Victoria Area Geotour

A collaboration of
MineralsEd and Vancouver Island University Earth Science Department
in support of Victoria area teachers
on the
Provincial Professional Development Day, Oct. 21, 2016

Led by
Dr. Jerome Lesemann, VIU Earth Science

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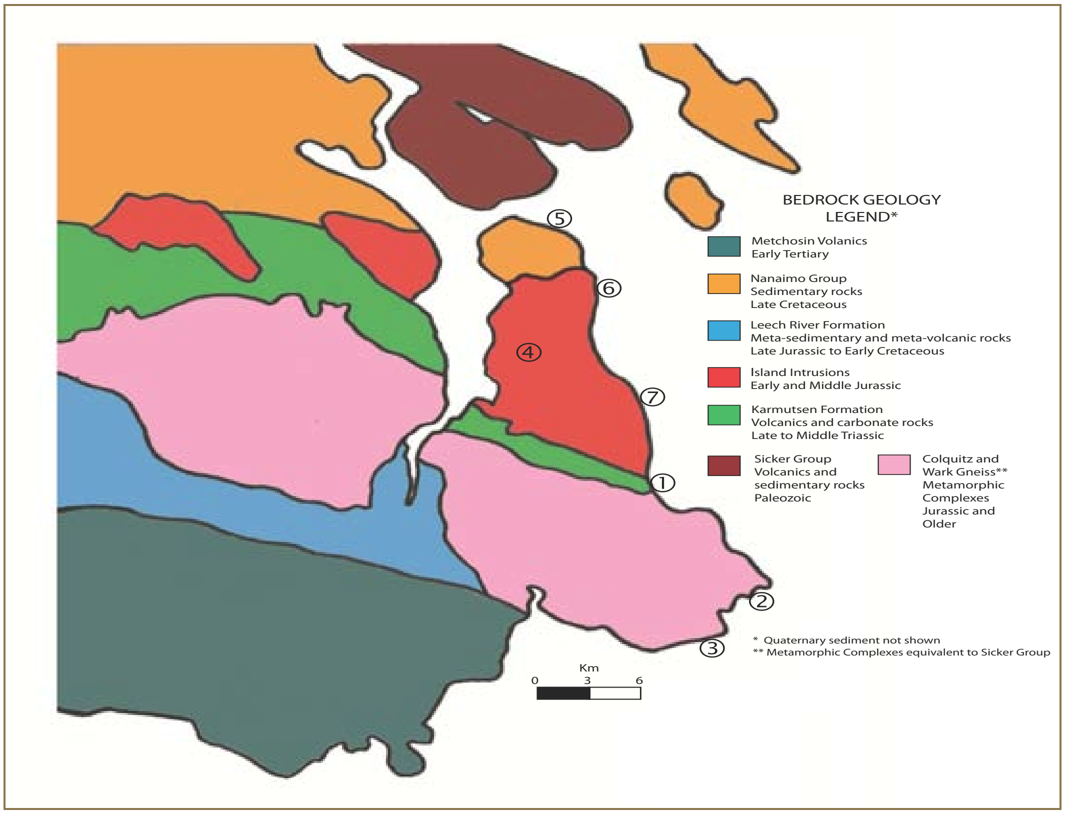

Figure 1 - Geological map of the field trip area showing the bedrock geology and field stop locations.

Figure 2 - (below) Stratigraphic units in the Victoria area, with field stop locations.

Era	Period	Age (Ma BP)	Formation/ Group	Description/ Rock Types	Stop Location
Cenozoic	Holocene	0-0.06	Surficial Sediments	Glacial and interglacial sediments, unconsolidated to semi-consolidated comprising sands, gravels, silts and tills	Island View Beach
	Pleistocene				
	Tertiary				
Mesozoic	Cretaceous	50-56	Metchosin Igneous	Intrusive and extrusive volcanics including gabbro, basalts, tuff and breccia	
		85	Nanaimo	Sedimentary rocks including conglomerates, sandstones, siltstones, shale and coal, some bearing fossils	Beach Road, Roberts Point
		65-206	Leech River	Metasedimentary and metavolcanics including slate, phyllite, schists, greywacke, meta-sandstones, metabasalts, metarhyolite, schist and chert	
	Jurassic	170-185	Island Plutonics	Intrusive volcanics including granodiorite, quartz, diorite, and feldspar porphyries	Mt. Newton, Roberts Point
		190-202	Bonanza	Volcanics including basalt and andesite flows with rhyolite, breccias, tuff, sandstone, conglomerate and limestone	
		200	Wark-Colquitz	Metamorphics dominated by gneisses, quartz diorite, tonalite, gabbro and metasediments	Cattle Point, Harling Point
	Triassic	221-227	Karmutsen	Volcanics including pillow basalts, breccias, and tuffs with lenses of sediments.	Cordova Bay, Roberts Point

Introduction

Welcome to the Victoria Area 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 of the Victoria area record many natural Earth processes and reveal a large part of the geologic history of Vancouver Island – a unique part of the Canadian Cordillera.

This professional development field trip for teachers looks at a selection of the bedrock in the Victoria 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 to support your teaching Earth Science topics in your classroom.

Attention!

As there are important outcrops in the intertidal zone, it is important to plan this trip when TIDE IS LOW!

Check with Fisheries & Oceans Canada:

http://www.tides.gc.ca/

The stops of this geotour may not be visited in stratigraphic order either because of tide considerations or more logical and convenient.

Acknowledgments

We would like to thank our partner and field trip leader, Dr. Jerome Lesemann. Dr. Lesemann is a geologist and Professor in the Earth Science Department at Vancouver Island University. His specialization is Quaternary geology, sedimentology and stratigraphy. He has worked for the Geological Survey of Canada and various universities. His research includes reconstructions of ice sheet dynamics and glacial processes and applications of these topics to aquifer characterization and mineral exploration in northern Canada.

This Victoria Area Geotour guidebook was originally developed for our 2013 Victoria Geotour by geoscientists Malaika Ulmi, Jane Wynne, and Vic Levson, with references taken from Chris Yorath's book, "The Geology of Southern Vancouver Island". In consideration of coastal outcrop accessibility Dr. Lesemann has revised the itinerary and selected a number of different outcrop stops that illustrate the fascinating geological history of this area.

We are grateful to Dr. Lesemann who has kindly shared his time and expertise to help build your interest in and understanding of the natural history of the Victoria area, and to inspire your teaching. Thank-you.

Sheila R. Stenzel, Director
MineralsEd

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Geologic Setting

Vancouver Island is on the leading edge of the **Cascadia Subduction Zone** (Figure 3), and is the western front of a series of **terranes** that have accreted on to the western side of the North American continent. The regional tectonic environment results in interesting and varied geology and topography, and also natural hazards that include earthquakes, volcanoes, tsunamis and landslides.

Today, the rocks that form Vancouver Island are recognized to make up a large (and most-recently accreted) terrane called **Wrangellia**, which also includes the Queen Charlotte Islands (Figure 4). Wrangellia is made up mostly of ancient (350-180 million years) volcanic and sedimentary rocks that are intruded locally by granitic rocks (Figure 2). Wrangellia's rocks represent an exotic terrane that formed out in the ocean basin and was accreted to the continent, along with other smaller terranes comprising the **Insular Superterrane**, by mid-Cretaceous time (100-115 million years ago).

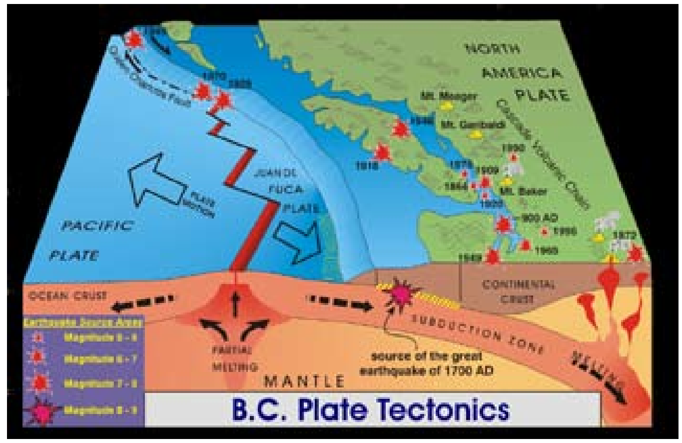


Figure 3: Schematic cross-section through the Cascadia Subduction Zone.

