SURFICIAL GEOLOGY, DISTRICT OF NORTH VANCOUVER

The surfical geology map for North Vancouver was used to help inform a detailed earthquake risk assessment for the District of North Vancouver. Outputs of this assessment are now being used by the community in development of an earthquake ready action plan to make the community more disaster resilient. In particular, this new surficial geology map was combined with information about the physiography and groundwater depth to assess the likelihood and magnitude of ground failure by liquefaction and earthquake triggered landslides and to inform the development of a site amplification map. Lessons learned from this case study are transferable to other communities who may face similar risks.

This map covers the lower flank of the North Shore Mountains from the shore of Burrard Inlet to about 500 m in elevation. The land rises northward to ~1400 m over a distance of 10 km from the sea. Except for a narrow deltaic plain, most of the area is characterized by steep slopes incised by high energy streams flowing in narrow flood plains. The bedrock is mainly diorite and granodiorite, part of an uplifted and faulted complex of plutonic and metamorphic rocks. Minor outcrops of terrestrial sedimentary rocks occur in the southern part of the area.

The mountains were extensively modified by glacial cycles during the Quaternary period. Major south-trending valleys were eroded along fault-weakened rocks and fracture zones. In general, each glacial cycle of advance and retreat was characterized by erosion and deposition of glacial, glaciofluvial, and glaciomarine sediments. Intervening non-glacial intervals were dominated by fluvial, mass wasting, and marine processes. Successive glaciations with sporadic erosion, deposition, and recycling of sediments resulted in a thick accumulation of unconsolidated deposits mantling the slopes of the north shore.

During past glaciations, valley glaciers flowed southward off the mountains into the Capilano, Seymour, and Lynn valleys while a large trunk glacier in Burrard Inlet abutted the flank of Mount Seymour as it flowed westward. The expanded glaciers depressed the crust so that sea levels were high and extensive marine inundation took place in front of the ice margins. Following several glacial cycles, the coastal lowlands became covered by thick sequences of glacial, glaciomarine, and fluvial sediments. Seismic data show old valleys that were completely infilled by glacial sediments. The floor of a buried valley along the Capilano River lies well below present sea level. In general, the surficial deposits are thickest below ~200 m elevation, the upper level of postglacial marine inundation, but thickness can vary considerably as the underlying bedrock topography is rugged. Bedrock is the dominant surface at higher elevations with only a thin discontinuous veneer of glacial deposits or colluvium.

At least two episodes of glaciation (stades) with intervening non-glacial intervals are recorded by stratigraphic sections in themap area, but most of the surficial deposits are associated with the last glaciation (Fraser Glaciation) and postglacial period. Any older sediments were probably reworked during the last glaciation. In the map area, the main deposits of the Fraser Glaciation are Quadra Sand, an advance phase outwash, and the overlying Vashon Drift. Deposits from minor ice advances have been recognized in parts of the Fraser lowland but have not been differentiated here. Vashon Drift is overlain by postglacial Capilano Sediments, which were deposited by glacial meltwaters flowing into formerly high sea and lake levels. Capilano Sediments are usually associated with rapid changes in base levels as the land rebounded. Modern deposits on contemporary slopes, lakes, and the sea are classed as Salish Sediments.

In summary, the Fraser Glaciation began ~26 000 radiocarbon years ago (BP) when glaciers accumulated in the cirques and uplands of the Coast Mountains, and culminated in an extensive ice sheet at least 1800 m thick. Initial ice flow was down mountain valleys but in time the Coast Mountains and lowlands where completely inundated. Two main ice-flow directions were recognized in the map area, although they may not have been coeval. The western two-thirds of the map area was dominated by ice flow from north to south and south-southwest caused by coalescent valley glaciers flowing off the North Shore Mountains. In contrast, the eastern third of the map area records a dominant ice flow along the flank of Mount Seymour to the south-west caused a trunk glacier flowing along the main axis of Burrard Inlet. The recorded ice flows were ultimately influenced by topography; however, it is not known whether the pattern formed beneath a thick contiguous ice sheet or by distinct glaciers or ice lobes during deglaciation. In any event, a thick glacial load depressed the earth's crust causing sea level to rise relative to the land. Consequently, the glaciers at first advanced into a high sea and floated producing extensive glaciomarine deposits. As glaciation intensified, thicker ice became grounded and in time the sea was completely displaced from the Strait of Georgia. Glacial till was deposited throughout the region during the glacial maximum. With deglaciation ~12 500 BP, the thinning ice was again susceptible to calving and glaciomarine sedimentation dominated once more. Deglaciation of the Georgia depression was probably rapid because the thinning ice margin would have became unstable with high seas flooding newly exposed fiords and bays. Accordingly, Vashon Drift is a collective term that includes not only till, but also the advance and retreat glaciomarine sediments, as well as some glaciofluvial deposits, especially those deposited close to former ice margins. This is in contrast to Quadra Sand which is thought to be distal outwash related to the Vashon advance.

