GOVERNMENT OF
NEWFOUNDLAND AND LABRADOR
**Department of Mines and Energy**
Geological Survey

# A SHORT HISTORY OF THE GEOLOGY OF THE BIRD COVE AREA: An Educational Resource and Field Guide

I. Knight and W.D. Boyce

Open File NFLD/2844

St. John's, Newfoundland
September, 2003

**NOTE**



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**FRONTISPIECE**

Meany's Point mounds, looking east across the mouth of Long Bottom toward Bird Cove.

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# INTRODUCTION

The mountains, hills and coastal plain of Newfoundland's Great Northern Peninsula are land-scapes of inspiring natural beauty. The west coast has been home to a necklace of small fishing and logging communities settled by the French, the English and the Scots for almost four centuries. Old Spanish church records indicate that the Basques hunted whale and fished along these shores before the English and French settlers arrived. No doubt, Norsemen venturing away from L'Anse aux Meadows at the dawn of the second millenium would have gazed from their ships across the shallow, low rocky shore, backed by the impressive plateaus and mountain summits. Before them, the coast was ranged by bands of mobile people who hunted and fished for thousands of years from small camps scattered among the embayments, estuaries, points and islands of this rocky shoreline. But, although the present landscape of the Great Northern Peninsula would have been familiar to those pioneers, they undoubtedly would have been unaware of the vast span of time represented by the rocks hidden beneath the shoreline, marshes and forests.

The first search for this antiquity began in 1861 when the geologist James Richardson surveyed the coast for the Geological Survey of Canada. He examined rocks and collected fossils as part of a larger reconnaisance survey of the Great Northern Peninsula coastline. His fossil collections and geological observations were published in the famous, "Geology of Canada", by Sir William Logan in 1863, and in a treatise on fossils by Elkanah Billings in 1865. As the century turned a leaf, Alexander Murray and James P. Howley of the Geological Survey of Newfoundland undertook a similar survey and mistakenly showed that Silurian rocks dominated much of the coast and coastal plain of the Great Northern Peninsula, near Bird Cove. Expeditions, funded principally by museums in the United States during the early part of the 20$^{th}$ century doggedly walked and sailed the coast to add to the geological understanding of the coast. Modern geological maps and studies of the region are principally, however, the work of the Geological Survey of Newfoundland and Labrador, work that began in the late 1970s and continues to this day.

# GEOLOGICAL HISTORY

The geological history of the Bird Cove area stretches back over 1.4 billion years. The oldest rocks are found in the Long Range Mountains, the rugged spine of the Great Northern Peninsula. These rocks form the southeast edge of the Canadian shield, an ancient granitic continental core that included North America, Greenland and parts of Europe (and perhaps parts of South America) and is known as **Laurentia** by geologists (Figure 1).

Lying west and north of the Long Range Mountains, lowlands include hills and a coastal plain underlain by rocks deposited in tropical, shallow shelf seas along the edge of the Laurentian continent. The shallow tropical shelf flourished for more than 60 million years beginning about 520 million years ago, a time spanning parts of the **Cambrian** and **Ordovician** periods (Figure 2). Fossils preserved in these rocks show that some of the earliest forms of invertebrate animal life flourished in the Cambrian and Ordovician sea that lay just south of the equator at the edge of the ancient **Iapetus Ocean**[1] (Figure 1).

[1] Iapetus is the father of Atlantis of Greek mythology. The ancient Iapetus Ocean is thus thought of as the forebear of the modern Atlantic Ocean.


**Figure 1.** *Earth, its continents and oceans, about 600 to 500 million years ago. The lower globe shows a supercontinent **Rhodinia** that split into various parts about 600 million years ago. **Laurentia** rifted apart and drifted gradually away from the supercontinent creating the Iapetus Ocean (upper globe). Western Newfoundland is indicated. (Adapted from Dalziel, 1997.)*

This Bahaman-like setting was gradually terminated around 460 million years ago, when tumultuous upheavals of the earth's crust battered the western Newfoundland area for the next 100 million years or more. A dynamic global process known as **plate tectonics**[2], saw the Iapetus Ocean narrow and volcanic oceanic islands and once distant continents from the far side of the ocean, collide with the Laurentian continental margin. The long-lived process, that ranged from the late Ordovician time through Silurian time and into Devonian time, is known as **orogeny**. During this time, huge masses of rocks from beneath the ancient ocean were slowly pushed into western Newfoundland, as for example the Tablelands of Gros Morne National Park and the White Hills of Hare Bay to the north. Simultaneously, the Cambrian and Ordovician shelf rocks of western Newfoundland were complexly folded and faulted and were uplifted together with the rest of Newfoundland to form the rugged mountain belt that today forms the north-eastern end of the Appalachian Mountains of eastern North America. The St. Barbe coast and the islands and bays of the Dog Peninsula and Old Ferrole Harbour (Figure 3) lie at the very westernmost edge of the mountain front, an area of sharp topographic contrasts, principally controlled by the location of large fractures (faults) through the earth's crust.

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[2] The earth's crust is made up of a number of large and small rigid plates that float upon the earth's mantle and core. Slowly, but surely, the plates move over the surface of the globe in response to processes deep in the centre of the earth. Each plate interacts with its adjacent plates in a dynamic process known as Plate Tectonics. New volcanic oceanic crust is added to growing edges of plates at the mid-oceanic ridges e.g., Iceland. Where plates collide, one plate dives below the other to form deep ocean trenches. Long strings of volcanic islands form as diving rocks melt and lava is forced to the surface, e.g., island chains of the Pacific Ocean. If continents collide (e.g., Europe and Africa or India and Asia) mountain ranges such as the Alps and Himalayan Mountains form. Plates rub against one another and cause tectonic events such as earthquakes, e.g., San Andreas Fault in California.