The bedrock geology of Wrangellia records Earth processes over hundreds of millions of years and is complex (Figure 2, 5; Yorath, 2005).

☼The oldest rocks (Paleozoic and early Mesozoic) record several periods of volcanism, the formation of new crust out in the ocean basin, and sedimentation in those environments.

☼Deformation of all these rocks occurred when Wrangellia collided with North America (100 mya), accompanied by intrusions of magma above the subduction zone.

☼Weathering and erosion of the new highlands generated huge volumes of sediments transported by rivers to the sea and deposited in rivers, deltas and a marine basins in what is now the Strait of Georgia.

☼Accretion of two other outboard terranes 54-42 mya (Pacific Rim and Crescent Terrane) to Wrangellia, that caused folding and faulting of the Wrangellia rocks and uplift of some of the oldest, and most deep-seated parts of the sequence.

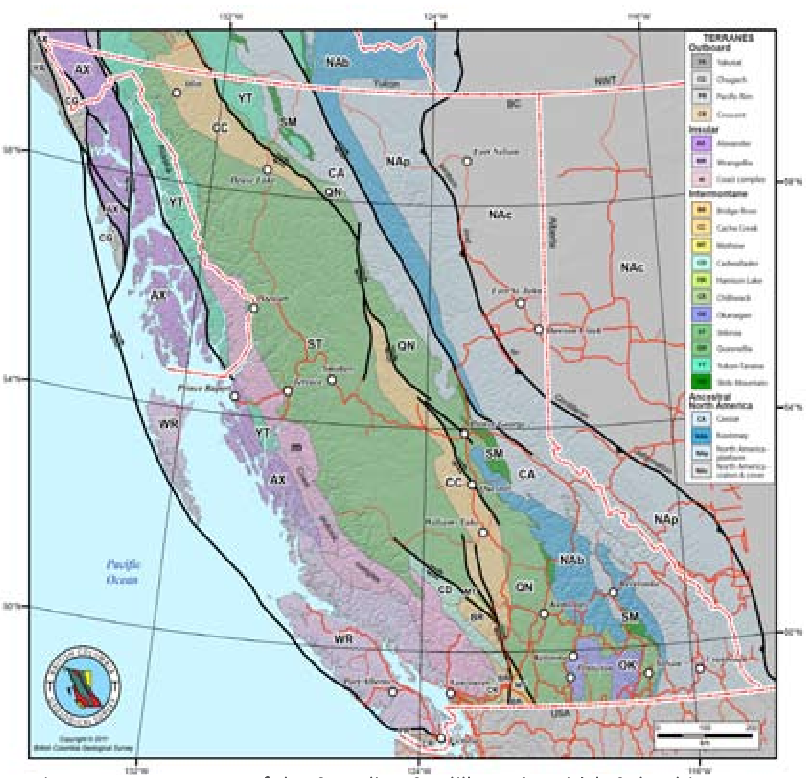


Figure 4: Terrane map of the Canadian Cordilleran in British Columbia. *From the BC Geological Survey.*

☼Several periods of glaciation beginning 30,000 years ago and ending about 10,000 years ago, sculpted the land and left behind a veneer of unconsolidated, ice- and water-deposited sediments during glacial advance and retreat.

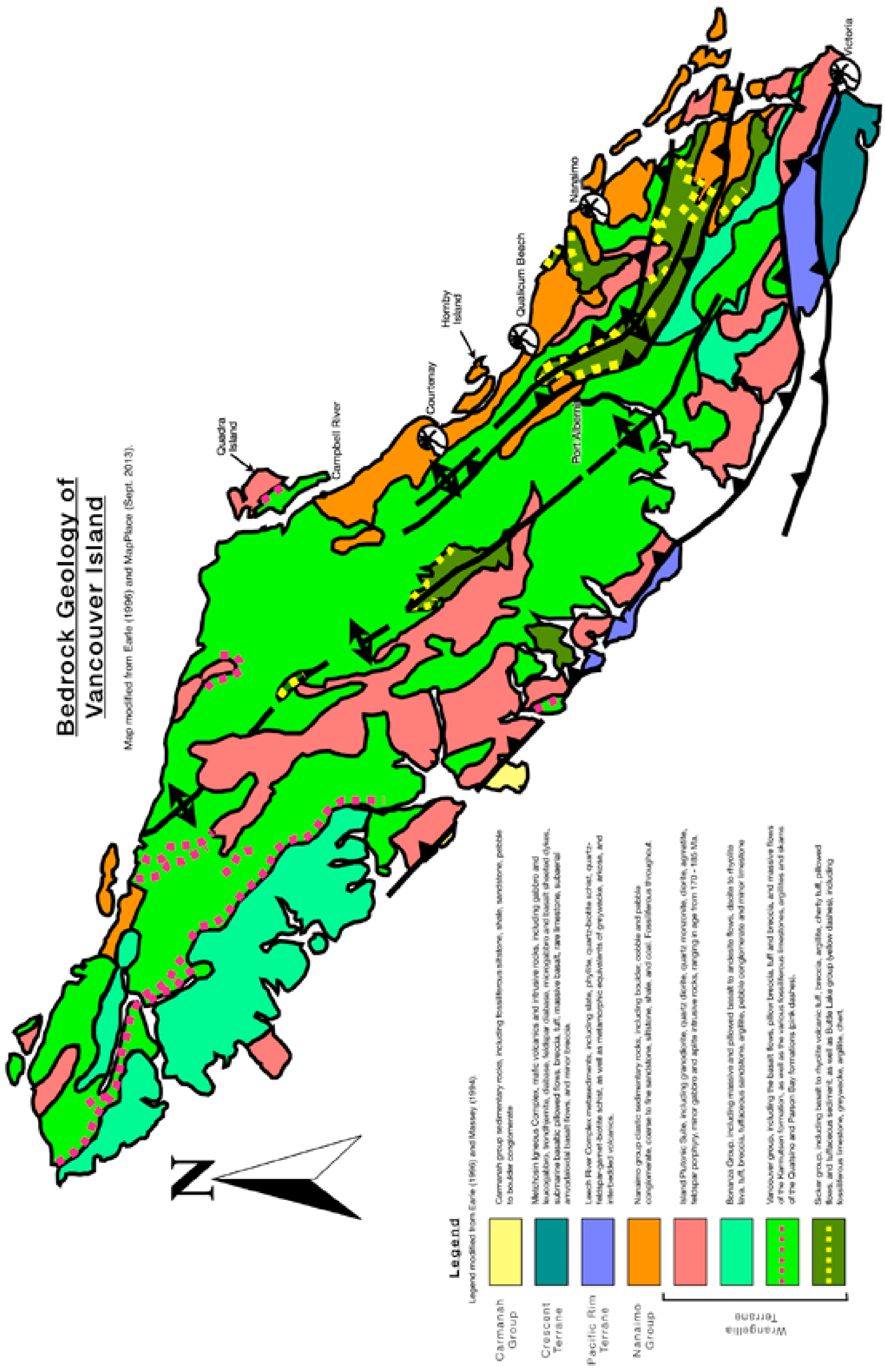


Figure 5: Bedrock Geology of Vancouver Island. (*From* Johnstone, 2013)

Stop 1
Cordova Bay Beach, Saanich (Far east end of Walema Avenue, stairs to beach)
Karmutsen Formation Volcanics and Carbonates
Triassic

Prominent outcrop of dark grey-black rocks on the point 10 m north of the stairs (Figure 7L). Mostly black or grey, very finely crystalline basalt? with mm-size white, feldspar **phenocrysts** (Figure 7R). Fractured and blocky, with weakly defined 15-30 cm thick layers. Mostly lacking internal structure, but with areas of swirl, light green-grey discolouration, possibly **epidote**, may define **pillows**.

At the second point of outcrop to the North, volcanic rocks similar to the first outcrop occur with an isolated block or sliver of lighter grey limestone with white, crystalline calcite blebs. Smooth worn limestone outcrop exhibits glacial polish and horizontal striations (Figure 8) .

Figure 6: Location of Cordova Bay outcrop below Walena Street.

Figure 7: (L) Karmutsen volcanic rocks on the Cordova Bay beach. (R) Close-up of volcanic rocks exhibiting very fine crystalline texture and mm-size feldspar phenocrysts (R).

Figure 8: Karmutsen volcanic rocks with glacial striations.

