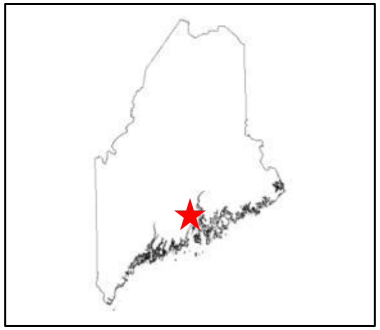
Geologic Facts and Localities

June 2017

The Passagassawakeag Rail Trail, Belfast, Maine



44°26‘25.1"N, 69°01'16.4"W

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Introduction

The Belfast (or Passagassawakeag or "Passy") Rail Trail is a relatively new walking trail in the Belfast area. The old track and railroad ties were pulled up in the fall of 2014 and the trail was officially open for use by the summer of 2016. The former railroad bed follows the western bank of the Passagassawakeag River from Belfast in the south to City Point in the north, a distance of 2.2 miles.

The trail affords excellent views of the river for much of its length, including a river crossing near the northern end of the trail, as well as opportunities to observe many facets of the area's natural history.

In this publication we aim to present some general aspects of the geological features of the area for you to consider as you make your way along the trail. These features include the bedrock geology, surficial geology, the Beavertail, the estuary, and the pockmarks of Belfast Bay.

Figure 1. A view of the Passagassawakeag River from the rail trail footbridge near City Point.

Trail Details

There are three parking lots that provide easy access to the trail (Figure 2). The lot at the northern end also provides access to the Hills-to-Sea trail and the Belfast and Moosehead Lake Railroad. The middle parking lot also provides access to the Stephenson Preserve (which has its own trail system), while the southern parking lot is situated next to the Armistice Bridge and allows easy access to the Belfast Harbor Trail.

The fact that the trail uses a former railroad bed means that the trail is both broad and essentially level. The surface is of crushed stone providing plenty of grip. In winter, provided there is snow on the ground, the trail is excellent for snow-shoeing and cross-country skiing.

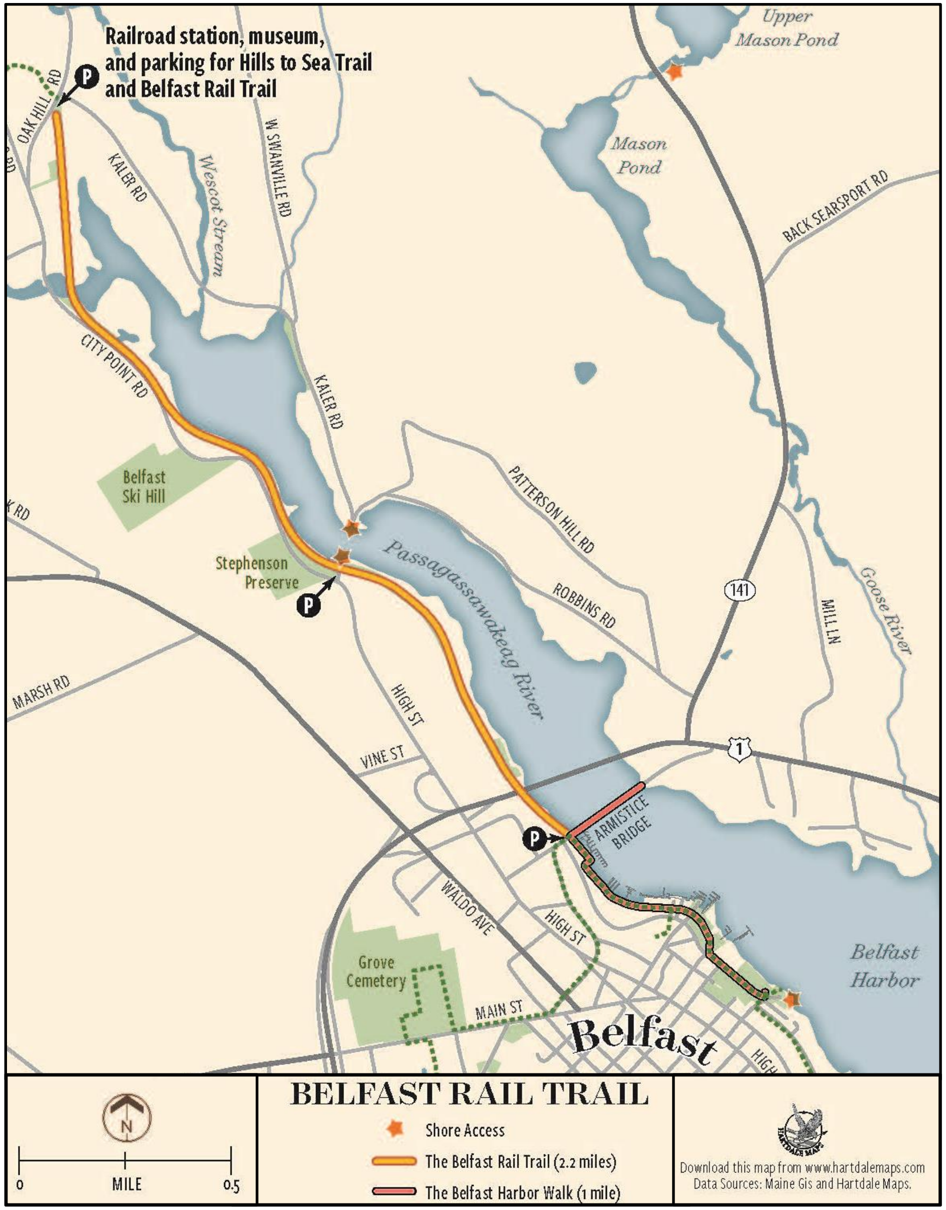


Figure 2. Location map of the Belfast Rail Trail. This map is an excerpt of a larger map of the area by Hartdale Maps (www.hartdalemaps.com).

Views Along The Trail

Figure 3. View to the north from the northern end of the trail. On the left is the Belfast and Moosehead Lake railway museum and station where you can find parking designated for trail users and a very welcome portable restroom. Across the tracks in the middle distance you can see signage at the Hills-To-Sea trailhead.

Bedrock Underlying the Trail

The bedrock of the Belfast area was recently mapped by Pollock (2012). An electronic copy of this map can be obtained through the Maine Geological Survey website (here).

The figure on the right shows that the rail trail traverses five NE-SW trending rock formations. From north to south they are:

- Bucksport Formation (on the map as SOb)
- Appleton Ridge Formation (on the map as SOar)
- Ghent Phyllite (on the map as SOg)
- A quartz-rich metasiltstone (on the map as Cm)
- Gushee member of the Penobscot Formation (on the map as OCpgu)

Note that much of the map is inferred. The bedrock in this area is largely obscured by overlying material, such as soil. However, with enough observations (all of the black symbols on the map), a basic picture can be composed. Along the trail you can find large outcrops of the Bucksport Formation as well as small outcrops of Appleton Ridge Formation.