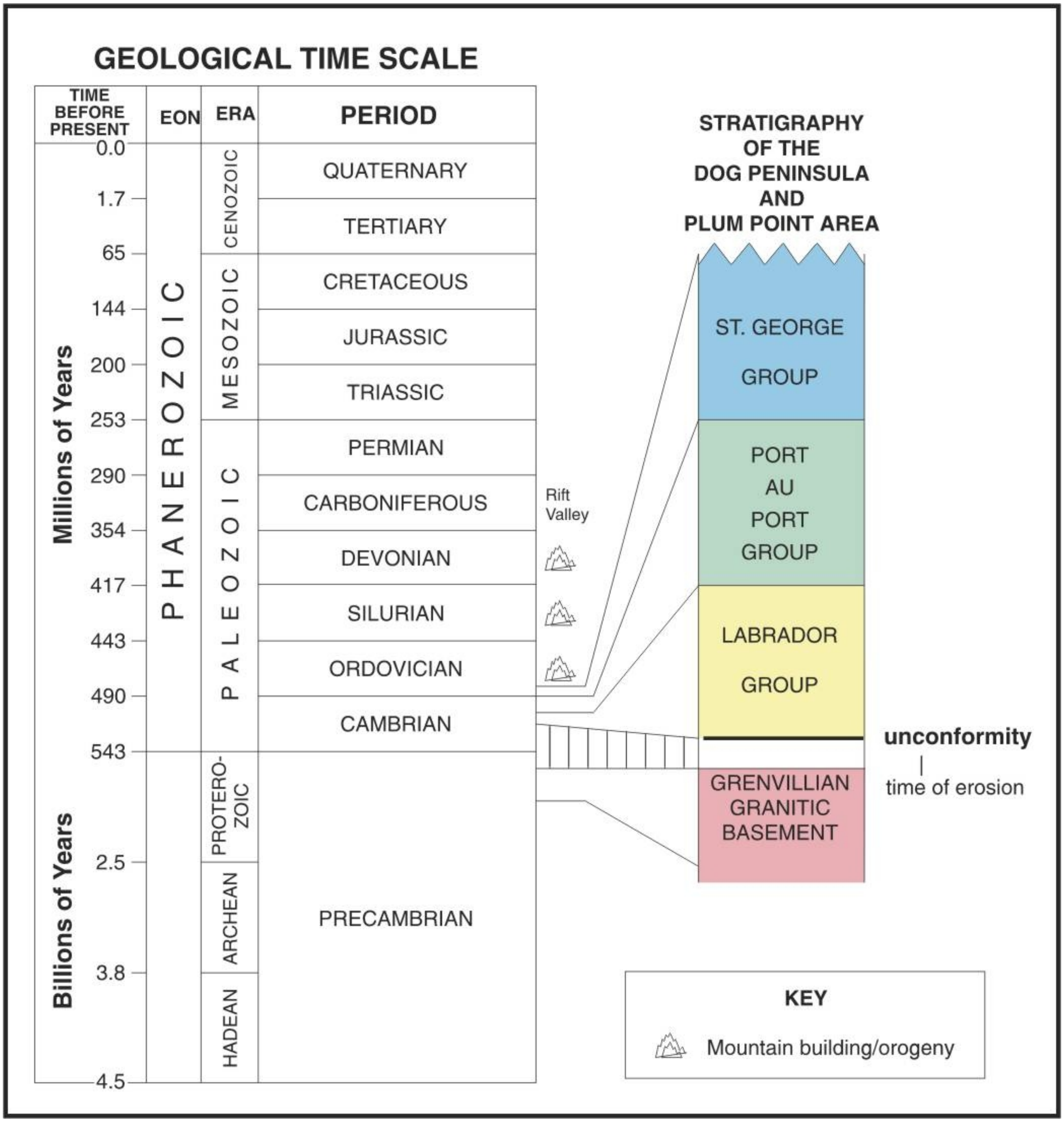
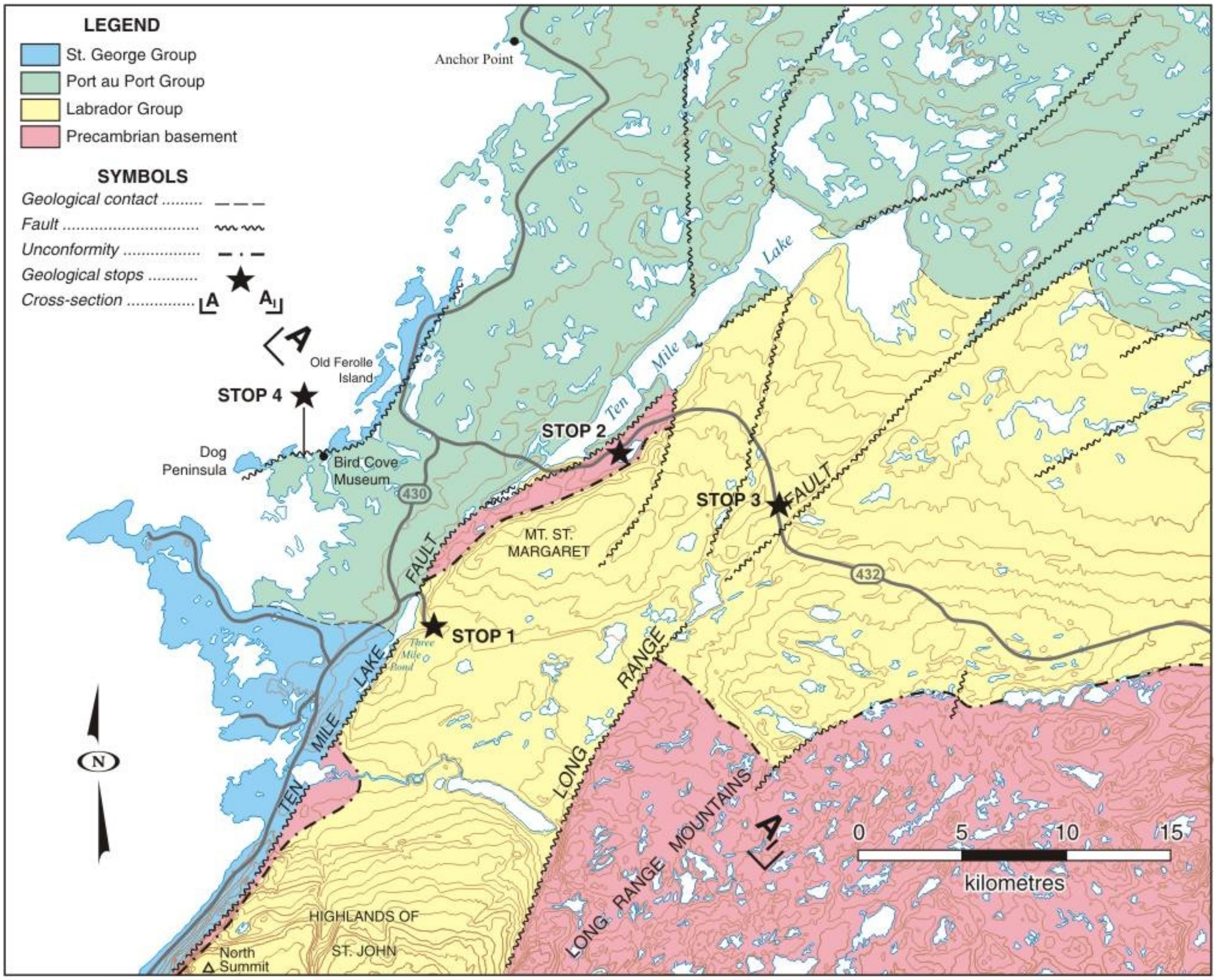



**Figure 2.** *Geological time scale and the stratigraphy of the sedimentary rocks of the Dog Peninsula and Plum Point area.*



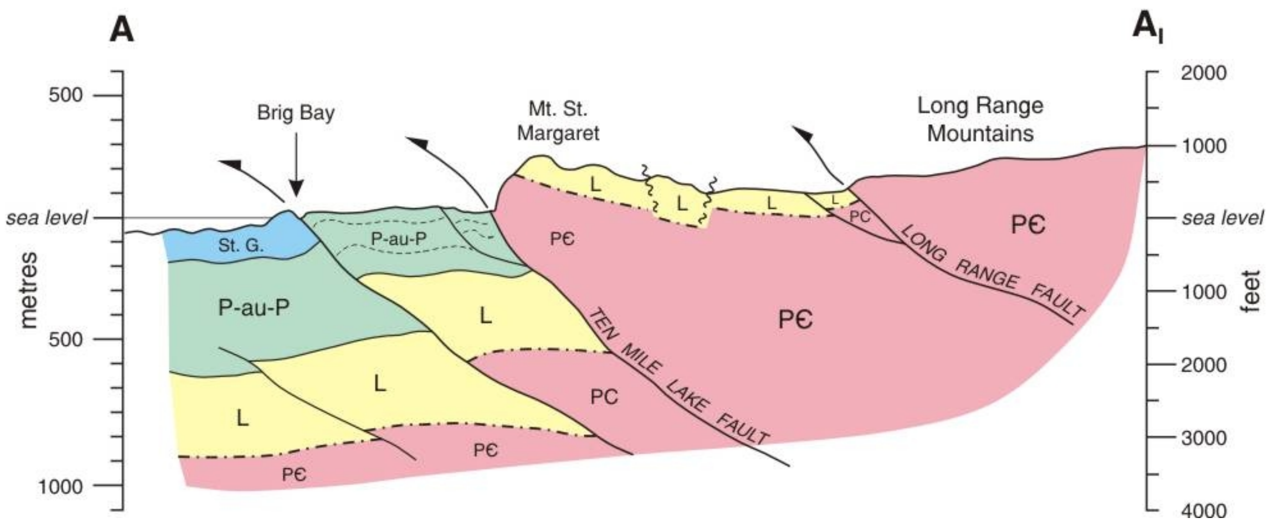




**Figure 3:** *Simplified geology map and cross section of the Bird Cove area (modified from Maps 84-24, 84-25 and 85-30, Nfld. Dept. of Mines and Energy).*

Although the Plum Point area provides no direct evidence for when and how often the faults moved during the next 300 million years, it is probable that the area was shaken repeatedly by earthquakes during the Carboniferous period (see Figure 2). Just 60 km to the east at Conche on the eastern shore of the Great Northern Peninsula folded Carboniferous sandstones and shales deposited by rivers and in lakes are confined to a fault-bounded rift valley. To form this rift valley, the Appalachian mountain belt would have been wrenched apart along major faults during the Carboniferous, creating a large landlocked depression that would have been filled by the non-marine sedimentary rocks. At this time, the climate was tropical to savannah to desert-like as Newfoundland remained near the equator. Close, modern day analogs, both tectonically and environmentally are provided by comparison to the valley of the Dead Sea in Arabia and Death Valley in California. Fault stresses in western Newfoundland that would have been large enough to form the rift valleys of the Conche area imply that major earthquakes certainly rocked the Dog Peninsula at that ancient time.

