Fraser Valley Geotour:

Bedrock, Glacial Deposits, Recent Sediments, Geological Hazards and Applied Geology: Sumas Mountain and Abbotsford Area

A collaboration in support of teachers in and around Abbotsford, B.C.
in celebration of National Science and Technology Week
October 25, 2013

MineralsEd and Natural Resources Canada, Geological Survey of Canada

Led by
David Huntley, PhD, GSC
and
David Thompson, P Geo

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Mineral Resources Education Program of BC

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Introduction

Welcome to the Fraser Valley Geotour!

Learning about our Earth, geological processes and features, and the relevance of it all to our lives is really best addressed outside of a classroom. Our entire province is **the** laboratory for geological studies. The landscape and rocks in the Fraser Valley record many natural Earth processes and reveal a large part of the geologic history of this part of BC – a unique part of the Canadian Cordillera.

This professional development field trip for teachers looks at a selection of the bedrock and overlying surficial sediments in the Abbotsford area that evidence these geologic processes over time. The stops highlight key features that are part of the geological story - demonstrating surface processes, recording rock – forming processes, revealing the tectonic history, and evidence of glaciation. The important interplay of these phenomena and later human activity is highlighted along the way. It is designed to build your understanding of Earth Science and its relevance to our lives to support your teaching related topics in your classroom.

Acknowledgments

We would like to thank our partners, the individuals who led the tour to share their expertise, build interest in the natural history of the area, and inspire your teaching.

Dave Huntley is a geoscientist who works with the Geological Survey of Canada in Vancouver. His expertise is in Quaternary geology and has worked in many parts of western Canada. He has published numerous papers, reports and geological maps covering geology, stratigraphy, sedimentology, mineral exploration and geological hazards in British Columbia.

Dave Thompson is a professional geologist who has worked in mineral exploration and in mining, most recently in the development of metallurgical coal in NE BC. Dave Thompson is also a teacher, and has taught secondary science in Vancouver area schools.

We would also like to thank our industry partners, the quarry operators who were involved in organizing and leading our visits.

Mainland Sand & Gravel, Cox Station & Jamieson Quarries
Ted Carlson, Proprietor
Dani Miller, Safety & Technical Compliance Manager
6850 Cox Rd
Fraser Valley H, BC V3G

Valley Gravel Sales
Barry McLean, Proprietor
700 LeFeuvre Road (office)
Abbotsford, B.C.

Fraser Pacific Enterprises, Kilgard Quarry
Jason Thiessen, Operations Manager
Sumas Mtn Rd
PO Box 49
Mt. Lehman, BC V4X 1Y5

Sheila R. Stenzel, Director
MineralsEd

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Geological Overview

This field trip will take participants around the rock cycle and on a journey through deep time, while also introducing the applied topics of economic and environmental geology. A variety of geological terms and concepts will be explained through analogy and examples highlighted at a number of field stops in the Sumas Mountain - Abbotsford study area (**Figure 1**).

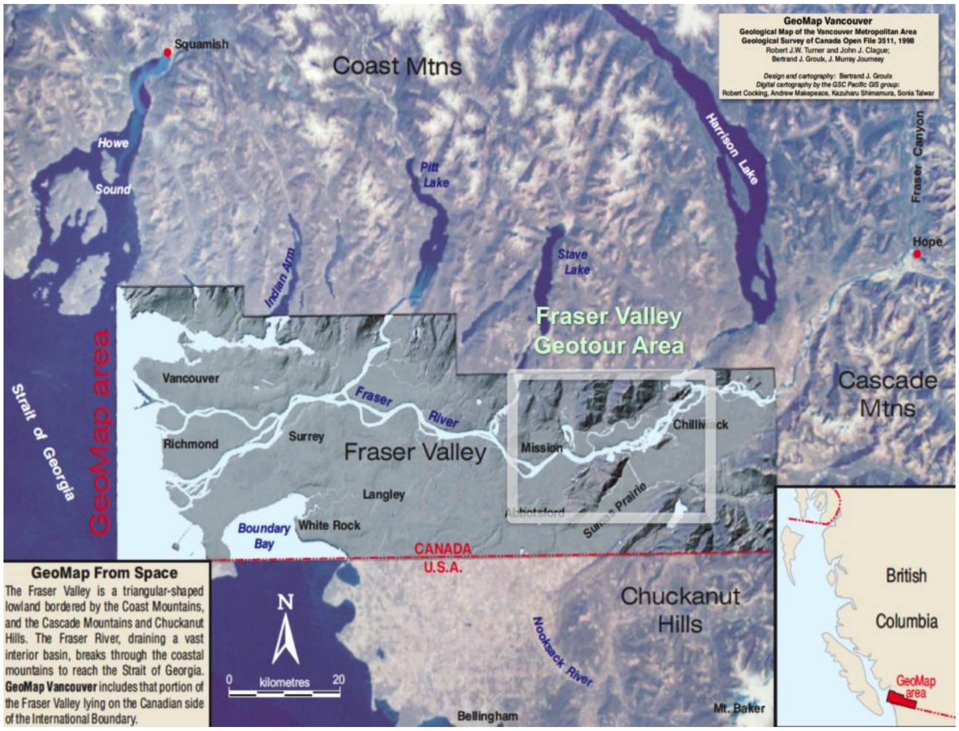

Figure 1 Location of field trip area in relation to the major landscape elements of southwestern British Columbia and northern Washington State (modified from Turner et al. 1998).

You will learn about …

- Physiography of southwestern British Columbia and the subsurface depicted as 3-D cross-sections
- Rock cycle and geological time
- Earth materials and their distribution as depicted on a geological map
- Plate tectonics, mountain building, mechanisms of uplift and erosion
- Igneous, sedimentary and metamorphic rocks and modern geological analogues
- Glacial deposits and environments during the last Ice Age, and modern analogues
- Post-glacial colluvium, alluvial, organic and lake sediments
- Geological hazards impacting vulnerable natural resources, farmlands, infrastructure and communities

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Introduction to the Rock Cycle

In outcrop and hand specimen, three major rock types can be readily distinguished using the following criteria:

- *Igneous Rocks* can be: **crystalline**, **massive**, **vesicular**, **fine grained** to **coarse grained glassy** or **fragmental** (pyroclastic)

- *Sedimentary Rocks* can be: **fragmental** (clastic/detrital), **crystalline** (reacting with HCl) or **organic**

- *Metamorphic Rocks* can be: **crystalline**, **massive**, **foliated**, or contain **relict igneous** and **sedimentary textures** and **structures**

These major bedrock types are linked through cycles of pressure, heat, chemical-fluid interactions, melting, crystallization, uplift and exposure, weathering, erosion and transportation, burial, compression, cementation, precipitation and biogenic fixing operating for 10's to 100's of millions years (**Figure 2**).

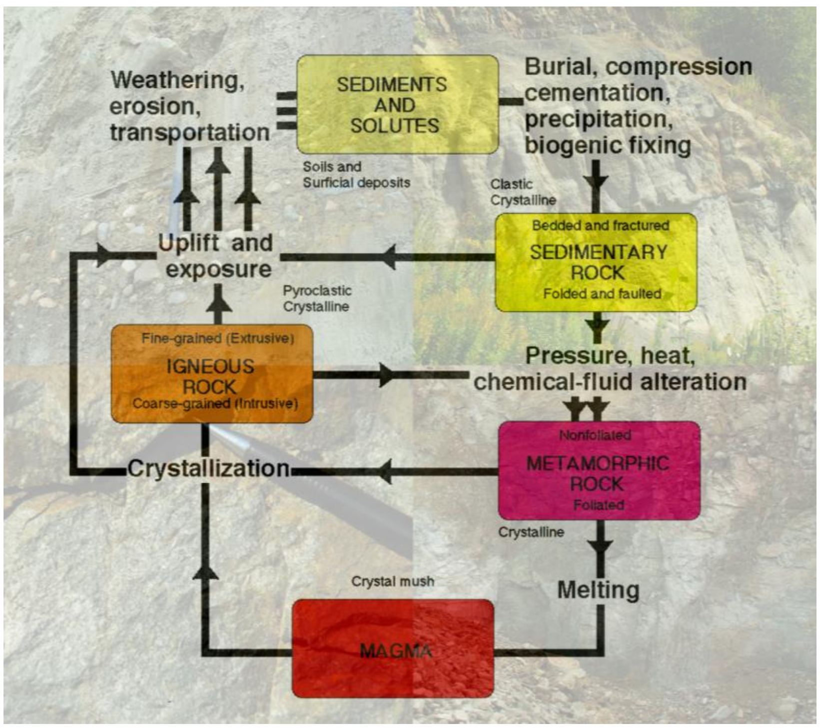

Figure 2 The rock cycle: showing the linkages and geological processes influencing the three major bedrock types.