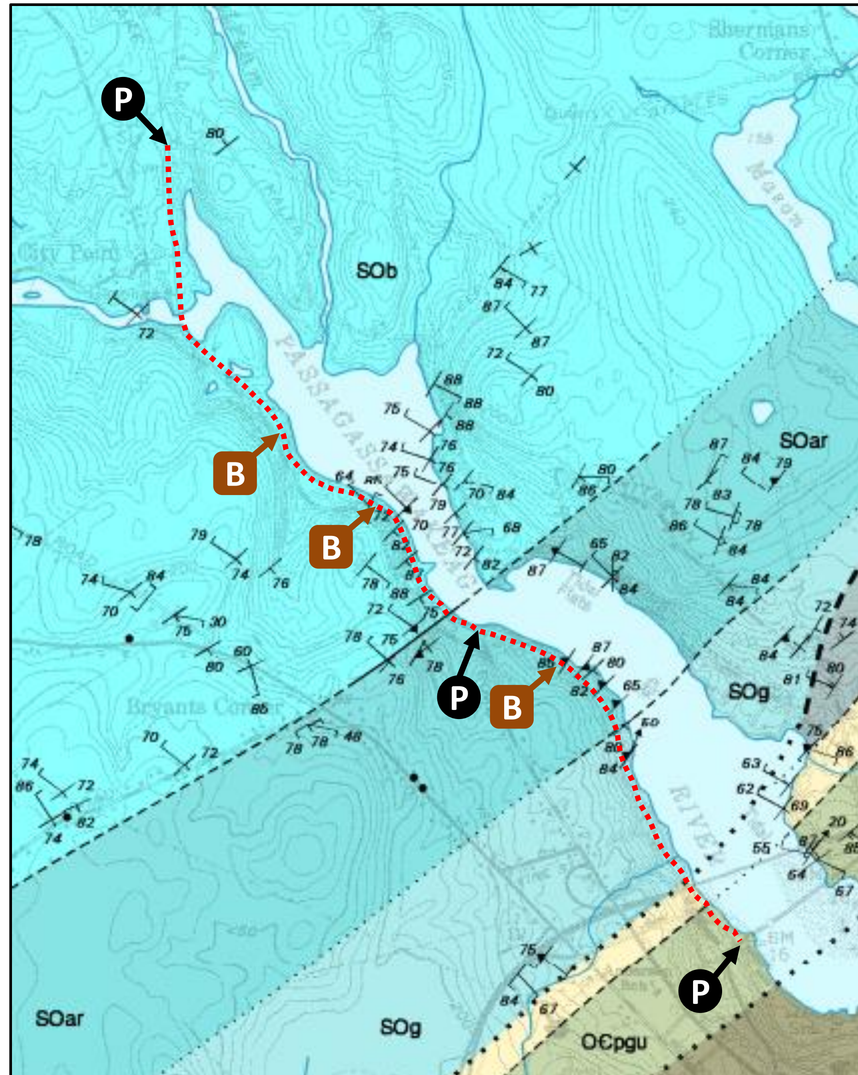


Figure 4. Excerpt from the Belfast 1:24,000 bedrock geologic map (Pollock, 2012) with overlay of approximate route of the trail (red dotted line), parking lots ("P"), and accessible rock outcrops ("B").

Primer: How to Spot Rocks

We are all interested in rocks at one level or another. However, what is that rock you picked up or saw at the side of the trail? What's in it? Does it have a name? How was it made? Why is it here? These and other questions have probably crossed your mind at some point. While we cannot answer all of these questions in this guide, we will certainly try and give you the basics for the rocks you can see on the trail.

Rock Type	Formation Process	Characteristics
Sedimentary	Clastic sediments (e.g. gravel, sand, silt, clay) after transport by water/wind/ice, (bio)chemical sediments (e.g. shells, salts) precipitated from water, and/or biological sediments (e.g. plant matter) are deposited and buried. Compaction and cementation during burial turns the loose sediments to rock.	May contain fossils and preserved features such as layering, ripples, mud cracks, tracks, etc. Porous (except salts). Grains, usually of similar size, may be rounded or angular.
Metamorphic	Existing rocks (from any of the 3 rock types) are subjected to high heat and/or pressure over very short time periods (e.g. meteorite strike) or long (millions of years) time periods.	Alignment of interlocking mineral crystals creates "layers" or sheets (sometimes wavy). OR Randomly oriented interlocking crystals; may preserve features from original rock (e.g. layers)
Igneous	Molten rock that formed in either the crust or the mantle will cool back into rock when it reaches the surface (extrusive igneous rocks) or within the crust (intrusive igneous rocks).	Usually has randomly oriented, interlocking crystals. Many crystals are of similar size. OR looks glassy, maybe bubbles. *No fossils. Layers uncommon.*

The Bucksport Formation

The northern half of the trail (from the Upper Bridge parking lot north) is underlain by the Bucksport Formation.

This formation is comprised of metasedimentary rocks - rocks that started out as sediments, later became sedimentary rocks, and were ultimately metamorphosed into new rocks - broadly called “granofels,” a rock type characterized by a fine-grained granular texture and that contains the minerals quartz and feldspar.

The original sediments are interpreted to have been layers of marine sands (turned to “biotite granofels,” a fine-grained granular rock that contains the mineral biotite in addition to quartz and feldspar) and marine calcareous muds (chalky muds turned to “calc-silicate granofels,” granofels containing calcium-bearing silicon- and oxygen-based minerals such as diopside or hornblende).

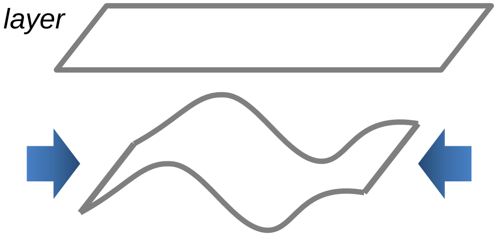
Figure 5. Layers within the Bucksport formation are tilted and dip steeply (~80°) in the direction of Belfast. They would have originally been deposited as horizontal layers on the ocean floor many millions of years ago, then later tilted during tectonic activity.

