Field Trip Guide to the Sooke Formation rocks and fossils of Muir Creek beach, southwestern Vancouver Island, BC.

Prepared by: Marji Johns, Tom Cockburn, and Raymond Graham

Location

Classic exposures of the Sooke Formation rocks and fossils at Muir Creek beach (Figure 1) are easily accessible during low tide. From Sooke, take the coast road (Hwy #14) past Sooke to Muir Creek. After parking at Muir Creek (left, just over the bridge), the site is about ½ km northwest of the mouth of Muir Creek along the beach (48.381409°N, 123.877287°W) (NTS map: 92B/5 west, Sooke).

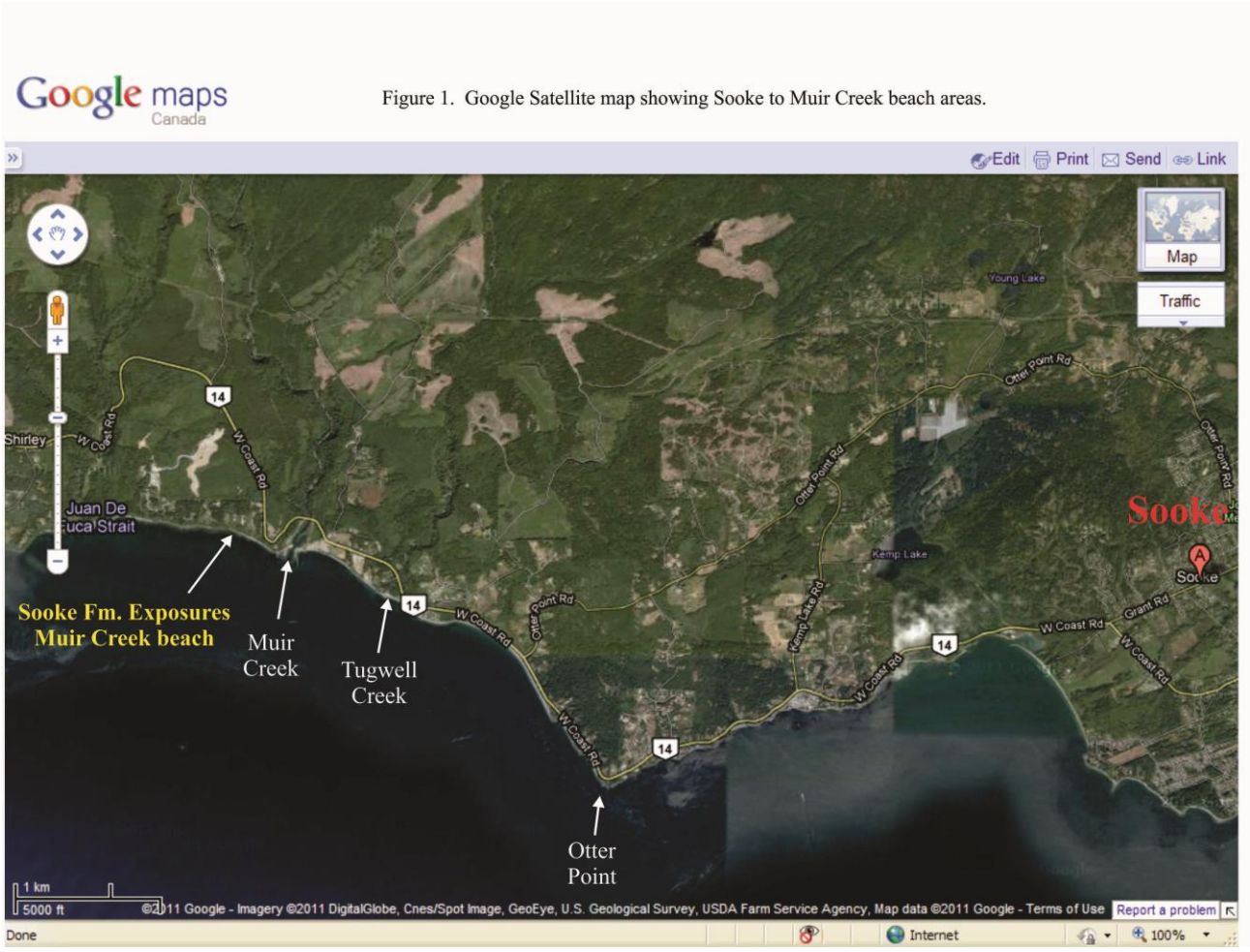


Figure 1. Google Satellite map showing Sooke to Muir Creek beach areas.

At the mouth of Muir Creek and looking southwest to the distant Olympic Mountains.

View of the Sooke Formation sandstone (left) and looking south to the point near the mouth of Muir Creek.

Modern coastal life and geology

On your walk to the site, observe the floras, faunas, rocks and sediments of this coastal beach habitat.

How does beach life differ in the sand flats versus the rocky areas?

Is there different life near Muir Creek versus farther down the beach?