Around the Rock Cycle …

This field trip is an opportunity to observe all parts of the rock cycle. Igneous, sedimentary and metamorphic rocks form the Coast Mountains, Sumas Mountain, and Cascade Mountains to the southeast (**Figure 3**). Surficial products of weathering, erosion and transport drape mountain slopes and bury a bedrock surface with considerable relief.

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Regional Geological History

Bedrock and surficial deposits of the Sumas Mountain – Abbotsford area record a 250 million year history that will be explored in this field trip. The surface expression of this record is depicted in **Figure 3**.

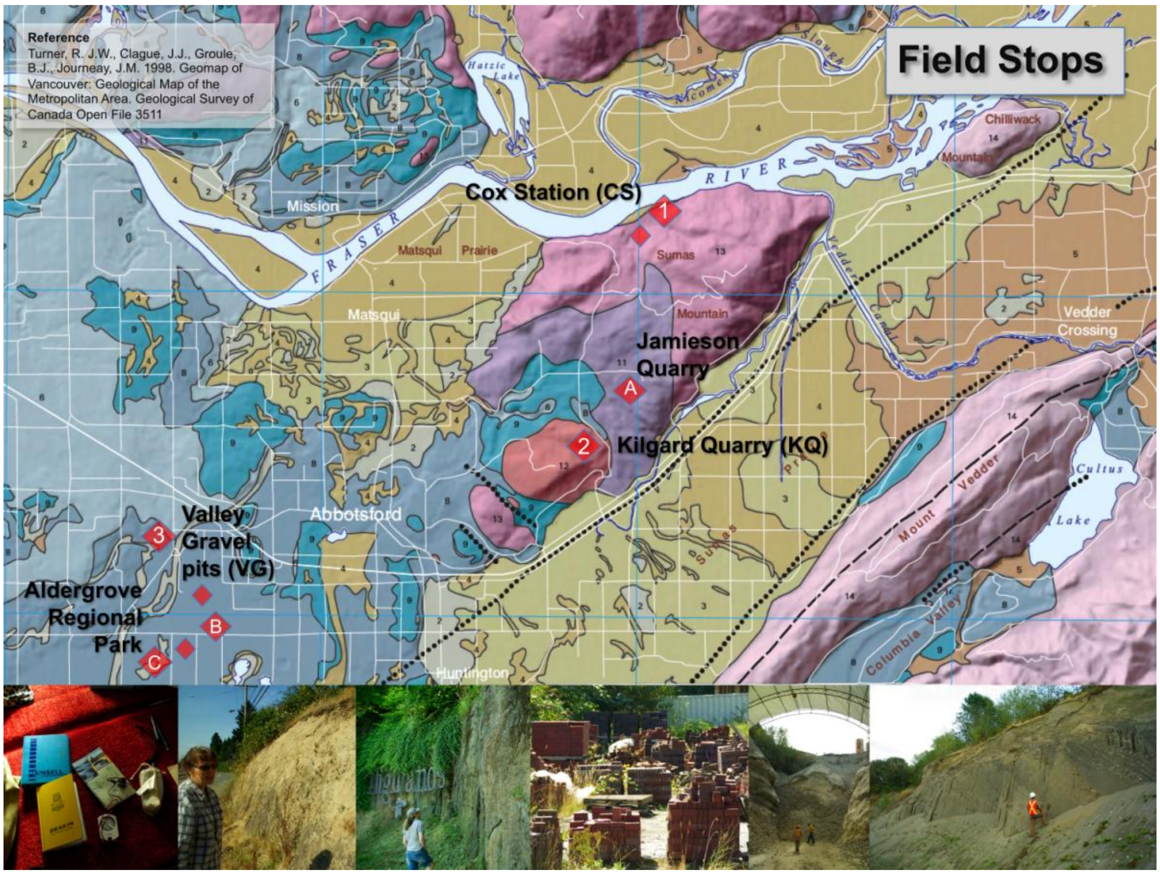

Figure 3 Bedrock geology of the Sumas Mountain – Abbotsford area with location of field stops: **CS** – Cox Station (Stop 1); **KQ** – Kilgard Quarry (Stop 2); VG – Valley Gravel Sales pit (Stop 3); A – Jamieson Quarry (additional stop); B – reclaimed Valley Gravel Sales pit (additional stop); C - Aldergrove Regional Park (additional stop). Modern surficial map units: 2 – Peat; 3 – Silt and clay; 4 – Sand and silt; 5 – Gravel and sand. Ice age surficial map units: 6 – Silt and clay; 7 – Sand; 8 – Gravel and sand; 9 – Till. Bedrock map units: 11 – Volcanic rock; 12 – Sandstone; 13 – Granitic rock; 14 – Foliated sedimentary and volcanic rock. Dotted lines – Sumas Fault (graben); dashed lines – Vedder Fault

Bedrock and Geological Structures

The oldest rocks in the Sumas Mountain –Abbotsford area can be observed at the Jamieson Quarry (**Figure 3**, A); and in outcrop on Vedder Mountain to the southeast of the study area (map units 11 and 14, **Figure 3** and **Figure 4**). These are Triassic (250-200 Ma [millions of years]) to Jurassic (200-145 Ma) **metamorphosed volcanic** and **sedimentary rocks**, interpreted as a portion of **Wrangellia** terrane.

Wrangellia had accreted to paleo-continental North America by the Cretaceous Period (145-66 Ma). A consequence of this major tectonic event was an increase in intrusive igneous activity and surface volcanism, together with metamorphism, folding and faulting of basement rocks (**Figure 4**). **Granitic rocks** observed at Stop 1A (Cox Station; **Figure 3**) were intruded into the metasedimentary and volcanic basement in Jurassic to Cretaceous times, 175-95 Ma, as part of the Coast Plutonic Complex (**Figure 4**).

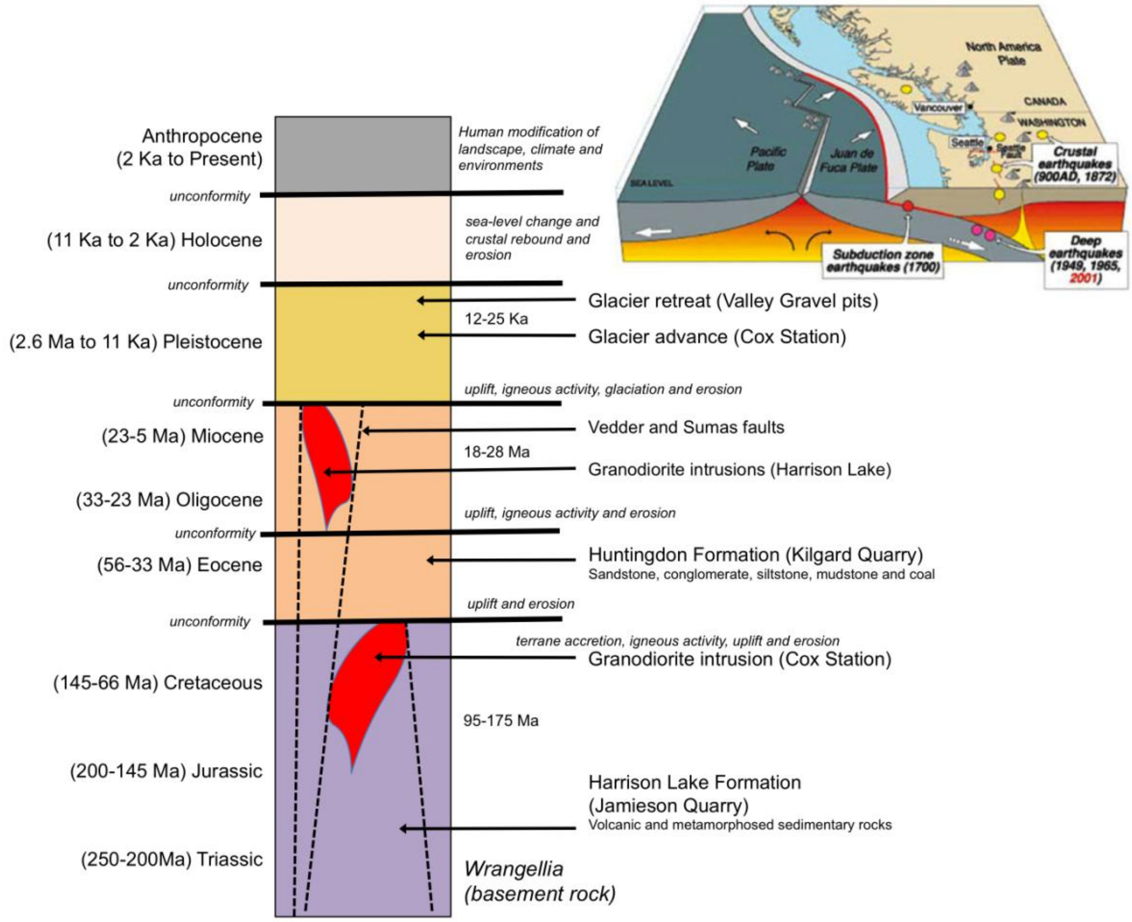

Figure 4 Generalized geological history of the Sumas Mountain – Abbotsford area, showing key events and geological time units; inset shows modern plate tectonic setting and significant historic earthquakes.