Tilting of Rock Layers

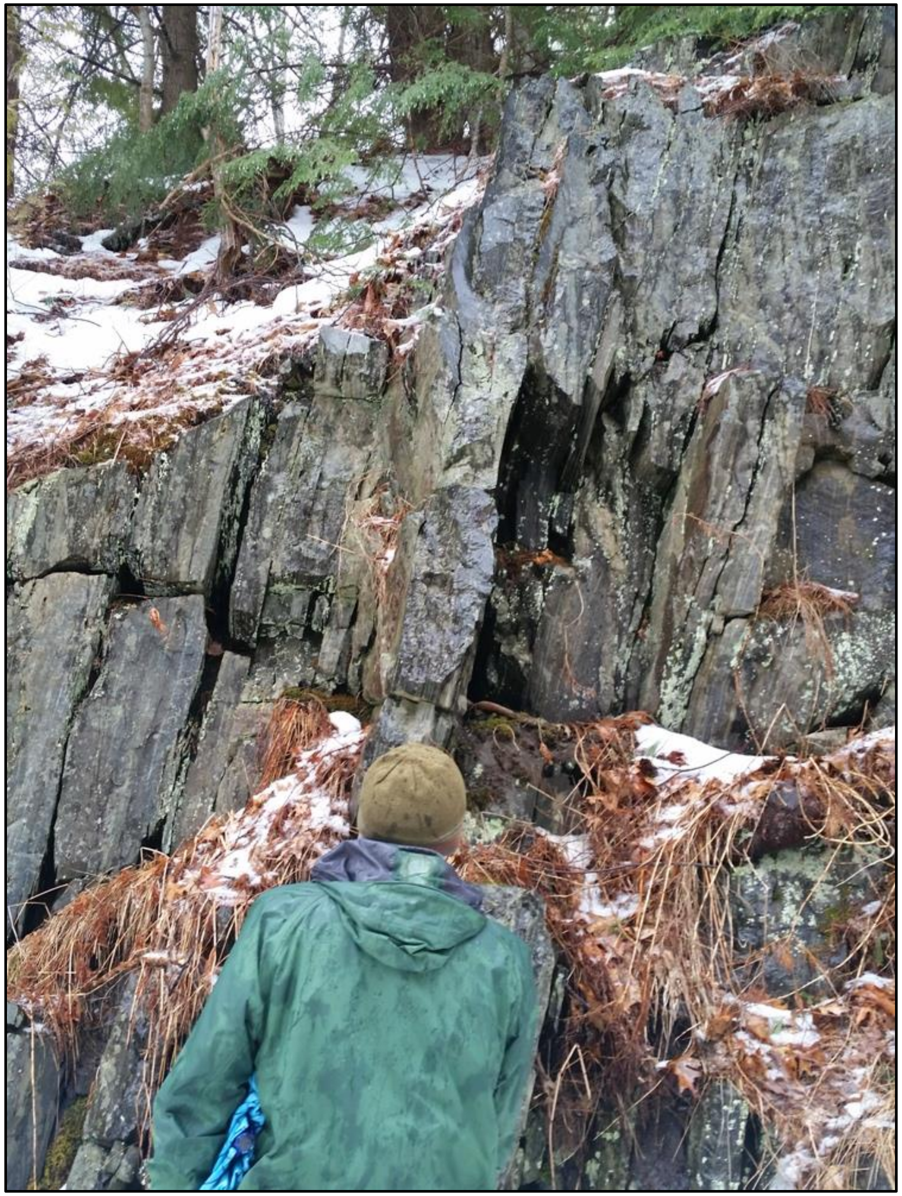
The bedrock outcrops on the trail show tilted layers. They were not always in this orientation. Geologists use the *Principle of Original Horizontality* to infer that rocks formed from sediments were initially flat lying (horizontal) and were tilted later by some geologic event(s).

In the case of the bedrock on the trail it is most likely collision of two tectonic plates that caused the layers to be tilted. Rocks respond to compression by shortening. This is achieved by faulting and/or folding of the rock. You can demonstrate the process of folding using this sheet of paper (representing a rock layer) like so:

Horizontal rock layer



After folding (a.k.a. ductile deformation) resulting from compression



The Bucksport Formation Close Up

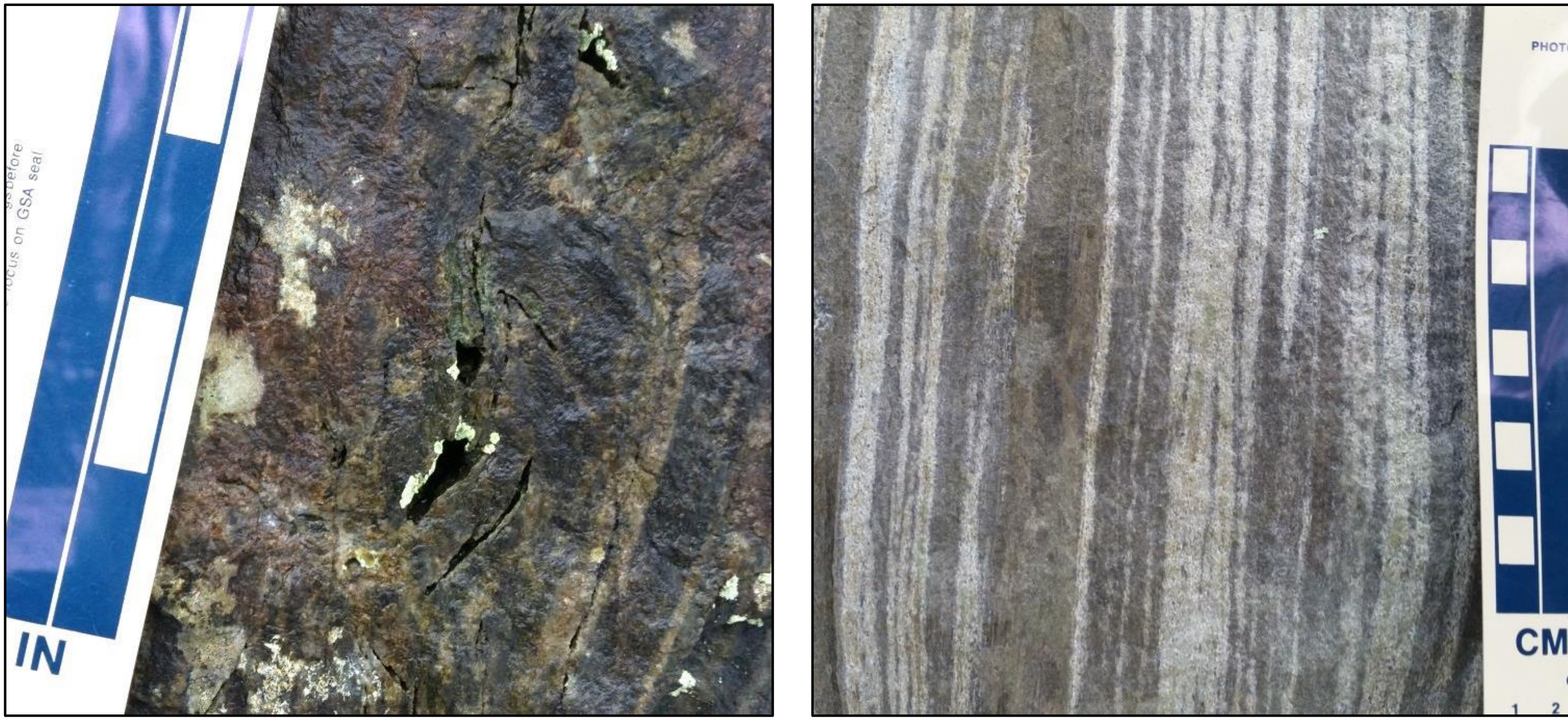
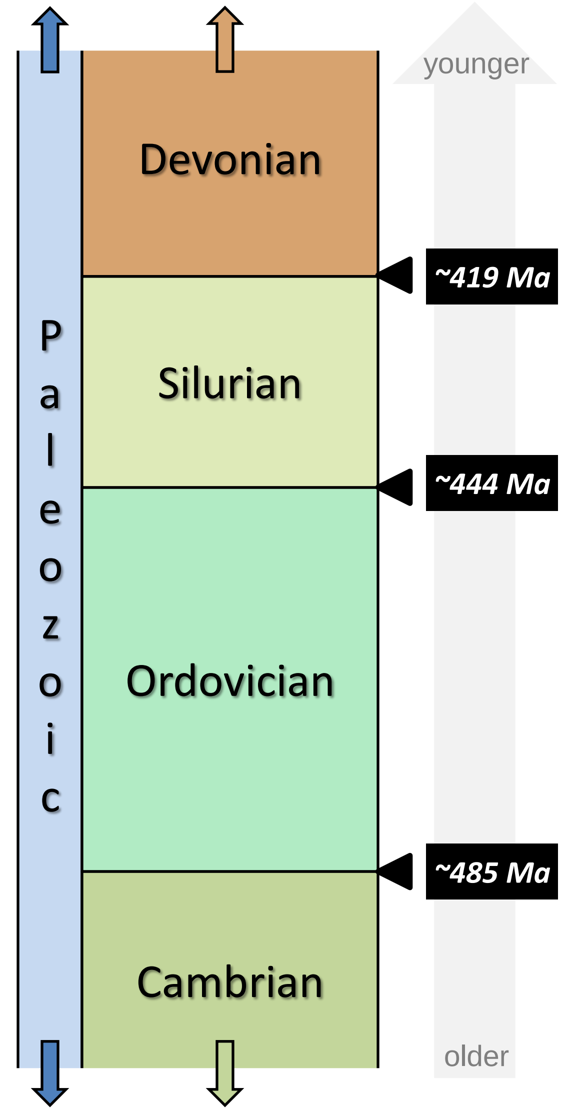