For the next 300 million years the geological history of western Newfoundland is largely obscure. For all of this time, the island as a whole formed a range of mountains that was effectively eroded under tropical, temperate and ice-age climates by rivers, seas and glaciers. The present day topography reflects the prolonged action of glaciers over the last few hundred thousand years upon an older landscape of river valleys and mountain plateaus.

# SOME SIMPLE GEOLOGICAL PRINCIPLES

The immediate neighbourhood of Bird Cove and Plum Point affords an opportunity to study some of the marine sedimentary rocks that formed in the tropical shelf seas of the Cambrian and Ordovician periods and some of the faults that deformed the rocks and gradually moved huge tracts of rock hundreds of metres during the fashioning of the Great Northern Peninsula.

Sedimentary rocks are formed when layers of sediment, e.g., sand and mud, are buried and the soft sediment is gradually converted over millions of years by a variety of burial and deformational processes into rock e.g., sandstone and mudstone. Sedimentary rocks are laid down in sequential layers, and the oldest layers are buried by younger layers to form a **succession**. The study of this layering (also known as strata and bedding) is called **stratigraphy**[3]. By studying the different layers of rock, the geologist gathers information that allows the reconstruction of the ancient environment in which the rocks were deposited.

To help in this reconstruction, the geologist first maps the rocks, describes the rocks according to their composition and sedimentary structures preserved, and collects fossils that will confirm the age of the

[3] The study of stratigraphy in Europe and North America over much of the last 300 years has resulted in the division of geological time into a number of time periods, each of tens of millions of years, e.g., Cambrian and Ordovician. The time periods are in turn grouped together into eras of many hundreds of millions of years, as for example the Paleozoic Era (Figure 2). Collection and study of fossils from strata was fundamental in leading to this division of time periods and eras and it was recognized that the first shelly fossils overlay strata that were devoid of similar fossils, hence the designation Paleozoic for this earliest time of complex animal life. Rocks of the pre-Paleozoic era were referred to the Precambrian. Subsequently, the latter was renamed the Proterozoic (time of the Protozoans) because Proterozoic sedimentary rocks provide abundant evidence that simple, single- and multi-celled organisms thrived for more than 2 billion years before the first shelly fossils appeared about 540 million years age.

rocks. Maps are constructed by grouping together rocks of similar type, distinguishing them from neighbouring rock groups of different type and then mapping the various groups through the country (Figure 3). Mapping also defines faults and folds that deform the rocks in an area. In the local area, faults are often the location of some of the larger lakes; for example Ten Mile Lake and Three Mile Pond.

Sedimentary rock types are dependant upon the original components that made up the soft sediment when it was first deposited. In the Plum Point area for example, sandstone formed from layers composed originally of sand; shale was originally layers of mud. Limestone, which is composed of calcium carbonate ($CaCo_3$), was originally layers of lime. Dolostone, also a carbonate rock related to limestone, but rich in magnesium ($CaMg\ (Co_3)_2$), formed in ways similar to limestone. Limestone and dolostone are mostly formed today on continental shelves and oceanic islands in tropical shallow seas where oceans are clear and free of suspended mud and sand discharged by large rivers.

When sediment is first laid down on the sea floor or at a shoreline, it is shaped by currents and other physical forces including organisms into **sedimentary structures**. For example, ripples are common on beaches and can be easily distinquished as ripple marks in rocks. Wet mud, when exposed to the hot sun for long periods, will dry out, shrink in volume and the surface of the mud will crack. Such mudcracks are common in many sedimentary rocks. Sediment on the sea floor is commonly burrowed by organisms such as crustaceans and worms. Traces of burrows are commonly preserved in sedimentary rocks and are termed **trace fossils**. These few examples illustrate the use geologist make of such features to understand the type of environment where a particular rock may have formed.

Fossils are extremely important in understanding the depositional environment and for dating sedimentary rock. For example, some animals such as sea urchins and related echinoids only tolerate normal oceanic water. Aquatic snails, however, survive in a broad range of marine salinities and also live happily in freshwater. Rocks are dated in a relative sense using fossils which are identified by a paleontologist. Particular fossils are found in rocks of known ages and time periods and this allows the geologist to confidently distinquish Cambrian from Ordovician rocks.

# GEOLOGY OF THE PLUM POINT AREA AND THE DOG PENINSULA

The map of the Dog Peninsula and the area inland of Plum Point distinguishes rocks of four groups (Figure 3). The four groups are Grenvillian granites, Cambrian Labrador and Port au Port groups and the Ordovician St. George Group. The first and oldest group of rocks is part of the Canadian Shield and consists of Precambrian Grenvillian granites and gneisses of a billion years and older (Figure 2). This archaic group formed an ancient continental landmass which was drowned when the Newfoundland part of Laurentia was flooded by the Iapetus Ocean about 520 million years ago. As such, the granitic rocks form the basement to the overlying sedimentary rocks.

The second and oldest sedimentary rocks in the area belong to the **Labrador Group**, so named, because the rocks are best exposed across the Strait of Belle Isle in southern Labrador. These rocks, which are fossiliferous, consist of sandstone, shale and limestone. Shales in this group are rich in trilobites, and the limestones and sandstones also host many trace fossils, as well as some of the earth's most ancient fossil reefs. The Labrador Group underlies the Highlands of St. John and Mount St. Margaret, east of the Viking Highway and south of Plum Point (Figure 4).

Overlying the Labrador Group, the succession consists of dolostone and limestone, and minor shale. This third group consists of Cambrian age dolostone and shale of the **Port au Port Group** and Ordovician limestone and dolostone of the **St. George Group** (both names are taken from the Port au Port Peninsula near Stephenville where similar rocks are well exposed). These rocks underlie the low-lying coastline near Plum Point and much of the marshy and lake-strewn rocky barrens to the northeast along, and inland of, the south shore of the Straits of Belle Isle. The limestones and dolostones were deposited in shallow tropical seas and shorelines similar to that seen in the Bahamas today (Figure 5).

As you will note, the rock layers are almost horizontal in the Bird Cove area and it is possible to walk along the present shoreline for many metres on a single bedding plane (a surface that represents an original depositional surface). This is akin to walking across fossilized ancient sea floor or shoreline. However, over broad zones close to faults, the rocks are buckled and fractured and faults are commonly marked by bodies of brecciated and broken rock.

**Figure 4.** *The North Summit of the Highlands of St. John as seen from the Viking Highway (Route 430). A well-bedded succession of almost flat-lying sedimentary rocks of the Cambrian Labrador Group are exposed in the mountain's scarp face. The narrow saddle between the scarp and the small hill to the west marks the trace of the major Ten Mile Lake Fault illustrated on the map (Figure 3).*

**Figure 5.** *The modern tropical carbonate shelf in the Bahamas compares to the environment of western Newfoundland in the Cambrian and Ordovician. Tidal flats occur behind and left of the island, the large white area is an oölitic tidal sand shoal. A shallow lagoon occurs in the foreground.*

# STOPS OF GEOLOGICAL INTEREST

A note of caution. Some of these stops are along main roads, others in quarries and some on the shoreline. Care should be taken along the roads to avoid stepping into traffic and to park without duly hindering traffic flow. At quarries, care should be taken to avoid falling over rock faces, or stepping beneath, or hammering samples below, rocks that may be liable to fall. The latter is common in spring and early summer when gravity and weathering will often release rock rubble weakened by winter frost and snow. On the shore, tides can run in fast along marine arms and long bays so that you may find yourself cut off or needing to walk farther to return to your starting point. Strong winds can generate significant waves at times. In addition, it is prudent to carry some extra clothing, a spare snack or two, some water and to let the museum staff know if you are planning to walk the coast of Dog Peninsula. Last, we are all grateful if you carry back your used food and drink containers to a garbage bin.

It is an advantage but not essential to have a hand lens, stone hammer and chisel, protective eyeglasses and if possible a small plastic bottle of 10% hydrochloric acid to use at the various stops. Newspaper, paper towels and toilet paper are excellent to wrap fossils or mineral samples you might wish to collect. A hand lens will allow you to easily inspect the details of fossils, crystals and rocks; the acid will fizz enthusiastically if a drop is added to a limestone but will not fizz if placed on dolostone; the hammer and chisel will enable you to break rocks and search for unweathered fossils.

Directions to stops commence at the Bird Cove Heritage Museum at Bird Cove.