Along the southwestern flank of the Coast Mountains, Eocene-Oligocene sedimentary rocks overlie a deeply eroded Coast Plutonic Complex. Well-exposed at Stop 2 (Kilgard Quarry) the sequence of interbedded **conglomerate**, **sandstone**, **fossiliferous siltstone**, clay-rich **shale** and **coal** records deposition between 56 and 23 Ma. Sedimentary structures, pebble composition, fossils, coal beds and clay-rich units interpreted as paleosols are consistent with a landscape comprising mixed coniferous and deciduous woodlands, wetlands, lakes and braided floodplains flanking deeply incised uplands and mountains.

Through Oligocene (33-23 Ma) and Miocene times (23-5 Ma) rivers delivered sediment eroded from uplifted terrain surrounding Sumas Mountain to a marine basin that evolved into the modern Salish Sea (Strait of Georgia). Granodiorite intrusions in the Harrison Lake area (north of the study area) and activation of the Sumas and Vedder faults occurred between 28 and 18 Ma (**Figures 3** and **4**). Regionally, renewed uplift, igneous activity and erosion continued through to the Pleistocene (2.6 Ma to 11,000 years before present [Ka]).

Glacial Geology and Geomorphic History

A glacial landscape …

Southern British Columbia, including the Sumas Mountain – Abbotsford area, was glaciated multiple times during the Pleistocene Period, although only the deposits of the last Ice Age are observed on the field trip. The unconsolidated sediments that drape Sumas Mountain and infill the Sumas and Matsqui prairies (**Figure 3,** map units 6, 8 and 9) were deposited during the last major Ice Age: the Late Pleistocene **Fraser Glaciation** (ca. 30-11 Ka); and preceding nonglacial period (Olympia Nonglacial Interval, 65-30 Ka) (**Figure 5**).

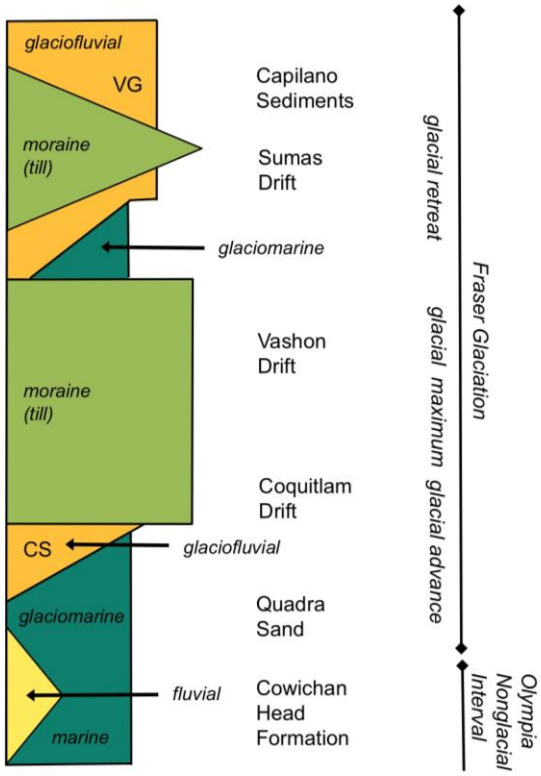

Figure 5 Generalized Late Pleistocene stratigraphy for the Sumas Mountain – Abbotsford area.

Stop 1B (Cox Station) is an opportunity to observe the early advance of the Cordilleran Ice Sheet over glacial outwash (Quadra Sand) and marine sediments (Cowichan Head Formation) (**Figure 5**). Glacial advance phase deposits were subsequently deformed, truncated and covered by **till** and gravelly ice-contact sediments (Vashon and Sumas drifts) between 24-14 Ka (**Figure 6A**).

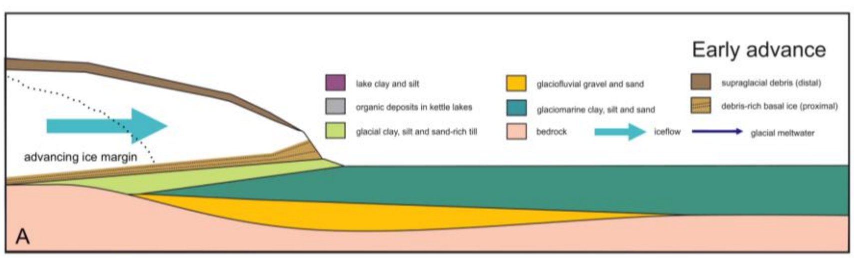

Figure 6A Fraser Glaciation model for Sumas Mountain – Abbotsford area: early glacier advance (ca. 30-24 Ka).

The Cordilleran Ice Sheet reached an elevation of 2,000 m in the southern Coast Mountains and northern Cascade Mountains around 18-16 Ka. The weight of this much ice depressed the crust under the Vancouver area (**Figure 6B**) by up to 300 m. Major south-flowing outlet glaciers of the Cordilleran Ice Sheet occupied the mountains, uplands and lowlands at this time. Bedrock weathered and eroded from the British Columbia interior was transported on top of the ice (**erratics**) to be deposited in the lower mainland as ice retreated. The orientation of glacial **striations**, **crag-and-tail** features and **drumlins** indicate that valley outlet glaciers coalesced in the Sumas Mountain – Abbotsford area, then drained into glacial Strait of Georgia (glacial Salish Sea) to merge with glaciers from Vancouver Island. At its maximum extent, the ice sheet extended more than 300 km south of the US-Canada border.

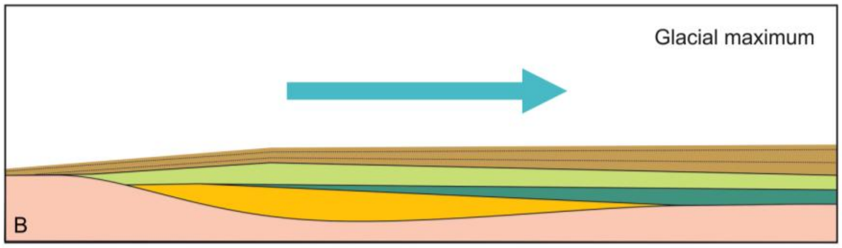

Figure 6B Fraser Glaciation model for Sumas Mountain – Abbotsford area: glacial maximum (ca. 18-16 Ka).

Deglaciation of coastal British Columbia spanned an interval of 5000 years from 16-11 Ka. The gravel pits observed at stops 3A to 3C are an opportunity to examine the deposits of ice retreat. As ice sheets around the globe began to melt, rising sea levels contributed to an initial rapid marine inundation of Fraser and Sumas valleys (**Figure 6C**).

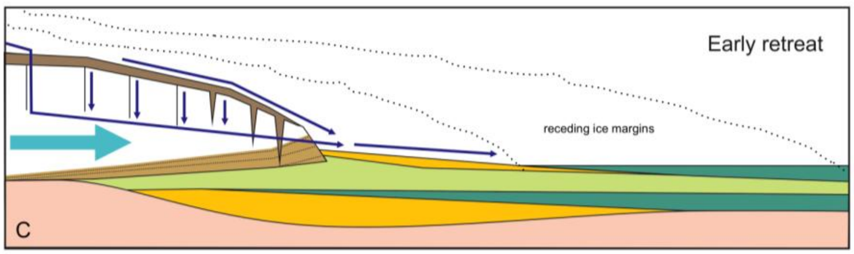

Figure 6C Fraser Glaciation model for Sumas Mountain – Abbotsford area: early glacial retreat (ca. 16-14 Ka).