Figure 6. Close-up photographs of layering within the Bucksport Formation, as seen in rocks on the trail. This layering is preserved from the original sediments and is not an artefact of the metamorphic process. The brownish black to dusky purple layers are biotite granofels, formerly marine sand layers, and the pale-green to gray layers are calc-silicate granofels, formerly chalky muds at the bottom of the ocean. The cavities in the rock on the left represent pockets that were once rich in calcium carbonate which has since weathered away.

The Bucksport Formation in Geologic Time

A brief study of the Belfast quad bedrock map will reveal that the Bucksport Formation is not confined to this area. Indeed the type section for this formation is in Bucksport, Maine, a little further north and east of Belfast, and the formation extends from the Maine coast south of Wiscasset up to New Brunswick, Canada (actually crossing the border as a wide swath of rock called the Flume Ridge Formation [Osberg *et al.*, 1985] between Calais in the south and the Chiputneticook Lakes in the north).

The Bucksport formation is currently thought to be Silurian* in age and is represented on new maps as Sb (S = Silurian, b = Bucksport). On earlier maps, including the 2012 map of Belfast quad, there was less confidence in age and you may see this formation represented as either SOb (O for Ordovician) or DOb (D for Devonian). The Silurian is a period within the Paleozoic Era (translates roughly to "era of ancient life") and it represents roughly 444 to 419 million years ago.



* The interested reader is referred to the International Commission on Stratigraphy for current thinking on ages, in years, of geologic time periods.

The Appleton Ridge Formation

The Upper Bridge parking lot on the rail trail (see figure below) sits near the inferred contact between the Bucksport (to the north) and Appleton Ridge formations (to the south). Like the Bucksport Formation, this formation is also comprised of metasedimentary rocks: granofels and schist in this case. The original sediments are interpreted to have been layers of marine sands (turned to granofels) and muds (turned to schist, a metamorphic rock containing aligned sheet-like crystals of mica).

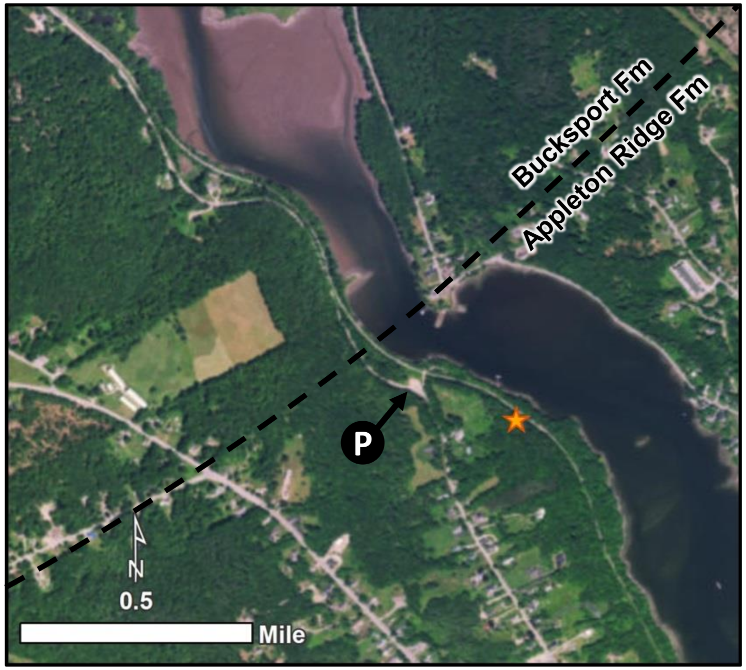


Figure 7. Location map of outcrops of Appleton Ridge Formation that are visible from the rail trail.

The Appleton Ridge Formation

The Appleton Ridge Formation is noticeably different from the Bucksport Formation. There are four major characteristics that you should note to help you make the distinction:

1. The Appleton Ridge is richer in flat, platy minerals (mica crystals) making it less granular in appearance than the Bucksport.

2. The layers are wavy.

3. The presence of rust-colored surfaces. Iron minerals formed in the deep ocean sediments are finally rusting now they are at the surface.

4. The presence of pods or veins of quartz (clear to white) containing blocky pink crystals of andalusite.

Figure 8. An outcrop of the Appleton Ridge formation showing rusty-weathering schist.

The Appleton Ridge Formation

Blocky pink andalusite crystals in the quartz veins and pods are relatively easy to spot and are a key indicator of the Appleton Ridge Formation.