**Locality 1: Trilobites, Trace Fossils and Shales – Three Mile Pond Quarry, Mount St. Margaret**
(NTS map area 12I/15, NAD 27 UTM 510067E 5648159N)

Travel east from the museum to Plum Point Motel, turn south onto the Viking Highway (Route 430) and proceed south past the junction with Route 432 to Main Brook and Roddickton. Continue south for approximately 9 km to the dirt road leading to Three Mile Pond Park. Turn east off the highway and follow the road for 2.5 km, past the head of the lake, past the park entrance and up into the quarry in the hill above. Ahead of you is a long quarry face with flat lying bedding.

The lower part of the quarry is excavated in shales of the Labrador Group and is best visited to the left of the entrance (Figure 6). The dark grey shales, which are Cambrian in age, were originally muddy deposits of a shallow sea that was rich in marine life so that both body fossils and trace fossils are abundant here (Figure 7). A few limestone beds also occur. The shales indicate that bottom conditions were generally quiet and rarely effected by storms. These shales are rich in potash and the shaly soils of this area have long been used to grow vegetables because of the excellent results.

**Figure 6.** *The quarry in Labrador Group shales, Mount St. Margaret. Trilobites are common in the low benches below the trees* (see below).

The most impressive and common fossils found are trilobites (Figures 8, 9 and 10), extinct arthropods distantly related to modern horseshoe crabs. As their name implies, trilobites are 3-lobed. A central axial lobe is bordered by two side lobes (the pleural lobes) along the three main body parts, a head (cephalon), a segmented thorax and a tail (pygidium). Most trilobites possessed a pair of compound eyes and all had a series of paired legs for each segment and paired antennae at the head. These appendages are rarely preserved. Like their distant cousins, the crabs and lobsters, trilobites possessed a hard exoskeleton and grew larger by periodically moulting, shedding their too small exoskeleton and growing a new larger shell. Consequently, the trilobites found in the quarry are usually disarticulated parts of

**Figure 7.** *A fossil-rich limestone bed between shales in the Labrador Group at Mount St. Margaret quarry. Both shale and limestone yield fossils of various kinds.*

**Figure 8.** Olenellus thompsoni *Hall (1859). Collected by W.D. Boyce in southern Labrador.*

**Figure 9.** Wanneria logani *(Walcott, 1910). Location in Bonne Bay.*

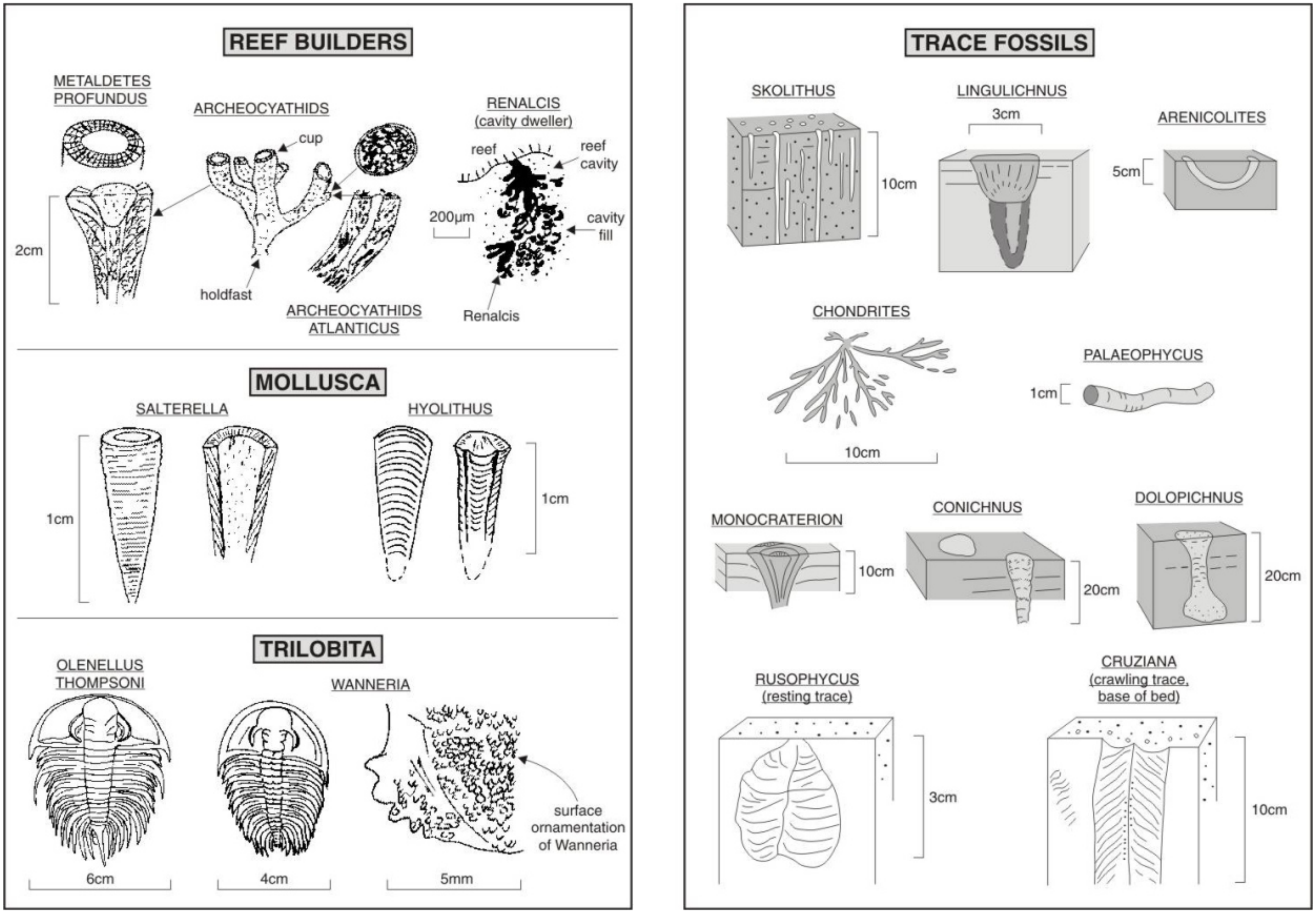



**Figure 10.** *Fossils and trace fossils of the Labrador Group.*

various sizes and growth stages but sometimes a complete fossil can be recovered. Trilobites lived by scavenging and by preying on other smaller organisms on, and above, the sea floor.

The most common trilobites here are *Olenellus thompsoni* (Hall, 1859), and *Wanneria logani* (Walcott, 1910). The former species is smooth shelled while the latter's shell is ornamented as though with overlapping scales. Associated fossils include small cone-shaped shells, *Hyolithes* and *Salterella*, and small, black, disc-shaped inarticulate brachiopod shells (*see* Figure 10).

Overlying the shales, the succession includes shale interlayered (interbedded) with thin beds of sandstone and limestone. Trace fossils abound in these beds and are best seen on the blocks and rubble at the base of the main quarry face. The sandstones show sedimentary structures which indicate that they were deposited by repetitive currents generated by storms that crossed the ancient shelf. Animals burrowed the sand layers once the storms had passed; vertical, u-shaped and long and short horizontal tubes are common evidence of burrowing and filter feeding organisms. The bases of beds are ornamented by other trace fossils that preserve the crawling and resting activity of marine animals on the muddy sea floor between storms. The legs of trilobites created distinctive crawling trails, Cruziana, and a bi-lobed resting and/or hunting trace called Rusophycus where the trilobite partly buried itself in the mud in much the same way crabs hide in beach sand (*see* Figure 10).

At the top of the quarry, within the trees, the rocks change to limestone, which preserve some of the oldest fossil reefs in the world. Unfortunately, these are not well exposed here and are best seen at Locality 3. However, if you are unable to visit the other stop, a search of large grey and pink limestone blocks on the floor of the eastern shale quarry will reveal the reef fossils. Modern reefs are rich in corals, but these ancient reefs were built by now-extinct sponges called archeocyathids (pronounced ark e o sigh ath id). The sponges consist of sheet, stick, cup and branching forms that superficially resemble types of modern coral.

**Locality 2: Precambrian Granitic Rocks – Ten Mile Lake**
(NTS area 12P/2 and 3; NAD 27, UTM 517000E 555350N)

Return to the junction of Route 430 with Route 432 to Roddickton. Proceed east along 432 for 6.7 km, crossing Ten Mile Lake before coming to a long roadcut to the southeast of the road. This roadside outcrop consists of Precambrian granitic rocks that form the core of the Long Range Mountains. The rocks are at least 1 billion years old and form the basement to the Cambrian age Labrador Group rocks. The granitic rocks are grey to pinkish in colour and crystalline in texture. White and grey-blue grains are quartz; pink crystals are feldspar. Brown and white, shiny, platy minerals that can be flaked using a penknife are micas. Dark green, robust and hard crystals are probably pyroxene or horneblende. Vertical sheets of black rock are dykes of volcanic origin that were squeezed (intruded) through weak fracture zones in the granite about 600 million years ago.