Karmutsen volcanics are interpreted to be lavas extruded onto an eroded, submarine volcanic plateau of older (Sicker Group) volcanic rocks. In many places outcrops reveal bulbous, pillow forms indicating the at lava was extruded into water (Figure 9, 10). Locally, where limestone is found in close association with the volcanic rocks, the contact is shown to be depositional, i.e. the lava flowed on top of the limestone (or carbonate sediment?)

Figure 9: How pillow lava forms.

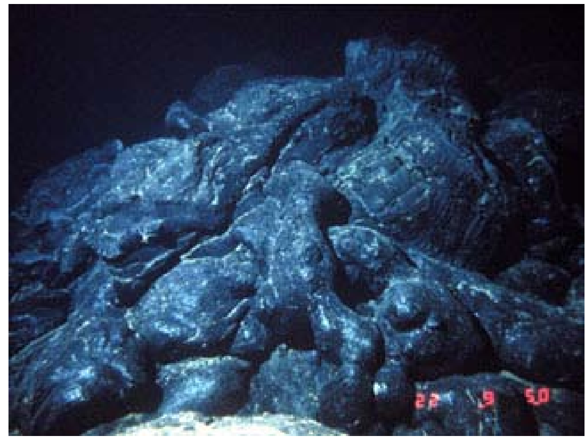


Figure 10: Pillow lavas on the ocean floor on the Juan de Fuca Ridge (SERC Media).

Things to Investigate:

Describe the colour, texture, hardness, mineralogy and weathering aspect of the rock in outcrop.

Look carefully for evidence of pillow lavas.

Look for change in these features as you move across the beach.

What properties distinguish the volcanic rocks from the limestone? Watch for the change from volcanic rock to limestone.

Measure or estimate the orientation of the glacial striations.

Stop 2
Cattle Point, Scenic Drive off Beach Drive, Oak Bay
Colquitz Gneiss
(Jurassic)

Excellent exposures of Colquitz Gneiss crop out in the intertidal and low coastal bluffs on both sides of the boat launch at Cattle Point (Figure 12). Colquitz (and Wark) Gneiss underlie and are exposed in many other locations in the greater Victoria area (Figure 1, 5; e.g. Mount Douglas, Finlayson Point, see Yorath, C., 2005).

Figure 11: Location of Cattle Point, Oak Bay, BC.


Figure 12: Colquitz Gneiss shoreline outcrop, Cattle Point.


Figure 13: Folded and faulted gneissic banding, Colquitz Gneiss, Cattle Point.

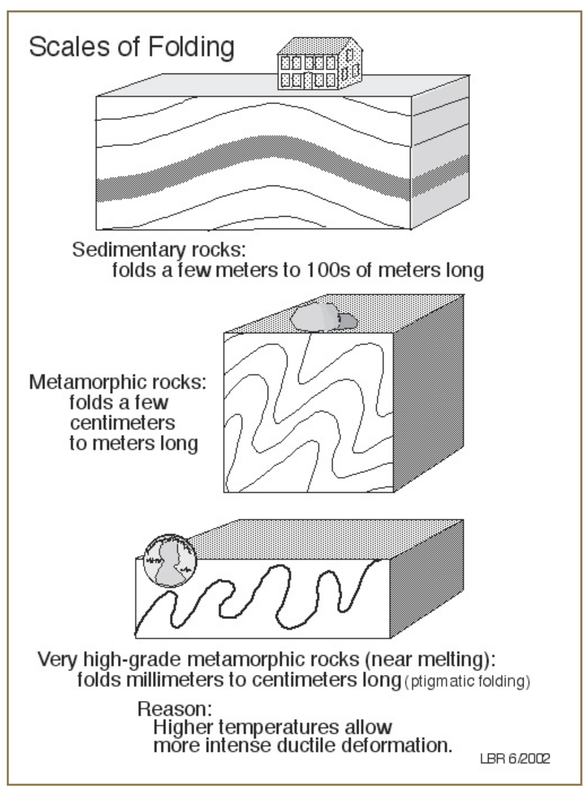
The Colquitz and Wark Gneiss are interpreted to be metamorphosed sedimentary and igneous rocks, possibly belonging to the Paleozoic (Upper Devonian, 374-360 my) Sicker Group (Figure 2), and metamorphosed in Jurassic time (Yorath, 2005). About 54 mya, when the Pacific Rim Terrane slammed into and was thrust under the edge of Wrangellia, the deep-seated gneisses were uplifted closer to the surface. Subsequent erosion made them visible today.

Northeast of boat launch:

Very dark grey –black, coarsely-crystalline gneiss with 2-3mm thick alternating bands of white and black (mafic) minerals. Gneissic banding very deformed, complexly folded, with isolated, discontinuous lenses of very coarsely crystalline quartz, which is also folded (Figure 13). Deformation includes small scale folds and truncated lamination.

Southwest of boat launch:

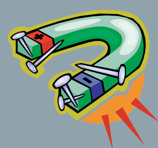
Rounded, bulbous weathering outcrop with evidence of glacial polish. No fresh surfaces of gneiss are visible. Close examination shows that gneissic foliation is oriented at odd angles to glacial polish which runs parallel to the shoreline.



Things to do:

Bring samples from your classroom. to the outcrop. Demonstrate parent rock and metamorphic equivalent, e.g. Granodiorite vs black and white gneiss; Orange granite vs. Orange gneiss; Limestone and marble. Highlight that metamorphic rocks, like igneous rocks are **crystalline**.

Demonstrate **deformation** as a feature of metamorphism caused by pressure. Squeeze multiple layers of clay or playdough. Insert pennies randomly and flatten to show how foliation forms.



Examine closely to determine the minerals making up the gneiss; check if magnetite is one of the mafic minerals.

Is the foliation oriented? If so, measure or estimate the direction? If so, does it reveal anything about the direction of deformation forces?

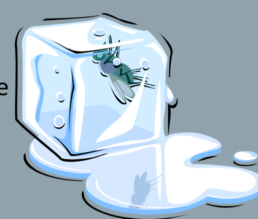
Discuss **metamorphic grade**: Chlorite, biotite, garnet, staurolite, kyanite. Are there **porphyroblasts** in this gneiss to help tell grade?

Classroom demonstrations:

1. Take 2 bars of McIntosh Toffee - put one in the fridge and sit on the other (to warm it up).

To model brittle and ductile deformation smash the cold bar (drop it on the counter or hit it with a hammer)= brittle deformation of cold rocks; bend the warm bar into folds by pushing on each end = ductile deformation of rocks subjected to heat and pressure.

2. Freeze water in a 500ml yoghurt container; put some sand and gravel in a second one, fill with water and freeze it too. Take the frozen lumps out of the container and drag each across an old cookie sheet - note which one does the most damage - the ice with sand and gravel is a model of the base of a glacier and demonstrates the erosional power of glaciers to carve the landscape.



Stop 3
Harling Point (Chinese Cemetery)
Wark-Colquitz Formation Meta-sedimentary Rocks
Paleozoic-Triassic

Figure 14: Location of Harling Point outcrop (Chinese Cemetery).

This stop complements the previous stop at Cattle Point by further examining some of deformed rocks associated with Terrane boundaries. At Harling Point, Paleozoic to Triassic-age **ribbon cherts** and **interbedded siltstone** show evidence of intense deformation. These rocks record deep water sedimentation. Potential causes of this deformation are thrust faulting and a 'fossil' subduction zone.

Also of note are marks of glacial abrasion (**striations**) and spectacular sculpted bedrock forms created by turbulent water flow beneath glaciers that covered the area during the last ice age (topic to be revisited during last field trip stop). The presence of granodiorite **erratics** on the sculpted bedrock result from either ice-rafting or melting out from the base of the ice sheet. These erratics are rock types similar to the Coast Mountains or those seen at Mt. Newton (next field trip stop).

Stop 4
Mt. Newton, Saanich
Island Intrusions of the Wrangellia Terrane
Jurassic, ~ 180 Ma

Outcrops of Saanich Granodiorite, are comprised of a very coarse grained (2-3mm), black and white speckled **granodiorite** criss-crossed by rectilinear fracture sets. Granodiorite contains widely-scattered mafic **xenoliths** (1-20 cm diametre, rounded, fine- to medium crystalline, dark grey diorite (?) (Figure 16).

Figure 15: Map showing the location of Mt. Newton.

Figure 16: Island Intrusion granodiorite with mafic **xenoliths**.