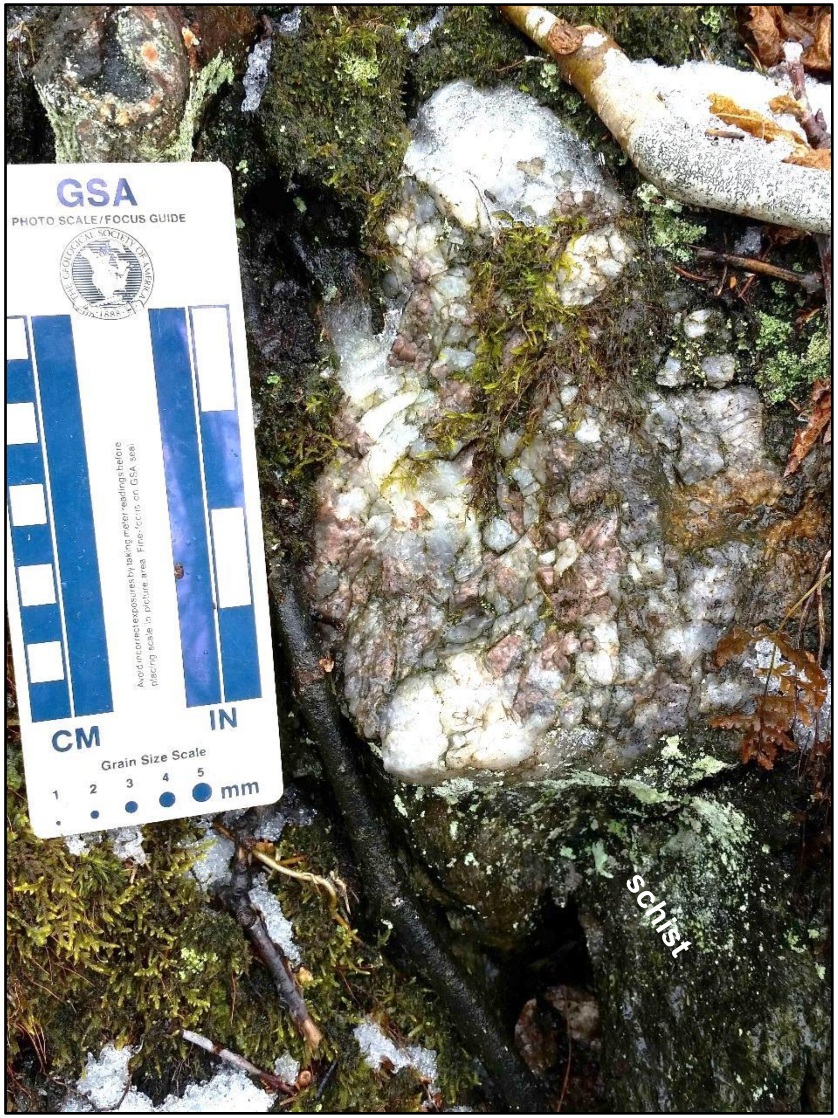


Figure 9. Two examples of quartz pods, embedded in schist, containing pink andalusite crystals. The photograph above was taken at a site just east of the Passagassawakeag River. The photograph on the left is from a site on the rail trail identified in Figure 7.

Other Bedrock Units Traversed by the Trail

Heading further south from the Upper Bridge parking lot on the trail you will soon cross the inferred contact between the Appleton Ridge Formation (to the north) and the Ghent Phyllite (to the south). Like the Bucksport and Appleton Ridge formations, this formation is also comprised of metasedimentary rocks: phyllite and schist in this case. The original sediments are interpreted to have been layers of marine mud and clay. We were unable to definitively identify any outcrops of the Ghent Phyllite on the trailside, but there are undoubtedly plenty of rocks to look at on this part of the trail.

Where the trail eventually crosses underneath the Route 1 road bridge is also the approximate location of the Sennebec Pond Fault. This fault separates rocks interpreted to have formed in different ways at different times. To the south is a thin strip of light-grey, quartz-rich metasiltstone. There are no outcrops of this unit on the trail.

Beyond that, and all the way to the southernmost point of the trail, you will be walking on top of the Gushee member of the Penobscot Formation. This rock is interpreted to be a metamorphosed tuff (a rock formed from the debris from volcanic eruptions). Unfortunately there are no outcrops of this unit on the trail either. However, both the Gushee and the metasiltstone can be observed at the shoreline on the other side of the river (West and others, 2016), and the Penobscot Formation in general is described in an earlier MGS Site of the Month (September 2007 – here).

How Were These Rocks Formed?

"The sea" in which the sediments of the Bucksport, Appleton Ridge, and Ghent Phyllite formations were deposited was a basin in the Iapetus Ocean (Reusch and van Staal, 2012) that closed by subduction (the process whereby one tectonic plate dives underneath another more buoyant plate) in the Late Silurian. Before that time the basin existed as a narrowing strip, also referred to as the Fredericton Trough, on the Gander plate between the continents of Laurentia (North America plus Greenland and Scotland) and Avalonia.

Image from the PALEOMAP Project: http://www.scotese.com/moremaps1.htm

Figure 10. A simplified reconstruction of the global distribution of continents in the early Silurian (440 million years ago). Continents are shown in gray, oceans in white, and several plate boundaries (lines) are also shown. Avalonia is the collection of small blocks to the left of Baltica (you might recognize the westernmost 'blob' of Avalonia as looking like Nova Scotia, coastal Maine, and Cape Cod, but this depiction is now understood to be inaccurate). The Iapetus Ocean is slowly closing bringing Avalonia and Laurentia, as well as a series of small volcanic island arcs, together by the early Devonian.
Note that all of this is taking place south of the equator. The rocks of Maine have travelled some distance to where they are today!

How Were These Rocks Formed?

During the early Devonian the Iapetus Ocean finally closed and a mountain building event known as the Acadian orogeny was underway. The sediments formerly deposited on the ocean floor were thrust upward, folded and tilted, and subjected to heat and intense pressure. During this process, the loose grains of the sediment were transformed into interlocking crystals within hard metamorphic rocks.

Much later, roughly 200 million years ago, when the Atlantic Ocean began to open up Avalonia split between North America and Europe/Africa. The little bit kept by North America during that split is what today we call mid-coast Maine, with further fragments downeast, and in maritime Canada (New Brunswick, Nova Scotia, and Newfoundland).

