New Westminster about 10,000 years ago and has since advanced about 25 km seaward. However, today sand is dredged to maintain the shipping channels below New Westminster, dykes straitjacket the river, and little sediment is now deposited at the front of the delta. As a result of these changes, parts of the delta front are slowly being eroded.

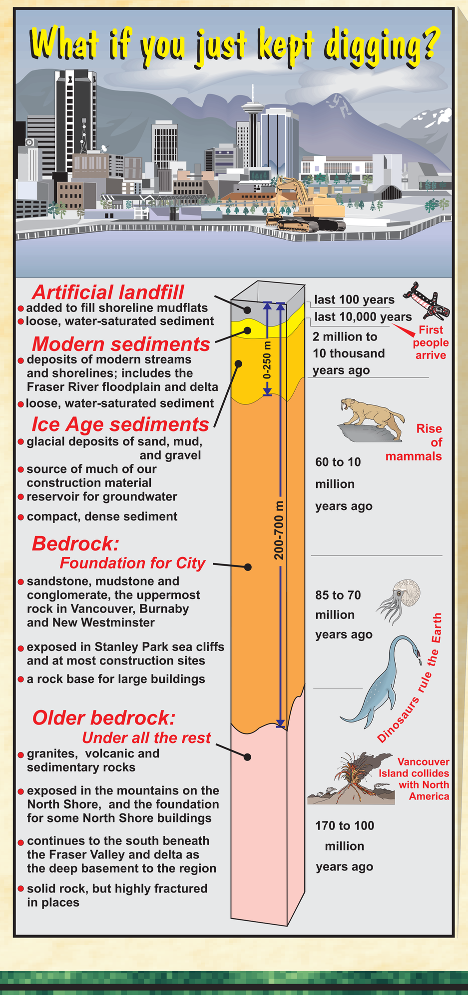
The Unstable Front

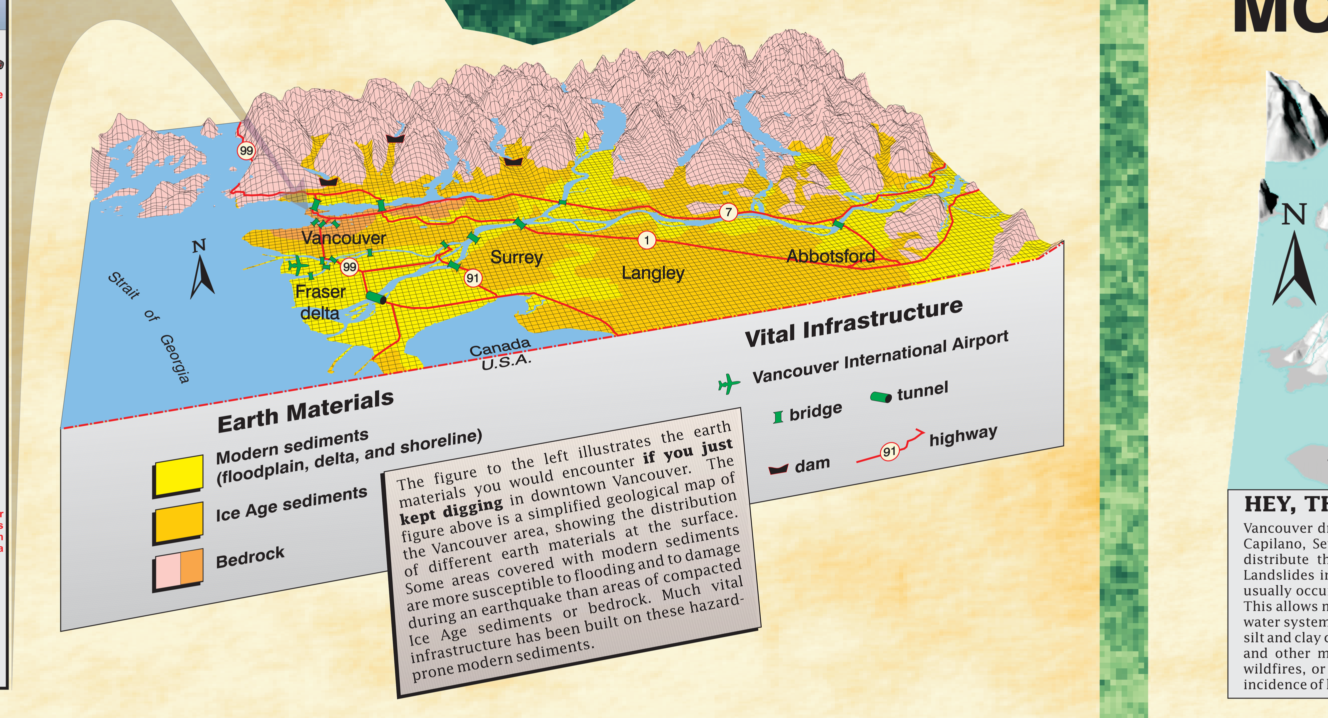
There have been both historic and prehistoric landslides on the submarine slope of the Fraser River delta. The delta slope could fail again if an earthquake hit the area resulting in damage to the coal port, ferry terminal, or submarine electric cables that supply much of the power to Vancouver Island.