Behind you, Ten Mile Lake occupies a deep linear trough, which was eroded by glaciers, along the trace of the Ten Mile Lake Fault. The fault separates the Precambrian rocks of Mount St. Margaret from younger dolostones of the Port au Port Group that underlie the lowlands to the west. Two points projecting out from opposite shores into the lake are remnants of a very large arcuate glacial moraine deposited by a late advance of the ice sheets and glaciers of the Great Northern Peninsula about 11 000 years ago.

**Locality 3: Archeocyathid Reefs of the Labrador Group – Route 432**
(NTS map area 12P/2 & 3, NAD 27, UTM 526915E 5653375N)

Proceed east from locality 2 for 14.3 km (21 km from the junction with Route 430) to a roadcut at the brow of a hill (Figure 11). Several reefs of archeocyathids are clearly visible in the low cliff face either side of the roadcut. When driving to the roadcut, it is possible to visit a number of large quarries on the south side of the road between localities 2 and 3. These are shale quarries, similar to Locality 1. They provide additional opportunities to find fossils and trace fossils for collection. Detailed knowledge of the stratigraphy of the Labrador Group tells us that the reefs occur above the shales and are thus younger in age.

**Figure 11.** *View of the roadcut, Route 432, through archeocyathid reefs and grainstone filled channels, Labrador Group.*

The rock face on the north side of the road displays several archeocyathid reefs, each about 5 m wide and high, separated by inter-reef channels of different widths (Figures 12 and 13). The channels are filled by oölitic grainstone containing lenses of fossiliferous grainstone. A bed of grainstone[4],1.5 m thick, but without reefs, overlies the reef layer at the top of the cliff. The fossiliferous grainstone includes the cone-shaped mollusc *Salterella*, the trilobite *Wanneria* and parts of echinoderms. The grainstone is pebbly in places where rock fragments were eroded from the adjacent reefs by currents and breaking waves.

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[4] Grainstone is a term used for a limestone that is made up of sand-sized grains. Oölites are small spherical grains that formed in shallow open-ocean settings where currents generated by waves and tides constantly roll the grains around on the sea floor. Shell fragments from dead animals provide the sand grains for fossiliferous grainstones.

**Figure 12.** *Closer view of an archeocyathid reef surrounded and overlain by crossbedded grainstone, Route 432.*

**Figure 13.** *Crossbedded grainstone surrounding and overlying Lower Cambrian archeocyathid reefs, Route 432. Three reefs are present here, the largest located closest to the reader. Crossbeds are best seen in the middle and left of the photograph.*

Sedimentary structure in the channel grainstone and the topmost grainstone bed is mostly crossbedding (Figure 13). The latter is the internal layered structure of sand wave and large ripples, which were created by tidal currents, as they swept through the channels between the reefs. Crossbeds are essentially sloping sediment layers that dip in the down-current direction of the currents that produced them. Many of these crossbeds face to the west suggesting that the main currents were from east to west. However, there are crossbeds that have the opposite sense of dip, evidence that tidal currents operated through the channels between the reefs.

The reef is built of dense packed to open clusters of large sheets, cups, sticks and branching bushes of a variety of archeocyathids. You will note that there are irregular patches of fossiliferous grainstone and structureless fine-grained grey and red limestone in the reefs. This indicates that the reefs, although rigid, were full of open spaces and cavities. These were filled by lime mud and shell debris washed into the reef by storms, waves and currents that flushed sea water through the reef. Beneath archeocyathids in some of the cavities, there are small, dark-grey, bushy structures. These are fossils of calcareous blue-green algae.

By standing above, or at the edge of, a reef on the north side of the road you can look south across the road and pick out the rest of the reef. By doing so, you can see that the reefs form a series of parallel reef walls, each trending almost due east, and each bounded by channels (Figure 14). This suggests

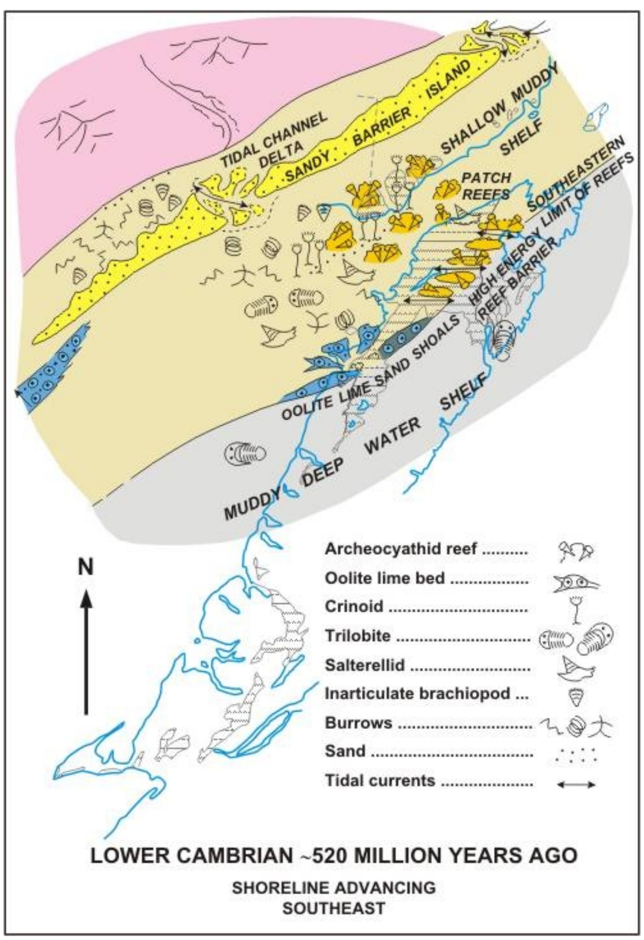


**Figure 14.** *A simplified sketch map of the Cambrian shelf in the area of the Great Northern Peninsula about 520 million years ago during the deposition of the middle part of the Labrador Group. This conceptual sketch is based on a number of studies of rocks of the Labrador Group. Note the high-energy reef and grainstone barrier complex dominating the area close to Locality 3.*

that the reefs were fashioned into this east–west orientation by the hydrodynamic forces of the prevailing weather and currents of that time in the Cambrian. The style of reefs and associated grainstone suggest that the reef complex grew in a high-energy, shallow-water setting on the Cambrian shelf. By comparison to modern reef and oölitic grainstone environments in the Bahama Banks of the Caribbean, the reefs probably grew close to the edge of a shelf bank with prevailing weather and currents from east to west implying ocean to the east and land or an island to the west.

**Locality 4: A Walk on the Dog Peninsula – Cambrian and Ordovician Tidal Flats and Algal Mounds and Quaternary Postglacial Raised Beaches**

The Dog Peninsula offers two alternative geological rambles (Figure 15); one, a long walk that will take at least 3 1/2 hours, the second a shorter walk which can be enjoyed in about a hour. In both cases, the trip is best done when the tide is falling.

Leave the museum and go west out to the wharves and fishing sheds at the mouth of Long Bottom. Walk to the stepping stones to cross midway down the sea arm and then walk along the far shore to Meany's Point to the north.

**4a: The Short Tour or the First Stop of the Long Tour**

**Cambrian Tidal Flats and Algal Mounds – Meany's Point and Long Bottom**

The rock strata at Meany's Point are almost flatlying and bedding surfaces can be walked on for long distances. This means you are walking over an ancient sea floor, in this case, part of a shoreline of lagoons and broad tidal flats that was flooded daily and exposed as the Cambrian tide ebbed and flowed. The rocks are dolostones of the Cambrian Port au Port Group; however, they are from a later time in the Cambrian than the rocks of the Labrador Group seen in Stops 1 and 3.

The succession found at Meany's Point is illustrated in Figure 16. Most striking about the dolostones are the clusters of large mounds lying upon thinly bedded dolostones. However, as the succession shows, different beds of dolostones preserve small ripple marks, mudcracks, thin pebble layers, salt crystal casts and burrows. The dolostones rarely have fossils, although some of the beach rubble has yielded small black-shelled inarticulate brachiopods.

The succession is cyclic in that dolostone having different characteristics and sedimentary structures are arranged repetitively in a set order. Three main types of dolostone occur here: 1) burrowed dolostone (Figure 17); 2) mound dolostone (Figures 18 and 19); and 3) thinly bedded and laminated, sometimes shaly, dolostone (Figures 20, 21, 22 and 23).