Based on shore lines in the map area, the early postglacial sea inundated the North Shore to ~200 m elevation. Deltas formed at the valley mouths where large volumes of sediment-laden meltwater issued from the retreating glaciers immediately upvalley. Moraines and ice-contact glaciofluvial terraces associated with the upper deltas mark the former ice margins near the marine limit. Nevertheless the high relative sea level was short-lived because of rapid crustal uplift. By ~10 000 BP sea level was only about 10 m above present. Consequently, the oldest, uppermost delta terraces were incised and/or reworked by channels grading to ever lower base levels. This resulted in stepped delta and river terraces descending to present sea level. Postglacial deposits related to these higher than modern base levels were classed as Capilano Sediments. Although deposition in the map area was mainly in a marine environment, Capilano Sediments also includes lacustrine and fluvial deposits but may also include deposits related to base levels below present sea level. There is evidence from elsewhere that sea level was at least 10 m below present ~8 000 BP.

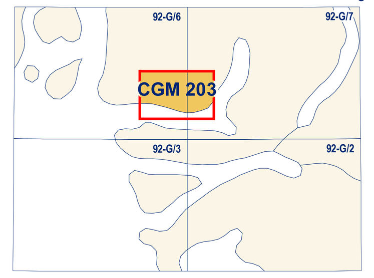
Salish Sediments refer to recent deposits less than ~5 m above base level associated with present sea, lake or river levels. However, Salish Sediments often contain reworked material, especially where modern rivers flow within valleys containing older Capilano outwash. The outwash provides a readily available source material for terraces and deltas. On steeper slopes, Salish Sediments include mass wasting deposits such as landslides; and steep channels incised on the mountain slopes feed alluvial fans and occasional debris flows. Humans have altered the original landscape of the map area with major land reclamations along the waterfront, significant infilling of some valleys and slopes to provide level building sites, and structures to mitigate flooding from mountain streams.

Abstract

The map area on the flank of North Shore Mountains is incised by three glacially-widened valleys. Glacial cycles caused sporadic erosion and deposition of sediments mantling the slopes. Most surficial deposits are from the last glaciation; however, some exposures and seismic data show older sediments, especially within buried valleys. During deglaciation, the sea level reached 200 m and meltwater issuing from the valleys formed glaciomarine deltas. Falling postglacial sea levels caused the deltas to be incised. Modern rivers mainly re-mobilize the older sediments. Other contemporary deposits include alluvial fans and debris flows on steep mountain slopes, and landslides on the flanks of incised valleys. Anthropogenic alterations of the landscape include land reclamation along the waterfront and infilling of valleys and slopes to provide level building sites and to mitigate the affects of flooding from mountain streams.

Résumé

La zone de la carte qui couvre le flanc des montagnes du North Shore est découpée par trois vallées élargies par la glaciation. Les cycles de glaciation ont causé une érosion sporadique et ont déposé des sédiments qui recouvrent les pentes. Bien que la plupart des dépôts superficiels remontent à la dernière glaciation, certains affleurements rocheux et des données sismiques indiquent la présence de sédiments plus anciens, notamment dans les vallées enfouies. Lors de la déglaciation, le niveau de la mer s'est haussé de 200 m et l'eau de fonte coulant dans les vallées a créé des deltas glaciomarins. La baisse postglaciale du niveau de la mer a causé l'encaissement des deltas. Les rivières modernes remobilisent surtout des sédiments plus anciens. Parmi les autres dépôts contemporains, on peut compter les cônes alluviaux et les coulées de débris sur les pentes raides des montagnes, ainsi que les glissements de terrain sur les flancs des vallées encaissées. Le paysage a été modifié par les humains, notamment les terre-pleins sur le front de mer, et le remplissage des vallées et des pentes pour aplanir les terrains à bâtir et atténuer les effets des inondations par les ruisseaux de montagne.