What Happens When It SHAKES?

Earthquakes pose special problems for the Fraser delta. Severe shaking turns loose, water-saturated sediment into a fluid (liquefaction). When sediments liquefy, the ground may subside irregularly, causing buildings that are not properly anchored to tilt or collapse. The thick delta sediments can locally dampen or intensify earthquake shaking; areas with intensified shaking experience greater damage.

WHAT'S UNDER OUR FEET?





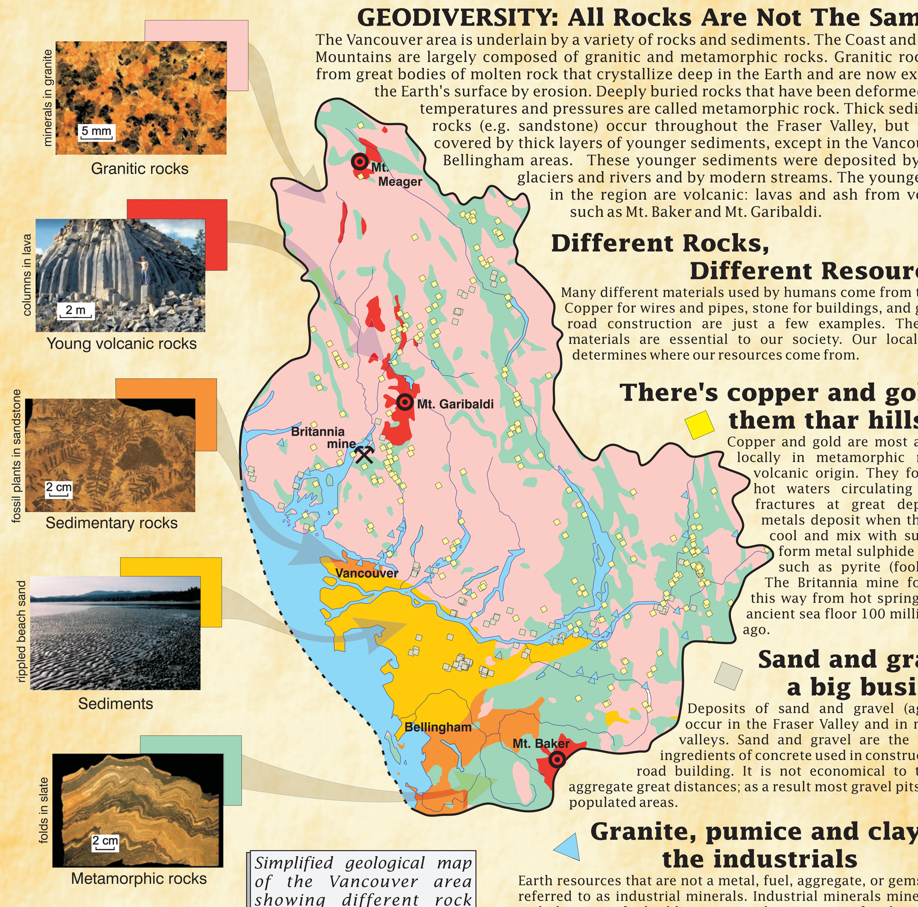
The figure to the left illustrates the earth materials you would encounter **if you just kept digging** in downtown Vancouver. The figure above is a simplified geological map of the Vancouver area, showing the distribution of different earth materials at the surface. Some areas covered with modern sediments are more susceptible to flooding and to damage during an earthquake than areas of compacted Ice Age sediments or bedrock. Much vital infrastructure has been built on these hazard-prone modern sediments.