The burrowed dolostone is characterized by a lot of simple tubular burrows which indicate that conditions at the time of deposition were suitable for some soft bodied animals to flourish. This suggests that the dolostones were laid down in a lagoonal setting and probably were rarely exposed when the tides went out. However, the lack of a variety of different burrow types and the absence of fossils in the dolostones suggests that the salinity of the lagoon was too high to be hospitable for most marine animals at the time.

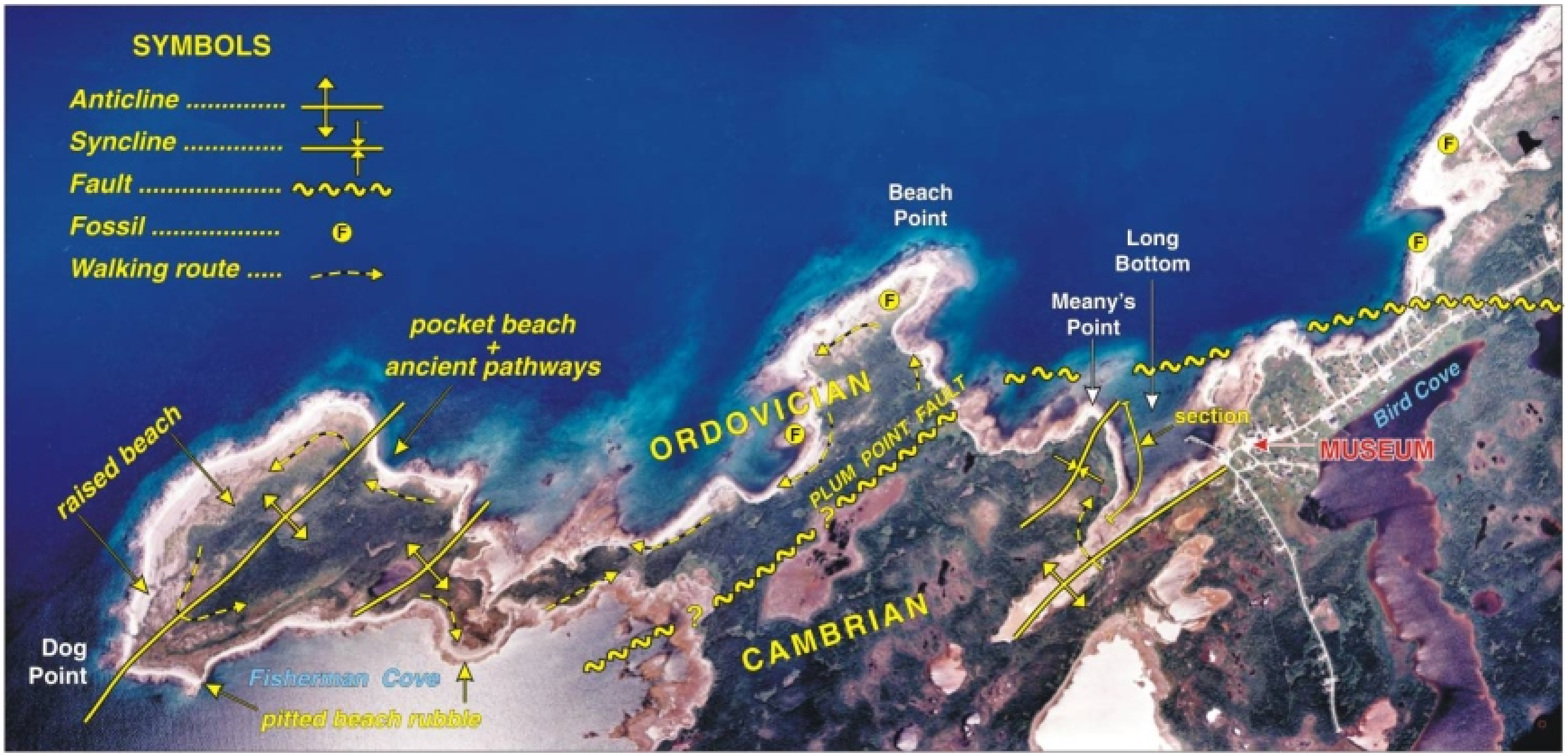


**Figure 15.** *Geological trail along the coast of Dog Peninsula from Bird Cove.*

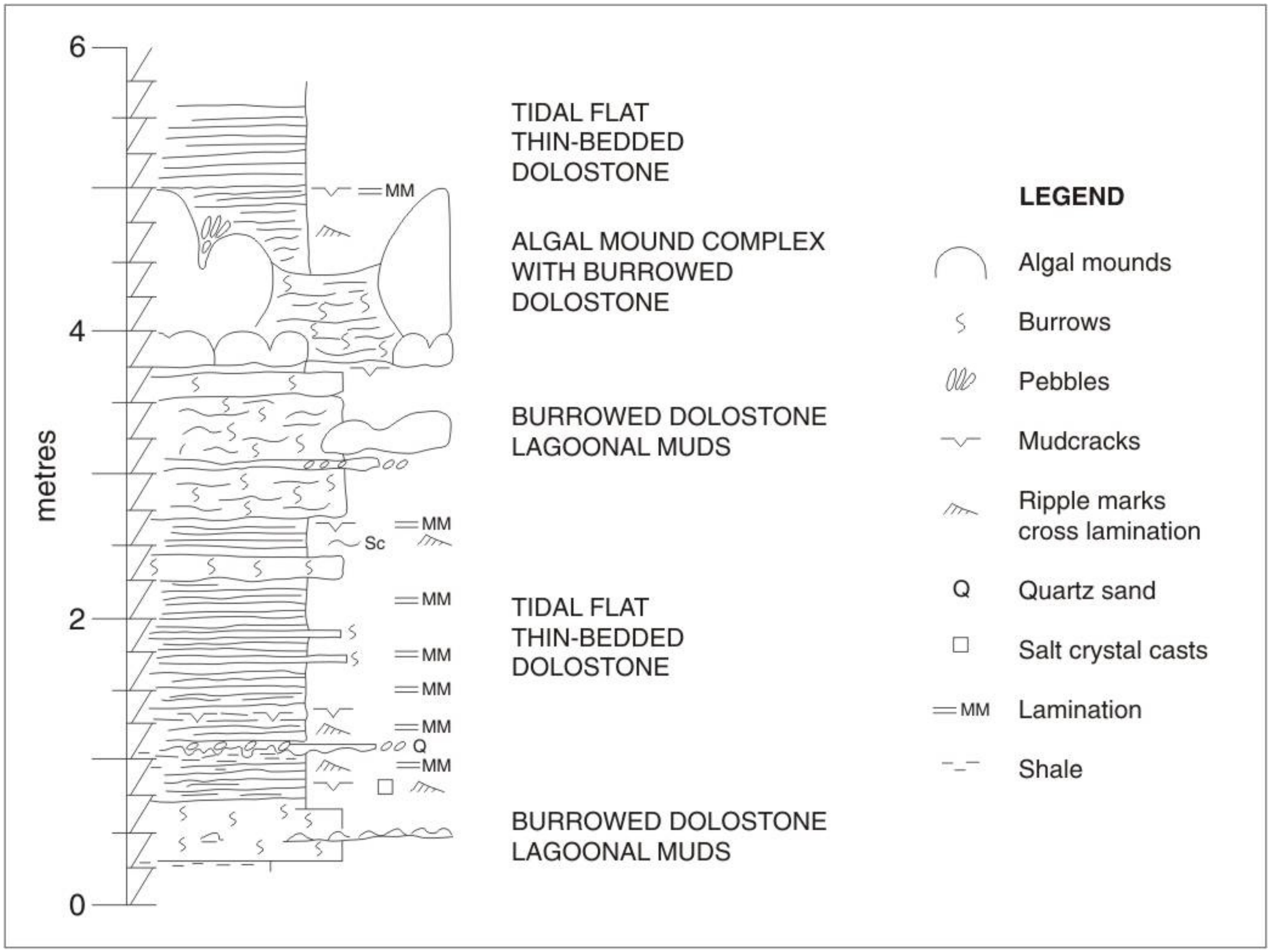


**Figure 16:** *A diagrammatic section of the dolostone succession at Meany's Point.*

**Figure 17.** *Small tubular burrows on the bedding plane of a dark grey dolostone bed.*

**Figure 18.** *Clusters of large algal mounds at Meany's Point separated by irregular low areas where intervening thin bedded dolostones have been eroded excavating the original mound shape.*

**Figure 19.** *Meany's Point algal mounds showing narrow channels between the mounds partly filled by thinly bedded dolostone. Paleontologist for scale.*

The mounds are robust bun-shaped structures that are known to have formed by the activity of algae and other microbes. Generally, algae are conceived as soft sticky green mats and woolly masses that flourish in ponds and pools during hot, bright summer months. However, modern studies of tropical shorelines in such places as the Bahamas and western Australia have discovered rigid limestone mounds and mats that are constructed of layers, clots and lumps of calcified[5] algae below living algal layers. These are believed to compare closely to the Cambrian fossil mounds. The **stromatolite** and **thrombolite** mounds[6], as they are called, occur in shallow water and in the lower part of the intertidal zone, where they are commonly exposed at low tide.