National Topographic System reference

Cover illustration
North Vancouver from the Ironworkers Memorial Bridge, North Vancouver, British Columbia. Photograph by N. Hastings. 2014-164

Catalogue No. M183-1/203-2014E-PDF
ISBN 978-1-100-24801-1
doi:10.4095/295128

Natural Resources Canada Ressources naturelles du Canada

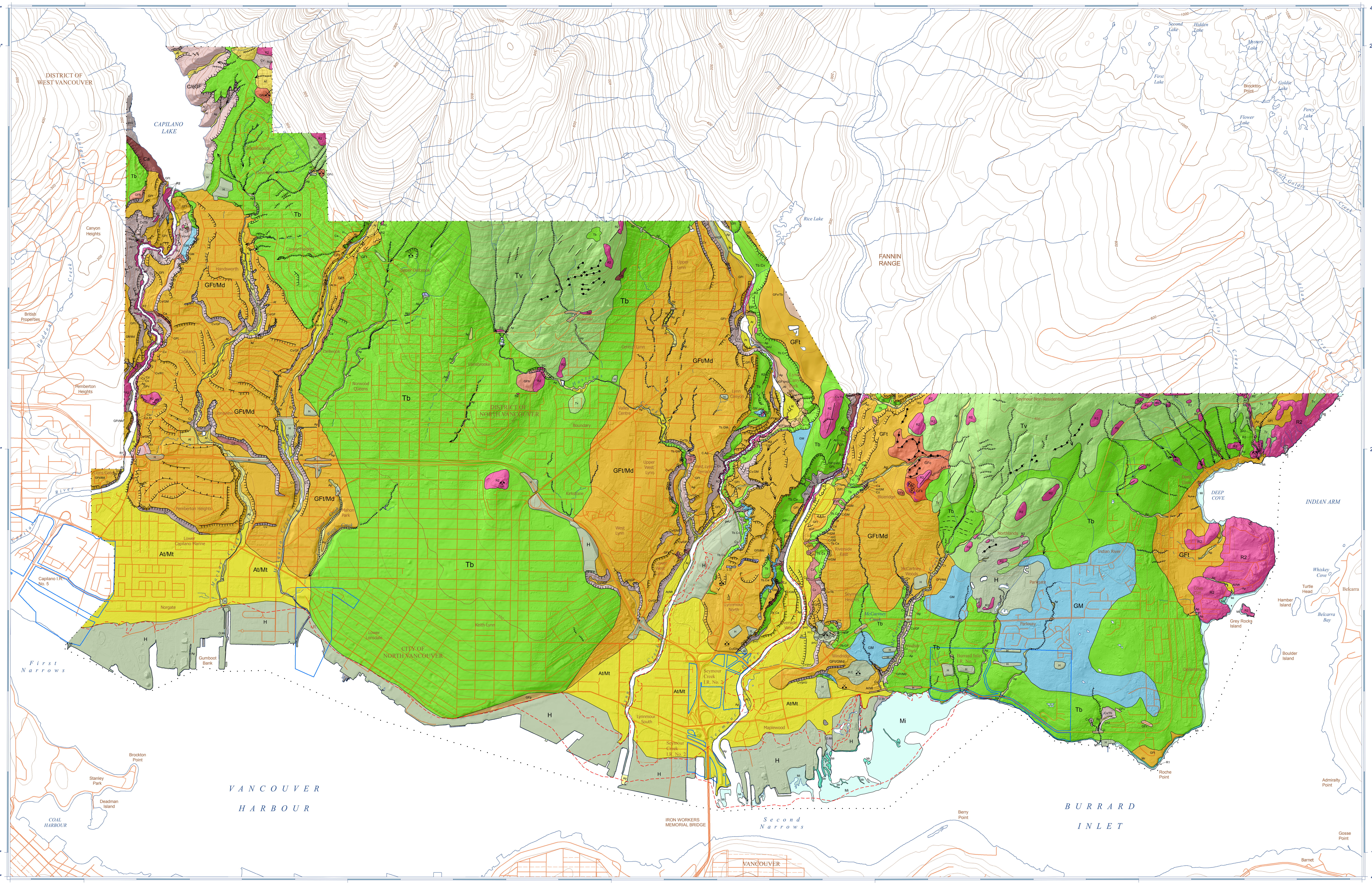
CANADIAN GEOSCIENCE MAP 203

SURFICIAL GEOLOGY

DISTRICT OF NORTH VANCOUVER

British Columbia

1:20 000



QUATERNARY

Post Last Glaciation

NONGLACIAL ENVIRONMENT

H	**ANTHROPOGENIC DEPOSITS:** culturally-made or modified geological materials; landfill including sand, gravel, till, crushed stone, and refuse; > 1 to 10 m thick.
O	**ORGANIC DEPOSITS:** accumulations of plant material in various stages of decomposition; bog or swamp deposits.
	COLLUVIAL DEPOSITS: mass wasting debris; diamicton deposited chiefly by gravity at the foot of slopes or cliffs.
Cz	**LANDSLIDE AND SLUMP DEBRIS:** diamicton, generally 1 to 10 m thick; hummocky topography; includes active and inactive landslides.
Ca	Forming a uniform apron along the base of a steep slope.
Cv	**COLLUVIAL VENEER:** thin and discontinuous cover of slump and/or slope wash material < 1 m thick.
C	Undifferentiated colluvium.
	Salish Sediments (deposits related to modern marine, river, and lake processes)
	FLUVIAL DEPOSITS: alluvium; sorted gravel, sand, silt, deposited by mountain streams; commonly stratified, may contain some organic detritus; alluvial sediments are often reworked glaciofluvial deposits.
Ap	**FLOODPLAIN DEPOSITS:** sorted gravel, sand, silt, and organic detritus >1 m thick; channel fill and overbank sediments forming active floodplains with meander channels and scroll marks.
At	**FLUVIAL TERRACE DEPOSITS:** >2 m thick; forming inactive terraces above the modern floodplain.
Af	**ALLUVIAL FAN DEPOSITS:** poorly sorted gravel, sand, and diamicton >1 m thick; occur where a stream issues from a narrow valley onto a plain or valley floor.
A	**ALLUVIAL DEPOSITS:** undifferentiated.
L	**LACUSTRINE DEPOSITS:** fine sand, silt, and clay deposited in lakes; exposed by a recent decrease in lake level; >1 m thick; may contain organic deposits.
	MARINE DEPOSITS: beach and intertidal sediments deposited by waves and currents along the present shoreline of Burrard Inlet
Mr	**BEACH DEPOSITS:** sand to sandy loam, up to 2 m thick, deposited by waves and currents at the present shoreline.
