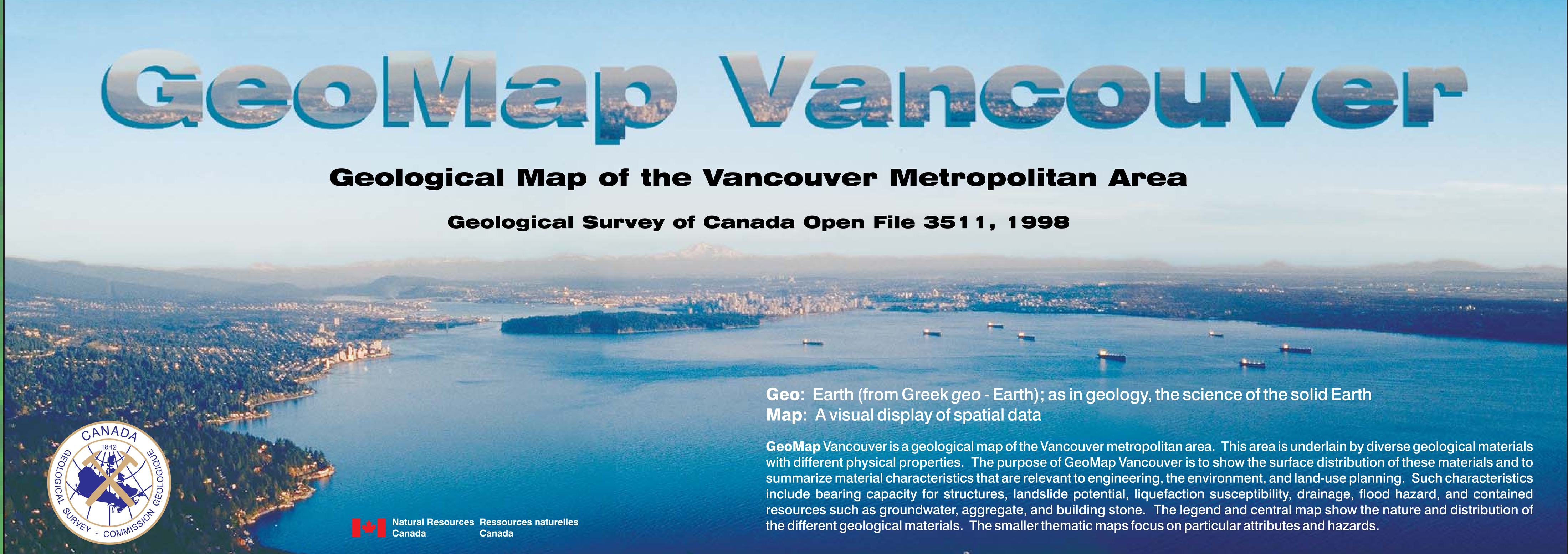
GeoMap Vancouver

Geological Map of the Vancouver Metropolitan Area

Geological Survey of Canada Open File 3511, 1998



Geo: Earth (from Greek *geo* - Earth); as in geology, the science of the solid Earth
Map: A visual display of spatial data

GeoMap Vancouver is a geological map of the Vancouver metropolitan area. This area is underlain by diverse geological materials with different physical properties. The purpose of GeoMap Vancouver is to show the surface distribution of these materials and to summarize material characteristics that are relevant to engineering, the environment, and land-use planning. Such characteristics include bearing capacity for structures, landslide potential, liquefaction susceptibility, drainage, flood hazard, and contained resources such as groundwater, aggregate, and building stone. The legend and central map show the nature and distribution of the different geological materials. The smaller thematic maps focus on particular attributes and hazards.

Natural Resources Canada / Ressources naturelles Canada

Panorama looking southeast over the North Shore, Vancouver city, and the Lower Fraser Valley. The Cascade Mtns and Mt. Baker form the skyline and southern margin of the Fraser Valley.

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Modern Sediments in Lowlands

About half of the Fraser Valley is flat, flood-prone land below 15 m elevation (mainly the **floodplains** of the Fraser River and its tributaries). This area is underlain by loose, water-saturated sediments that are less than 10,000 years old (i.e. **Holocene** age). Fraser River floodplain sediments consist mainly of gravel and sand from Hope to Mission; sand and silt dominate farther downstream. The Nicomekl-Serpentine and Pitt River valleys and Sumas Prairie are underlain by sand and silt. Poorly drained areas of floodplain are mantled by peat, and landfill has locally extended shorelines. Floodplains contain rich agricultural soils, but are generally poorly drained due to the flat terrain and shallow water table. Although still predominantly rural, some lowlands are areas of rapid urban growth (Richmond). Most communities on floodplains are protected by dykes from all but the largest floods.

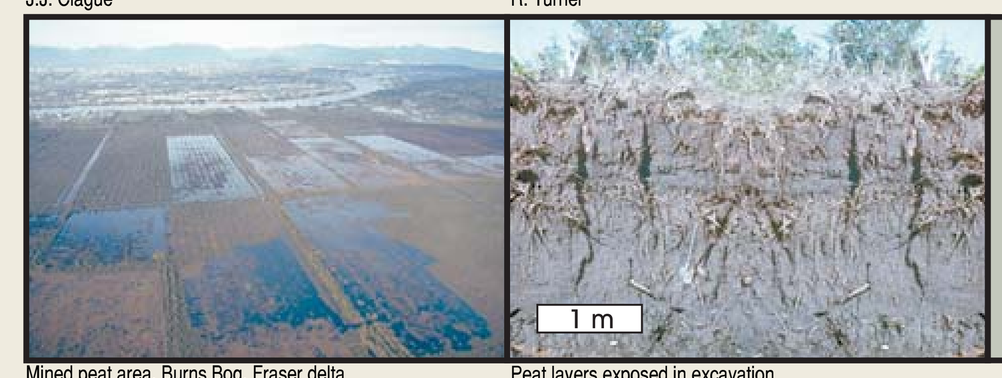
Sand landfill along False Creek
J.J. Clague

Port Mann landfill
R. Turner

1

Landfill

Landfill is material deposited by humans. Fill materials have been dumped in shallow waters and on tidal flats and other wetlands to extend the area of useable land. Recent recognition of the ecological importance of areas destroyed by this practice has led to limitations on placements of fills. Landfill in the Vancouver area is found mainly along shorelines, both marine (False Creek and Burrard Inlet) and river (Annacis Island). It is heterogeneous and includes sand and gravel, till, and/or crushed rock. Landfill also includes waste materials disposed of in municipal dumps (Burns Bog in Delta, Port Mann landfill); these dumps can contribute leachates to local surface and groundwaters and therefore require containment systems. Poorly designed and compacted landfills can be problematic for foundations, and could liquefy and settle during a strong earthquake.



Mined peat area, Burns Bog, Fraser delta
J.J. Clague

Peat layers exposed in excavation
J.J. Clague

2

Peat

Peat is partly decomposed plant material found below bogs, swamps, and marshes. Peat up to 5 m thick covers much of the Fraser delta east of Highway 99 and the Nicomekl-Serpentine lowland. It also occurs locally on the Fraser River floodplain between New Westminster and Mission, at the base of some upland escarpments, at mountain fronts, and within poorly drained depressions in upland areas. Several bogs (e.g. Pitt Meadows bog, Burns Bog) have been mined for sphagnum peat moss, and the peatlands on the Fraser delta are important producers of blueberries and cranberries. Because of their high compressibility, peats are extremely poor foundation materials. Recognition of the ecological importance of bogs has led to increased efforts to protect them from development.

Tidal mud, Serpentine River estuary
A.C. Clague

Modern clayey silt, Serpentine River estuary
A.C. Clague

3

Silt and clay

Silt, clay, and loam (mixed clay, silt, and sand) are common on the Fraser River floodplain below Mission, the Pitt River floodplain (Pitt Polder), the Fraser delta, and the Nicomekl-Serpentine flats. These sediments were deposited over thousands of years by seasonal floodwaters that spread across these lowlands. Silt and clay beneath the Nicomekl-Serpentine flats are ancient marine deposits. They were formed by the slow settling of fine river-borne sediment onto the sea floor. These fine-grained sediments make poor foundation materials because of their low bearing capacity, but are generally not prone to liquefaction. They are important agricultural soils, although poor drainage can be a problem.