EARTH RESOURCES

A LIVING FROM THE LAND

GEODIVERSITY: All Rocks Are Not The Same

The Vancouver area is underlain by a variety of rocks and sediments. The Coast and Cascade Mountains are largely composed of granitic and metamorphic rocks. Granitic rock forms from great bodies of molten rock that crystallize deep in the Earth and are now exposed at the Earth's surface by erosion. Deeply buried rocks that have been deformed at high temperatures and pressures are called metamorphic rock. Thick sedimentary rocks (e.g. sandstone) occur throughout the Fraser Valley, but they are covered by thick layers of younger sediments, except in the Vancouver and Bellingham areas. These younger sediments were deposited by Ice Age glaciers and rivers and by modern streams. The youngest rocks in the region are volcanic: lavas and ash from volcanoes such as Mt. Baker and Mt. Garibaldi.



Simplified geological map of the Vancouver area showing different rock types and earth resources.

Different Rocks, Different Resources

Many different materials used by humans come from the earth. Copper for wires and pipes, stone for buildings, and gravel for road construction are just a few examples. These earth materials are essential to our society. Our local geology determines where our resources come from.

There's copper and gold in them thar hills

Copper and gold are most abundant locally in metamorphic rocks of volcanic origin. They form from hot waters circulating through fractures at great depth. The metals deposit when the waters cool and mix with sulphur to form metal sulphide minerals such as pyrite (fool's gold). The Britannia mine formed in this way from hot springs on an ancient sea floor 100 million years ago.

Sand and gravel: a big business

Deposits of sand and gravel (aggregate) occur in the Fraser Valley and in mountain valleys. Sand and gravel are the principal ingredients of concrete used in construction and road building. It is not economical to transport aggregate great distances; as a result most gravel pits are near populated areas.

Granite, pumice and clay: the industrials

Earth resources that are not a metal, fuel, aggregate, or gemstone are referred to as industrial minerals. Industrial minerals mined locally include granite for building stone, volcanic pumice for abrasives, and clay for pipes and tile.

MOUNTAIN CORRIDORS

OUR ECONOMIC LIFELINES

All of the road and rail traffic between Vancouver and the B.C. interior, as well as power transmission lines, gas pipelines, and fiber optic cables, pass through narrow mountain valleys: the Fraser Canyon; the Coquihalla which crosses high, avalanche-prone country; Highway 3, once blocked by the Hope Slide; and the Sea to Sky route via Squamish and Whistler. All of these corridors are vulnerable to blockage by landslides and avalanches, disrupting transportation, power, and communications to Vancouver.

Rockfalls in the Fraser Canyon

Rockfalls from steep faces have repeatedly disrupted the Trans-Canada Highway and derailed trains. Perhaps the most costly natural disaster in Canadian history was a rockfall at Hell's Gate in 1914 triggered by blasting on the CN rail line. The rockfall created an obstacle for migrating salmon that caused a dramatic decline in the Fraser River salmon fishery.

What Can Be Done?

Steep slopes can be made more stable by removing or bolting threatening rock. Slopes covered with metal mesh or sprayed with concrete prevent loosened rock from reaching the road or railway. Holes drilled into the slope allow groundwater to drain more easily, reducing water pressures that might trigger a rockfall.