Mi	**INTERTIDAL DEPOSITS:** mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high water lines.
Md	**MARINE DEPOSITS:** deltaic sediments.
Mt	**MARINE TERRACE DEPOSITS:** forming a terrace above the present littoral zone.

POSTGLACIAL OR LATE PLEISTOCENE

PROGLACIAL AND GLACIAL ENVIRONMENTS

	Capilano Sediments (deposits related to former marine, river, and lake levels)
	Vashon Drift (glacial deposits; may include sporadic glaciomarine deposits of the Coquitlam Stade)
	GLACIOFLUVIAL DEPOSITS: stratified sand and gravel, well to poorly sorted with minor diamicton; deposited behind, at, or in front of the ice margin by glacial meltwater.
GFp	**PROGLACIAL OUTWASH DEPOSITS:** 2 to 10 m thick; braided outwash plains deposited as valley trains in front of retreating ice margins; grade into raised delta deposits where valley meets the coastline.
GFt	**OUTWASH TERRACE DEPOSITS:** 1 to 10 m thick; forming terraces along valley sides; in places, perched above modern fluvial deposits.
GFk	**GLACIOFLUVIAL KAME DEPOSITS:** proximal outwash forming a kettled terrace.
GFv	**GLACIOFLUVIAL VENEER:** < 1 m thick; thin and discontinuous.
GFc	**ICE-CONTACT STRATIFIED DEPOSITS:** poorly-sorted sand and gravel with minor diamictons; 1 to >20 m thick; deposited in contact with the retreating glacier.
GFh	Hummocky topography.
GF	Undifferentiated glaciofluvial deposits.
GM	**GLACIOMARINE DEPOSITS:** silt, sand, and minor gravel, 1 to 10 m thick, deposited into the sea by glacial meltwater during former high sea levels; commonly stratified; locally, may contain marine shells and/or diamictons of ice rafted debris.
	TILL: diamicton deposited directly by glaciers; sandy to clayey matrix with many clasts of various lithologies.
Tb	**TILL BLANKET:** >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units.
Tv	**TILL VENEER:** < 1 m thick, discontinuous till cover, underlying bedrock surface is discernible; thicker pockets of till can occur in depressions.
	Pre-Vashon Deposits (sand, gravel, silt, clay, and till underlying Vashon Drift)
qGF	**QUADRA SAND:** glaciofluvial channel fill and floodplain deposits; crossbedded, sorted sand, minor gravel, and silt; may include stratified deltaic deposits; 3 to 30 m thick.
pvU	**PRE-VASHON NONGLACIAL, GLACIAL, AND GLACIOMARINE SEDIMENTS:** sporadic deposits of nonglacial Cowichan Head organic sediments; Semiahmoo glaciomarine, glaciolacustrine, glaciofluvial sediments, and till.