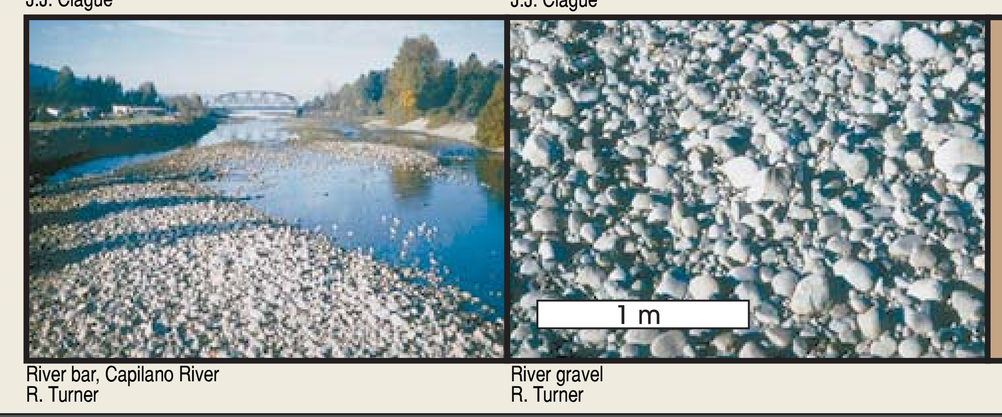
Locarno Beach
J.J. Clague

Beach sand
J.J. Clague

4

Sand and silt

Interlayered sand, silt, and loam underlie parts of Sumas Prairie, the Fraser River floodplain downstream of Mission, and the Fraser delta. Similar sediments also occur along some small streams. The **sand and silt** unit, like the aforementioned **silt and clay** unit, was deposited during floods. Construction of dykes has greatly reduced such flooding and interrupted the natural deposition of these materials. Sand and silt are important agricultural soils and can be important shallow groundwater reservoirs (**aquifers**). Sand-rich deposits have moderate to high bearing capacity and are good foundation materials, but could liquefy during a strong earthquake.



River bar, Capilano River
R. Turner

River gravel
R. Turner

5

Gravel and sand

Deposits of gravel and sand occur along steep-gradient streams in mountain valleys (Chilliwack Valley), on alluvial fans and marine deltas at valley mouths (Capilano and Seymour rivers, North Vancouver), and on islands and bars of the Fraser River upstream of Mission. Gravel and sand also occur as beach deposits (Jericho, White Rock) and as debris cones and fans at the base of mountain slopes. Most areas mapped as gravel and sand are at risk of flooding and have a moderate to high liquefaction potential. Gravel and sand deposits are **permeable** (they transmit water), and are thus important shallow **aquifers**. They are also potential sources of aggregate, but shallow water tables limit their use for this purpose.

Ice Age Sediments in Uplands

Ice Age sediments deposited during the **Pleistocene Epoch** (2 million to 11,000 years ago) underlie gently rolling uplands (15 to 250 m elevation) of the Fraser Valley. Most Ice Age sediments in the Vancouver area date to the last glaciation, about 25,000 to 11,000 years ago, and in particular to the period of glacier retreat when areas below 200 m elevation were covered by the sea. These sediments include **till** deposited directly by glaciers, gravel and sand laid down by streams flowing off the melting ice (**outwash**), marine clay and silt, and beach gravel and sand. Deposits older than the last glaciation are only exposed in steep escarpments along the margins of uplands. Most cities and towns in this region were built on the uplands to avoid the flood and drainage problems of lowland areas. Upland sediments are good foundation materials and are generally not susceptible to liquefaction. Soils developed on gravel and sand are well drained, whereas those developed on silt, clay, and some till deposits are poorly drained. Flooding is limited to the narrow valley bottoms of small streams incising the uplands.

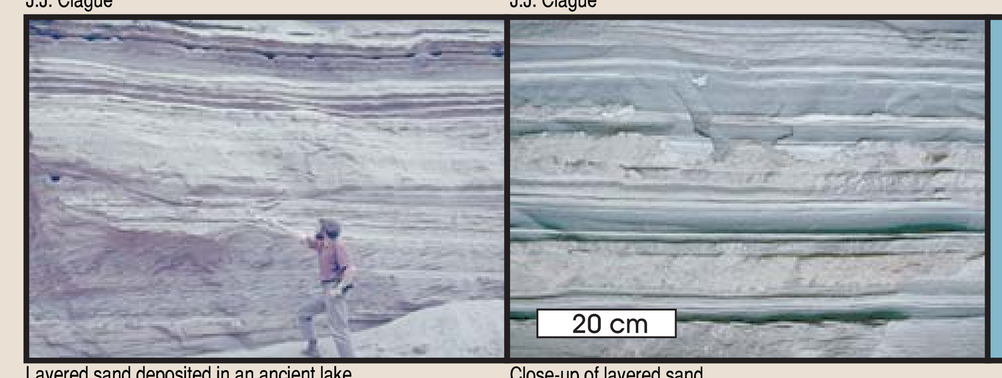
Blocky weathering, massive marine clay
J.J. Clague

Layered silt and clay
J.J. Clague

6

Silt and clay

Thick silt and clay of marine origin are the most widespread surface sediments in the Surrey, White Rock, and Langley-Aldergrove uplands. This unit includes massive and bedded sediments with variable bearing capacities, depending partly on whether or not they were overridden and loaded by glaciers. In general, deposits east of Aldergrove have been loaded by ice and thus have higher bearing strengths. Water infiltration is poor because the sediments are fine grained; this can result in poor surface drainage if the land is flat. Silt and clay deposits on steep slopes (>20°) are prone to landsliding. Silt and clay deposits exposed during construction activities erode easily and can be a major source of stream siltation.



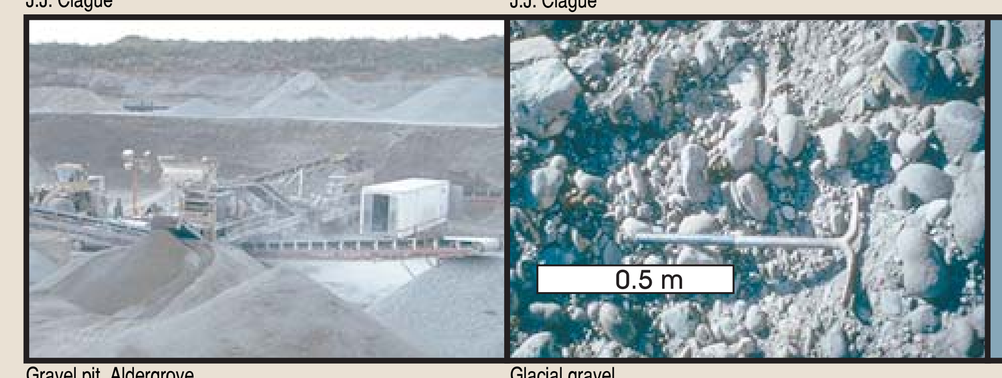
Layered sand deposited in an ancient lake
J.J. Clague

Close-up of layered sand
J.J. Clague

7

Sand

Scattered sand deposits up to 5 m thick occur on the Vancouver, Tsawwassen, White Rock, and Surrey uplands; they are absent from uplands east of Langley. The sands are beach deposits that formed when uplands emerged from the sea at the end of the last glaciation. They have good bearing strength, but are generally too thin to affect foundations. Water passes through sands with ease, thus soils developed on these materials are well drained.