In some locations the granodiorite exhibits metre-wide **fracture zone**s in which the rock is cross-cut by numerous sub-parallel fractures and ground to a homogenous beige rock body (Figure 17). This **brittle deformation** post-dates emplacement of the granodiorite which is seen locally to intrude the Colquitz Gneiss.

Saanich Peninsula intrusions are interpreted to be the deep-seated **magma chambres** of Jurassic-age (180 mya) volcanoes that formed on the surface of Wrangellia as oceanic crust was subducted beneath it. Volcanic rocks of that same age, the **Bonanza Group** rocks, are preserved locally in this southern part of Vancouver Island, but underlie and are better exposed along the northwest coast of the island (See Figure 5.).

The plate interactions and magmatic activity during the Jurassic contributed to the uplift of Wrangellia, and by the end of this period much more of it was exposed above sea level. Several dark, mafic dykes cross-cut these granitic rocks. The radiometric age of these dykes isn’t known, but they are younger than the intrusions that they cross.

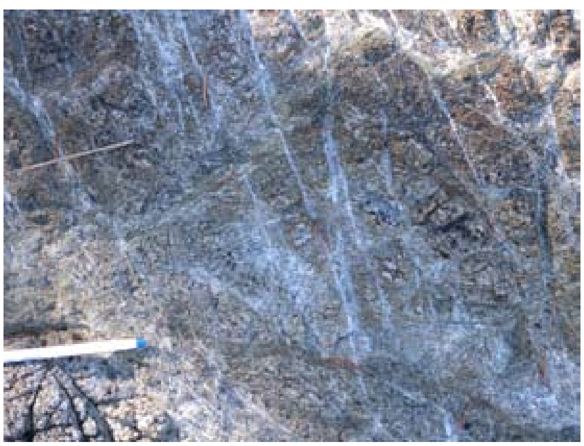


Figure 17: Brittly deformed granodiorite with crushed mineral grains and criss-crossing fractures.

Things to Do

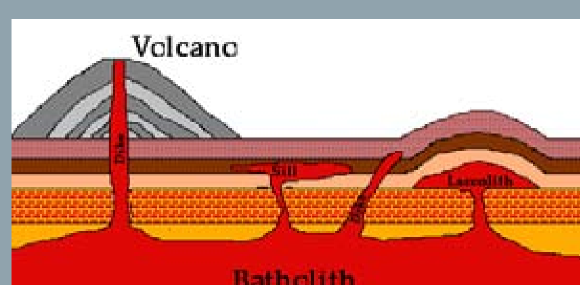
Examine the outcrop and describe the composition and texture of the rock.

Use a magnet to explore the minerals making up the rocks to identify what % of the black minerals are magnetite.

Examine the beach sediment. Is is mostly sand or gravel?

Discuss which processes affect the sediment.

Do a pebble count of a $50cm^2$ area. What are most of the pebbles composed of? Where did they come from?



Stop 5
Beach Drive, Sidney (Park at the South end of Beach Road (off Tyrone Rd.)
Nanaimo Group
Cretaceous

Figure 18: Location of Beach Drive outcrop, Sidney.

On the beach (west of the path leading to the beach) are intertidal and 6-7 m high cliff exposures of deformed (steeply -dipping at 45°), interbedded sandstone, siltstone and mudstone Figure 19). The outcrop is predominantly dark grey, very fine sandstone or siltstone and mudstone (to 1 m thick) with 10-20 cm think, discontinuous beds (lenses) of orangish brown-weathering, fine-medium grained sandstone. Sandstones locally exhibit small-scale ripple cross-lamination or larger-scale cross-lamination (Figure 21). Look closely, siltstone and mudstone beds contain broken pieces of black (carbonaceous) plant fossils.

Figure 19: Fine-grained Nanaimo Group strata at Stop 5, Beach Road seashore, Sidney.

Pebbly beach with no outcrop continues ~100m southwest of the path. Nanaimo Group strata cropping out on the point are different than those exposed at the North end: they are dark grey, medium-grained, massive bedded sandstone (Figure 20), overall coarser and lacking the silts and muds that are dominant in outcrop to the east.

Figure 20: Thick-bedded, coarser-grained Nanaimo Group strata at the SW point of the beach, Stop 5, Sidney.

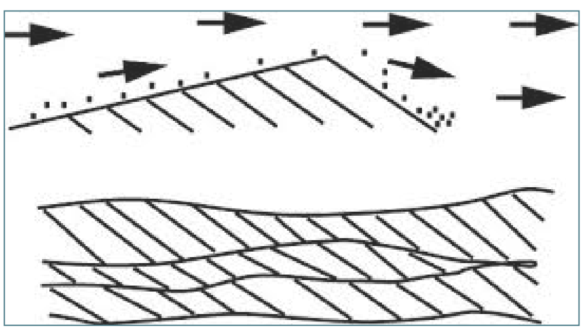


Figure 21: Cross-bedding in sandstone forms by migrating ripples and dunes moved by water.

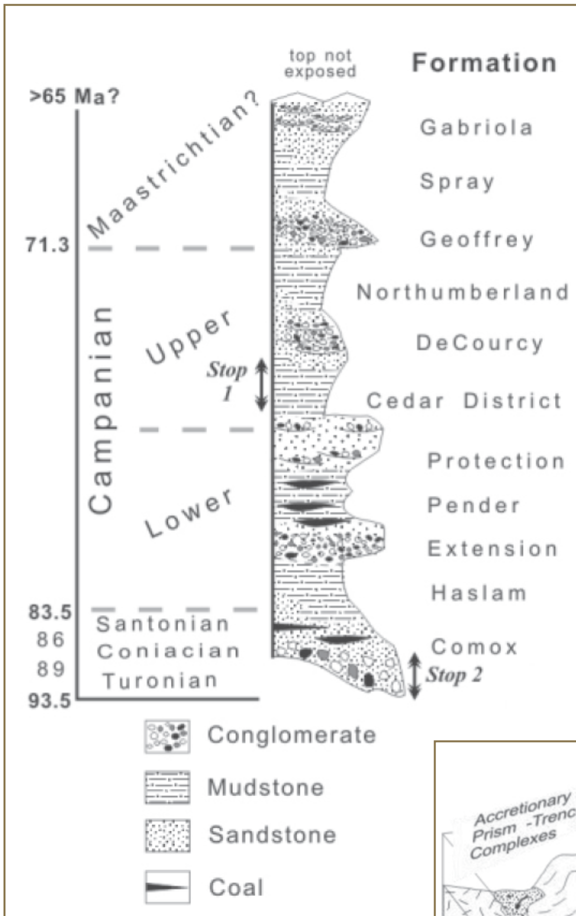
Things to do:

Discuss: How do geologists tell what types of environments sediments are deposited in? Was there water, wind or ice? Was it marine or non marine? Was the water deep or shallow? Was the water moving?

Look carefully for sedimentary structures and fossils. What do these tell you about the environment?

Collect sand from one of the sandstone beds or a hard rock sample. Compare the composition and the texture of this deposit to modern beach sediment and Pleistocene glacial sands.

What does the composition of the sandstone tell you about the land areas eroded?



Strata exposed here are but a small part of the Nanaimo Group, a very thick (up to 4 km) sequence of sedimentary rocks (Figure 22) derived from the erosion of uplifted land areas located to the East that were created by the accretion of Wrangellia to North America during Cretaceous time The sequence is an **overlap assemblage** as the strata were deposited on Wrangellia rocks and those forming the Coast Plutonic complex. Most of eastern Vancouver Island is underlain by Nanaimo Group strata. There are equivalent rocks cropping out in Stanley Park in Vancouver.

Nanaimo Group sediments are interpreted to have been transported and deposited in rivers, deltas and deeper marine environments that flowed into a NW-SE trending, elongate "foreland basin" now occupied by the Strait of Georgia (Figure 23). The land mass was situated in tropical latitude during Cretaceous time, with a climate favourable for the growth of lush forests. Vegetation accumulating in swamps gave rise to coal upon burial, over enormous time becoming a mineral resource that fuelled settlement and development of the colony of BC millions of years later.

Figure 22: Generalized stratigraphy of the Nanaimo Group (Levson et al., 2011).