When a Mountain Fell

On January 9, 1965, a huge mass of rock fell from a mountain high above Highway 3 east of Hope. Four motorists were buried under tens of metres of blocky debris, enough to fill the BC Place football stadium many times. The landslide drove a wave of muddy debris high up the opposite valley wall. What triggered the landslide is not known - there was neither unusual weather nor an earthquake at the time. Large landslides like the Hope Slide are far less common than rockfalls and debris flows, but are potentially far more destructive.

Avalanches Along The Coquihalla Highway

Deep snow accumulations on slopes can fail, triggering an avalanche. There are an average of 100 avalanches per year along the Coquihalla Highway southwest of the summit. Most are small and pose no threat to motorists, but some reach the highway.

The B.C. Government collects weather data throughout the winter, analyzes the stability of the snowpack, and issues avalanche forecasts at least once a day during hazardous periods. Dams, basins, mounds, and a snowshed have been built to stop or deflect avalanches, and explosives are used to bring down avalanches under controlled conditions.

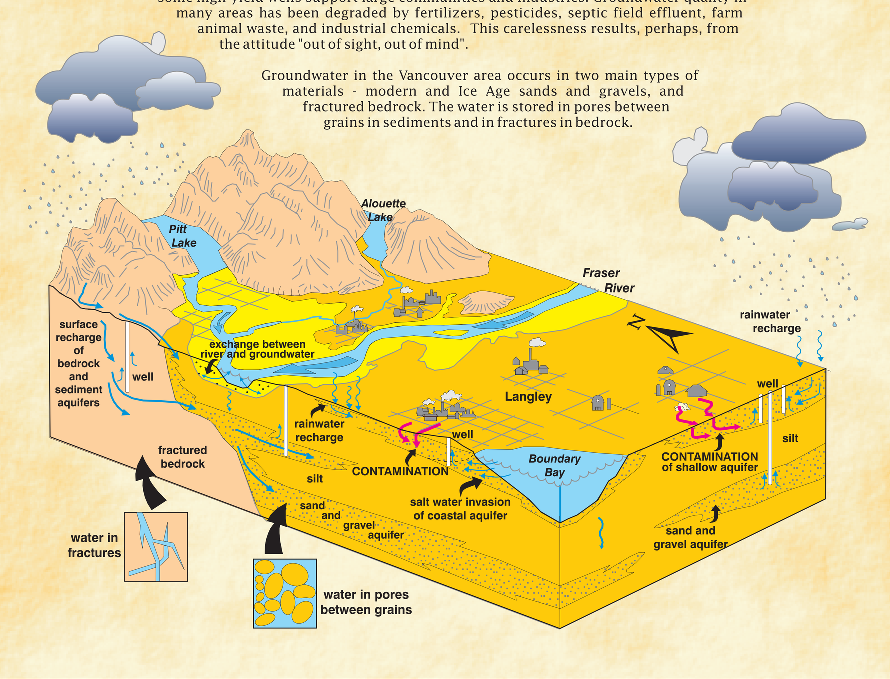
Avalanche areas along a section of the Coquihalla Highway are shown in red on this map.