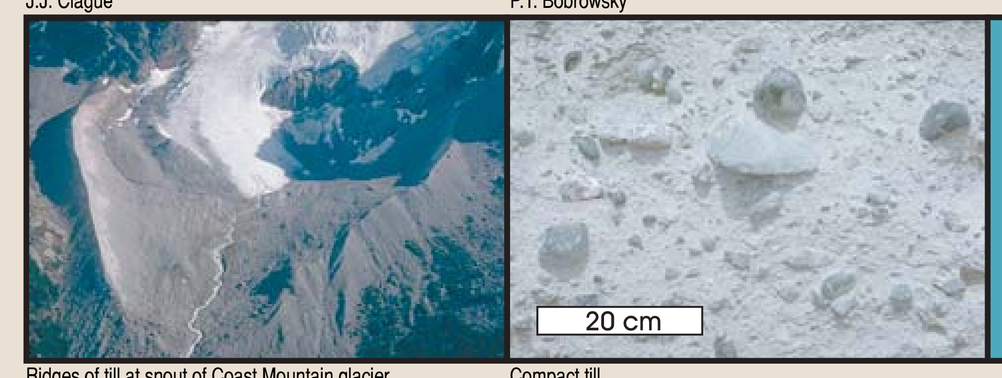
Gravel pit, Aldergrove
J.J. Clague

Glacial gravel
P.T. Bobrowsky

8

Gravel and sand

Deposits of gravel and sand up to 40 m thick are widespread on uplands between Langley and Abbotsford, and north of the Fraser River between Pitt Meadows and Mission. Important deposits also occur on the North Shore, adjacent to the Capilano, Seymour, and Coquitlam rivers, and in the Columbia Valley south of Cultus Lake. Gravel and sand have high bearing capacity and excellent drainage. Thick gravel and sand deposits are important sources of aggregate; there are numerous gravel pits south and east of Aldergrove, and south of Langley. Gravel and sand are also important **aquifers** (the Abbotsford and Brookswood aquifers). Shallow aquifers are vulnerable to contamination from agricultural and industrial activities.



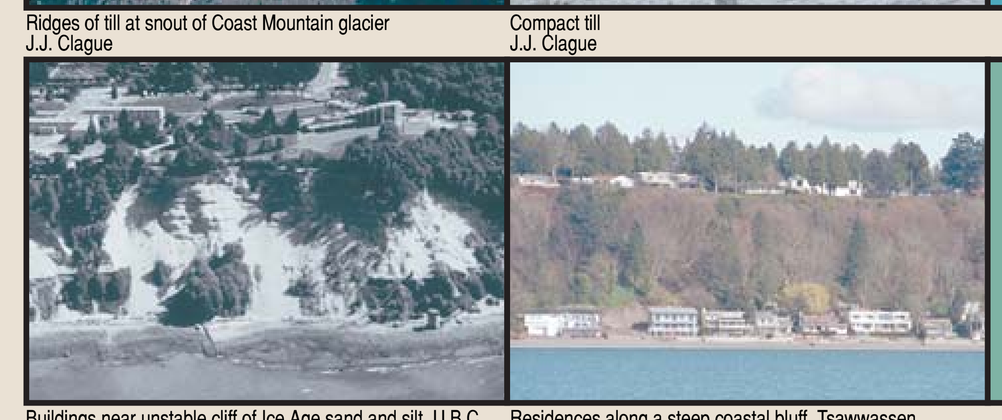
Ridges of till at snout of Coast Mountain glacier
J.J. Clague

Compact till
J.J. Clague

9

Till

Till is a heterogeneous glacial deposit consisting of clay, silt, sand, and stones ranging from pebble to boulder size. Till up to 25 m thick is the dominant surface and near-surface material over much of the Vancouver upland, where it is overlain by patchy marine silt and sand. Farther east, till is an important, but less extensive surface material; it is buried by thick silt and clay in the Surrey and Aldergrove areas. The lower slopes of the Coast Mountains are mantled by up to several metres of till. Some tills are compact and concrete-like, whereas others are sandy and loose. Till commonly has a high bearing capacity and thus is an excellent foundation material. Compact till is nearly impervious; for good drainage, the surface must slope. Silt- and clay-bearing tills disturbed during construction activities can be a major source of stream siltation.



Buildings near unstable cliff of Ice Age sand and silt, U.B.C.
University of B.C.

Residences along a steep coastal bluff, Tsawwassen
J.J. Clague

10

Steepland sediments

Steep escarpments occur locally at the borders of uplands. Escarpments expose Ice Age sediments that, elsewhere on the uplands, are covered by younger sediments, discussed above. These older sediments include clay, silt, sand, gravel, and **till**. The bases of some escarpments are being actively undercut by ocean waves (Tsawwassen, White Rock, Point Grey) or streams (Chilliwack, Capilano, Seymour, and Coquitlam rivers), making them vulnerable to landsliding. Many residential areas extend to the edges and bases of escarpments; even small slides in these localities can damage or destroy houses, roads, and other structures.

Bedrock in Mountains

Solid bedrock forms the Coast and Cascade Mountains, as well as smaller mountains that protrude through thick sediments in the Fraser Valley (Burnaby Mountain, Grant Hill, Sumas Mountain, Chilliwack Mountain). Bedrock is commonly mantled by several metres of till, sandy gravel, or rock fragments; less than 10% of the mountain area is actually exposed rock. Bedrock in this region can be grouped into four main units described below. Landslides occur where weak rocks are exposed on steep slopes. Rock weakness can stem from the presence of faults, fractures, sedimentary layers, or platy mineral layers (**foliation**) that dip in the direction of the slope. Thin sediments overlying bedrock can slide into stream channels during rainstorms, triggering flows of sediment, water, and plant debris (**debris flows**) that move downstream at high velocity.

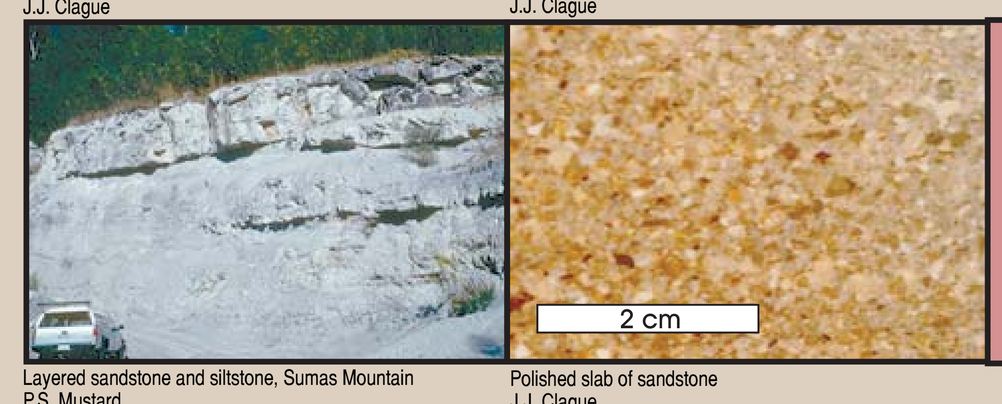
Basalt with columnar jointing, near Whistler
J.J. Clague

Queen Elizabeth Park -- an old basalt quarry turned into a garden
J.J. Clague

11

Volcanic rock

Dark, fine grained volcanic rocks, chiefly **basalt** and **andesite**, are exposed at the northern edge of the Fraser Valley. These rocks formed as lavas, shallow intrusions, and volcanic ash deposits. Most volcanic rocks are resistant to erosion and form prominent hills in the Fraser Valley (Sentinel Hill, Queen Elizabeth Park, Grant Hill). Young volcanic rocks (35-17 million years old) occur as thick tabular **sills**, parallel to the layers in the rocks into which they were injected (Grant Hill) and as smaller subvertical **dykes** that cut across rock layering (Prospect Point, Stanley Park). Much older (185 million years) volcanic rocks are exposed on Sumas Mountain and near the confluence of the Harrison and Fraser rivers.