At this time, outlet glaciers and ice-contact outwash in the major valleys were flooded. As a result, terminal ice margins became periodically uncoupled from underlying glacial deposits and bedrock, leading to episodes of rapid ice flow (or surging) and deposition of large volumes of sediment and freshwater into glacial Salish Sea (**Figure 6D**). The Sumas Drift is interpreted as a late glacial advance into lowlands ca. 12 Ka (**Figure 5**). Iceberg calving and rapid drainage of ice and meltwater during such events contributed to the rapid drawdown of the Cordilleran Ice Sheet in the British Columbia interior and retreat of remnant valley glaciers in the Sumas Mountain – Abbotsford area.

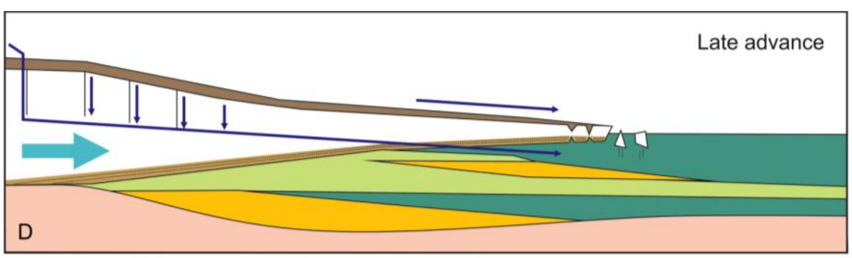

Figure 6D Fraser Glaciation model for Sumas Mountain – Abbotsford area: late glacial advance (ca. 14-12 Ka).

The final retreat of glacier ice and marine recession from the Sumas Prairie is recorded in the gravel and sand deposits at Stop 3 south of Abbotsford (map unit 8, **Figure 3**). As the Cordilleran Ice Sheet retreated from coastal areas, the crust rebounded and relative sea level began to fall, significantly changing the regional paleogeography.

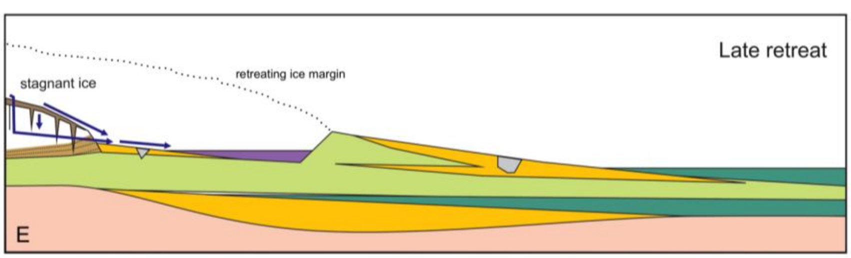

Figure 6E Fraser Glaciation model for Sumas Mountain – Abbotsford area: late glacial retreat (ca. 12-11 Ka).

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After 11 Ka, end moraines, ice-contact glacial outwash and marine sediments (Capilano Sediments, **Figure 5**) were raised above sea level. Deglaciated valleys and exposed glacial marine slopes were draped with unconsolidated, saturated and unstable clay, silt, sand, and cobble-rich sediments (**Figure 7**). By 10 Ka, glaciers had retreated to cirque basins and local ice caps in the Coast and Cascade mountains.

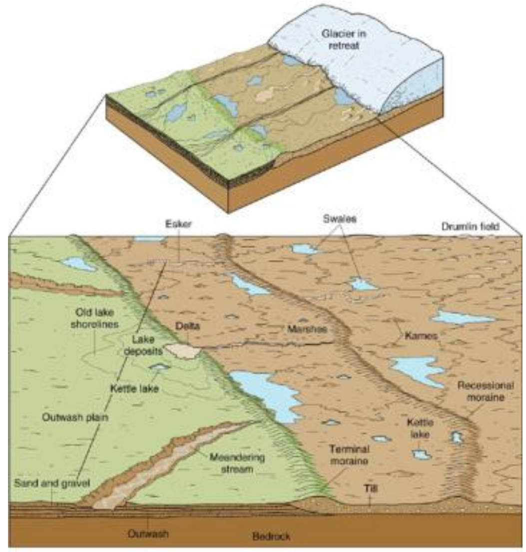

Figure 7 Common glacial landforms observed upon ice retreat, some of which are observed in the Sumas Prairie and highlighted during the field trip (examples: outwash plain, kettle lake, delta, moraine and till).

Holocene Geological Hazards and Anthropocene Risks

The major recognizable landscape elements were established during Holocene times: with Sumas Mountain forming an upland massif surrounded by fluvial, lake and organic deposits in the lowlands of the Sumas and

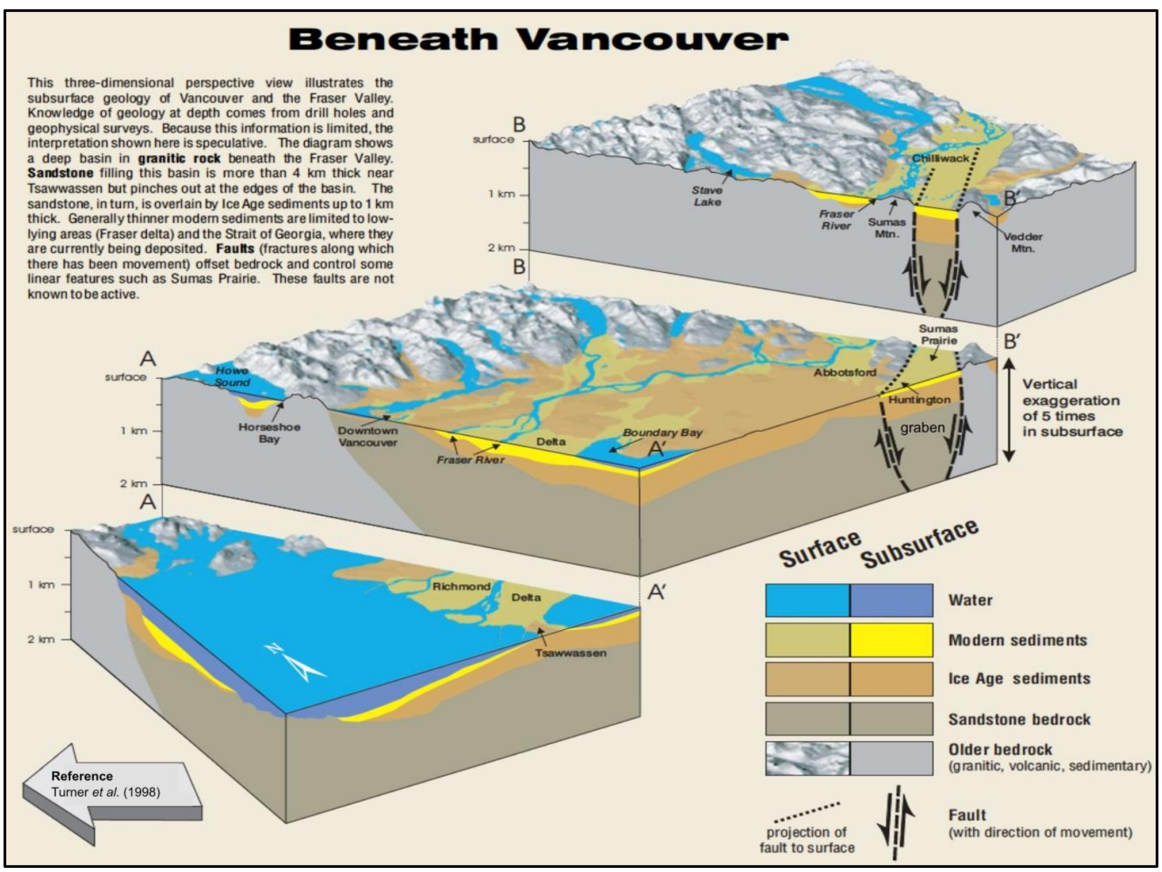

Figure 8 Schematic 3D block diagrams showing the relationship of surface and subsurface bedrock, unconsolidated surficial sediments and water in the Sumas Mountain – Abbotsford area (modified from Turner et al. 1998).

Matsqui prairies (**Figures 3** and **8**). Modern creeks and rivers derive much of their sediment from eroding bedrock slopes covered by Pleistocene debris. Proglacial lakes, raised kame-deltas and outwash terraces were deeply entrenched by creeks and rivers rejuvenated with falling relative sea level. Weathered bedrock and eroded surficial deposits were transported by glacially fed rivers and deposited as deltas in the post-glacial Salish Sea, for example Fraser River and Pitt River deltas and Hatzic Prairie (**Figures 3** and **8**). Human activity over thousands of years had little environmental impact on the Sumas Mountain, and the Matsqui and Sumas prairies. The rapid changes in landscape and environment observed in the 21st Century reflect contrasting land stewardship practices of pre-historic First Nations and Eurasian settlers of the 19th and 20th centuries.