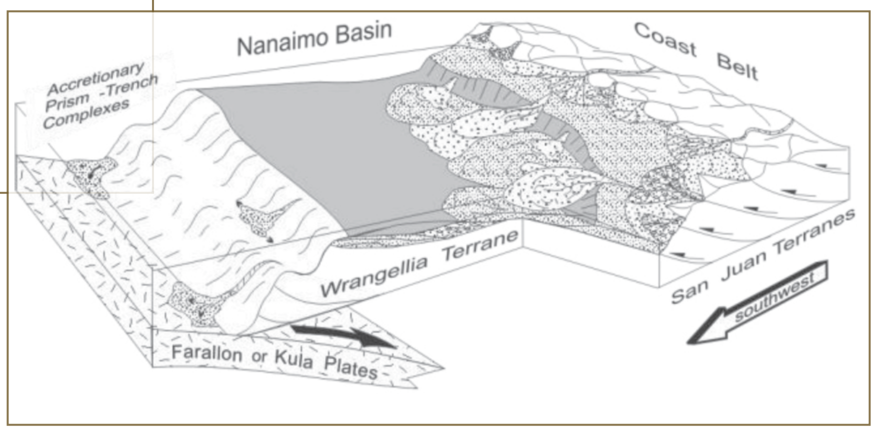


Figure 23: Schematic reconstruction of the depositional environments of the Nanaimo Group (Levson et al., 2011).

Fossils of the Cretaceous (From *Fossils of Vancouver Island* poster, Johnstone, S., 2013)

Most of the sedimentary rocks of the Nanaimo Group were deposited in marine environments, however on the southern part of the island, the older units of the Nanaimo group were deposited on land or very near shore.

These near-shore rocks contain some amazing examples of Cretaceous flora, including palms, ferns, and the leaves and flowers of flowering plants. It is in these plant-rich near-shore sedimentary rocks that most of Vancouver Island's coal deposits are found.

The marine fossils found higher in the sequence include the clam *Inoceramus vancouverensis*, which can be up to a metre in size, as well as **ammonites**, crabs, and lobsters. Some of the more impressive discoveries include shark vertebrae and teeth, teeth from **mosasaurs** (crocodile-like marine reptiles), bird bones, and even a few bones from a **pterosaur**.

Most spectacular is the skeleton of an **elasmosaur** recovered in Courtenay, a reptile that looks similar to artists' renderings of the Loch Ness Monster, with a long neck and tail, tiny head, and flippers to propel itself through the water!

Stop 6
Roberts Point, Sidney
Paleozoic - Cretaceous

Figure 24: Location of Roberts Point, Sidney.

This is an optional stop depending on time and tides. This site is of interest as it encompasses, in a very small area, many of the rocks and key relationships that have been observed at previous stops. It's a 'small-scale' representation of geologic events.

At this site, dark (**mafic**) volcanic rocks of Permian to Triassic age are exposed on the edge of the beach. These rocks are known as the **San Juan Volcanics** and are likely correlated with the **Karmutsen Formation** (field trip Stop 1). The **Saanich Granodiorite** (field trip Stop 4) cross-cuts theses volcanic rocks.

Further north along the beach are coarse-grained rocks from the **Nanaimo Group** (Comox Formation). These differ markedly from the Nanaimo Group rocks observed at the previous stop. Coarser textures suggest more proximal depositional conditions. The exact depositional environments for these rocks can be discussed and contrasted with the previous site.

Stop 7
Island View Beach, Saanich (Walk South along the beach toward Cowichan Head)
Glacial sediments
Pleistocene, ~ 25 ka

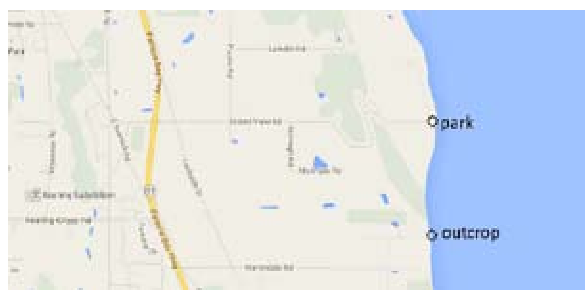


Figure 25: Location of Island View Beach.

Cliffs (~30 m high) lining the beach South of the parking area (~ 5 minute walk) are comprised of soft, white, mostly fine-grained sand or silty sand (Figure 26). Sediments appear massive, but do exhibit large scale, low angle cross-lamination. The top 8m distinguished by orangish stain and visible, pebble-size grains. Quaternary geologists who have closely examined this section see many more distinctive units (Figure 27; Korath, 2005)

Figure 26: Cliff exposure of Pleistocene sands, Island View Beach.

Along with the rest of Vancouver Island and almost all of British Columbia, the Victoria area was repeatedly glaciated over the past million years or more. As the ice of the most recent glaciation (the Fraser Glaciation) advanced south down the Strait of Georgia into the Strait of Juan de Fuca, layers of gravel, sand, silt and clay were deposited in front of it from melt-water outflows.

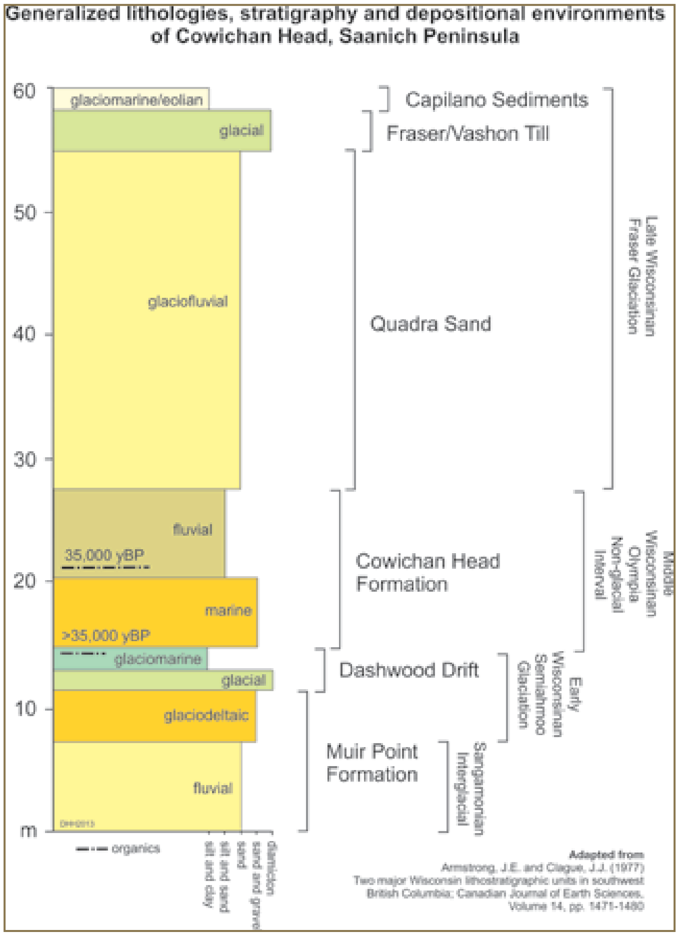


Figure 27: Stratigraphy of the Pleistocene sediments in the cliff at Island View Beach (Courtesy of Dave Huntley, GSC).

Did you know? (From Wikipedia)

☼ Glacier motion occurs from four processes, all driven by gravity: basal sliding, glacial quakes, bed deformation, and internal deformation.

☼ Glacial motion can be fast (up to 30 m/day, observed on Jakobshavn Isbræ in Greenland) or slow (0.5 m/year on small glaciers or in the center of ice sheets).

☼ The Comox Glacier on Vancouver Island is located 30 km (19 mi) SW of Courtenay and 1 km (0.62 mi) W of Argus Mtn. You can hike there.

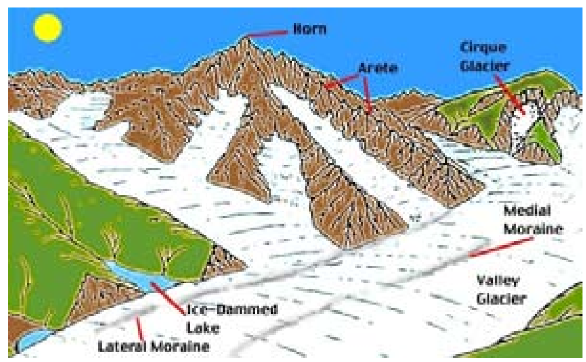


Figure 28: Root of drowned tree, intertidal zone, Island View Beach.