Where do shells accumulate at the beach?

What life is at the high tide area versus more seaward in the low tide zone?

Walking northwest to the Sooke Formation rocks at Muir Creek Beach.

Observe further:

What vertebrates are in the area?

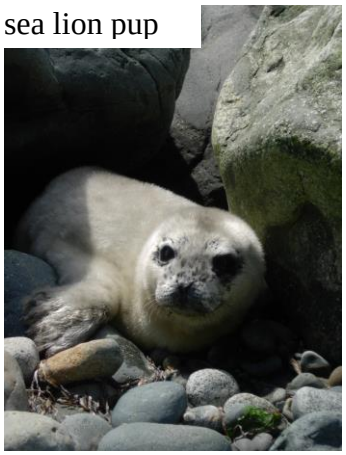
What plants and trees grow along the beach?

Where do logs, branches, and leaves accumulate at the beach?

Where do marine algae grow and not grow?

What is living in the algae areas?

What rocks do you see and how do they change along the beach?



sea lion pup

Some examples of modern beach life.

Clinocardium nutallii

If everything was suddenly buried by sediment on this beach – what would it look like in the geological / paleontological record 1 million years from now?

Saxidomus gigantea

Crassostrea gigas

Mytilus californianus

Nucella lamellosa

Euspira lewisii
moon snail

Lottia pelta (limpet) &
Solidobalanus hesparius
(barnacle)

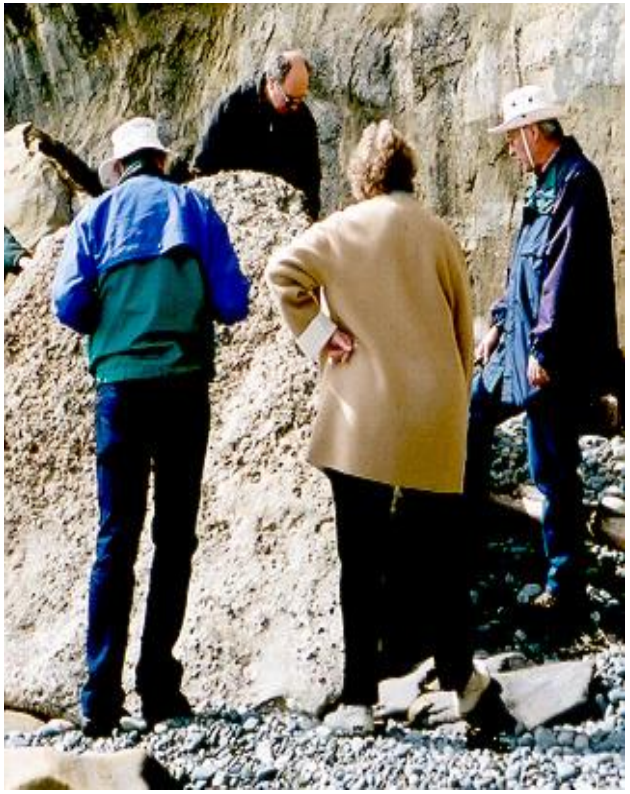
Collecting etiquette

Fossils in BC are considered to be a heritage item. They are a limited resource. Over-collecting and destructive collecting is strongly discouraged. Please respect this site and only collect fossils that are being eroded or destroyed by sea waves.

Photography is the best collection tool. Fossil collecting should be done conservatively to respect the natural beauty of the area and its importance for outdoor recreation to local and other communities.

Scatter any rock debris from collecting areas and try to leave the beach looking as natural as possible.

Collecting in the cliff face is strongly discouraged. Firstly, permission should be obtained from the land owner. Secondly, the cliffs are commonly overhanging and dangerous should rocks and other debris fall from above. Thirdly, the rocks of the cliff faces are very hard and the fossils are difficult to extract intact.



Rare specimens observed in the cliff faces should be brought to the attention of researchers or professionals (e.g. at Royal BC Museum) so that permission may be obtained to carefully extract the fossil using appropriate methods and tools.

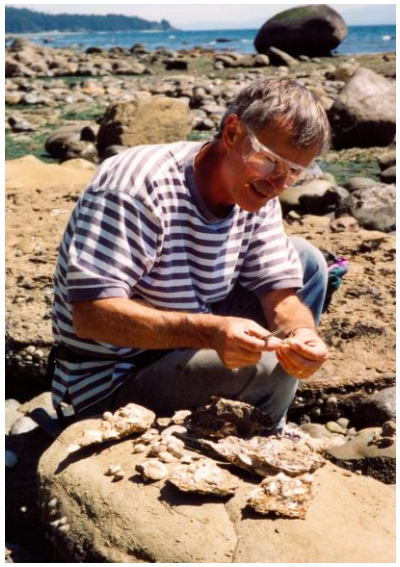
Fossil collecting may be appropriate in rocks that have fallen from the cliffs onto the beach. There are many blocks of Sooke Formation rocks scattered along the beach that have been loosened from the cliffs during winter storms or other types of erosion in the area.