The algal mounds at Meany's Point are draped, locally, by burrowed dolostone and have a robust steep-sided bun shape sitting on flat, gently rippled and burrowed surfaces. This implies that the mounds probably grew in shallow water and mostly were permanently submerged and never dried out due to prolonged exposure. The flat to gently pillowed top of the larger mounds implies that they probably grew up to sea level and probably emerged above low tide mark, a height of about 1 m. Smooth shallow furrows that occur between each pillow and continue down the steep sides of some mounds are possibly drainage shoots fashioned by runoff of sea water splashed by waves onto the top of the mounds at low tide.

The mounds, which are individually about a metre in diameter, coalesced into large complexes up to 8 to 10 m wide, essentially algal reefs or banks. Elongate, although somewhat sinuous, mound-free areas, up to 10 m wide, wander between the mound complexes. They are interpreted as channels and suggest that there was enough tidal and/or wave energy to sweep the sea floor between and around the mounds clean of mud and sand. Flat disc-like pebbles are locally wedged together in the narrow spaces between tops of mounds. They provide another piece of evidence that the mounds grew to sea level and that waves had enough energy to move pebbles off the sea floor and flip them up, onto, and between, the mounds.

The channels roughly trend due south and straight-crested ripple marks in the succession, including the channel area, have crests trending almost due east. This, plus the slight oval shapes to some mounds, probably implies that the main currents and, by implication, the prevailing wind and weather patterns were dominantly north-south.

The last rock types associated with the cycles in the Meany's Point dolostone succession are the thinly bedded dolostones. The dolostones typically break into thin flagstones due to thin shale partings between dolostone beds (Figure 20). Much of the dolostone is featureless and bedding planes have a planar to undulose to bumpy aspect. However, a careful examination of the section south of the mounds on

[5] Calcification - a process whereby soft tissues of organism are replaced by the mineral calcite or aragonite, both crystals of calcium carbonate, so that the structure is turned to rock whilst the tissue is alive or soon after death.

[6] Stromatolites display distinct layering on a millimetre-scale, called lamination. The stromatolite consists of calcified laminations of sediment trapped by algal laminae. The interplay of many environmental factors with the algae promotes interesting growth forms within mounds, ranging from columns through domes, bulbs, digits, buttons and sheets. Thrombolites, although forming visually similar mounds, are made up of clotted structures (hence thromb) rather than fine layering. The clots are made up of calcified coccoid (clustered microscopic spheres of fine carbonate) growths of various algae and are believed to have flourished mostly in subtidal shelf settings where they may have formed large algal barrier reefs. Tops of mounds sometime have a brain-like look.

**Figure 20.** *Typical flaggy thin bedded dolostone seen at Meany's Point.*

the west shore of Long Bottom will be rewarded with the discovery of small straight ripple marks (Figure 21), layers of small pebbles (called **conglomerate**) resting upon irregular erosion surfaces and locally mixed with scattered quartz sand grains (Figure 22), and angular mudcracks locally associated with salt crystal impressions (Figure 23). Internally, many beds show flat lamination (bedding on a millimetre scale) and cross lamination (the internal millimetre scale layering of ripple marks which is akin to cross-bedding).

The generally flat, thin strata imply that the lime sediments were laid down repetitively in thin layers over a broad, flat depositional area, such as a tidal flat. The dolostones were probably deposited by diurnal, seasonal and storm-dominated tides, which transported fine sediment onto the tidal flat, where it was stranded by receding tides and trapped by the growth of sticky algal mats. Bumpy surfaces of small pincushion- and kidney-shaped protuberances indicate the importance of algal mats growing on the tidal flat and trapping sediment. The presence of small ripple marks suggests gentle wave action in shallow water and the mudcracks indicate that the higher parts of the tidal flat were exposed to the tropical sun and desiccated repeatedly for long periods. Storms periodically swept across the tidal flat and ripped up semi-consolidated sediment to form thin layers of pebbles lying upon erosional surfaces. Scattered quartz sand which is found in some of these pebble layers, was probably blown by wind and implies a source in the continental interior.

Impressions of cubic salt crystals lying on mudcracked bedding planes shows that the salinity of the tidal flats was at times very high. The salt crystal (also called **halite**) itself is not preserved but its shape marks where the crystal settled into a mud layer and left a mold when the crystal was dissolved. This particular crystal form is called a hopper crystal (the best example found so far is in the Bird Cove Museum).

**Figure 21.** *Thin-bedded dolostones at Meany's Point displaying small straight ripple marks created by gentle wave action on the Cambrian tidal flat.*

It has a square shape with vague square layers that indicate that the crystals grew in several stages. The crystal seeded at the surface of a shallow pool of very salty brine where the surface tension of the brine allowed the crystal to float unaided. The pool on the tidal flat was probably gently flooded with sea water at high tide and the brine generated as the pool evaporated. The crystal then grew larger, layer by layer, until it floated raft-like on the pool. Generally, as the crystals enlarge, they eventually overcome surface tension and sink to the bottom of the pool where they settle on the mud floor. The crystal impression is preserved in the mud when the crystal later dissolved and the mold is filled with sediment to form a cast of the halite crystal (Figure 23). The presence of mudcracks on the bedding plane indicates that eventually the pool dried up, so perhaps it was then that the hopper crystal settled into the saline mud to be later dissolved when less salty water flooded the pool.

From the stratigraphic succession at Meany's Point it is thus possible to construct a good picture of the ancient Cambrian tidal flat of the Dog Peninsula area. A number of features such as the algal mounds

**Figure 22.** *A flagstone showing a mudcracked dolostone bed overlying a conglomerate bed of dolostone pebbles, likely generated by a storm eroding the tidal flat. Thin bedded tidal flat dolostones, Long Bottom.*


**Figure 23.** *A flagstone of dolostone displaying square casts of hopper crystals of halite (salt) (below the lens cap) and mudcracks. From the thin bedded tidal flat dolostones, west shore of Long Bottom.*

the lack of shelly fossils and the hopper salt crystals all suggest that the tidal flat and adjacent lagoon was saltier than normal sea water. Hypersalinity of the seawater of a hot tropical shoreline would discourage most marine animals while at the same time providing ideal conditions for the proliferation of algal mats and mound-building algae similar to tidal flats and modern stromatolite mounds in western Australia. The thickness of the cycles and the maximum height of the algal mounds suggest that water depths and the tidal range of the ancient shoreline was probably only a metre or two. Both, this and the increased salinities, imply that the area was isolated from, and possibly far away from, the open ocean of that day. The association of different types of dolostone suggests that the shoreline had a shallow offshore lagoon in which large algal mound banks nucleated close to the shore and emerged into the intertidal zone. Behind, and hence sheltered by, the mounds and largely limited between the low and high water marks lay a broad tidal flat, which was repeatedly influenced by rising and falling tides, and baked by a hot tropical sun.

## 4b: The Rest of the Long Tour

### Major Faults and Ordovician Algal Mounds – Meany's Point to Beach Point

The geology of the coast between these two points is only accessible at low tide. The wave-cut rock bench, which is visible at low tide in the intervening cove is, however, the location on land of the most western fault of the Appalachian orogen known in western Newfoundland. The fault separates Cambrian dolostones of the Port au Port Group to the east from limestone and dolostone of the St. George Group to the west. The fault lies approximately midway across the cove where it trends (strikes) northeast and dips steeply (75°) to the southeast.The strata are folded on both sides of the fault (Figure 24). The fault now juxtaposes rock layers, which were originally separated by 400 to 600 m of intervening rock layers, representing a time interval of at least 10 million years. This is, without doubt, a major fault. Mapping of the fault (Figure 3), however, shows that its trace bends as it is followed eastward to Bird Cove and Plum Point (*see also* Figure 15). This suggests that the dip of the fault shallows in an easterly direction. Because we know that the rocks lying above the southeast-dipping fault plane have moved both northwestward and upward to a higher level and that older rocks are now emplaced above younger rocks, the fault is described as a moderately to steeply dipping **reverse fault**.