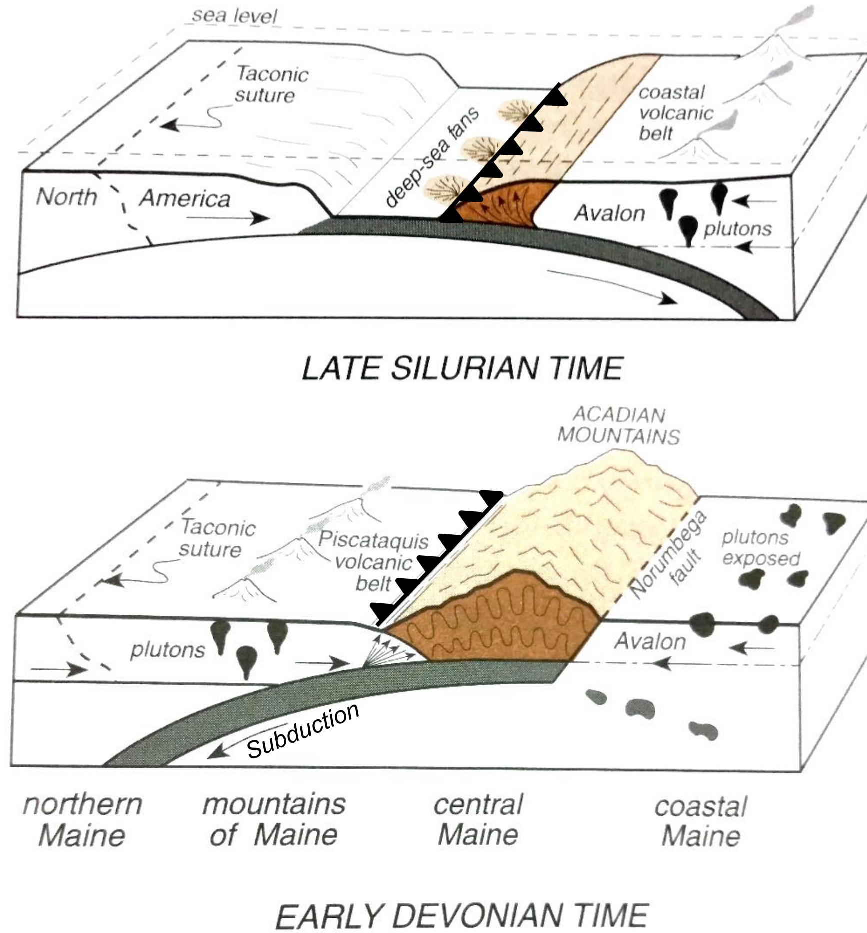


Figure 11. These diagrams, modified from the Roadside Geology of Maine (Caldwell, 1998), represent one hypothesis of several for the tectonic origins of coastal Maine. The tectonic evolution of New England is still a hot topic in the geologic community. These diagrams are only used here to provide the reader with a general 3-dimensional picture of plate tectonic processes. Both diagrams show convergence (collision of tectonic plates) with the boundary between plates indicated by the black line with "teeth".

Glacial History

Belfast, like the rest of Maine, was covered by a large glacier, called the Laurentide ice sheet, during the most recent glacial period which lasted from 85,000 to about 11,000 years ago. The ice sheet entered Maine around 35,000 years ago, reached its maximum position (around Long Island, New York, on the east coast) by about 25,000 years ago, and began to retreat north by 18,000 years ago. Several landscape and bay-bottom geologic features, which are largely invisible from the trail, but are worth mentioning here, are the result of the movement of the glacier over the landscape and its subsequent retreat.

On the following page are recently acquired images that show end moraines (piles of debris that develop at the glacier's edge). Using the map on this page we can estimate that the Belfast area moraines were formed about 13-14 thousand years ago as the ice sheet retreated northward.

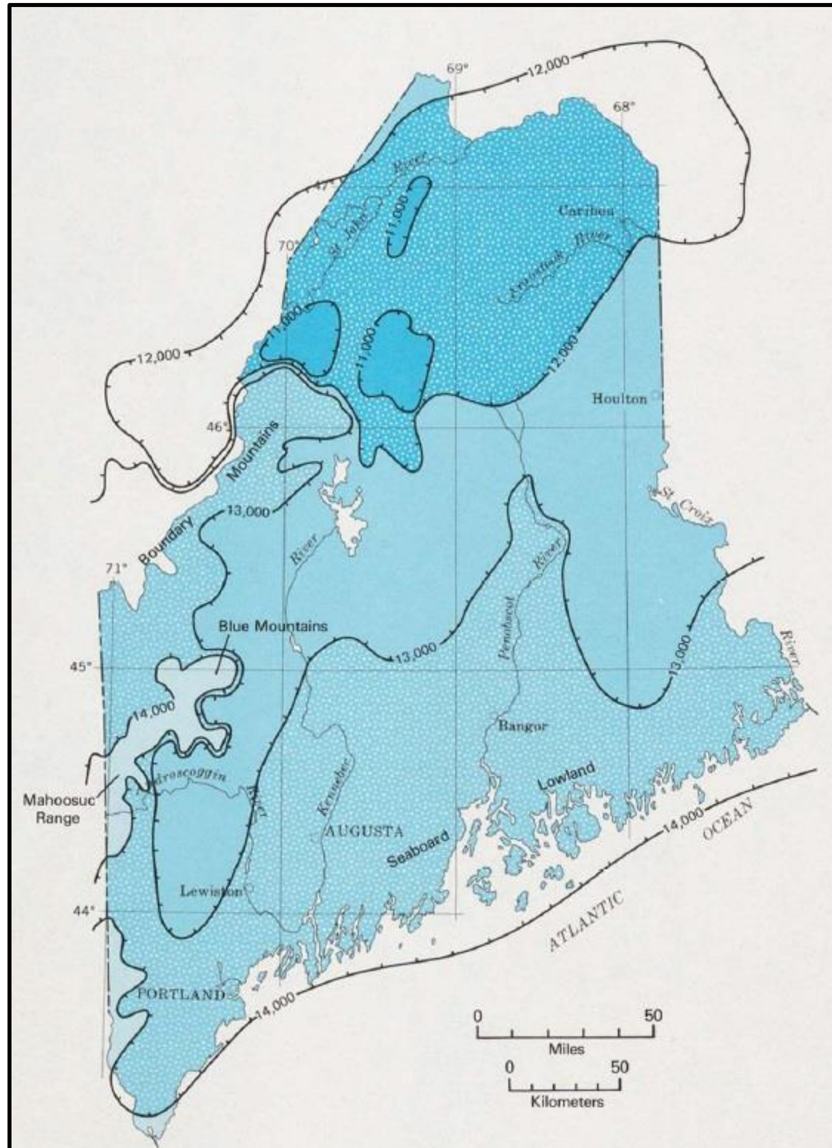


Figure 12. Progress of deglaciation in Maine (Thompson and Borns, 1985).