Collecting should start with photographs of: the site, the position of the fossil in the rocks, and the fossil itself (using a scale bar next to it). Data about the site, location, geology, fossil, and associated fossils should be recorded in a notebook. A GPS reading at the site is very desirable. Location information on a label is the most important thing you should keep with your fossil.

Fossil extraction

When using rock hammers and chisels, safety glasses or goggles and gloves are recommended. Also, care should be taken when breaking rocks apart to prevent flying debris from hitting other people nearby.

Chiseling and hammering are carefully done to reduce the size of a rock matrix containing fossils or to extract a fossil in a matrix from the rock. In the field, it is best to extract the fossil with matrix to prevent damage to the fossil and then prepare the fossil at a later date such as in a laboratory with special preparation tools.



Fossil bivalves and gastropods are easily spotted at the Muir Creek beach site. They are about 25 million years old.

A fossil can be wrapped with its label in bubble-pack foam, newspaper, or other light-weight materials and then taped or bagged. Old film or pill containers are excellent for storing small fossils with a bit of soft packing material.

Example label

Field #: _____ **Collect Date:**_____

Common Name: _____

Scientific Name: _____

Collector: _____

Geology: Carmanah Group, Sooke Formation

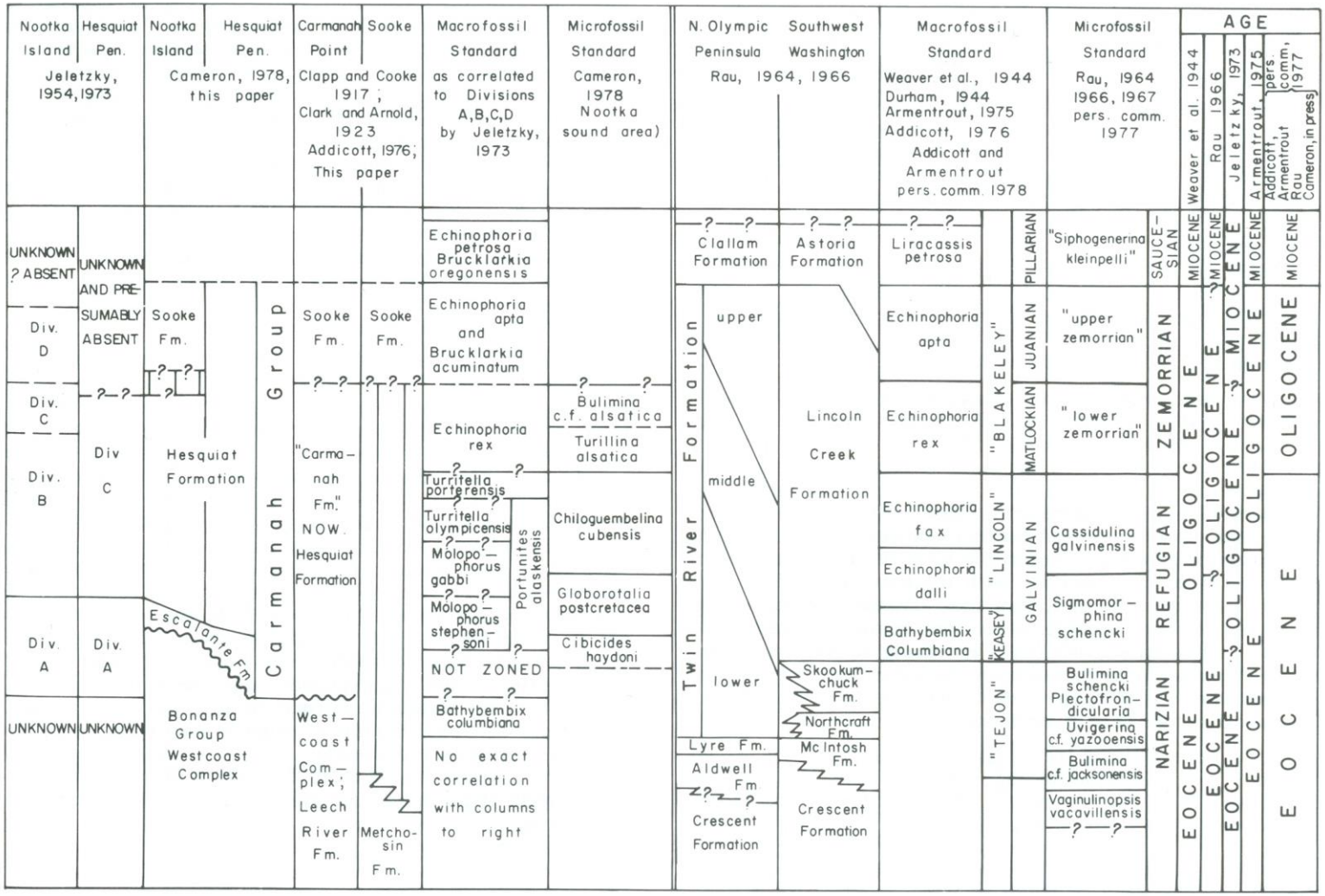
Age: approx. 25 million years old

Location: Muir Creek Beach, Vancouver Island, BC, Canada

Paleontology

A comprehensive study of Sooke Formation fossils was produced by Clark and Arnold in 1923. Taxonomic updates are provided by Cockburn et al. 1999. Many fossils have been collected locally such as at Muir Creek beach, Kirby Creek and French Beach. Correlation of Cenozoic formations and fossil zones are shown in Muller et al. 1981 (*below*).