As you continue to walk around the peninsula, there will be many linear fractures cutting the rocks, some of which are small faults, mostly with the same orientation as the fault in the cove. Beds steepen close to the faults and the dip attitude of beds changes locally indicating that a number of gentle folds are present along the shoreline (Figure 25).

Rocks of the St. George Group on the west side of Beach Point are dark grey, thin bedded limestone replaced by dark grey dolostone and dolostone rich in irregular veins of white crystalline dolomite. Dolomite replaces fossils and burrows in the limestone in this area. Nicely preserved fossil snails (**gastropods**) can be seen locally (Figure 26). Stromatolite mounds – very like those of Meany's Point – but made of dark grey limestone, also occur in the St. George Group along the shore (Figure 27).

**Figure 24.** *Steeply dipping Cambrian dolostones adjacent to the Plum Point Fault in the cove south of Beach Point, Dog Peninsula.*

## The Raised Beaches of the Dog Peninsula – Dog Cove, Dog Point and south around Fisherman Cove

The shoreline along the north shore of Dog Peninsula is a mixture of rocky coves and points of gently folded Cambrian and Ordovician dolostones and limestones. Dog Cove and Dog Point are rimmed by raised beach terraces and cliffs. These ancient marine shoreline deposits were stranded as the area gradually rebounded (i.e., was uplifted) following the melting of the Pleistocene ice sheets that once covered much of the Great Northern Peninsula. The mass of the ice sheet (about 1.5 km high) weighed down the land over tens of thousands of years so that when the icesheets began melting and retreating about 10 000 to 12 000 years ago, the land was drowned by the sea.

Ancient beach deposits, which occur stranded along the steep scarp slopes of the Highlands of St. John and Mount St. Margaret over 100 m above the present sea level, indicate that the shoreline, 10 000 years ago, lapped the western face of the spine of the Long Range Mountains. Once the ice load was removed, the earth's crust in the region responded to the removal of its heavy ice overburden and began

**Figure 25.** *A minor fault associated with small folds in dolostones at Dog Cove.*

**Figure 26.** *Coiled fossil gastropod (by coin) lying in a burrowed Ordovician limestone bed of the St. George Group, north side of Beach Point.*

**Figure 27.** *Large algal mounds in Ordovician limestones of the St George Group, Beach Point. Note how similar they are to the Cambrian mounds at Meany's Point (Figure 18) although they are at least 25 million years younger.*

to spring back slowly over several thousands of years to levels appropriate for the crust if it had not been loaded by thick ice, a process called **isostatic rebound**. Consequently, a series of beach deposits occur at successively lower altitudes in the region, each lower beach being younger than the beach above. Detailed dating of stranded beach and marine deposits indicate that the rebound was rapid at first (between 11 000 and 5000 years before present (BP)), gradually slowing to the present. Stranded beach ridges near the present shore are the youngest in the area and date from about 5000 to 2000 years BP. Clearly as rebound occurred, higher parts of the sea floor would emerge from the sea first, some as rocky islands, and these would later connect to the mainland to form peninsulas such as Dog Peninsula.

To explain the process of **isostatic rebound**, it is best to clarify possible misconceptions and apply some analogies. It is probable that most of us think of the earth's crust as being strong, rigid, uncompressible, after all it is composed of rock that leaves indelible impressions on us if we fall. But on the grand scale of the earth, rocks have flexibility as well as rigidity and strength. In addition, the earth's crust is essentially floating on semi-molten rock deep in the earth which allows the crust to regionally sink and depress when a load is applied.

For want of an analogy, visualize a spring board used in diving competitions or a wooden plank resting between two supports or a trampoline. The spring board is fixed at one end, and without a diver on it, it essentially protrudes straight out. If a person walks out to the end of the board, the board is bent or loaded downward and remains so, as long as the weight is maintained. When the person walks away, the weight is removed and the board returns to a horizontal attitude. The board is both rigid and flexible and responds temporarily to the weight by bending, i.e., loading. When the load is removed the board returns to its original shape, i.e., isostatic rebound. Likewise, a weight on a plank or in the middle of a trampoline is even closer in analogy to the ice sheet on the earth's crust as the plank is bowed down by a weight in the middle and becomes straight again when the weight is removed. A weight in the middle of a trampoline will create a basin-like depression like the ice sheet weighing down on the earth's crust This must suggest to you that a thick ice sheet in Labrador and northern Newfoundland would effectively load the earth's surface at the ice centre at the same time as depressing a much wider zone of earth's crust, hence affecting distant shorelines far from the position of the ice sheet. However, it is important to realize that the geological process of ice loading, then ice retreat and finally isostatic rebound occurs at a snail's pace of thousands of years, not the instantaneous response of a trampoline during play, training or competition.

But back to the western part of the Dog Peninsula. The Peninsula protrudes boldly into the Strait of Belle Isle so that its northern shore is afforded no shelter especially from prevailing autumn and winter gales. Rock ledges of gently folded and fractured Ordovician dolostone are swept clean of sand and gravel. However, at the western side of Dog Cove, there is a small pocket cove with a well developed curved pebble strand between rocky headlands (Figure 15). This beach, which faces northeast, is frequently subject to surf generated by ocean swells moving southwest along the Straits
and by strong local wind conditions. The modern beach is a steep shelving deposit of round pebbles of various sizes resting on bedrock. The pebbles are of locally derived rock, suggesting that the pebbles have been shaped and polished over a long time period during perhaps the past thousand years when there has been very little change in sea level.

This is in contrast to the stranded raised beaches in the cove and around the higher part of the Peninsula (Figure 15). They lie up to 10 m above present sea level and may be at least 5000 years old. They are composed of flat, angular, brown and yellow-weathered dolostone gravel. Overgrown with low evergreen and other shrubbery, there are a number of abandoned beach ridges here, one of which has traces of paths possibly constructed by fishermen many centuries ago (Figure 15). The lack of rounded pebbles and the deep yellow weathering is a feature of many of the raised beaches all around the western end of the Dog Peninsula (Figure 28). This suggests that waves and storms did not abrade and shape

**Figure 28.** *A raised beach of angular yellow-weathered dolostone rubble lying on the north side of Dog Peninsula. A cliff of dolostone which overlooks the beach has beds that dip toward the sea.*

the locally derived dolostone beach material. Rather it implies that the beaches either were sheltered somehow from the brunt of storms or that the ancient beaches spent very little time within the intertidal zone. In other words, the beaches were quickly abandoned as the coastline emerged and relative sea level fell, allowing no time for pebble abrasion and shaping. Long stranded above sea level, the angular pebbles were frozen in the imbricated stacked pattern[7] of the original beach slope and became deeply weathered so that the iron in the dolostones imparted the yellow colour to the raised beach.

Once abandoned, the beach pebbles were pitted by dissolution. Limestone and dolostone terrains worldwide are famous for the particular and often spectacular scenery, landforms and subterranean cave systems that are sculpted by the dissolving action of water. The particular physical landforms are grouped together under the name **karst**. Limestone and dolostone, both carbonate rocks, are readily dissolved by rain and groundwater, especially when charged with weak organic acids. This process operates on large and small scales and the latter is illustrated by the dolostone pebbles of the south side of Dog Point and the shores of Fisherman Cove where they are pitted and weathered (Figure 29). If you turn over a pebble you will find that it is not pitted. This suggests that the pitting is a surface effect of exposure to weather and local condition. As these beach gravels are of great antiquity and have lain undisturbed for thou-

**Figure 29.** *Pitted dolostones rubble on a raised beach on the shore of Fisherman Cove. Note the outline of algal mounds in the large block.*

[7] To visualize an imbricate pattern, take a stack of plates (tiles will also do) and spread them out so that each plate is overlapping the one below. As you can see each plate tilts in the same direction, that is they form an imbricated stack.

sands of years, it is likely the pitting could be ancient, the effect of sea spray and mist, rain, melting of snow and leaching by weak acidic organic solutions, as water seeped through piles of sea weed or marshy layers along the shore to the rubble below.

Continue to walk the shore of Fisherman Cove to the head of the cove, cross the narrow grassy valley back to the north shore of the Peninsula and return to Long Bottom and Bird Cove.

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