PRE-QUATERNARY

BEDROCK

R2	Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.
R1	Upper Cretaceous sedimentary rocks of the Nanaimo Group.

NOTE: In areas where the surficial cover forms a complex pattern, the area is coloured according to the dominant unit and labelled in descending order of cover (e.g. Tb.Ca). Where different surficial deposits are suspected to overlie each other areas are coloured according to the overlying unit and labelled in the following manner: At/Mt.

- Geological boundary
- Limit of mapping
- Esker
- Fluting (ice flow direction known)
- Fluting (ice flow direction unknown)
- End moraine
- Stream channel large (some are meltwater channels)
- Stream channel, small, known (some are meltwater channels)
- Stream channel, small, unknown (some are meltwater channels)
- Pre-development coastline
- Escarpment
- Strandline
- Marine limit strandline
- Striation (direction known)
- Pit (abandoned or active)
- Quarry (abandoned or active)
- Kettle
- Landslide, small

REFERENCES

Armstrong, J.E. and Hicock, S.R. 1979. Surficial Geology, Vancouver, British Columbia; Geological Survey of Canada, Map 1486A, scale 1:50 000. doi:10.4095/108876

Armstrong, J.E. and Hicock, S.R. 1980. Surficial Geology, New Westminster, West of Sixth Meridian, British Columbia; Geological Survey of Canada, Map 1484A, scale 1:50 000. doi:10.4095/108874

Maynard, D.E. 1977. Guidebook for geologic field trips in the Lynn Canyon – Seymour area of North Vancouver, British Columbia; Adventures in Earth Sciences Series No.22. University of British Columbia 56 p.

Maynard, D.E. 1978. Surficial Geology, Figure III-2, *in* Geomorphic Constraints to Urban Residential Development in the Seymour Area, District of North Vancouver, British Columbia; M.Sc. Thesis, University of British Columbia.

Recommended citation
Bednarski, J.M., 2014. Surficial geology, District of North Vancouver, British Columbia; Geological Survey of Canada, Canadian Geoscience Map 203 (preliminary), scale 1:20 000. doi:10.4095/295128

ess.nrcan.gc.ca

Canadian Geoscience Maps

Author: J.M. Bednarski

Geology by J.M. Bednarski, 2010–2011

Airphoto, Lidar, and satellite interpretation by J.M. Bednarski, 2010–2011

Geology conforms to Surficial Data Model v. 2.0.1

Geomatics and cartography by M. Lagassé and W. Chow

This project was supported by the Canadian Safety and Security Program (CSSP_project number Risk 09/10-0001SCP Quantitative Risk Assessment Project) which is led by Defence Research and Development Canada's Centre for Security Science, in partnership with Public Safety Canada. Partners in the project include District of North Vancouver, North Shore Emergency Management Office, Federal Emergency Management Agency, and University of British Columbia

SURFICIAL GEOLOGY

DISTRICT OF NORTH VANCOUVER

British Columbia

1:20 000

500 0 500 1000 1500 2000m

Map projection Universal Transverse Mercator, zone 10. North American Datum 1983

Base map at the scale of 1:50 000 from Natural Resources Canada, with modifications. Elevations in feet above mean sea level

Waterbody and Indian Reserves data obtained from District of North Vancouver's GeoWeb. Contains information licensed under the Open Government Licence - North Vancouver.

Some geographic names on this map are not official.

Shaded relief image derived from the digital elevation model supplied by the District of North Vancouver. Illumination: azimuth 345°, altitude 65°, vertical factor 1x

Magnetic declination 2014, 16°53'E, decreasing 11' annually.

The Geological Survey of Canada welcomes corrections or additional information from users.

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

This map is not to be used for navigational purposes.

Preliminary publications in this series have not been scientifically edited.

CANADIAN GEOSCIENCE MAP 203
SURFICIAL GEOLOGY
DISTRICT OF NORTH VANCOUVER
British Columbia

Canada