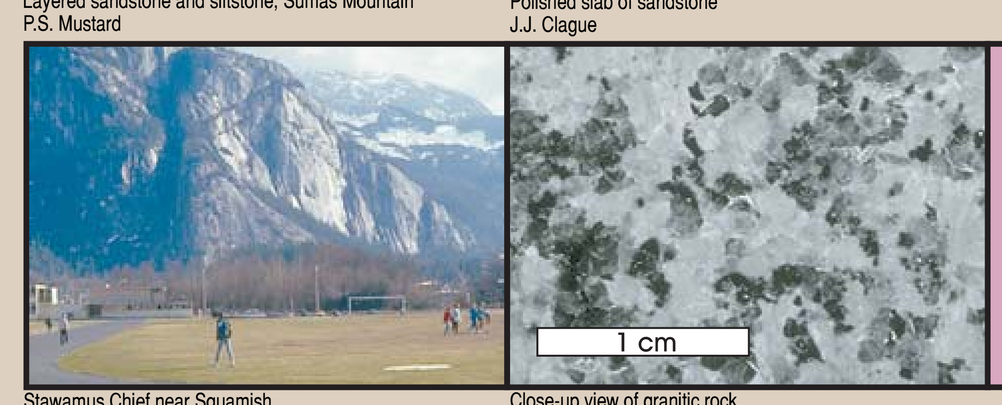
Layered sandstone and siltstone, Sumas Mountain
P.S. Mustard

Polished slab of sandstone
J.J. Clague

12

Sandstone

Sandstone, siltstone, and conglomerate (85-37 million years old) occur as scattered outcrops in Vancouver, Burnaby, and on the North Shore (Stanley Park, Kitsilano, Burnaby Mountain, Capilano River). These rocks also occur at depth through much of the Fraser Valley. Sandstone layers resistant to erosion and tilted down to the south form ridges with steep north-facing bluffs and gentler south-facing slopes (Burnaby Mountain, Stanley Park). Ridges are separated by valleys eroded into softer siltstone (First Narrows, Burrard Inlet). These rocks are weakly cemented and can be excavated without blasting. About 5-15% of the rock is open pore space making deeply buried sandstones potential natural gas reservoirs.



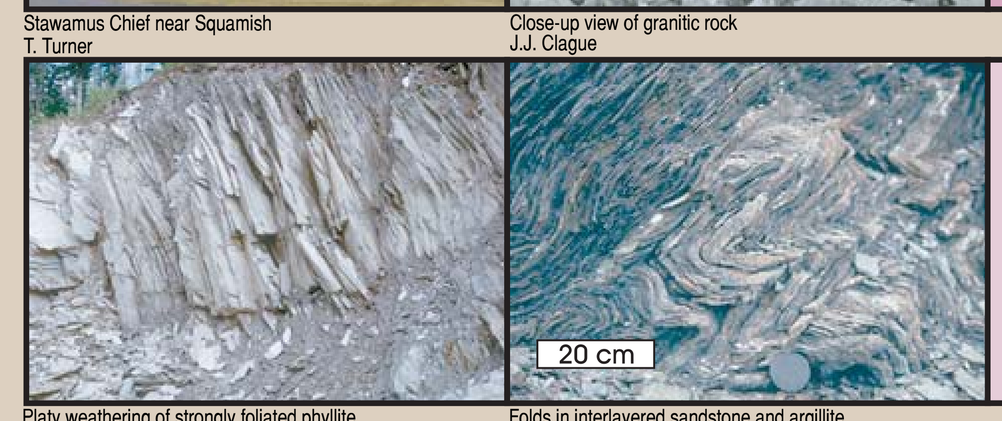
Stawamus Chief near Squamish
T. Turner

Close-up view of granitic rock
J.J. Clague

13

Granitic rock

Granitic rocks are a family of medium- to coarse-grained igneous rocks (**granite, granodiorite, quartz diorite, diorite**). They consist of interlocking light-coloured grains of **feldspar** and **quartz**, and dark-coloured **biotite** and **hornblende**, which give the rock a distinctive "salt-and-pepper" texture. Granitic rocks in the map area range from 165 to 95 million years old. Where not extensively fractured and faulted, granitic rock is resistant to erosion and can form steep mountain slopes. Granitic rock is locally quarried for use as building stone and crushed rock (Pitt River).



Platy weathering of strongly foliated phyllite
J.J. Clague

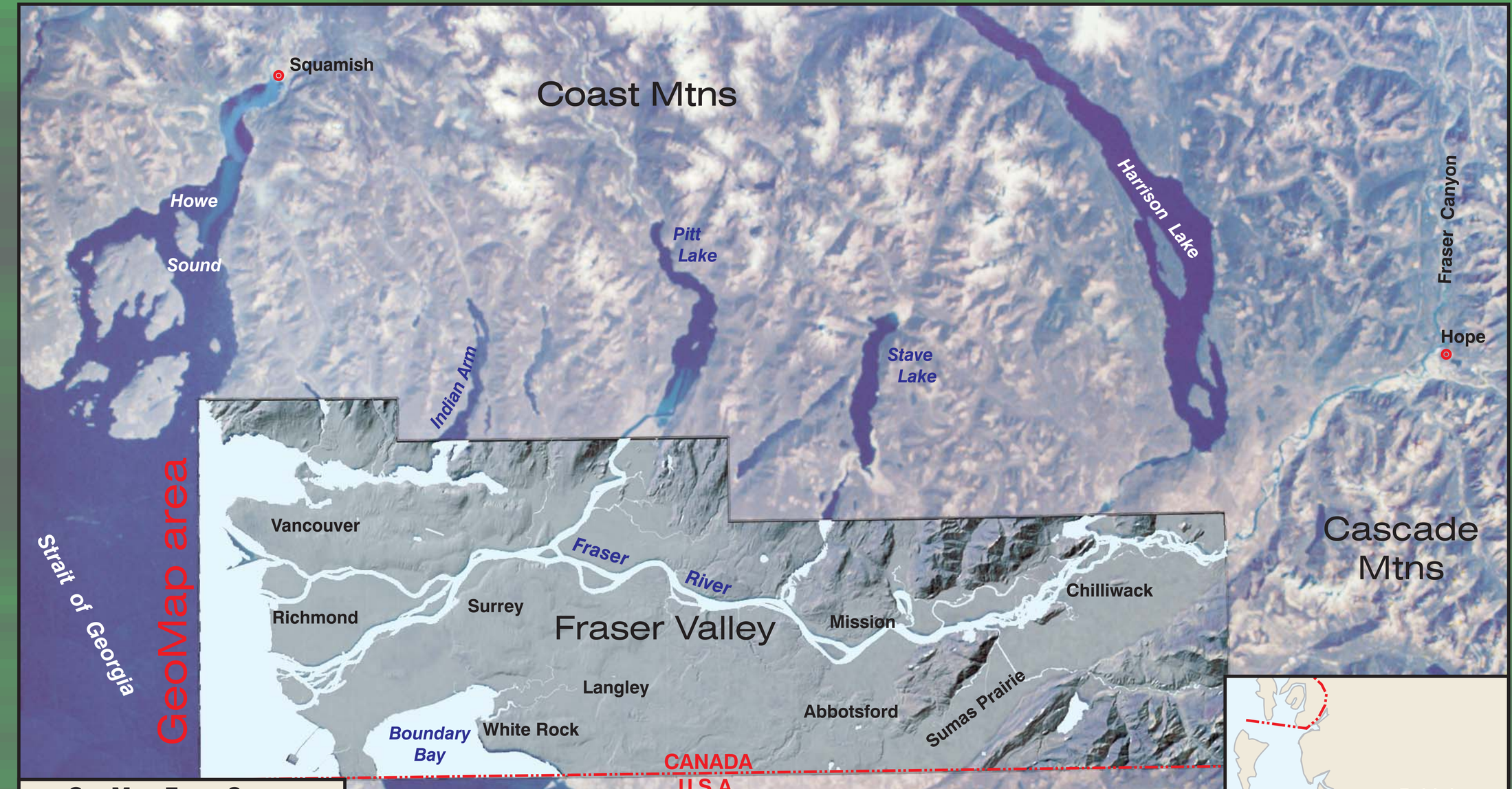
Folds in interlayered sandstone and argillite
J.M. Journeay

14

Foliated sedimentary and volcanic rock

Metamorphosed sedimentary and volcanic rocks occur widely in the Cascade Mountains, and also form small hills in the eastern Fraser Valley (Chilliwack Mountain). These rocks are characterized by a planar fabric (**foliation**) formed during burial, deformation, and metamorphism of the rock. This fabric reduces rock strength, causing some rock types to weather into thin platy fragments. Bedrock exposed on Vedder Mountain and east of Cultus Lake is made up of thinly layered, dark **argillite**, and lesser **phyllite**, **gneiss**, **limestone**, and **chert**. Volcanic rock with interlayers of limestone, argillite, and sandstone is exposed on mountain slopes in the upper Chilliwack River basin.