Correlation of Cenozoic formations of Vancouver Island and Western Washington, USA. From Muller et al., 1981

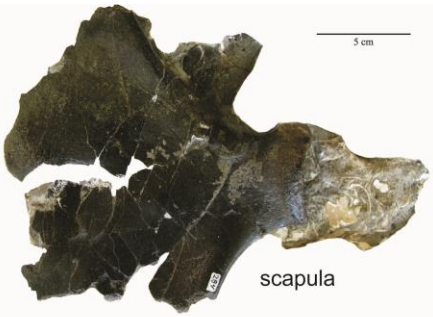


Muir Creek beach fossils are 25 million years old. The most common fossils are invertebrates (clams and snails). However, a good diversity of other fossils may be found in these Sooke Formation rocks.

Vertebrate fossils are shown below from the Sooke Formation rocks at Muir Creek beach. Many are yet to be identified. Bird bones (left) are rarely preserved because of their thin and fragile nature. However, a family with sharp eyes found these novel fossil specimens and other vertebrate bones. They made careful collections. The family was honoured by having a new bird named after them. Other fossils include herbivore mammals called desmostylids. They lived along the shorelines and fed on sea grasses. At Muir Creek beach, *Cornwallius sookensis* is younger than the *Behemotops* specimen (~33.6 million years old) (bottom right) that was found further up the coast at Sombrio Beach.

