## Long Ago...

Most of the rocks at Green Cove formed during the Devonian period, which lasted from 419 to 359 million years ago. At that time, the Earth's oceans teemed with fish, and early amphibians were venturing onto land—no dinosaurs existed yet. Although 400 million years may seem unimaginably long ago, it is relatively recent in terms of geological time, considering that the Earth is more than 10 times that old (4,600 million years).

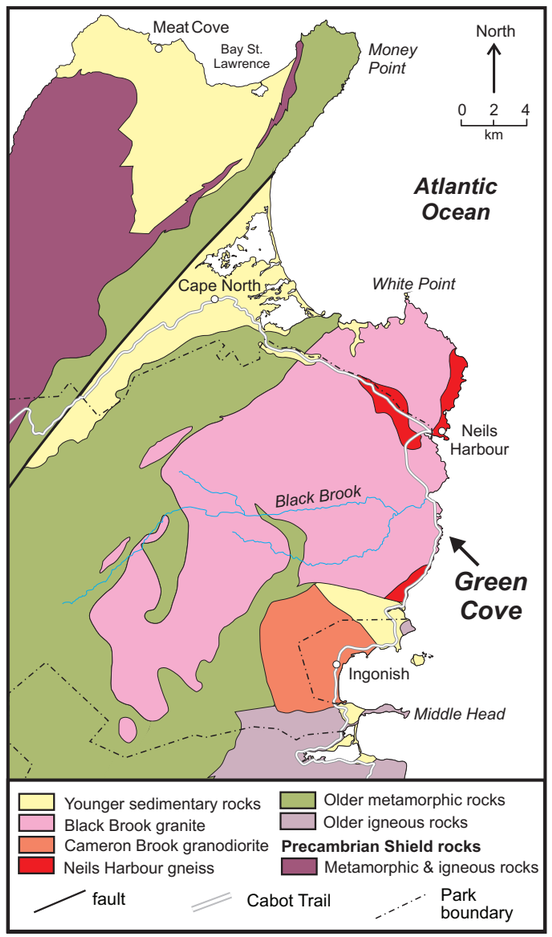
During the Devonian period several tectonic plates converged and collided along what is now the eastern edge of North America, including Cape Breton Island. During these collisions, rocks 10 to 15 kilometres below the surface were hot and under great pressure. The heat and pressure caused these rocks to recrystallize to form metamorphic rocks, and some of them melted to form molten rock (magma). The magma cooled and crystallized deep underground to form bodies of igneous rock. Magma also filled cracks in the surrounding solid rock. The result was a complex "plumbing system" now spectacularly exposed at Green Cove (photo below).

**Note: It is illegal to collect or disturb any natural object including plants, animals, and rocks in a National Park.**

**Safety: Be careful to stay away from steeply sloping rock surfaces, or areas where waves are breaking on the rocks. Wet rocks are slippery and rogue waves may occur at any time.**

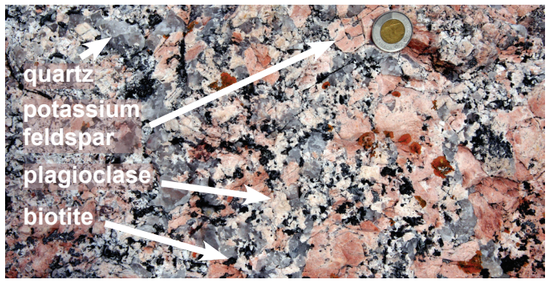
## Rocks in the Green Cove Area

Over time, erosion has resulted in the exposure of a variety of rocks of different origins and ages in the Green Cove area (see map below). Most of the rocks are igneous and part of the Black Brook granite (see adjacent panel). The magma that formed the Black Brook granite also intruded nearby older igneous rocks (Cameron Brook granodiorite) and older metamorphic rocks (described later). During the early Carboniferous (359 to 323 million years ago), sedimentary rocks covered the igneous and metamorphic rocks in some places, such as Ingonish Harbour.