GeoMap From Space

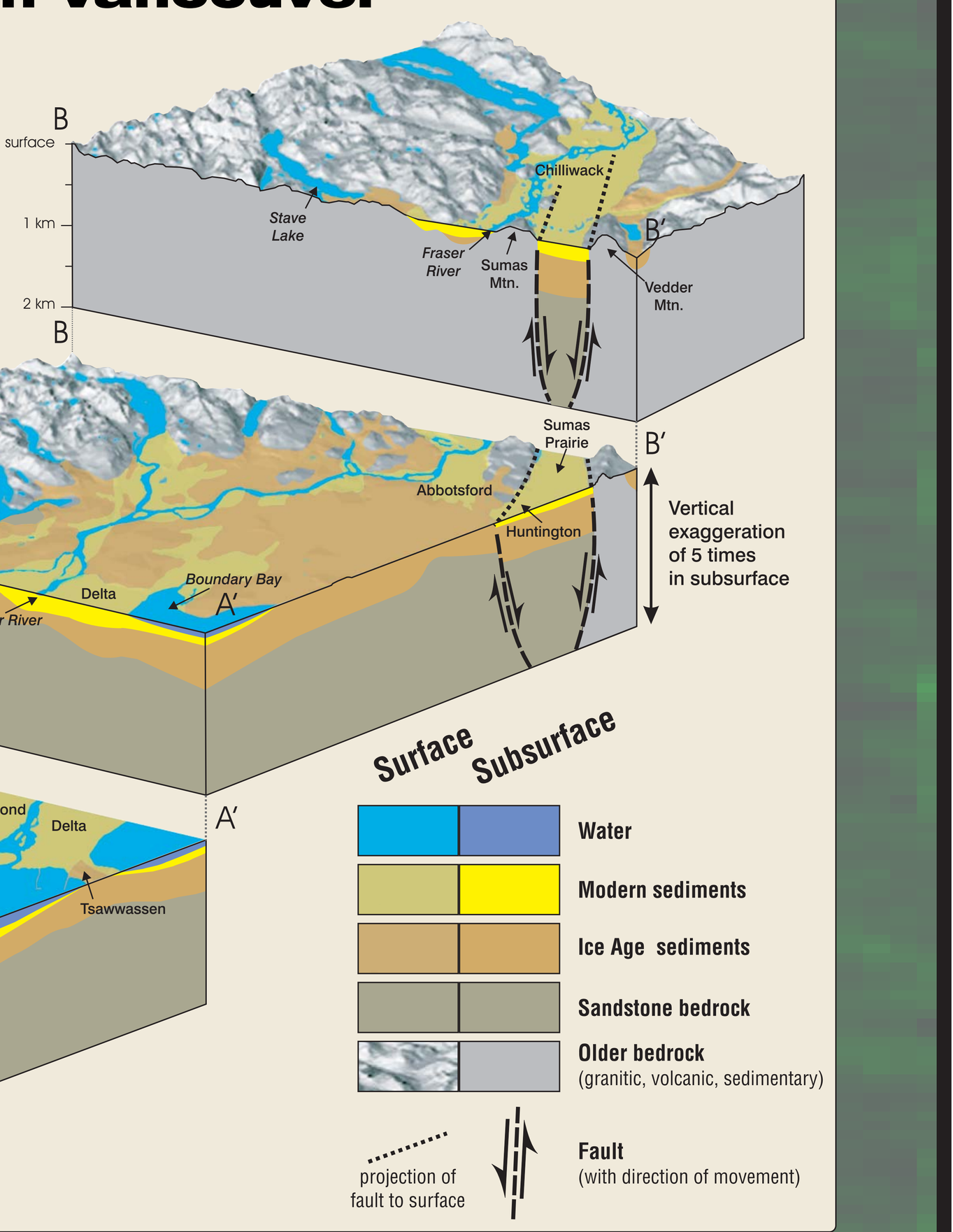


The Fraser Valley is a triangular-shaped lowland bordered by the Coast Mountains, and the Cascade Mountains and Chuckanut Hills. The Fraser River, draining a vast interior basin, breaks through the coastal mountains to reach the Strait of Georgia. **GeoMap Vancouver** includes that portion of the Fraser Valley lying on the Canadian side of the International Boundary.

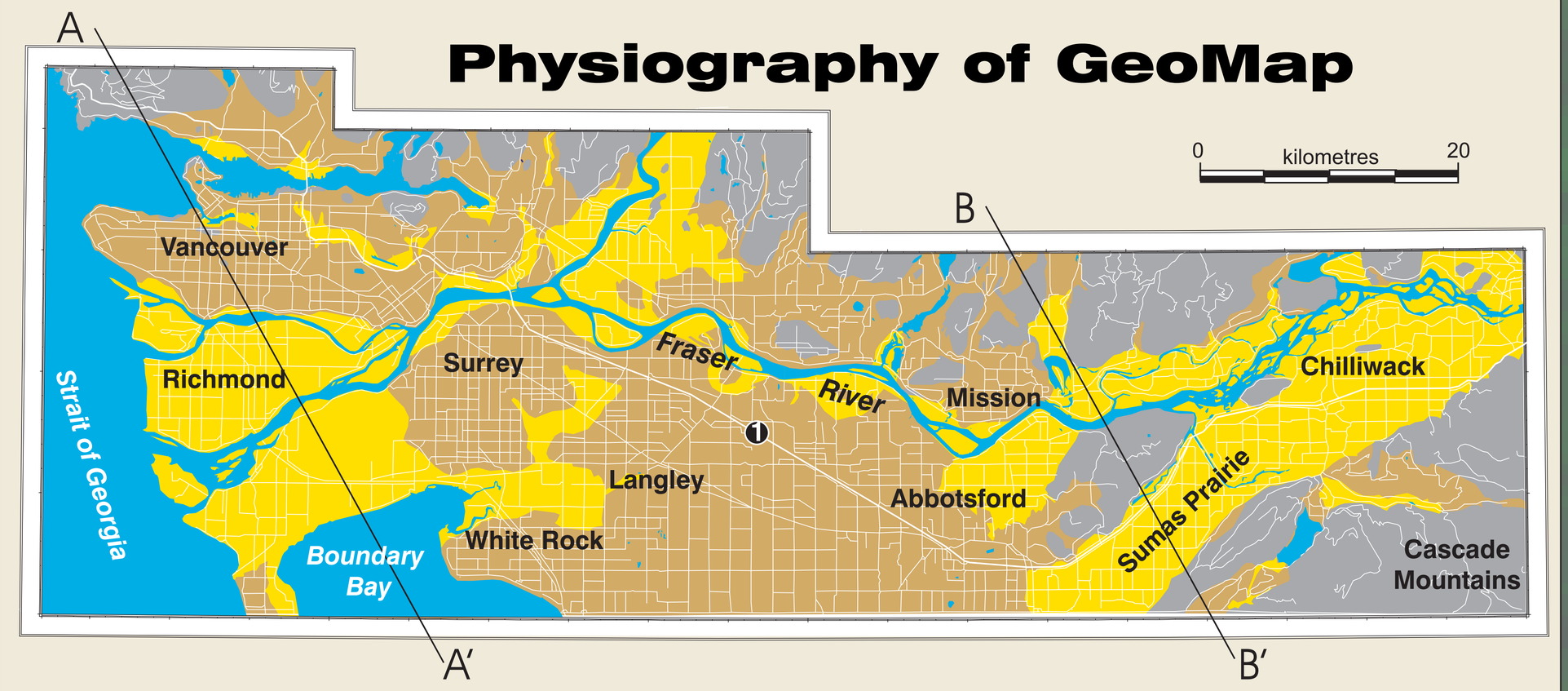
Additional Information

Beneath Vancouver

This three-dimensional perspective view illustrates the subsurface geology of Vancouver and the Fraser Valley. Knowledge of geology at depth comes from drill holes and geophysical surveys. Because this information is limited, the interpretation shown here is speculative. The diagram shows a deep basin in **granitic rock** beneath the Fraser Valley. **Sandstone** filling this basin is more than 4 km thick near Tsawwassen but pinches out at the edges of the basin. The sandstone, in turn, is overlain by Ice Age sediments up to 1 km thick. Generally thinner modern sediments are limited to low-lying areas (Fraser delta) and the Strait of Georgia, where they are currently being deposited. **Faults** (fractures along which there has been movement) offset bedrock and control some linear features such as Sumas Prairie. These faults are not known to be active.