Stemec suntokum Kaiser et al., 2015

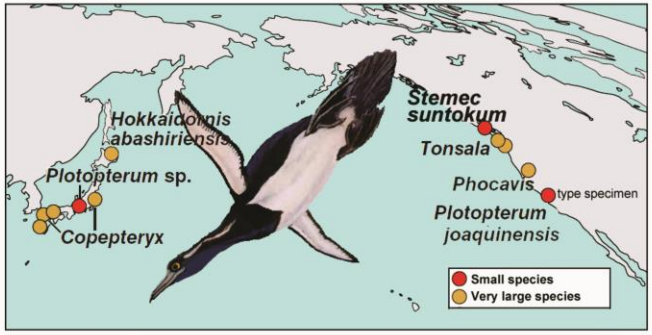
bird leg bones



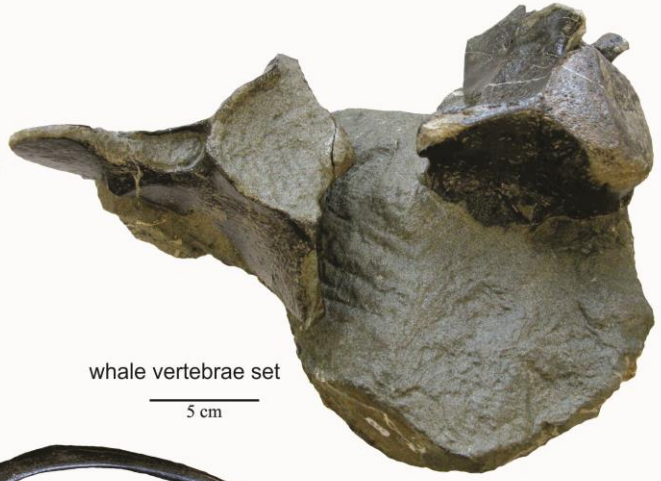
scapula

atlas

Cornwallius sookensis
Cornwall, 1922



Distribution of fossil Plotopteridae Kaiser 2015

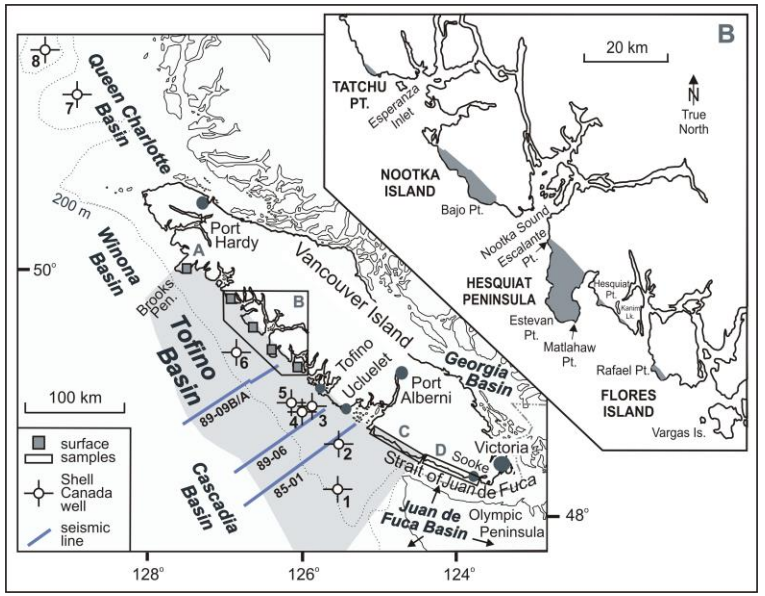


rib

Behemotops cf. *B. proteus*
Beatty & Cockburn, 2015
Carmanah Group, Sombrio Beach

Cenozoic Stratigraphy

The Carmanah Group rocks are exposed along western Vancouver Island from Sooke to Tatchu Point and to the southern margin of the Brooks Peninsula (*see right*). They include strata of the Escalante, Hesquiat, and Sooke formations. Many of these rocks are associated with both the Pacific Rim and Crescent terranes (see pgs. 12–13) and are comparable to units in the offshore Tofino Basin and in Washington State. The Carmanah Group rocks contain excellent Eocene to middle Pliocene fossils (about 40 to 4 million years old). The faunas lived in slope (bathyal; 150–2000m) to nearshore (littoral–neritic; 1–150m) environments.



Strata of the Escalante Formation in the Nootka Sound area consist of fault-repeated sandstone and conglomerate with Late Eocene faunas. Mollusks were interpreted to be littoral to supratidal and neritic in some parts whereas foraminifers (microscopic single-cell protests) represented neritic to upper bathyal environments and rapid deepening. In some sections, abundant bathyal foraminifers, slope sedimentary structures, and shallow water fossils occurred indicating sediment transport down the slope.

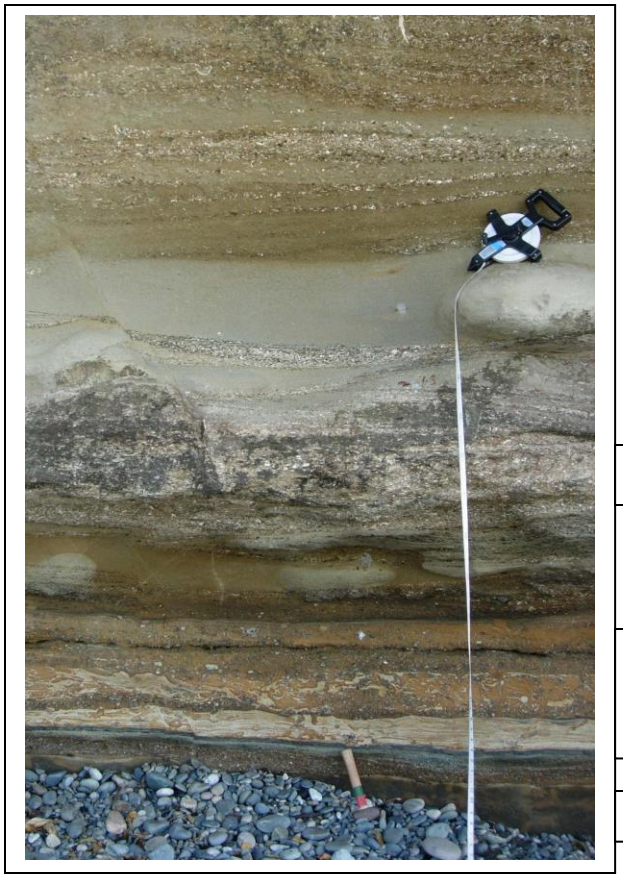
The Hesquiat Formation (e.g. Hesquiat Peninsula) conformably overlies the Escalante Formation and proximal units grade from resistant Escalante sandstone to Hesquiat distal shale. Faunas represent Late Eocene–Oligocene ages (~40–30 Ma). On Nootka Island, the Hesquiat Formation is a distal shale facies with bathyal faunas. The overlying Sooke Formation fauna indicates Late Oligocene to middle Pliocene ages (~25–4 Ma) (Muller et al. 1981) and shallow marine waters.