Exposure of these sediments records **isostatic rebound** of the ice-weighted land after the ice left the area. However, an interesting feature of this location is a spot at the North end of the cliff with exposed reddish brown mud and peat with several roots of drowned trees (Figure 28). The roots have dated at 2040 years old and record coastal subsidence or sea level rise since glaciers retreated some 10,000 years ago.

Coastal erosion of the cliff and beach is a problem here. One property owner has lost more that 45' since 1963 by wave erosion and slumping. Property owners atop the cliffs wish to fortify the base of the cliff with **rip rap**. Other property owners to the North who want the sand to drift down shore, do not.

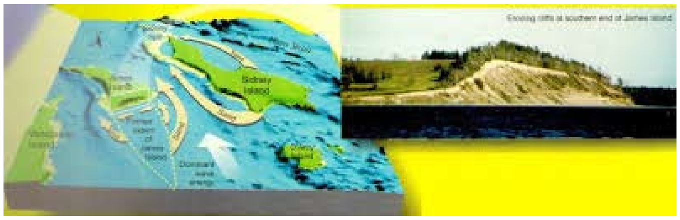


Figure 29: James Island in the Strait of Georgia is a drumlin composed of unconsolidated glacial sediments.

Island View beach provides a superb view of **James Island** and an erosional cross-section through a **drumlin** (Figure 29). A drumlin is a glacial deposit, one formed by the movement of ice over unconsolidated glacial sediments (Figure 30). The landform is asymmetrical, with a steep up-ice side and more gentle sloping down-ice side, which indicates the direction the ice moved.

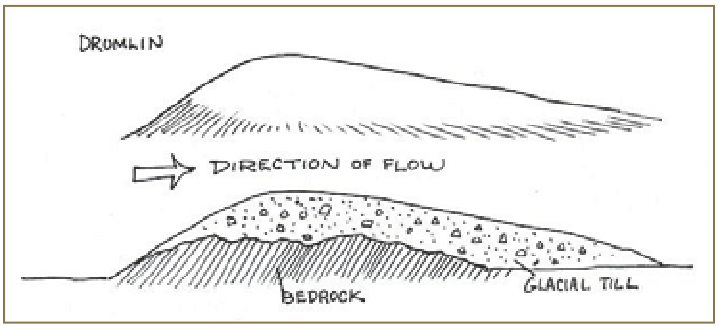
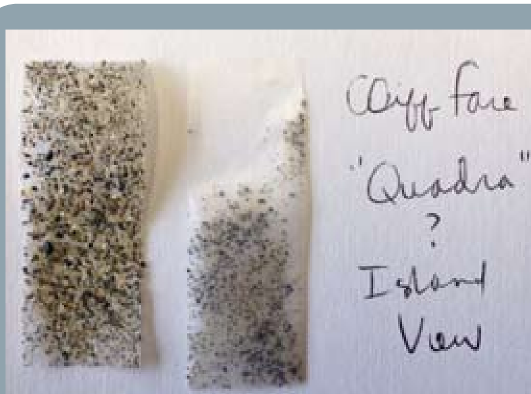


Figure 30: Schematic illustration of how drumlins form when glacial ice moves over unconsolidated sediments.



What to do at the beach:

Compare **beach sand** with **glacial sand** in outcrop.

Carry out a **sand study** using tape and hand lens. Examine and collect a sand sample to determine its composition and texture. List the colours of the grains (dark vs light); are there rock fragments or only minerals? Are there organic (shell or carbon) fragments?

Determine if any of the grains are magnetic.

Discuss where the sand may have come from.

References and Resources

The Salish Sea geology, seascapes and landscapes are described in:
Salish Sea Geotour: Geology on, under and around the Salish Sea of British Columbia, 2011, Natural Resources Canada, Victoria. Download at: http://publications.gc.ca/site/eng/378742/publication.html

Teacher resources for geological hazards.

These files include presentations, activities, marking guides for earthquakes, tsunamis and landslides using Canadian examples. Download at: http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=289872

The geology of the Southern Vancouver Island area is described in:
Yorath, C; Sutherland Brown, A; Massey, N, 1999, *LITHOPROBE, southern Vancouver Island, British Columbia*. Geological Survey of Canada, Bulletin 498, 145 p.

A good summary of the geology of southern Vancouver Island is provided in:
Yorath, C., 2005, Geology of Southern Vancouver Island Revised Edition, Harbour Publishing, Victoria.

Information on the geology of the Victoria area is available on the:
Geoscape Victoria site and poster at:
http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/3e806a5a-d124-5ace-8bf7-c3e0a1e59859.html

Johnstone, S. (2013). Fossils of Vancouver Island, Poster. URL: https://live-science-technology.pantheonsite.io/sites/default/files/fossilsofvancouverisland.pdf

Earle, S., 2012, *The Geology and Geological History of Vancouver Island,* Powerpoint presentation (web.viu.ca/earle/mal-cut/geology-of-vancouver-island.ppt

Levson, V., Massey, N., Mustard, P., Ferri, F., Hickin, A., and Walsh, W., 2011. Geology of Southern Vancouver and Islands, Field Trip Guidebook, April 4, 2011 (For the 5th British Columbia Unconventional Gas Technical Forum)

Pacific Geoscience Centre
9860 West Saanich Road, Sidney, BC

Scientists at the **Pacific Geoscience Centre** (PGC) (Figure 31) are engaged in geoscientific research aimed at increasing our understanding of the geological history, processes, and hazards affecting Western Canada. As part of the Institute of Ocean Sciences, the Pacific Geoscience Centre is the western headquarters of the Canadian seismic network and staff here record, locate and research earthquake events and their mechanisms.

The Pacific Geoscience Centre (PGC) is the western-most office of the Geological Survey of Canada. PGC is a centre of expertise in geohazards, including earthquakes, and geosciences in both marine and land-based environments. PGC scientists, technicians, students and volunteers research geological processes and geohazards across Canada. As a data centre for the Canadian National Seismographic Network, seismologists at PGC locate and analyze more than 2,000 earthquakes a year in Western Canada (Figure 32). Staff also conduct research into earthquake processes and geodynamics, and their findings help to improve Canada's building code.

Figure 31: Location of Pacific Geoscience Centre, Sidney, BC and Island Intrusions.

The PGC also has displays (Figure 33) of geological and geophyscial materials. PGC staff often make themselves available to take school groups on site tours and explain their research and activities.

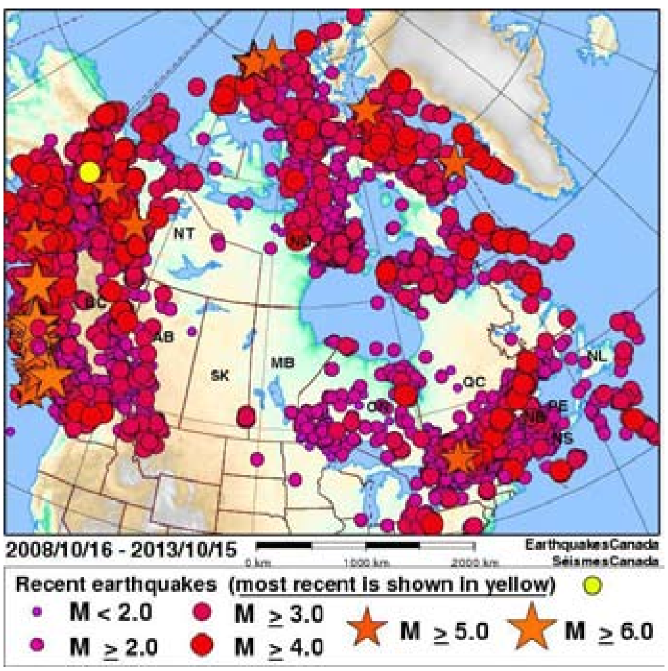


Figure 32: Map of Canada showing the location of earthquakes over 5 years.

Figure 33: Pillow basalt from the Juan de Fuca Ridge (spreading centre), PGC, Sidney.