Living in a rainforest …

Surface slopes range from level over the lowland prairies to greater than 20^{o} on the flanks of Sumas Mountain. Steep, fractured slopes with high relief promote better soil drainage and groundwater flow; but are also prone to failure when stability is compromised, for example by stream erosion, quarrying or urban construction. Most historic landslides in the lowland and upland areas involved **slumps** and **slides** of glacial sediments and were triggered by intense rainstorms. **Rockfalls** and **rockslides** occur on the steep bedrock slopes of Sumas and Vedder Mountains. **Debris flows** and **torrents**, originating in high gradient creeks and gullies also have potential to adversely impact lowland areas close to mountainside. Low-lying terrain adjacent to rivers (underlain by map units 4 and 5, **Figure 3**), are prone to flood hazards. Significant portions of the Sumas, Matsqui and Hatzic prairies, Fraser River and Vedder Creek have been dyked to protect people, farmland, industry and property. These areas are still at risk from significant storm events, rare large floods, exceptional tides, seismic shaking and liquefaction.

… Above a subduction zone

The Sumas Mountain – Abbotsford area lies in a region of moderate seismic hazard, where earthquakes could cause damage by a combination of ground vibration, liquefaction and landslides. Urban and industrial developments and infrastructure now incorporate structural designs to withstand ground acceleration and velocity values based on analysis of past earthquakes (**Figure 4**, inset) and geotechnical properties of bedrock and surficial earth materials. Fluvial deposits (units 4 and 5, **Figure 3**) are most prone to **liquefaction**: during an earthquake water-saturated **silt and sand** can lose cohesive strength and liquefy (**Figure 9**). **Gravel-rich** kame-delta and outwash **deposits** (map unit 8, **Figure 3**) and deeper glacial sediments beneath the Matsqui and Sumas prairies are more consolidated and **less prone to liquefaction**. Liquefaction can also contribute to landslides on shallow slopes: cohesive silt or clay overlying loose sand can slide under the influence of gravity laterally towards river cutbanks or railway embankments, for example. Highway, bridge and building foundations, in addition to buried sewer, water, gas and cable lines can be damaged by liquefaction.

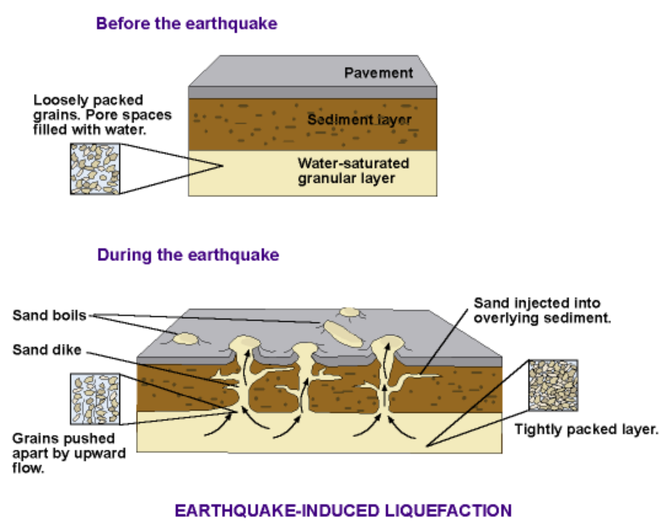

Figure 9 Liquefaction process in water-saturated sediments.

… Water everywhere

The city of Abbotsford derives most (95%) of its drinking water from Norrish Creek Cannell Lake (north of Mission). Glacial deposits and modern sediments that underlie the Sumas and Matsqui prairies are host to aquifers that are important sources of high quality water for drinking, agriculture and industry. The Abbotsford Aquifer is heavily used by agricultural and is a highly **vulnerable shallow aquifer,** easily contaminated by downward infiltration of water laden with fertilizers, pesticides, manure, septic effluent, or hydrocarbon spills. Groundwater potential for faulted and fractured igneous and porous sedimentary bedrock underlying Sumas Mountain has not been assessed, but may be similar to **bedrock aquifers** north of Fraser River, for example in the Mission area. Bedrock aquifers are highly vulnerable because a thin cover of unconsolidated debris affords little protection against contamination. Sediment and bedrock aquifers may also have poor water quality because of naturally elevated chloride, iron, sulphur, fluoride and radon levels.

From mines to parks …

Bedrock and surficial deposits have been mined in the Sumas Mountain – Abbotsford area for over 100 years. At Cox Station (Stop 1), granitic rocks are quarried for **granular aggregate** that is used for road bases, clear crushed rock, rip rap and washed products. Similar products are derived from volcanic rocks at the Jamieson Quarry (Stop A). In the Kilgard Creek area, there is a long history of mining fireclay, initially for refractory brick manufacture, and later quarrying the high alumina sandstone and shale for cement manufacture and other uses (Stop 2). Valley Gravel Sales (Stop 3A) is an active pit and provides access to fresh exposures of Pleistocene valley fill. Examples of reclaimed gravel operations can be seen at 29295 Huntingdon Road (Stop 3B) and, in a more advance state, at Aldergrove Lake Regional Park (Stop 3C).

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STOP 1

(A) Cox Station Quarry: Cretaceous Granitic Bedrock

Sumas Mountain granite is part of the Coast Plutonic Complex, a tiny part of a 60-200 km wide belt that stretches up to the Yukon border. This enormous rock body comprises numerous intrusive events into pre-existing country rock from mid-Jurassic to mid-Cretaceous (ca. 175-95 Ma) and in Oligocene to Miocene (ca. 28-18 Ma) time. These rocks represent deep-seated magma chambers below a series of volcanos that formed above a long-lived subduction zone that ultimately placed the Wrangellia Terrane onto the edge of North America. Uplift related to accretion brought the granitic rocks formed at depth to form mountains subsequently weather and eroded.

Figure 10 View of the active Cox Station quarry face.

At Stop 1A we can study the mineralogy, and geological structures, hydrogeological properties of a Cretaceous granitic intrusion (**Figure 10**).

Figure 11 Granitic rock from Cox Station.

At least two phases of granitic intrusions are recognized in the Cascade and Coast Mountains (**Figure 4**). Bedrock underlying a large part of the Sumas Mountain, particularly on the NE end, is granitic. Cox Station Quarry is a crushed aggregate mining operation in this granitic rock (**Figure 10**). Here, most of the bedrock is orange granite. It is very-coarsely crystalline (0.5-10mm) with 60-70% orange K-spar, <10% quartz, and 20% mafic minerals (biotite, hornblende) with light green epidote on fracture surfaces (**Figure 11**).

You Might Ask …

What compositional and textural features identify this as an igneous rock?

How do you explain the difference in composition compared to the North Shore Mountains bedrock?

Is there evidence of the country rock into which the granite intruded?

Why is this rock great as aggregate? Would it be useful for dimension stone (e.g. countertops)?

Interesting that the Fraser River flows between the North Shore Mountains and Sumas Mountain? Why?

Outcrop Activity

1) Collect a representative hand sample of bedrock from the Cox Station quarry site (Stop 1A):

A) Describe the general colour of a fresh (unweathered) surface.

B) Describe the mineral texture and grain size.

C) Identify the minerals and percentage proportions present in your hand specimen.

D) Identify what type of igneous rock(s) sampled.

2) Sketch the quarry face showing fracture patterns and changes in bedrock characteristics (e.g., mineral textures, alteration zones, dykes and faults).

STOP 1

(B) Cox Station Access Road: Pleistocene Glacial Deposits

Overlying the crystalline rocks is evidence of environmental conditions during the advance and maximum phases of the last (Late Pleistocene) glaciation across Sumas Mountain (**Figures 5** and **7**).

At Stop 1B, **Quadra Sand** (**Figure 5**) is represented by greater than 2 m of interbedded gravel and pebbly sand overlain by a 1.5 m gravel and **diamicton** package. The upper 0.5 m displays soft sediment deformation structures. This is abruptly overlain by 2 m of **Vashon Drift** (**Figure 12**). This till is capped by **Sumas Drift**, 1.5 m of till, sand and gravel (map unit 9, **Figure 3**); the uppermost metre of which is oxidized and disturbed by quarry activities.