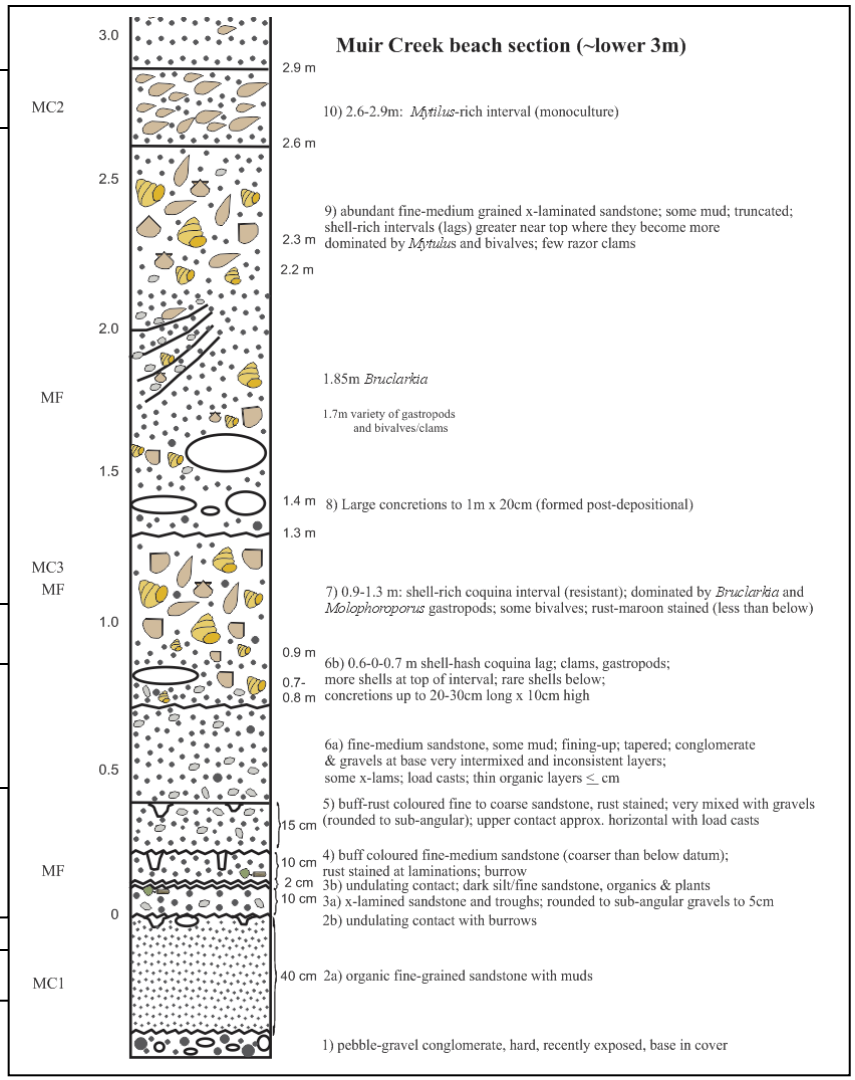
Beach cliff exposures showing Sooke Formation fossils.

Faunas of the Sooke Formation at southwestern Vancouver Island correlate with a reversed magnetozone and Chron C6Cr (latest Oligocene ages, 24.1–24.8 Ma) (Prothero et al. 2008). Strontium isotope ages from foraminifers at nearby Kirby Creek (to the northwest) support a slightly older age at 25.5 Ma (M. Johns, pers. comm. 2011).

Diverse lithologies of the Sooke Formation reflect various sediment sources from uplifted and eroded rocks (Bream 1987). Bream divided the Sooke Formation into 11 facies and subfacies. At Muir Creek Beach the sandstone cliffs (*left*) show cross-stratified sandstone, conglomerate, coquina-like shell-rich beds, burrowing, and other fossil-rich intervals.

We are currently documenting fossils and associated lithologies (rock types) in a section at Muir Creek beach. Results support a high energy and disturbed beach facies somewhat similar to the beach today. The fossils indicate sea level trends and overall shallowing water depths up the section. Distinctive fossil intervals include: an organic fine-grained sandstone near the base of the section which has been burrowed (2a); gravels and sandstones with low fossil occurrences (3, 4 & 5); cross-laminated sandstones and channel lags which are gastropod-rich (dominated by *Bruclarkia* and *Molopophorus* specimens)(7); and sandstones dominated by the mussel *Mytilus* (10). Higher up in the section (not shown) are sandstones overlain by a bed dominated by clams (e.g. *Saxidomus*).