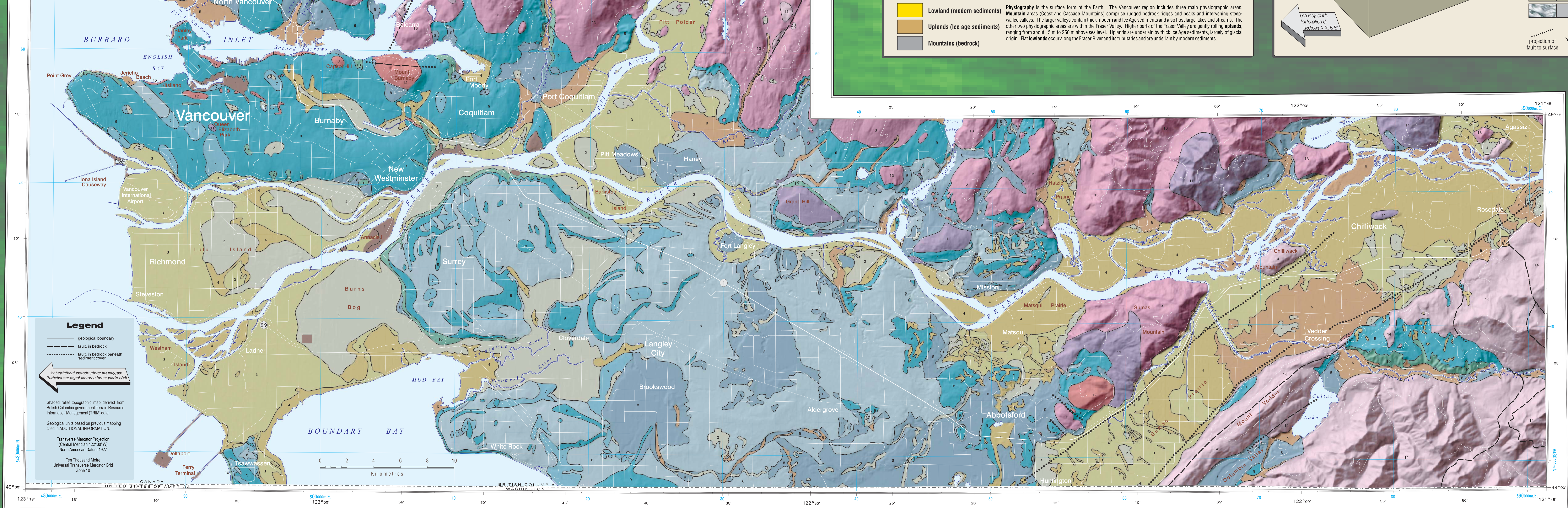


Physiography of GeoMap

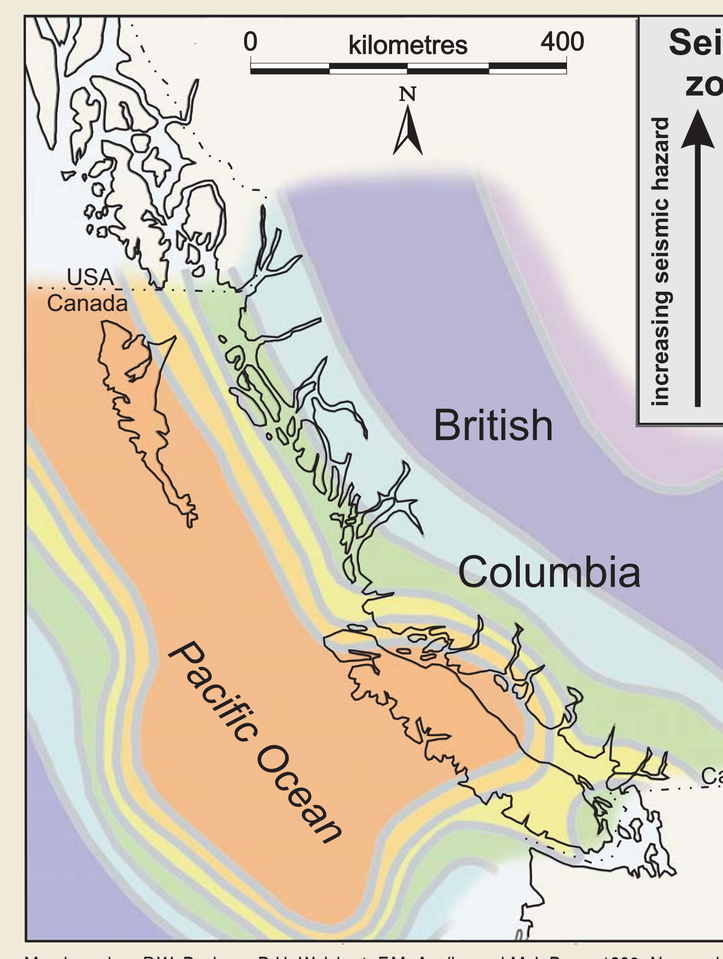


Lowland (modern sediments)
Uplands (Ice age sediments)
Mountains (bedrock)

Physiography is the surface form of the Earth. The Vancouver region includes three main physiographic areas. **Mountain** areas (Coast and Cascade Mountains) comprise rugged bedrock ridges and peaks and intervening steep-walled valleys. The larger valleys contain thick modern and Ice Age sediments and also host large lakes and streams. The other two physiographic areas are within the Fraser Valley. Higher parts of the Fraser Valley are gently rolling **uplands**, ranging from about 15 m to 250 m above sea level. Uplands are underlain by thick Ice Age sediments, largely of glacial origin. Flat **lowlands** occur along the Fraser River and its tributaries and are underlain by modern sediments.



Earthquake Ground Motion

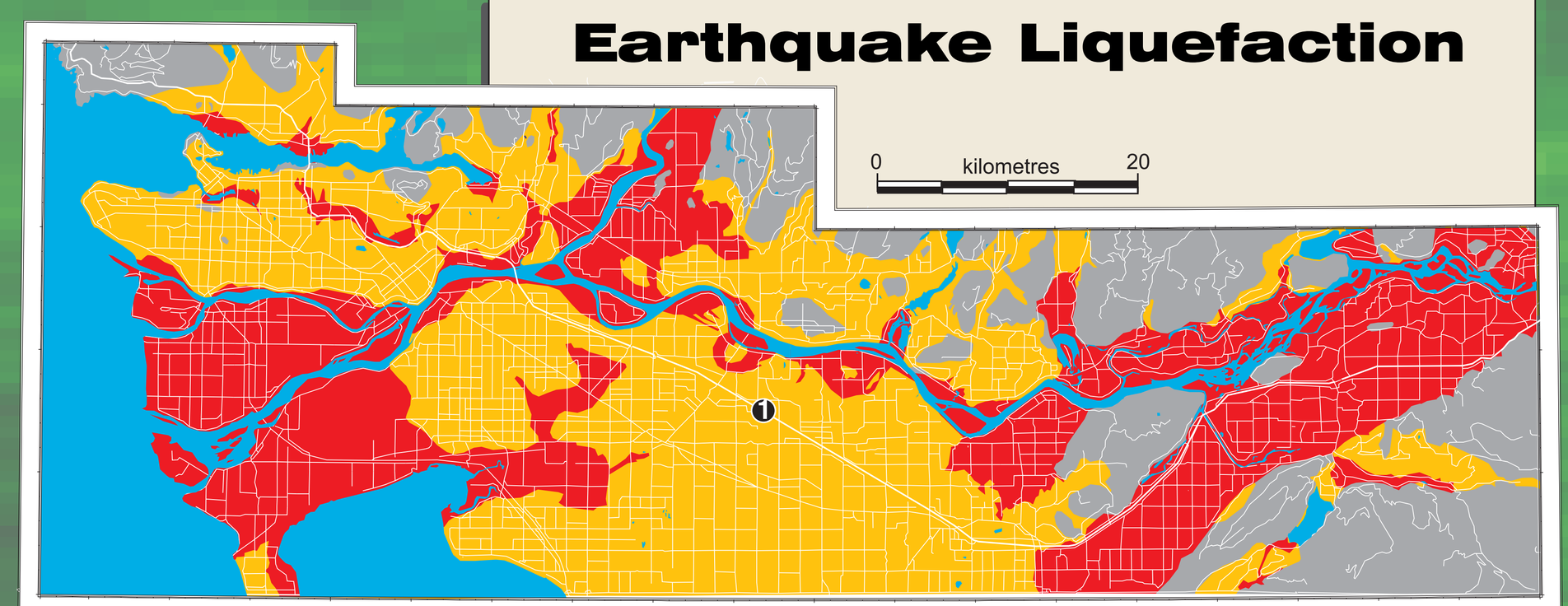


Map based on P.W. Basham, D.H. Weichert, F.M. Anglin, and M.J. Berry, 1982, New probabilistic strong seismic ground motion maps of Canada: a compilation of earthquake source zones, methods and results, Geological Survey of Canada, Earth Physics Branch Open File 82-33, 202 pp.