WATER UNDERGROUND

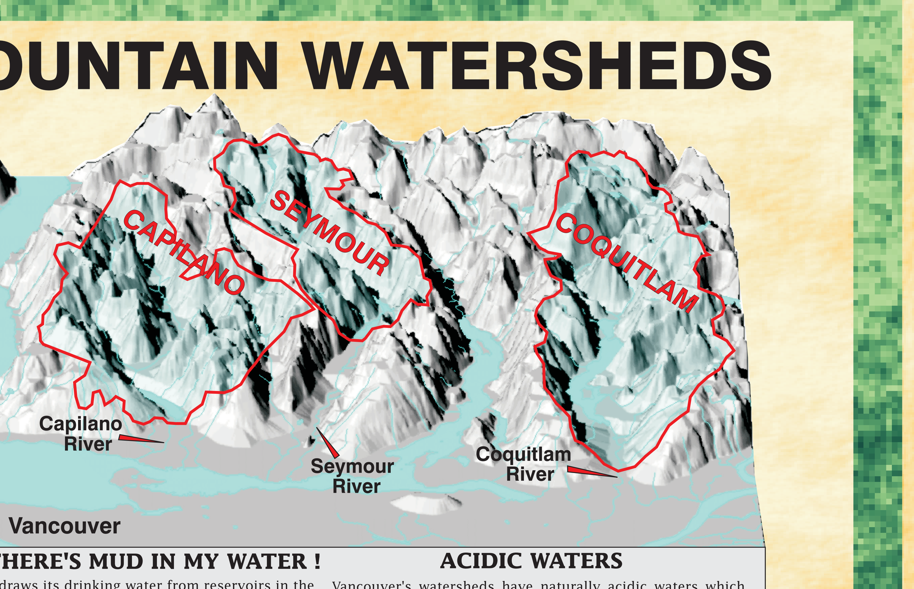
VITAL BUT VULNERABLE

Groundwater is a hidden, often forgotten resource, yet it meets about half of the total water needs of areas not served by the North Shore reservoirs. Groundwater is supplied from over 10 000 wells in the Fraser Valley. Most of these are small household wells, but some high-yield wells support large communities and industries. Groundwater quality in many areas has been degraded by fertilizers, pesticides, septic field effluent, farm animal waste, and industrial chemicals. This carelessness results, perhaps, from the attitude "out of sight, out of mind".

Groundwater in the Vancouver area occurs in two main types of materials - modern and Ice Age sands and gravels, and fractured bedrock. The water is stored in pores between grains in sediments and in fractures in bedrock.



MOUNTAIN WATERSHEDS



HEY, THERE'S MUD IN MY WATER !

Vancouver draws its drinking water from reservoirs in the Capilano, Seymour, and Coquitlam watersheds. Pipelines distribute these waters throughout the Vancouver area. Landslides in the watersheds are natural phenomena that usually occur during heavy rains, exposing soil to erosion. This allows mud to wash into reservoirs where it enters the water system. While cloudy water is not itself a health risk, silt and clay can reduce the ability of chlorine to kill bacteria and other microorganisms. Natural phenomena, such as wildfires, or poor forestry practices can also increase the incidence of landslides within B.C's mountainous areas.

ACIDIC WATERS

Vancouver's watersheds have naturally acidic waters which tend to corrode pipes, dissolving copper, iron, zinc, and lead. Elevated levels of lead in drinking waters can pose a health concern. The waters are acidic because the area is underlain by rocks resistant to chemical reactions that reduce the natural acidity of rain. Also, rainwater rapidly runs off the steep slopes, leaving little time for these chemical reactions. Plans are in place to reduce this water acidity through improvements in the water treatment process.

WHEN THE FRASER FLOODS

Floods, Dykes, and Floodplains

River flats (floodplains) adjacent to the Fraser River and its tributaries have formed from repeated seasonal floods that spread silt-laden waters over large areas. These areas are now protected by long earthen ridges (dykes), built to prevent rivers from overtopping their banks. Floods along the Fraser River occur during early summer when warm rainy weather rapidly melts mountain snowpacks. Floods along smaller streams can occur at any time of the year, but are particularly common during torrential autumn rains. Coastal areas can be flooded by the sea when severe storms coincide with high winter tides.

BIG FLOODS

Over the last 100 years, the Fraser River has risen to flood heights more than 25 times. Serious flooding of the lower Fraser Valley in June 1948 caused more than $20 million damage (1948 dollars). Since then, governments have spent $160 million building and improving dykes along the Fraser River, allowing more than $13 billion worth of new development on the floodplain behind the dykes.

Levels reached by various Fraser River floods marked on a cabin near Hatzic.

Looking south across Hatzic area in the Fraser Valley during the 1948 flood.

Catastrophic dyke break near Hatzic, 1948.

Dykes have been improved to prevent disastrous flooding like that in 1948.

SO WHAT CAN BE DONE?

Floodwaters can be confined to river channels by constructing dykes. Dams built for hydro-electric power generation also regulate river flows during periods of high runoff. Zoning by-laws, subdivision regulations, and building codes discourage development on floodplains and encourage other uses of these areas. Finally, buildings can be designed to withstand floods or can be placed on gravel platforms above flood level.

For additional copies contact the Geological Survey of Canada publications office at (604) 666-0271