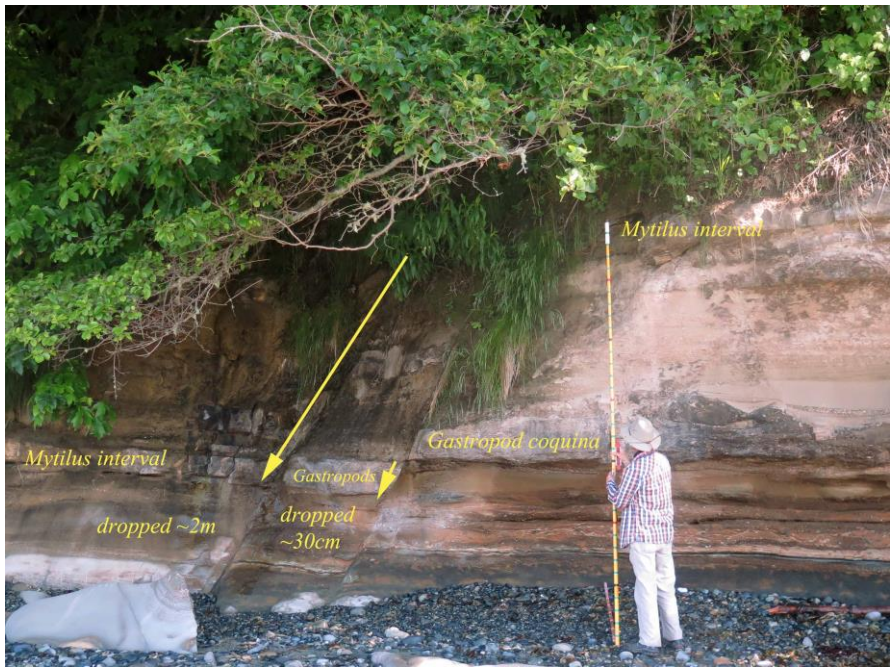


A dynamic geological history is recorded at Muir Creek beach. Structural features (faults, fractures, and load casts) associated with the sediments indicate an active tectonic environment. The strata and fossils are uplifted and deformed in an anticline. Many of the loose boulders on the beach are volcanic, igneous, and metamorphic rocks — having originated from the local Crescent Formation and Vancouver Island rocks, or transported great distances by glaciers from the Coast Mountains.

Burrows (left) penetrated conglomerate to the underlying sandstone.

Load casts and a small fault (above) show deformation in the Sooke Formation rocks. Another fault nearby shows ~2 metres displacement (below).

This distinct contact (left) separates two different sandstone facies of the Sooke Formation at Muir Creek beach.

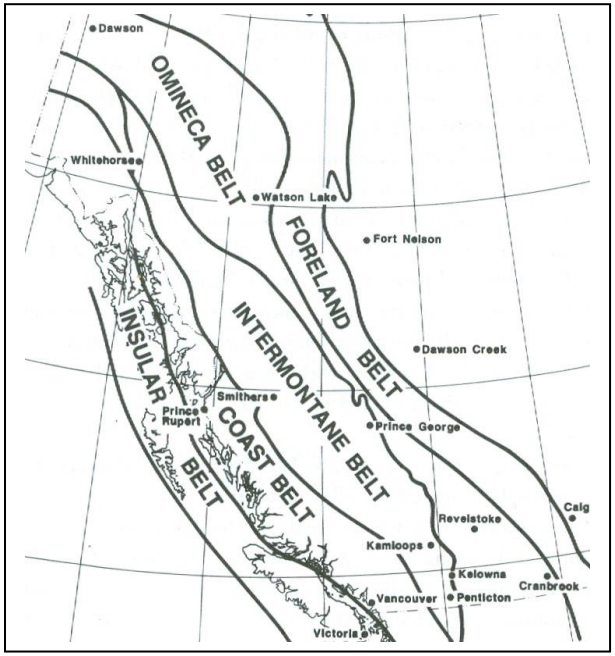


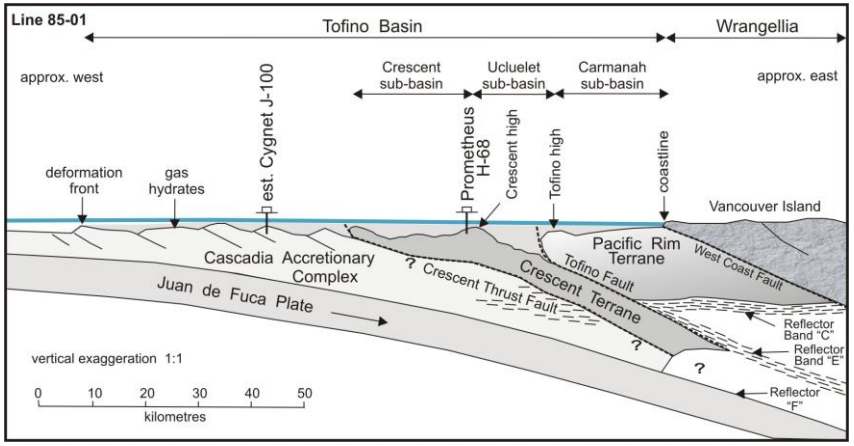
Tectonic history and geologic overview

Vancouver Island belongs to the **Insular Belt** which is the westernmost of five different northwesterly trending subdivisions of the Canadian Cordillera. In BC, the **Cordillera** consists of all the systems of mountain ranges, volcanoes, plateaus and strata from the Alberta and USA borders to the bottom of the continental slope off the west coast of Vancouver Island and Haida Gwaii (formerly Queen Charlotte Islands). The Insular Belt, consists of Vancouver Island, Haida Gwaii, and parts of Alaska and the Yukon. It is the result of the collisions between the western edge of North America and "exotic" pieces of the earth's crust which formed at other latitudes and collided with the continent about 100 million years ago.