Ground motion, the definitive characteristic of earthquakes, causes damage directly by vibration and indirectly through secondary effects such as landslides and liquefaction. Structural design in earthquake-prone areas such as southwestern British Columbia is based on anticipated peak horizontal ground acceleration and velocity values provided by the Geological Survey of Canada. These parameters are derived from statistical analysis of past earthquakes and require an understanding of the causes of earthquakes in various regions and estimates of ground motion attenuation relationships (how quickly shaking decreases with distance from an earthquake). This information is incorporated into the National Building Code of Canada in the form of seismic zoning maps.

The map to the left shows seismic zones in British Columbia. The zones are based on levels of peak horizontal acceleration with a 10% probability of being exceeded over a 50-year period. This acceleration zoning map is centred near 5 Hertz (5 oscillations per second) - a frequency of ground motion that can damage small or rigid structures. A similar zoning map (not shown) in the National Building Code for peak seismic velocity is centred near 1 Hertz, a frequency that can damage larger structures (e.g. 10-storey buildings). Engineers use this information to design earthquake-resistant structures. These maps represent the intensity of shaking on rock. Local geology and topography may amplify ground shaking at some frequencies and may de-amplify shaking at other frequencies. There is no map yet for Vancouver and the Fraser Valley showing areas of expected ground amplification or de-amplification. The map shown here does not include possible effects of rare, very large, subduction-type earthquakes west of Vancouver Island; shaking produced by these earthquakes will be considered in the next generation of seismic zoning maps.

Earthquake Liquefaction



Moderate to High (modern lowland sediments)
Low (Ice Age upland sediments)
Nil (bedrock)

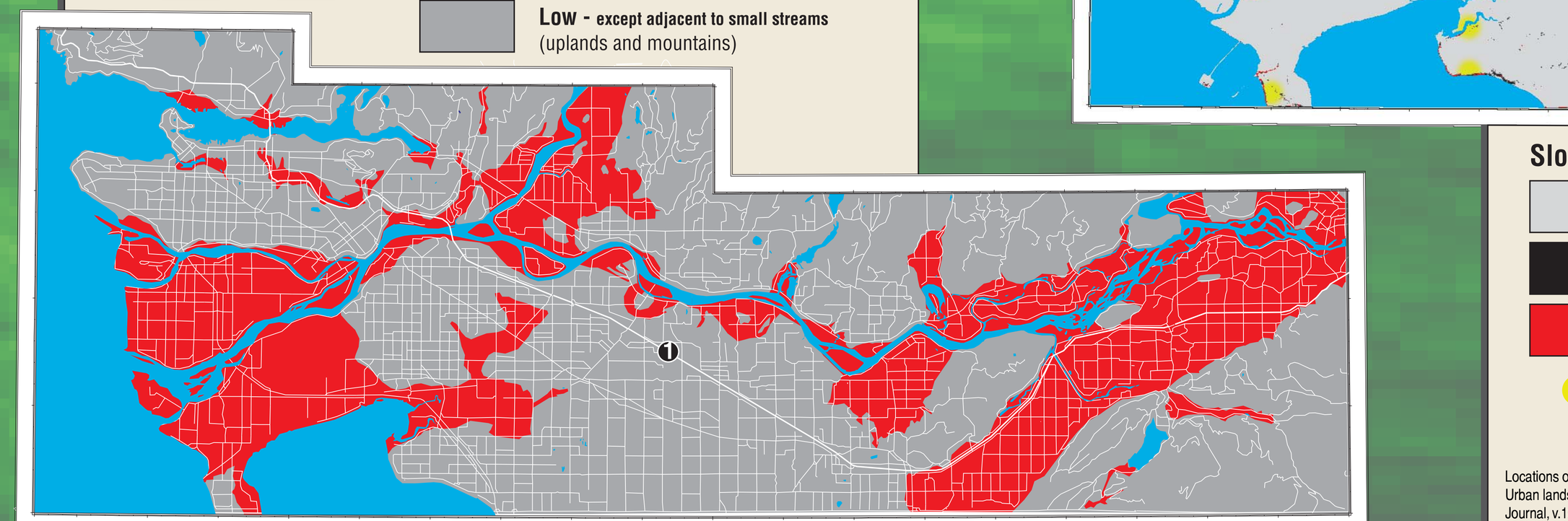
During an earthquake loose water-saturated silts and sands at shallow depth may lose their strength and transform into a fluid (**liquefaction**). Deeper sediments are more consolidated, have higher confining pressures, and consequently are less likely to liquefy. When sand beneath a layer of silt or clay liquefies, the capping layer may "glide" laterally under the influence of gravity towards a slope, such as the bank of a nearby river channel, causing ground cracking. Foundations of highways, bridges, and buildings, as well as buried sewer and gas lines, can be damaged by such movements. Liquefaction can also trigger landslides at the front of the Fraser delta. The red zone shows areas of relatively loose, saturated lowland sediments (i.e. lowlands). Liquefaction is likely to occur during a strong earthquake in those parts of the red zone where there is shallow subsurface sand and coarse silt, for example the Fraser delta.

This map provides only a generalized interpretation of liquefaction susceptibility during an earthquake and should not be used for local geotechnical evaluation.

Flood Hazard

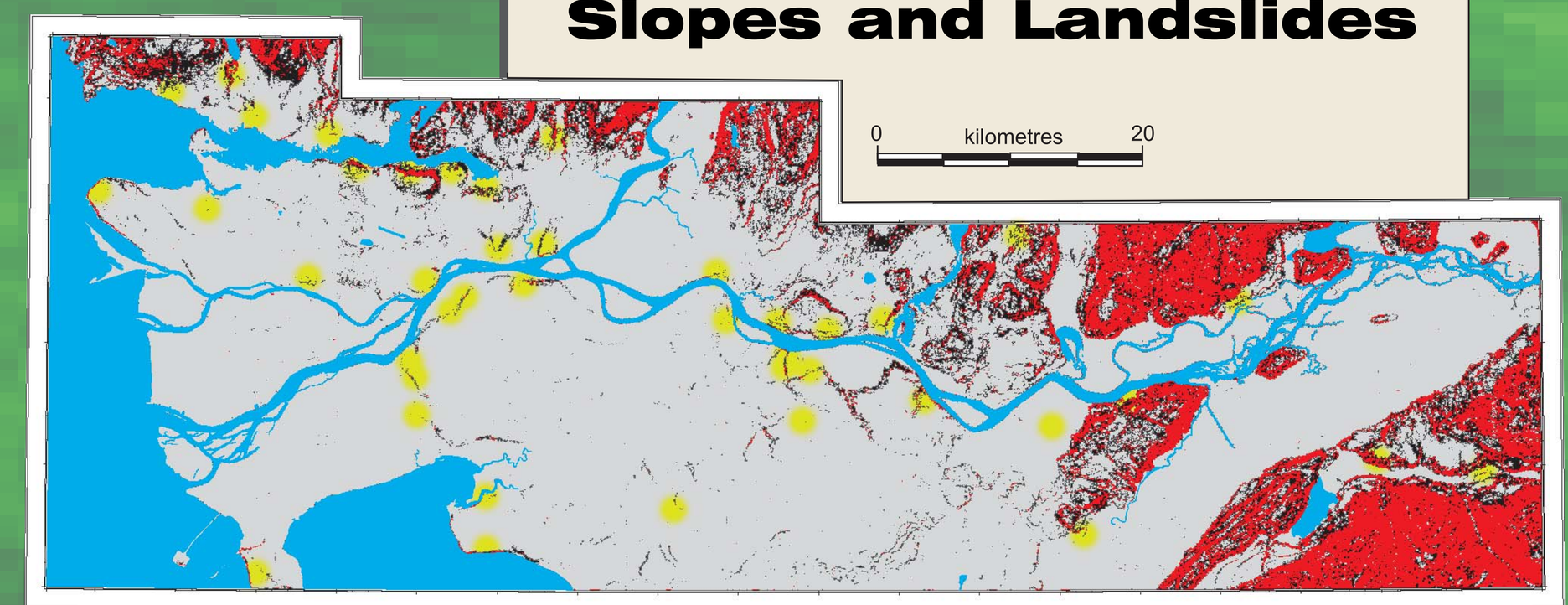
This map provides a generalized interpretation of hazard based on the distribution of modern flood deposits. Low-lying areas adjacent to rivers and the sea shore are coloured red. These areas are underlain by modern flood and coastal storm deposits. The red zone includes **floodplains** of the Fraser River and its tributaries, and gently sloping fans at the mouths of the Chilliwack, Coquitlam, Seymour, Capilano rivers. This zone also includes poorly drained areas in the Nicomekl and Serpentine river valleys. Although most of these areas have been dyked to protect people and property, they are still at risk from rare, exceptionally large river floods. Low-lying shorelines exposed to waves and strong winds can also be flooded during exceptional storms if the winds push water inland. Localized flooding can occur at the front of the Fraser delta when a storm or high tide coincides with a Fraser River flood. In both the red and grey zones on the map, small streams, which are not shown at this scale, can also overflow their banks. These relatively small floods are triggered by heavy rainstorms.