Plate Tectonics and Foamies (Developed by Jane Wynne)

Equipment

☼2 Thinsulite foamies, about 2m long
☼1 piece of 4" foam rubber about 50 x 80 cm
☼masking tape
☼8 small laminated arrows (25 cm long, two different colours)
☼2 big laminated arrows (same two colours as the small arrows)
☼labels for Pacific Plate, Juan de Fuca Plate, North America Plate, Juan de Fuca Ridge, Cascadia Subduction Zone
☼a couple of cones made out of brown construction paper (volcanos)

Key learning outcomes:

1. Circulation in the mantle causes lithospheric plates to move
2. There are three different types of plate interactions in our backyard; convergent (subduction zone), divergent (spreading ridge) and transform faults (strike slip faults)
3. A record of the reversals of the Earths magnetic field through time is recorded on the sea floor
4. The oldest oceanic plate material is farthest from the spreading ridge

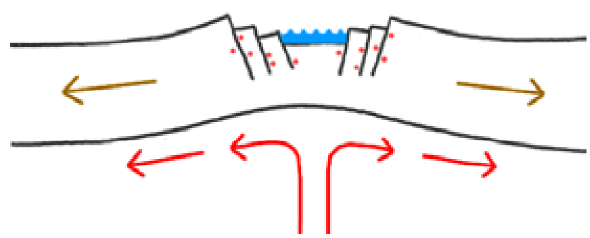
Moving Plates

1. Have two students crouch, on their knees, back to back facing in opposite directions, with their feet almost touching, ready to do a somersault.
2. Drape the two thin foamies over the backs of the children, and tuck it in behind them.
3. Have them do a somersault and have the rest of the class observe what happens to the two foamies.

The foamies will move in opposite directions, away from each other, just as the oceanic plates do on opposite sides of a spreading ridge. The somersaulting students are the circulating mantle material; the foamies are the plates moving on the surface of the mantle.

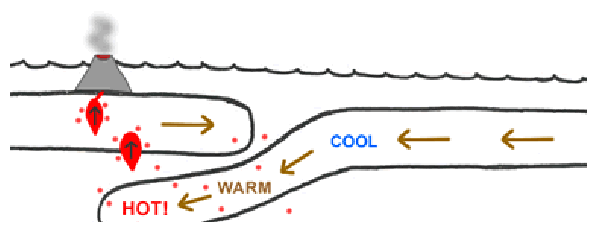
Plate Interactions

Divergent plates occur in a spreading ridge, where new volcanic material is added to the oceanic plates and the plates move away from the ridge. (This is the foamie spreading ridge.)



1. Put the two thin foamies together and in between two desks pushed close together or between two arms of an obliging assistant. These could be labeled Pacific and Juan de Fuca plates.
2. Pull the leading edge of the foamies up (vertically) and move them away from each other (horizontally). This models the creation of new oceanic material at the ridge and the conveyer-belt motion of the oceanic plates away from the ridge.

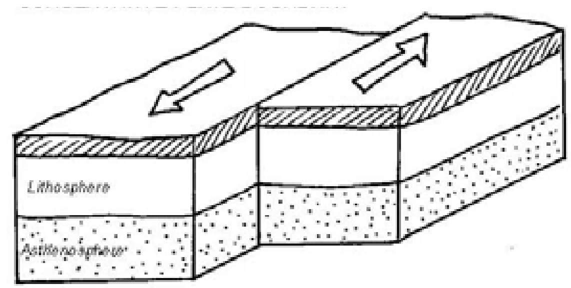
Convergent plates off the west coast of Vancouver Island are the thin (about 7 km thick) oceanic Juan de Fuca Plate and the thick (20 to 40 km) continental plate of North America. The net velocity that these two plates approach each other is between **4 and 7 cm per year**, about the rate your fingernails grow. The thinner, more pliable, and denser oceanic plate is being over-ridden and subducted beneath the leading edge of North America.



1. Use the thin foamie for the oceanic plate and the thick foamie for the continental plate and model the subduction of the oceanic plate. Label the plates, the ridge (where new oceanic plate material is created) and the subduction zone (where the oceanic plate is consumed).

2. Place the volcanoes on the North American Plate - they are caused by melting in the mantle, above the descending oceanic plate.

Transform Faults

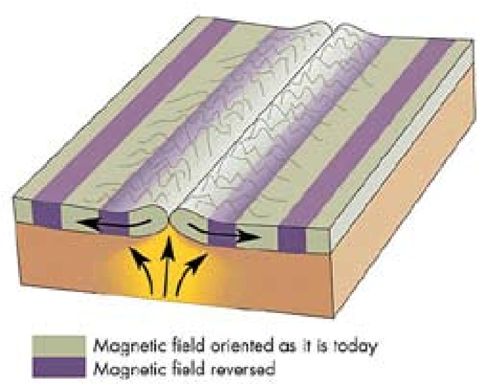


Where two plates slide past each other, they are separated by a transform fault. The San Andreas Fault in California is a transform fault where part of the Pacific Plate is sliding past the North American Plate. The Queen Charlotte Fault along the western margin of the Queen Charlotte Islands is a transform fault again separating the Pacific Plate from the North American Plate.

1. Take one of the thin foamies and the thick foamie and slide them past each other edge to edge. Label the plates.

Record of Magnetic Field Reversals

Every 700,000 years or so the Earth's magnetic field reverses, or changes polarity. After the next field reversal the needle on our compasses will point South! When rocks form, magnetic minerals in them become aligned in the direction of the Earths field. Therefore they record the direction of the Earth's magnetic field at the time that they formed.



1. Designate one student to be the Earth's magnetic field, give him/her the large arrow, have them hold it up over their head and pointing at the back of the classroom.

2. Equip each team of students with a pair of thin foamies and 10 small arrows.

3. Align the "spreading ridges" with the direction of the Earth's field (say parallel to one wall of the classroom).

4. Have the ridges spread a bit and stick arrows on either side of the ridge (the central crack), both pointing in the same direction as the Earths magnetic field (towards the back of the classroom).

5. Have the Earth's field switch directions and point to the front of the classroom.

6. Have the ridges spread a bit more and stick arrows on either side of the ridge, both pointing in the new direction as the Earth's magnetic field (towards the front of the classroom).

7. Keep going in this fashion until the arrows are all used up.

The striped magnetic pattern created on the ocean floor, symmetrical about the ocean ridges, was one of the critical observations that helped persuade scientists that sea floor spreading was indeed going on. This phenomenon could only be explained by plate tectonics.

Q - What causes polarity changes?

A - The flow of the outer core is complicated and turbulent. Every so often the flow is such that the electric current generated by the flow dies down, and the consequently the field generated by the electric current dies down. When the electric current picks up again the direction of the magnetic field may or may not be in the same direction. Either configuration (Normal or Reversed) is equally stable/likely. A change in the direction of the flow is not responsible for the change the magnetic polarity.

The age of Oceanic Crust

This is a variation of the spreading ridge demonstration, which takes place over an entire week.

1. In the back of the classroom set up two desks close together and on Monday start a foamie spreading ridge. (see Divergent Plates on the preceding page.) Label the leading edges “Monday”. (You will have two labels, one on each side of the ridge.)

2 On Tuesday, have the ridge spread a bit more and label the area closest to the ridge “Tuesday”.

3. Continue spreading a bit each day, labelling as you go.

By Friday you will have the foamies almost fully “spread” and labels going from Friday to Monday from the ridge to the leading edge of the two plates. Then ask the class where the oldest oceanic crust material can be found - near the ridge or far away from the ridge?

Discussion and Beach Activities

What do we call this natural feature? What is the main feature? What is noticeably missing?

What processes are operating here?

Is the tide going up or going down? How can you tell?

What feature of sedimentary rocks might you expect to find on the surface of the beach?

What might you see if you dug a trench in the sand?

Dig a trench and look carefully at sand exposed in the wall. What do you see? Sketch it.

Do you see and signs of life on the beach? Look for trails of creatures. What are the creatures who made them doing?

Do you see evidence of anything living below the surface in the beach sand? What are these creatures doing? How woudl burrowing change sedimentary layers?

Collect a sand sample on double sided sticky tape and examine it with your hand lens. What is the size of the grains? Are they well-sorted or poorly-sorted? Are they angular or rounded? What colours do you see? What minerals do they represent?

Colour	Colour of Grains	Grain Size (mm)	Round or Angular	Sorting (well, farily well, poor)

Are any grains organic? What do they look like? Can you identify what they were a part of?

Are there any grains that are ROCK fragments rather than mineral grains? Describe them.

Estimate the percentage of black grains. Are any magnetic?

(If you bring rock samples with you, you can pass them around and ask students to determine what type most closely resembles the sand and could be the source of the sand on the beach.)