Wrangellia is a piece of crust that includes Vancouver Island and Haida Gwaii. During about 375 million years of its history, Vancouver Island has had three major periods of volcanism separated by periods of sediment accumulation. Furthermore, Vancouver Island rocks have been compressed and fractured as other exotic fragments of the earth's crust rammed into (accreted) and plunged (subducted) beneath Vancouver Island. Then, beginning about 3 million years ago, the climate cooled, and thick glacial domes covered most of Vancouver Island, BC and Canada.

Five geologic zones or belts of the Cordillera.



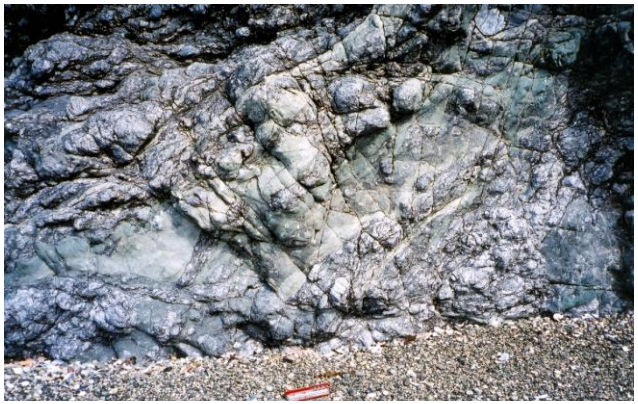


Tectonic elements of the margin offshore Vancouver Island. Modified from Hyndman et al. 1990.

Offshore Vancouver Island and primarily underwater, the present-day active western tectonic margin includes scraped-off and accreted oceanic sediments of the Pacific Rim and Crescent terranes and other sediments as the Juan de Fuca plate subducted obliquely below western North America (e.g. Davis and Hyndman 1989; Hyndman et al. 1990). Also, parts of the Pacific Rim and Crescent terranes are uplifted and form the southern tip and parts of the western margin of Vancouver Island. Cenozoic sediments associated with these terranes include the Carmanah Group rocks (Escalante, Hesquiat, and Sooke formations) which are exposed along western Vancouver Island (from Sooke to the Brooks Peninsula).

Pacific Rim Terrane rocks at Sombrio Beach, BC.

The Pacific Rim Terrane consists of Triassic to Lower Cretaceous rocks which are deformed continental slope facies. These rocks are overlain by Cenozoic and younger strata. Units of this terrane have different metamorphism (heating and alteration) which indicate two periods of deformation: Late Cretaceous (99–83 Ma) (Rusmore and Cowan 1985) and Late Eocene time (41–39 Ma) (Fairchild and Cowan 1982).



Pacific Rim Terrane rocks near Ucluelet, BC.

The Crescent Terrane consists of Cenozoic sediments overlying volcanic rocks of the Crescent Formation (Metchosin Igneous Complex on southern Vancouver Island) (e.g. MacLeod et al. 1977; Muller 1980; Massey 1986). Emplacement of the Crescent Terrane adjacent to the Pacific Rim Terrane is broadly constrained by the age of the Metchosin Igneous Complex (early Eocene; 54 Ma) that is overlain by sediments of the Sooke Formation (Late Oligocene; 25 Ma). Emplacement also corresponds to a basin-wide unconformity during mid–late Eocene and activity on the Leech River Fault during the middle Eocene and Oligocene (e.g. MacLeod et al. 1977; Fairchild and Cowan 1982; Yorath et al. 1999; Groome et al. 2003).

The Crescent Formation rocks commonly consist of pillow basalts that can be seen along the roadside (Hwy 14) near Sooke (on the way to Muir Creek), in East Sooke Park, and other locations in the Sooke area. Pillow basalts form underwater when magma is expelled during volcanic eruptions and then cooled. One theory is that the Crescent Terrane rocks are linked to an offshore ridge spreading centre, a triple plate junction, and volcanic activity on Vancouver Island about 52–30 million years ago (Haeussler et al. 2003).

Pillow basalt

The Olympic Mountains in Washington State consist of uplifted strata of the Crescent Terrane and overlying sediments. These rocks began to uplift about 10 million years ago. During this phase of tectonism, the subducting oceanic plate had a shallower plunge angle than offshore Vancouver Island. This resulted in greater uplift of the Olympic Mountains than those offshore Vancouver Island which had a steeper plunge angle and in part were subducted beneath Vancouver Island. Some of the rocks of the Crescent Terrane, overlying sediments, and younger accreted sediments are still submerged offshore.

Protection of important West Coast Vancouver Island fossil and geological sites.

Much of the west coast of Vancouver island is protected within parks (e.g. Juan de Fuca Provincial Park, Pacific Rim Park Reserve, Hesquiat Peninsula Park, etc.). However, many of the scientifically important fossil sites especially on southwestern Vancouver Island beaches still remain unprotected (e.g. Muir Creek Beach, Kirby Creek, French Beach, Nootka Island, and others). These are potential candidates for future fossil management and heritage site protection.

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Vista of coastal Vancouver Island rocks of the Pacific Rim and Crescent terranes at Sombrio Beach. The Olympic Mountains (USA) are in the distance across the Strait of Juan de Fuca.

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