Glacial Moraines in the Belfast Area

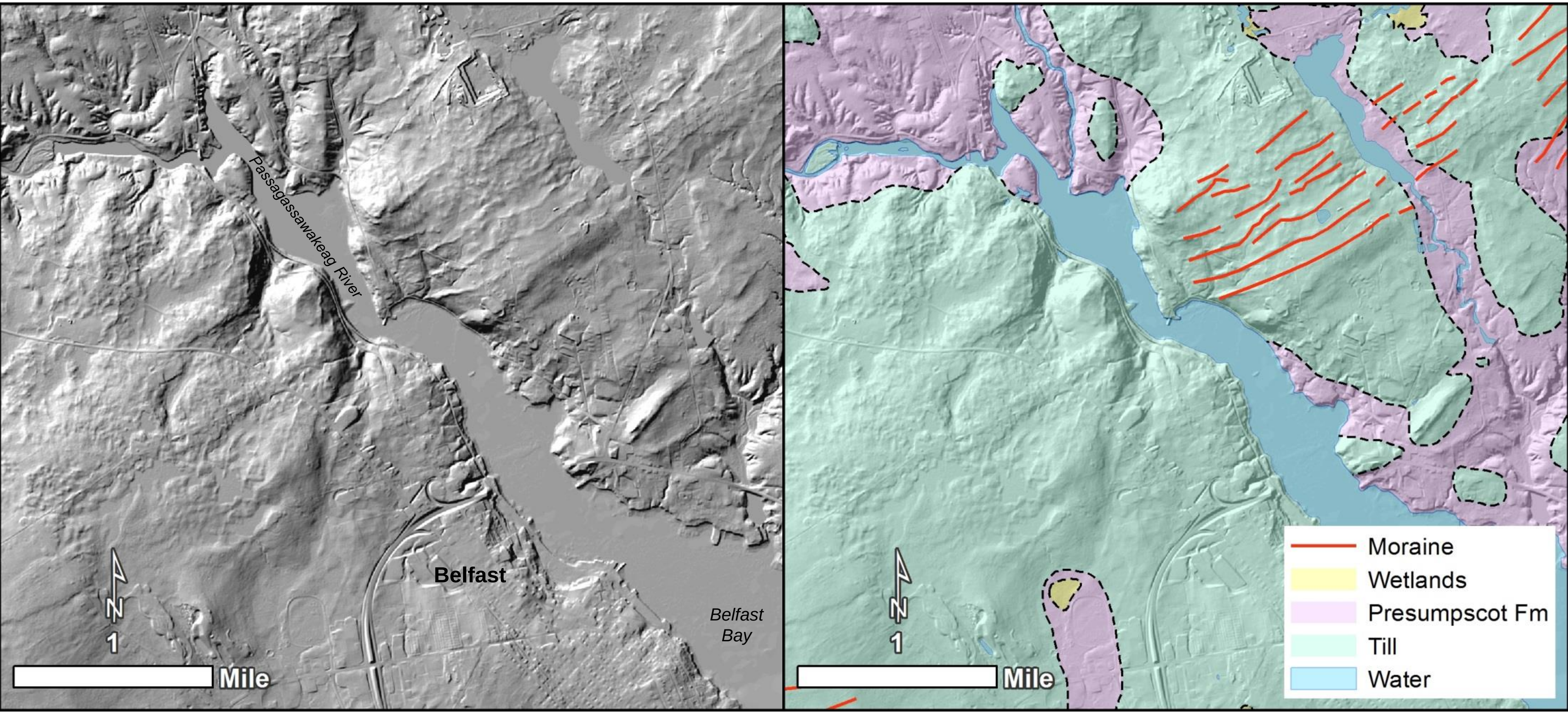


Figure 13. LIDAR (LIght Detection And Ranging) image of the Belfast area (left) and surficial geology map (right; after Weddle 2014). LIDAR, because it effectively "sees through" vegetation, reveals land surface elevation changes as small as a couple of feet. This technology has helped reveal a number of moraines in the Belfast area that might otherwise not be observed. All mapped moraines are located on the opposite side of the river to the rail trail and are obscured from view by vegetation. Learn more about LIDAR images of Maine at the Maine Geological Survey's interactive web map.

Surficial Units Traversed by the Trail

Mantling much of the bedrock in this area are deposits of glacial till (see figure 13). There are no particularly noteworthy cross-sections of the till along the length of the rail trail, in part due to the construction of the railroad itself, but it is evident as random cobbles and boulders on nearby slopes. Till is a mixture of sediments (from clay to boulders) that gets deposited at the base of a glacier.

At the northern end of the trail, where you cross the Passagassawakeag River, the surficial geology is composed of the Presumpscot Formation. This formation is also glacial sediment, but is deposited when a glacier ends in the ocean and different grain sizes are sorted by their transport through water (as opposed to ice). The Presumpscot is quite recognizable as a sticky blue-gray silt/clay and can be found at sites up and down the coast of Maine as well as far inland to points such as Farmington and Lincoln. However, no outcrops are readily identifiable from the trail. An introduction to the Presumpscot Formation, including descriptions of fossils that an be found within it, can be found in an earlier MGS Site of the Month (October 2000 – here).

For further information on the glacial history of Penobscot Bay there is a May 1999 Site of the Month.

Pockmarks in Belfast Bay

Beyond the mouth of the Passagassawakeag River in Belfast Bay lie enigmatic landforms on the sea floor known as pockmarks. These have been featured in an earlier Site of the Month (November 1997, link here) but are briefly mentioned again here in light of continued research of the phenomena.