Beach Pebbles

(if accessible at low tide) Explore the pebbles and cobbles in the intertidal. Are they round or angular? What is the grain size range in cm or m. Look at 3--6. Describe them in the table below:

General colour	Grain Size (mm)	Colour(s) of grains & percentage (e.g 15% white)	Texture (crystalline of cemented grains)	Hard/ coherent or soft/crumbly	Special features (e.g. layers, holes, fossils)	Rock Type

Where did these boulders come from ? How did they get where they are now?

Nanaimo Group strata

Collect a sandstone sample and examine it with your hand lens. Describe the sample using the table below.

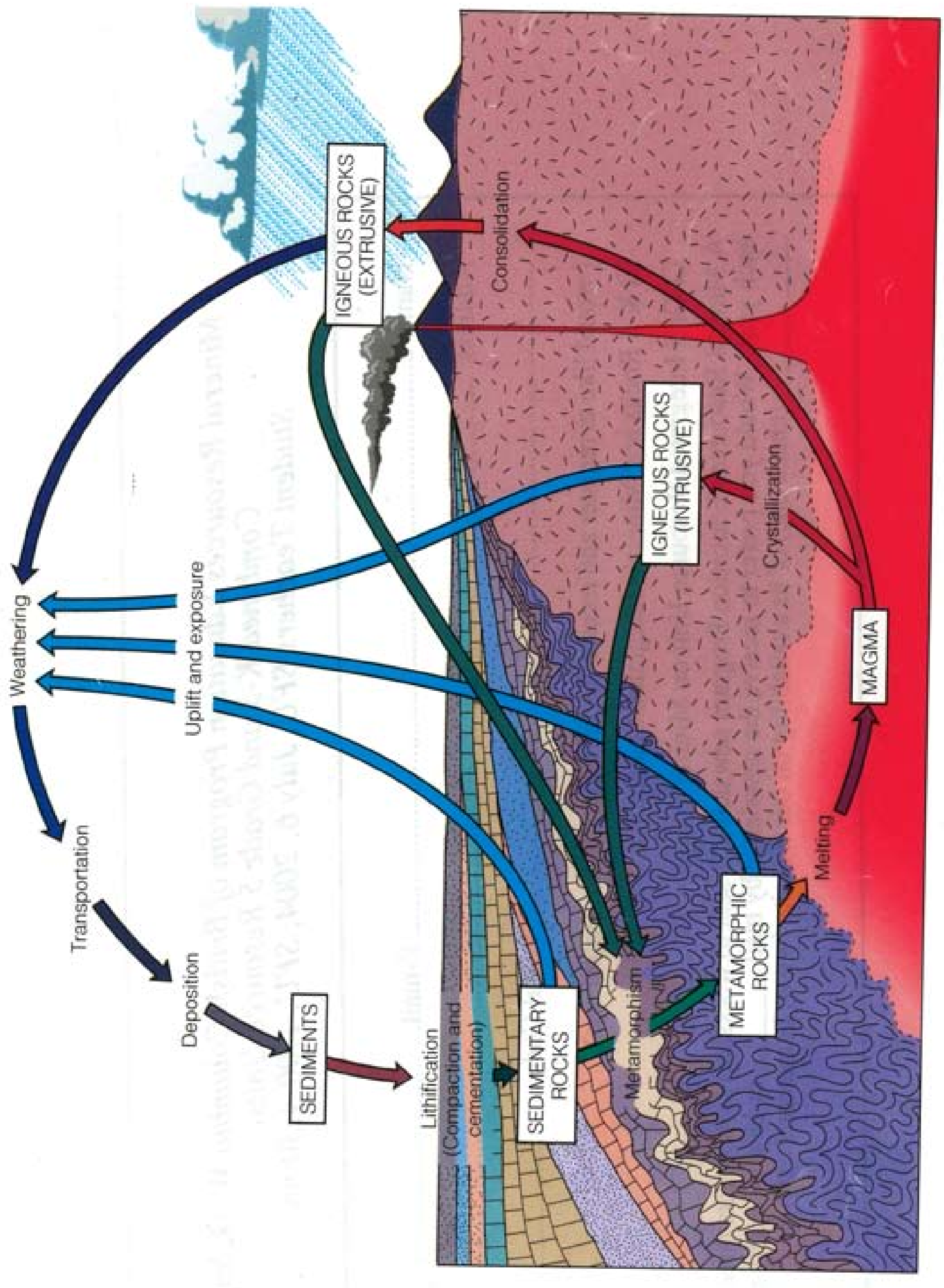
Colour	Colour of Grains	Grain Size (mm)	Round or Angular	Sorting (well, farily well, poor)

Are there any grains organic? If so, what are they?

Are there any grains that are ROCK fragments rather than mineral grains? Describe them.

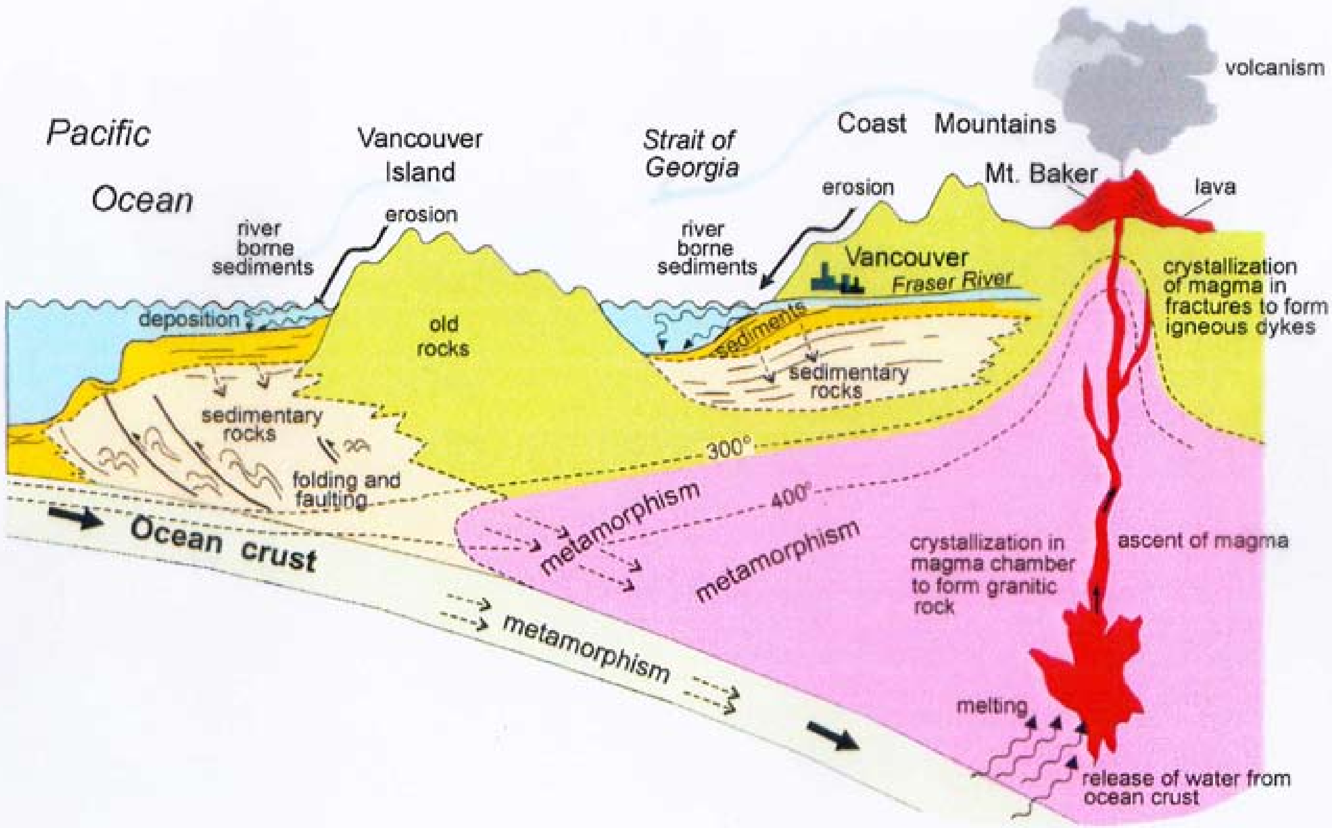
Estimate the percentage of black grains. Are any magnetic?

Compare this sand with the beach sand collected at Island View Beach. Is this the source of the sand at Island View? Why or why not?



Transparency 4 (Figure 1-15)
The rock cycle

Geologic Processes in Coastal B.C.



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