Moderate to High (modern lowland sediments)
Low - except adjacent to small streams (uplands and mountains)



For more detailed information on flood hazard contact the responsible municipal or regional government or the British Columbia Ministry of Environment, Lands and Parks, Water Management Division.

Slopes and Landslides



Slope Angle
< 10°
10 - 20°
> 20°
landslide

The slope of the land surface ranges from nearly horizontal on floodplains to more than 20° through much of the Coast and Cascade Mountains and on escarpments bordering uplands in the Fraser Valley. Why is slope important? First, it affects surface drainage -- in a general sense, drainage improves as the land surface steepens. Second, slope is an important factor in the stability of the land surface -- most landslides in the Vancouver area occur on slopes that are steeper than 20° (red areas on this map). Locations of many of the landslides that have occurred in this century in the Fraser Valley are plotted on the map (landslides in the Coast and Cascade Mountains are not included). Most landslides in the Fraser Valley involve Ice Age sediments and are triggered by intense rainstorms. In contrast, many of the landslides in the Coast and Cascade Mountains are in bedrock (**rockfalls** and **rockslides**). A common type of landslide in both regions is rapid flows of water-saturated debris (**debris flows**).

Locations of landslides from Armstrong and Hicock 1979, 1980 (see ADDITIONAL INFORMATION) and G.H. Eisbacher and J.J. Clague, 1981, Urban landslides in the vicinity of Vancouver, British Columbia, with special reference to the December 1979 rainstorm, Canadian Geotechnical Journal, v.18, pp. 205-216. Slope data derived from British Columbia government Terrain Resource Information Management (TRIM) data.

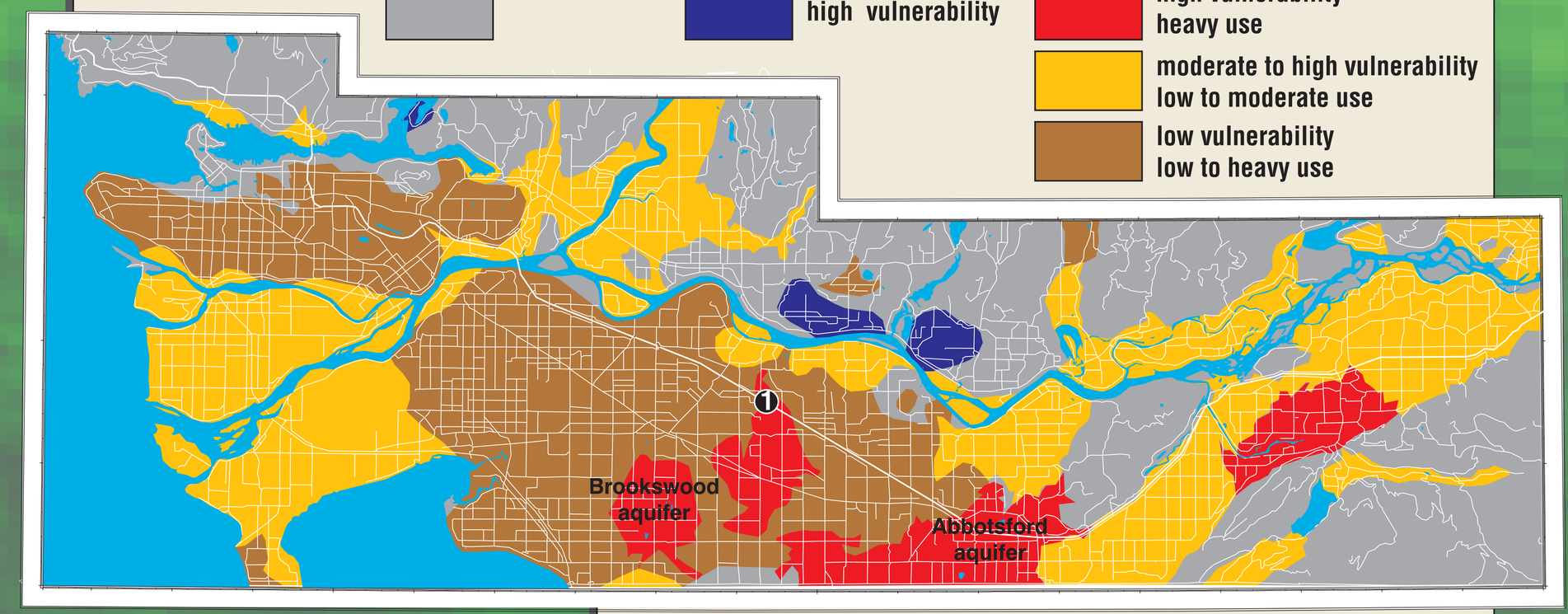
Groundwater and Aquifers

Aquifers are bodies of sediment or rock that are saturated and sufficiently permeable to provide subsurface water to wells. Most groundwater in the Fraser Valley is derived from aquifers in modern and Ice Age sediments. These aquifers are a major source of high-quality water for drinking and other uses. The British Columbia Ministry of Environment, Lands and Parks has classified 71 aquifers in the Fraser Valley according to current levels of use and vulnerability to contamination. Almost two-thirds of the aquifers are shallow and can be easily contaminated by downward infiltration of waters laced with agricultural fertilizers and pesticides, manure, septic effluent, or gas and oil from leaking storage tanks. The most heavily utilized of these highly vulnerable aquifers occur in the Abbotsford and Langley/Brookswood areas. Less developed, but highly vulnerable aquifers occur in sediments below the floodplain and delta of the Fraser River. Deeper aquifers overlain by silts, clays, or tills of low permeability are less vulnerable to contamination. The most important of these deep aquifers occur in the Aldergrove area; others underlie the uplands of Vancouver, Burnaby, Surrey, and Langley, and the lowland of the Nicomekl and Serpentine rivers. Some groundwater is also pumped from fractured bedrock, for example, at Grant Hill, Mission, and Belcarra. The thin soil cover over these bedrock aquifers makes them highly vulnerable to contamination. Some aquifers, in both sediments and bedrock, have poor water quality due to elevated levels of naturally occurring substances such as chloride, iron, sulphur, and fluoride.

Aquifers not assessed

Aquifers in Bedrock
high vulnerability

Aquifers in Sediment
high vulnerability, heavy use
moderate to high vulnerability, low to moderate use
low vulnerability, low to heavy use



Map based on R. Kreye and M. Wei, 1994, A proposed aquifer classification system for groundwater management in British Columbia, British Columbia Ministry of Environment, Lands, and Parks, Water Management Division, Hydrology Branch, Groundwater Section, 67 p.