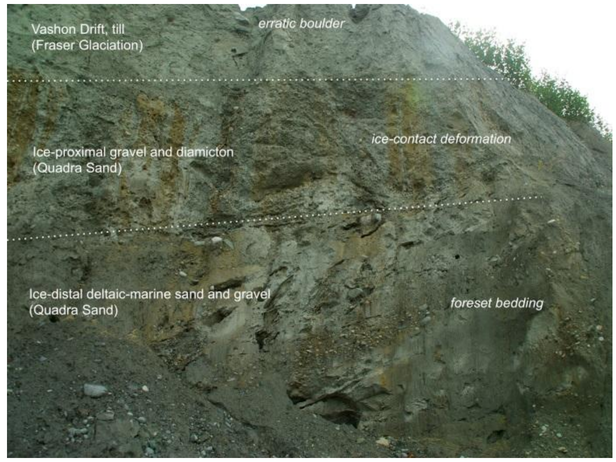


Figure 12 Advance phase outwash (Quadra Sand) truncated and overlain by Fraser Glaciation till (Vashon and Sumas drifts) at Stop 1(B).

Diamicton – a generic term for poorly sorted boulders, cobbles, sand, silt and clay with no implied interpretation of origin.

Till – diamicton transported by ice and deposited through lodgement, deformation and meltout of debris at the base and surface of a glacier.

This 10 m sequence records glacial advance **and** retreat (**Figures 5** and **6A**). Quadra Sands are interpreted as being deposited in outwash fans and plains in front of glaciers that eventually advanced over the sediments, depositing poorly sorted Vashon Drift (**Figure 6B**). Better-sorted sediments at the top mark the return to deposition in glaciofluvial systems in front of retreating ice (**Figure 6C**).

Outcrop Activity

1) Sketch the glacial sediments exposed here. Note the nature and thickness of sediment types in vertical section. Annotate this diagram, highlighting the vertical sequence of sediments observed; for example show the exposed extent of Quadra Sand, the Vashon and Sumas drifts, and weathering zones.

2) Collect representative samples of gravel, sand and diamicton (enough to fill a small ziploc bag). Identify the dominant types and shapes of rock fragments contained in each. Describe the colour, texture, sorting, sedimentary structures, degree of consolidation and contact relationships.

Follow-up

1) Describe the relationship between the granitic rocks exposed at Cox Station, Stop 1A and the glacial sediments. What is the geological contact called? How much time does it represent?

2) Explain the changes in composition and texture of the glacial units sampled at Cox Station. Compare and contrast your observations from this stop with similar information collected at the King Road pit (Stop 3A).

3) Explain the changes in the shape of pebbles and cobbles in the glacial units sampled at Cox Station; compare and contrast your observations from this stop with similar information collected at the King Road pit (Stop 3A).

Additional Stop A: Jamieson Quarry

Bedrock in Jamieson Quarry has been mapped as Early - Middle Jurassic volcanic rocks (map unit 11, **Figure 3**). They are considered to be a part of the Harrison Lake Formation, which in other locations also includes conglomerates, fine sedimentary rocks, volcanic flows (e.g. **Figure 13**) and breccias, and are similar in age and composition to Late Triassic to Middle Jurassic bedrock exposed on Vancouver Island.

This assemblage is interpreted to represent an island arc that formed atop oceanic crust, and which was later (Cretaceous) intruded by granitic magmas generated by subduction. These are the country rock into which the Cox Station granite is intruded.

Figure 13 Microscope thin section of volcanic rock showing the very small mineral crystals under magnification. Field of view is 7mm.

You Might Ask …

What features indicate these rocks are igneous? What features indicate they are volcanic?

How can you determine if they formed underwater or on land?

What would you expect the contact between Cox Station granitic rocks and these volcanics to look like?

How is the age of these rocks determined?

Outcrop Activities

1) Collect a representative hand sample of bedrock from Jamieson Quarry:

A) Describe the general colour of a fresh (unweathered) surface.

B) Describe the mineral texture and grain size.

C) Identify the minerals and percentage proportions present in your hand specimen.

D) Identify what type of igneous rock(s) sampled.

2) Look at the geological map (**Figure 3**). Jamieson rocks are interpreted to the basement rocks into which the Cox Station granitic rocks intruded. What geologic evidence would prove this interpretation?

STOP 2: Kilgard Quarry

Figure 14 Kilgard Quarry exposing sandstone, mudstone, siltstone, conglomerates and coal.

Between the Jamieson Quarry (Additional Stop A) and the Kilgard Quarry (**Figure 14**) is a significant geological transition from Mesozoic basement rocks (map unit 11, **Figure 3**) to Eocene-Oligocene sedimentary rocks – the Huntingdon Formation (map unit 12, **Figure 3**). This gap (or unconformity of tens of millions of years indicates a period of faulting, uplift, weathering and erosion (**Figure 4**).

Huntingdon Formation exposed in Kilgard Quarry is a several hundred metre thick sequence of interbedded mudstone, siltstone, sandstone, conglomerate and rare coal seams (**Figure 15**). The base of the sequence is seen locally to rest directly on weathered Harrison Lake volcanic rocks. Overall the sequence becomes coarser-grained up-section; mudstone and siltstone are dominant near the base, while coarse sandstone and conglomerate are dominant at the top (**Figure 16**).

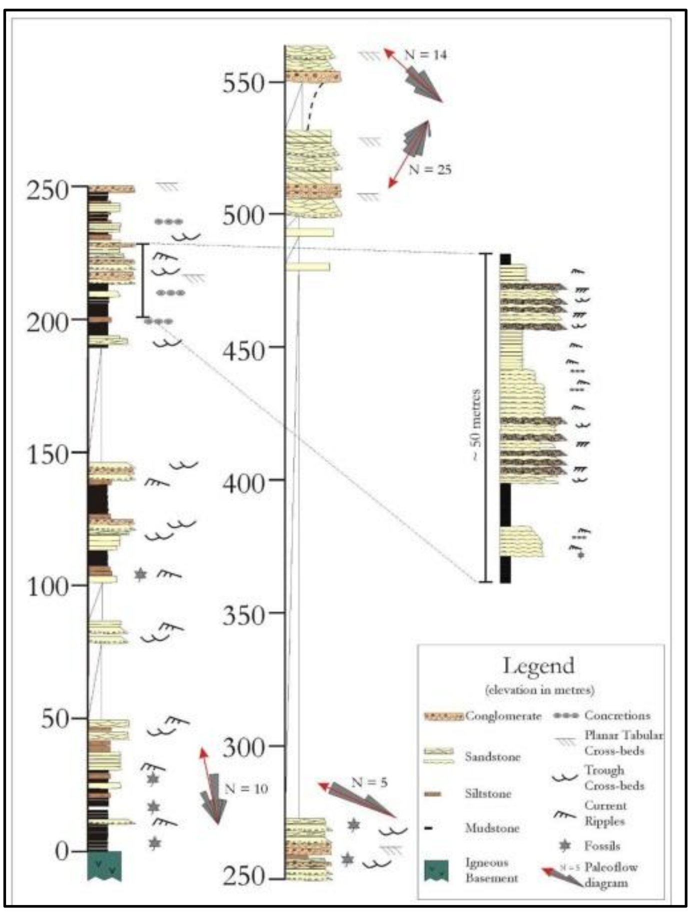


Figure 15 Stratigraphic logs of the Eocene-Oligocene Huntingdon Formation.

Figure 16 Quartz pebble conglomerate with Cretaceous, Jurassic and Triassic clasts.

The fine-grained beds exhibit laminations and contain fossil debris, particularly leaves, at some horizons. Coal seams up to 30 cm thick occur with the finer-grained strata near the base. The sandstone beds from a few 10s of cm to 3 m thick are seen to have scoured bases and locally cross-bedding or ripple cross lamination. Conglomerates range from a few 10s of cm to 12 m thick higher in the section.

You Might Ask …

How can you tell these sediments were deposited by water and not by air or ice?

What would you look for to determine if these sediments were deposited in freshwater or marine?

How much time do you think each bed of sandstone represents? How about a bed of shale?

The Huntingdon Formation is interpreted to record deposition in sand-dominated river system, with an active floodplain (**Figure 17**). Analysis of the sedimentary structures and an analysis of the pebbles in the conglomerates (mostly types of chert) indicate the source lay in nearby Cascade oceanic terranes to the East).