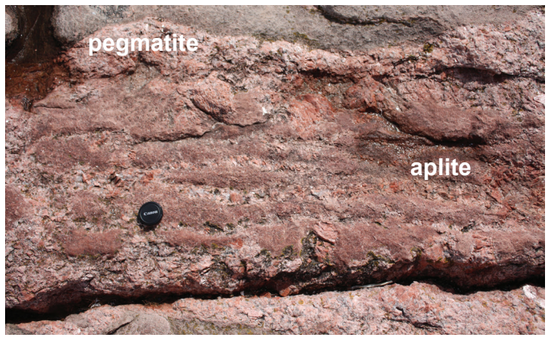



## Black Brook Granite

Most of the rocks at Green Cove are grey and pink varieties of the Black Brook granite. The crystal size varies from less than a millimetre to several centimetres across. One pink variety, pegmatite, has very large crystals. Another, aplite, has small crystals that give it a sugary appearance. Sheets of these two varieties cut across areas of grey granite with medium-sized crystals. All three types formed about 373 million years ago.



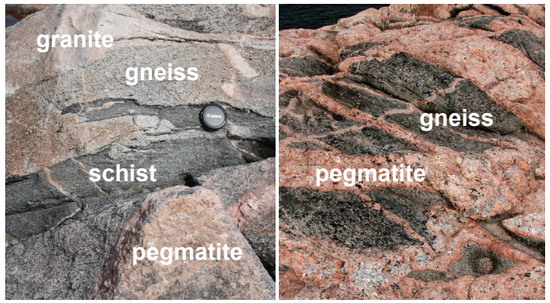

Granite consists mostly of 3 minerals. They are easiest to see in pegmatite (photo above): quartz (grey), potassium feldspar (pink), and plagioclase (white). This granite also contains small amounts of flaky mica, typically dark (biotite) but less commonly transparent (muscovite).




Pegmatite and aplite often occur in the same sheet or vein (photo above). Both formed when magma filled cracks that opened as the grey granite solidified. The amount of water in each batch of magma determined the crystal size: with a lot of water, the crystals grew more quickly, forming pegmatite; with small amounts of water, crystal growth slowed down to form fine-grained aplite.

## Metamorphic Rocks

Two types of metamorphic rocks occur as blocks in granite and pegmatite at Green Cove (photos below). Metamorphic rocks with aligned bands of various granular minerals like feldspar and quartz are known as gneiss (pronounced "nice"). Those with abundant aligned flaky minerals like mica are called schist (pronounced "shist").




**(Left) Metamorphic rocks (schist and gneiss) in blocks of various sizes, shapes, and colours in granite and pegmatite. (Right) Blocks of gneiss surrounded by pegmatite.**

The blocks of gneiss are from the Neils Harbour gneiss (see map). This gneiss formed mainly by metamorphism of granodiorite, a type of plutonic igneous rock similar to granite, but with more dark-coloured (iron- and magnesium-rich) minerals. Prior to metamorphism the granodiorite had large pink potassium feldspar crystals. You can still see these in the gneiss in some places surrounded by smaller crystals, as in the photo below.

## Old, Older, and Oldest...

The ages of granite and granodiorite can be determined by analyzing the abundance of radioactive elements such as uranium in tiny crystals of the mineral zircon in the rock. Analyses of zircon in the gneiss have revealed that the original granodiorite from which the gneiss formed is 403 million years old—30 million years older than the Black Brook granite.

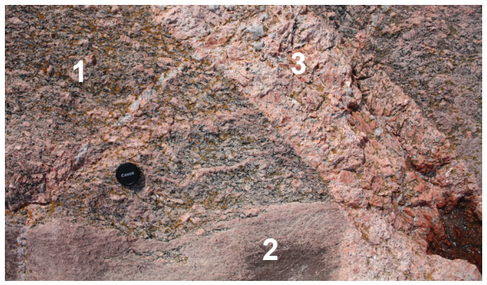
The Cameron Brook granodiorite in nearby Ingonish (see map) is also 403 million years old and, like the Neils Harbour gneiss, it contains large crystals of potassium feldspar. The gneiss fragments at Green Cove are probably metamorphosed pieces of the Cameron Brook granodiorite, picked up by the Black Brook granite magma as it intruded.

The oldest rocks at Green Cove are the rare blocks of schist (photos below). Some blocks of schist contain an especially large abundance of flaky, black mica (biotite) crystals, which sparkle in the sun. Clues like cross-cutting relations suggest that it is old, but no one has yet determined the age of the schist blocks at Green Cove.