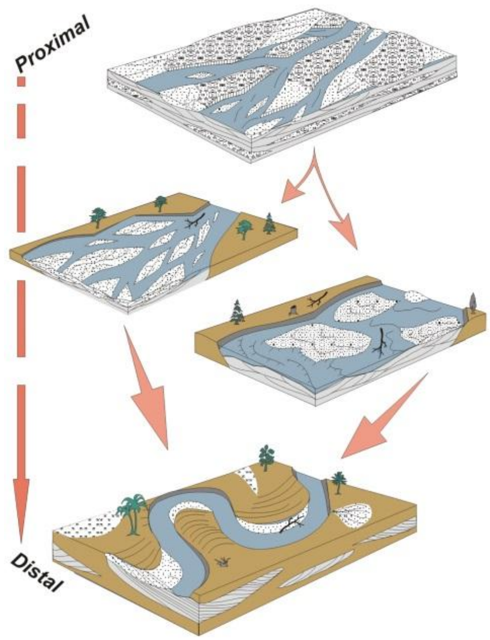


Figure 17 Interpretation of the depositional environment of the Huntingdon Formation.

Outcrop Activities

1) Sketch the quarry face (**Figure 14**) showing changes in bedrock characteristics (e.g., rock type, bedding planes, sedimentary structures, fossiliferous horizons, weathering).

2) Collect representative hand samples of bedrock exposed in quarry (conglomerate, sandstone, shale and coal [if possible]). For each sample:

A) Describe the grain shape and grain size.

B) Identify the mineral and rock fragments and estimate the percentage proportions.

C) Identify any fossil materials found.

D) Identify what type of sedimentary rock(s) sampled.

3) What can you tell about the source of the sediments by the composition and texture of the grains in the sandstone?

4) What can you tell about the source of the sediments and nature of the river by the composition, shape and size of the pebbles in the conglomerate?

5) Sketch recognizable fossils. What are they and what picture do they help establish for the landscape in Huntingdon time?

Follow-up

1) Review and discuss. What part of the Huntingdon Formation was mined for 100 years? What clay mineral ingredient makes this unique and valuable?

2) What is mined in this quarry today? How is this raw material used?

A Long History of Mining …

Fraser Pacific Enterprises operates this Kilgard quarry for owners Clayburn Industries and Lafarge. Clayburn Industries owned and operated the clay mining operation here for over 100 hundred years, supplying feed for their brick manufacturing plants, first in Clayburn and later in Abbotsford. The plant closed in July 2011. Clayburn manufactured bricks for construction, but unique fireclay deposits in the Huntingdon Formation were used in the production of higher value **refractory bricks**. These bricks possess very low thermal conductivity and are used to line industrial furnaces, kilns, fireboxes and fireplaces.

STOP 3

(A) Valley Gravel Sales, King Road Pit

The King Road pit provides the opportunity to observe virgin quarry faces of Pleistocene sediments underlying the Fraser Lowlands southwest of Sumas Mountain. These sediments have not been previously examined and studied by geologists. We will visit two faces, one a sequence dominated by gravel; the other dominated by sand.

Nearby quarries, Valley Gravel Sales and Lafarge pits (**Figure 18 and 19**), expose gravel and sand deposited in ice-contact marine settings during the **retreat** phase of the Late Pleistocene Fraser Glaciation (Capilano Sediments, **Figures 5**, **6D** and **6E**).

Nearly 20 m of coarse sand and gravel at the base exhibit low-angle lamination, low-angle truncation surfaces, changing to high angle cross-bedding up section, and planar lamination near the top. They are interpreted to have been deposited by a prograding delta formed by deposition in a meltwater stream flowing into a marine water body. Deltaic sands are overlain by peat and pebbly clays containing a variety of plant fossils in adjacent areas of the pit. This signals the establishment of a terrestrial landscape.

Figure 18 Foreset-bedded sand and gravel (Capilano Sediments). Note the dipping beds indicating the front slope of a kame-delta (Lafarge Quarry, 1080 Bradner Road).

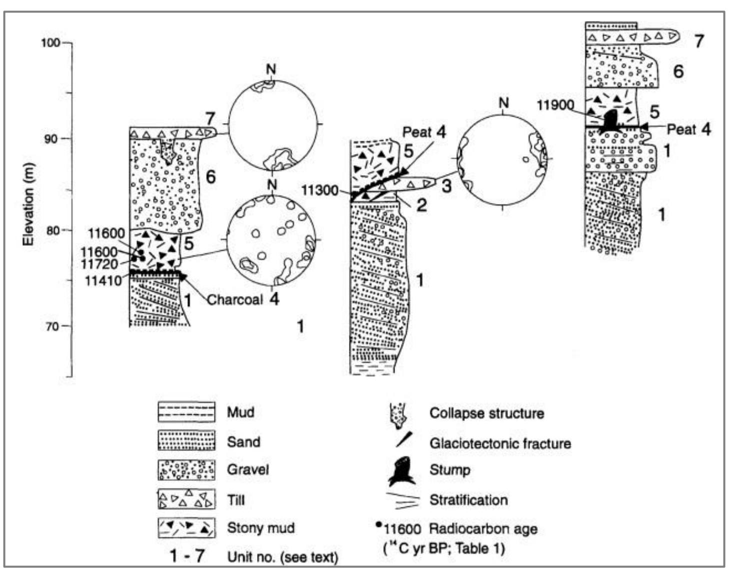


Figure 19 Schematic cross-section of Quaternary sediments exposed at nearby Lafarge gravel quarry on Bradner Road.

Outcrop Activities

1) Sketch the glacial sediments exposed here. Note the nature and thicknesses of sediment types in vertical section, colour changes and sedimentary structures, if present.

2) Collect representative grab samples of gravel and sand (enough to fill a small Ziploc bag):

> **A)** Identify the 10 pebbles in your gravel sample.
>
> **B)** How does the composition of these glaciofluvial sediments compare to those observed at Stop 1b and in the Huntingdon conglomerate?
>
> **C)** Examine the sand with hand lens and describe the colour and texture (grain size and sorting). What are the dominant grains? Rock fragments? Minerals?

3) What aggregate products are currently produced at the King Road pit?

STOP 3

(B) Valley Gravel Sales, Huntingdon Road Quarry

Our field trip will make a short visit to an aggregate pit that operated for several years, and which was decommissioned and reclaimed in 2013.

This is an opportunity to see the initial stages of reclamation of a gravel pit, activities it entailed, the materials applied, and to learn about the end land use goal of this piece of land.

You might ask …

What was this land used for before it became a quarry?

How long did the quarry operate?

When did reclamation begin?

Who regulates this phase of your operation?

Follow-up

1) Applying knowledge of unconsolidated earth materials beneath the Sumas Prairie, explain why glaciofluvial deposits make good aquifers but are highly vulnerable to contamination.

STOP 3

(C) Aldergrove Lake Regional Park, Lefeuvre Road

Aldergrove Park (**Figure 20**) is one of Metro Vancouver's regional parks that in the Earth Science community with two "claims to fame". It is host to an enormous, glacial erratic (**Figure 21**) and features "the restoration of Aldergrove Bowl, which has been converted from a mined-out gravel pit to a recreational area including a marshy pond for waterfowl, new hiking trails, and picnic area."

Figure 20 Gentle rolling anthropogenic landscape of Aldergrove Bowl in Adergrove Lake Regional Park.

Valley Gravels Sales operated the quarry for several years and was involved in all aspects of site reclamation and design for recreational use beginning in 1996 and concluding in 2000.

The pre-existing gravel pit and the glacial erratic here are evidence that Pleistocene sediments mantle this part of the valley too. The erratic measures 10.8 x 12 m at the base, and is nearly 8 m tall is estimated to weigh 3,175,130 kg (**Figure 21**). Geologists interpret this chunk to come from the Jackass Mountain Group, the nearest outcrop of which is by Hope, B.C.

Figure 21 Jackass Mountain erratic transported and deposited by the Cordilleran Ice Sheet.

Glacial erratic transport paths, along with striations, crag-and-tail features, drumlins, are very useful iceflow direction indicators. A more specialized application is **till geochemistry**, which is used by exploration geologists to find ore minerals and diamonds. Like a stream, ice picks up and carries ore over which is flows, and redeposit grains, like breadcrumbs, as the ice retreats.

Paleographic reconstruction …

Stop 3 provides the opportunity to observe landforms, sedimentary structures and deposits from the retreat phase of the Late Pleistocene Fraser Glaciation (Capilano Sediments, **Figure 5**).