**(Left) Small fragment of schist in granite. (Right) Larger block of biotite schist surrounded by pegmatite.**

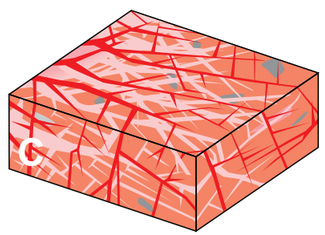
## Reading the Rocks

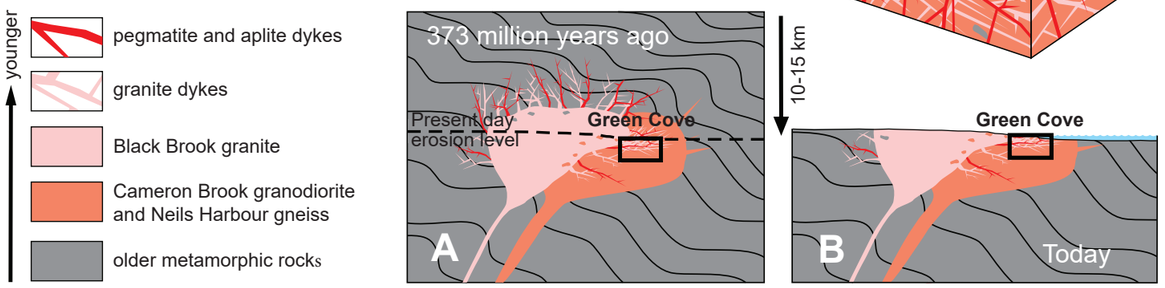
Cross-cutting relations indicate relative ages of the rocks at Green Cove. In the photo below, the Neils Harbour gneiss with large pink potassium feldspar crystals (1) has been intruded by a dyke of Black Brook granite (2) and both are intruded by a pegmatite dyke (3).




## Interpreting Geological History

The rocks visible at Green Cove today formed 10 to 15 kilometres below the surface and were later exposed by tectonic uplift and erosion. At the bottom of the page are two views cutting down through the Earth's crust to show the Cameron Brook granodiorite and Black Brook granite with a related network of cracks filled by granite, pegmatite, and aplite: (A) deep in the Earth 373 million years ago; and (B) exposed today at the Earth's surface. The block diagram (C) represents the area within the box on views (A) and (B) and schematically illustrates the rocks in and beneath the outcrop at Green Cove.




## Protecting a Rare View

The rocks at Green Cove illustrate processes that take place deep in the crust where Earth's tectonic plates converge and collide. Similar rocks, for example, are probably being formed today beneath the Himalayan Mountains as India collides with Asia. An accessible display of rocks that so clearly and beautifully illustrate these deep-seated processes is rare.

It is fortunate that Green Cove is a designated Nova Scotia Geoheritage Site protected by its location in a National Park. Here you can walk on rocks that preserve unsurpassed evidence about the ancient history of the Cape Breton Highlands. They provide a treasured glimpse into the Earth's distant past and invaluable insights about Earth processes.

**Other Recommended Resources**
(available at http://atlanticgeosciencesociety.ca)
*Nova Scotia Rocks: Explore Our Geology* (2nd edition)
Donohoe, H.V. Jr., White, C.E., Raeside, R.P. and Fisher, B.E. 2005. *Nova Scotia Geological Highway Map* (3rd edition)
*The Last Billion Years: A Geological History of the Maritime Provinces of Canada*. Nimbus Publishing, 2001.
*Four Billion Years and Counting: Canada's Geological Heritage*. Canadian Federation of Earth Sciences. Nimbus Publishing, 2014.
Hild, M.H., and Barr, S.M. 2015. *Geology of Nova Scotia: Touring through time at 48 scenic sites*. Boulder Publishing.
**Notes:** This brochure was prepared by Sandra Barr, Rob Fensome, and Martha Hickman Hild for the Atlantic Geoscience Society. Andrew MacRae drafted the original diagram showing the origin of the Black Brook granite, and Bill MacMillan provided the initial geological map. Nikole Bingham-Kozlowski, John Calder, Miranda Dodd, and Kersti Tacreiter reviewed drafts of the text. Graphic design was by Eugene MacDonald.

# Geology of *Green Cove*

### A Nova Scotia Geoheritage Site

**Natural exposures of rock are invaluable to anyone interested in our planet's past. The rocks at Green Cove in the Cape Breton Highlands National Park of Canada are safely accessible and continuously swept clean through the actions of weather and waves, making them wonderfully informative.**

**This brochure explains how the colourful mixture of rocks at Green Cove formed. The story begins deep in the Earth's crust and deep in the past.**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