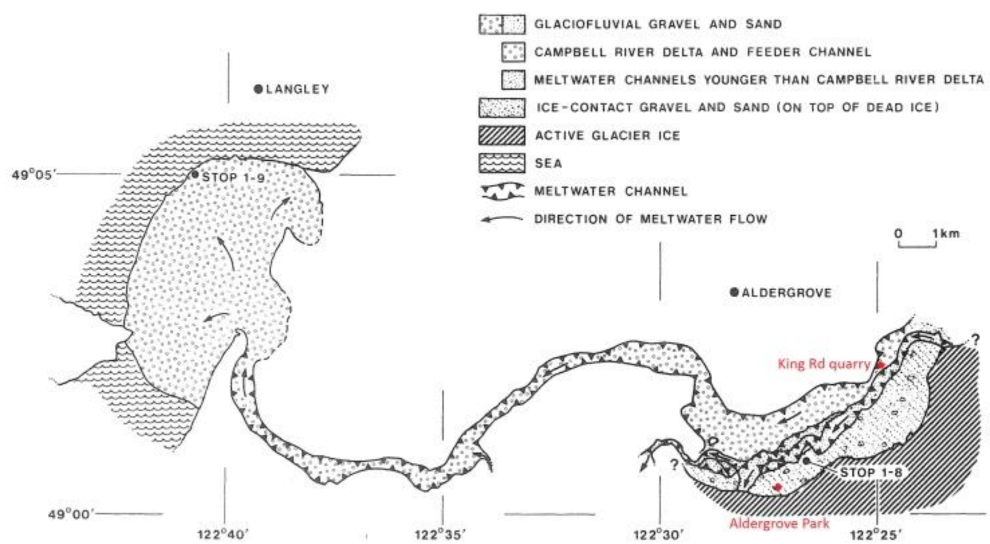
As ice retreated, **erratics** carried by glaciers from distant sources were deposited over till plains and partly buried by glacial outwash and post-glacial organic deposits.

Gravel and sand (map unit 8, **Figure 3**) was deposited in an ice-contact **kame-delta** complex, connected by a **meltwater spillway** to a **glaciomarine delta** south of Langley (**Figure 22**) as the last glaciers melted in the Sumas Prairie and Fraser River valley.

Kame-deltas formed in proximity to **end moraines** marking stable ice margin positions and **kettle lakes** formed by melting stagnant ice in outwash.

These features were abandoned as ice and glaciomarine waters retreated from the Sumas Prairie and Fraser River valley.

Figure 22 Key late glacial landforms of Stop 3. From (Clague and Lutenauer, 1983)



Outcrop Activity

1) Locate the erratic boulder, describe its dimensions and shape, and identify the rock type.

2) Describe the appearance of present day "Aldergrove Bowl".

3) Compare the "Aldergrove Bowl" with the recently reclaimed Huntingdon Road Quarry.

You might ask …

What aspects of this boulder indicate it was deposited by ice?

Where do geologists believe this rock came from?

Follow-up

1) Describe the changes in depositional environments of glacial deposits observed in the King Road pit and at Aldergrove Park. Explain the significance of the circular lakes near the U.S. border, south of Stop 3 (see **Figure 3**).

2) Consider the geology observed at Stops 1, 2, and 3. In the event of an earthquake where would you prefer your home to be? Which would be the least desirable location? Why?

3) Compare and contrast the aquifer properties of granodiorite with those of volcanic and sedimentary rocks on Sumas Mountain, and fluvial and glacial deposits beneath the Matsqui and Sumas prairies.

References

The following theses, journal articles, guidebooks and government reports were used in the preparation of this field guide.

Archer, J.D. 2013. Sumas Lake, Vancouver Traces Web site, http://vancouvertraces.weebly.com/sumas-lake.html

B.C. Geological Survey. 1985. Sumas Mountain. Minfile Record Summary, Minfile No. 092GSE024

Cameron, V.J. 1989. The Late Quaternary geomorphic history of the Sumas Valley. M.A. Thesis, 167 p. Simon Fraser University

Clague, J.J. 1981. Late Quaternary geology and geochronology of British Columbia; Part 2: Summary and discussion of radiocarbon-dated Quaternary history. Geological Survey of Canada Paper 80-35: 41 p.

Clague, J. J, and Luternauer, J.L. 1983. Trip 6 Late Quaternary Geology of Southwestern BC. Geological Association of Canada, Victoria Section. 100p.

Clague, J. J., Mathewes, R. W., Guilbault, J.-P., Hutchinson, I . and Ricketts. B. D. 1997. Pre-Younger Dryas resurgence of the southwestern margin of the Cordilleran ice sheet, British Columbia. Canada. Borc,us, Vol. 26, pp. 261 278. Oslo.

Clarkson, R. 1977. Geology of the Abbotsford-Chilliwack Area, BC. Dept. Geological Sciences, UBC.

Gilley, B.T.H. 1999. Facies architecture and stratigraphy of the Paleogene Huntingdon Formation at Abbotsford, British Columbia. M.Sc. Thesis, 162 p., Simon Fraser University

Ham, M., Lee, K. and McLean, B. 2000. *Pit to Park: Gravel Mine Reclamation Using Biosolids*. Proceedings of the 24th Annual British Columbia Mine Reclamation Symposium in Williams Lake

Journeay, M.J., Williams, S.P., and Wheeler, J.O. 2000. Tectonic assemblage map, Vancouver, British Columbia-USA. Geological Survey of Canada Open File 2948a; scale 1:1,000,000

Mathews, W.H. and Fyles, J.G. 1970. Postglacial crustal movements in southwestern British Columbia and adjacent Washington State. Canadian Journal of Earth Sciences Vol. 7, pp. 690-702

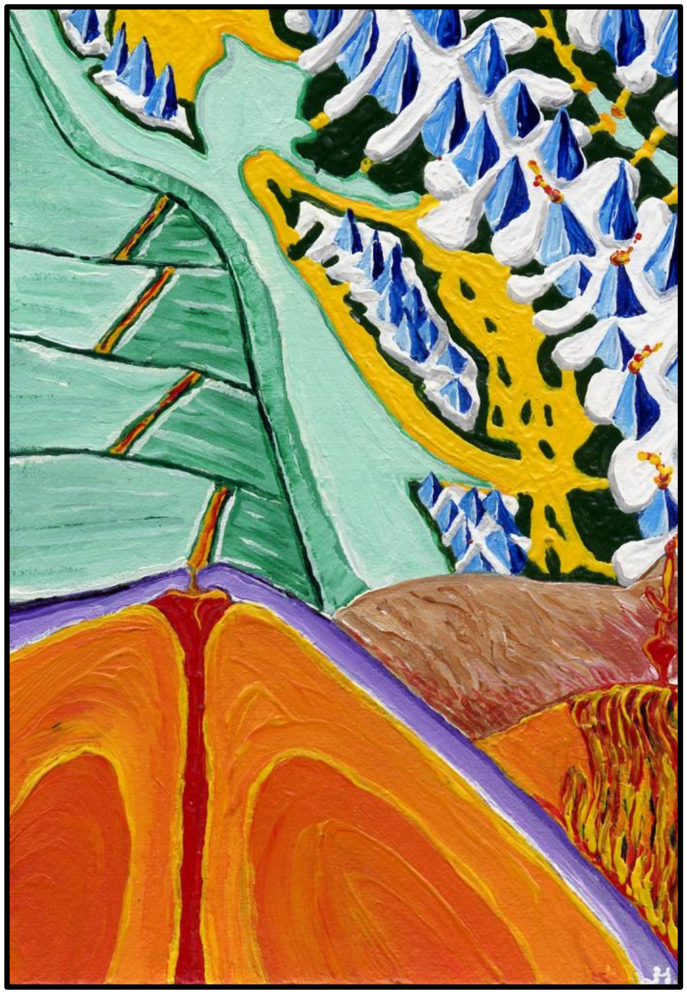
Mathews, W.H. and Monger, J. 2005. Roadside geology of southern British Columbia. Mountain Press Publishing Company, 403 p.

Mustard, P. and Gilley, B., 2009. The Paleogene Huntingdon Formation: Vancouver's Roots, A one day field trip to the type area at Sumas Mountain, Abbotsford, B.C. 23p.

Turner, R. J.W., Clague, J.J., Groule, B.J., Journeay, J.M. 1998. Geomap of Vancouver: Geological Map of the Metropolitan Area. Geological Survey of Canada Open File 3511 (poster available online @ http://geoscan.nrcan.gc.ca/)

Wilson, R. and Wong, R. 1995. Edu-Brick Plant Tour: Teachers' Field Trip Notes, Clay Mining and Brick Making in the Sumas Mountain Area, BC. For Natural Resources Canada Mineral Development Agreement, 39p.

Notes



Subduction at 25 Ka

David Huntley
(2001)
5 x 7 inches
Acrylic on cotton