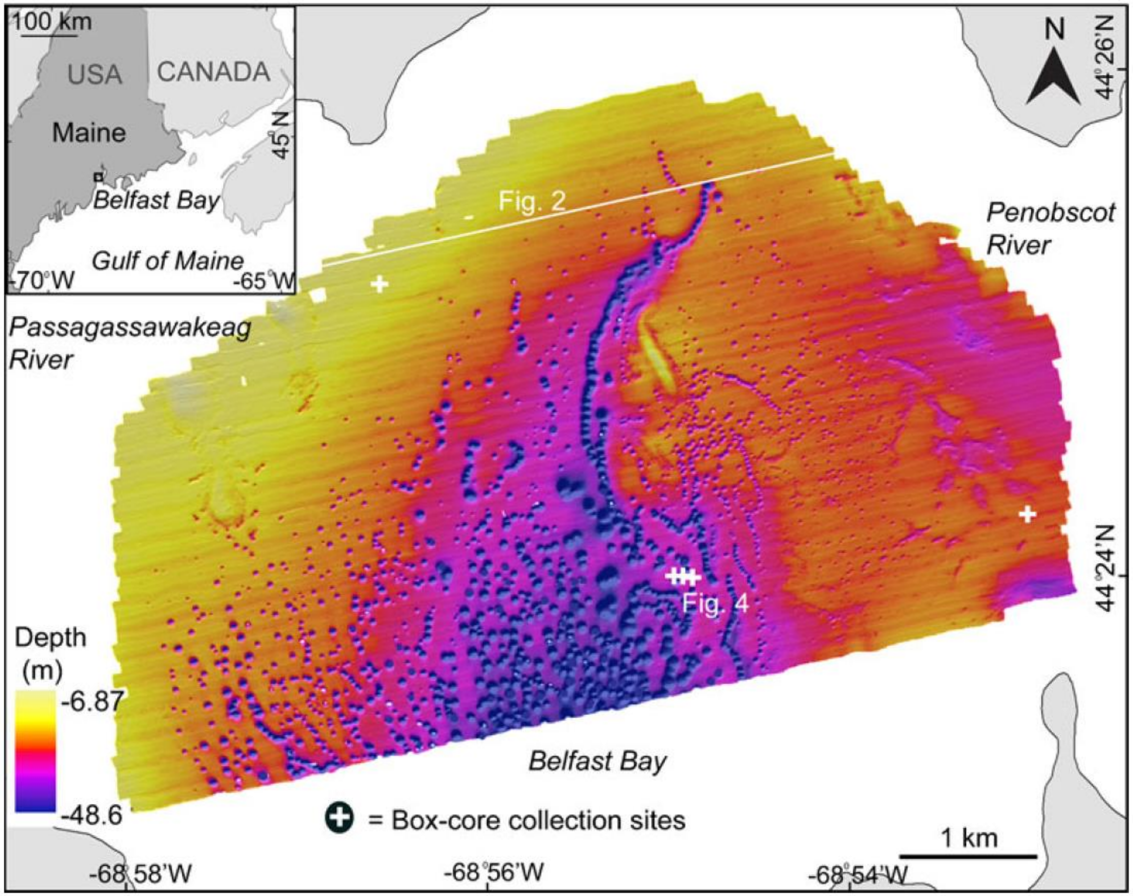


Figure 14. This image from Brothers and others (2011) shows the pockmark field in Belfast Bay. Pockmarks are round depressions on the sea floor. These depressions were noted during sea floor surveys as early as 1872. Comparison with more recent datasets (1947, 1999, 2006, and 2008) show that the field has not changed significantly over time.

The main hypothesis for pockmark formation is escape of methane gas, but how the pockmarks remain clear of sediment is still a mystery.

Pockmarks in Belfast Bay

The methane gas is thought to have developed from decaying plant matter that was deposited in bogs and lakes during a brief period of time between retreat of the ice sheet from the area and flooding by seawater as a result of rising sea level (Rogers and others, 2006).

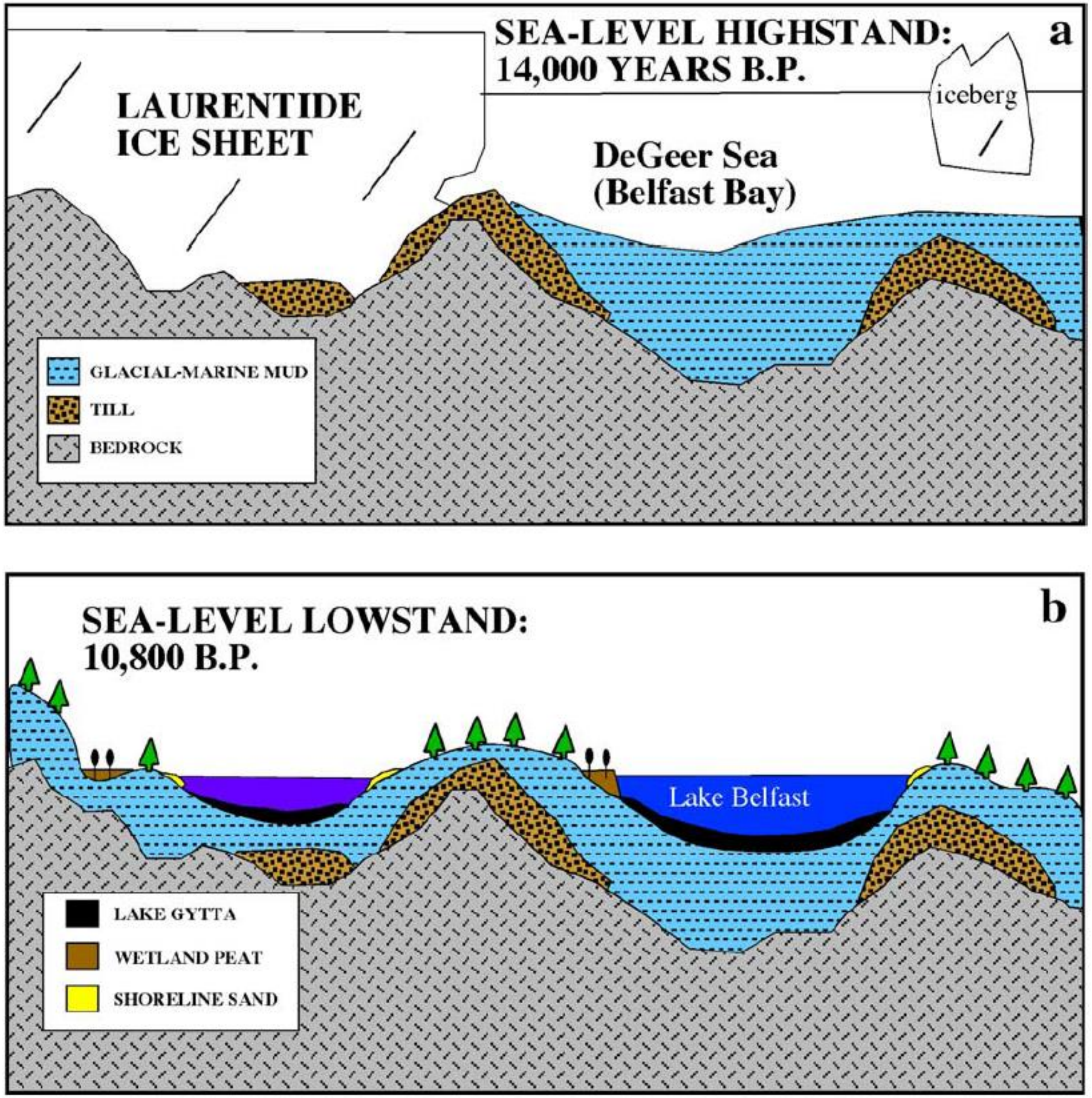


Figure 15. These cartoon cross-sections from Rogers and others (2006) depict the leading hypothesis for the origin of the methane gas (and therefore the pockmarks) in Belfast Bay. In the top panel the "glacial-marine mud" is the Presumpscot Formation. In the bottom panel the "lake gyttja" and "wetland peat" are the sediments rich in plant matter that today are covered with ocean sediment and are a source of methane in the bay.

Views of the Trail

Figure 16. Looking north toward a bridge that crosses the Passagassawakeag River. As you cross to the northern side look down to the right – except at high tide you will get another view of rocks of the Bucksport Formation. The sign on the left indicates that at this point you are 2 miles from Belfast.

Views of the Trail

A large semi-circular granite bench sits at the side of the trail north of the Upper Bridge parking lot. The City of Belfast reports that it was created by Bonin Masonry.

The lack of layering (or alignment of mineral crystals), the mixture of a handful of different minerals (dominated by feldspar), and the size of the crystals would help a geologist identify this rock as an intrusive igneous rock.

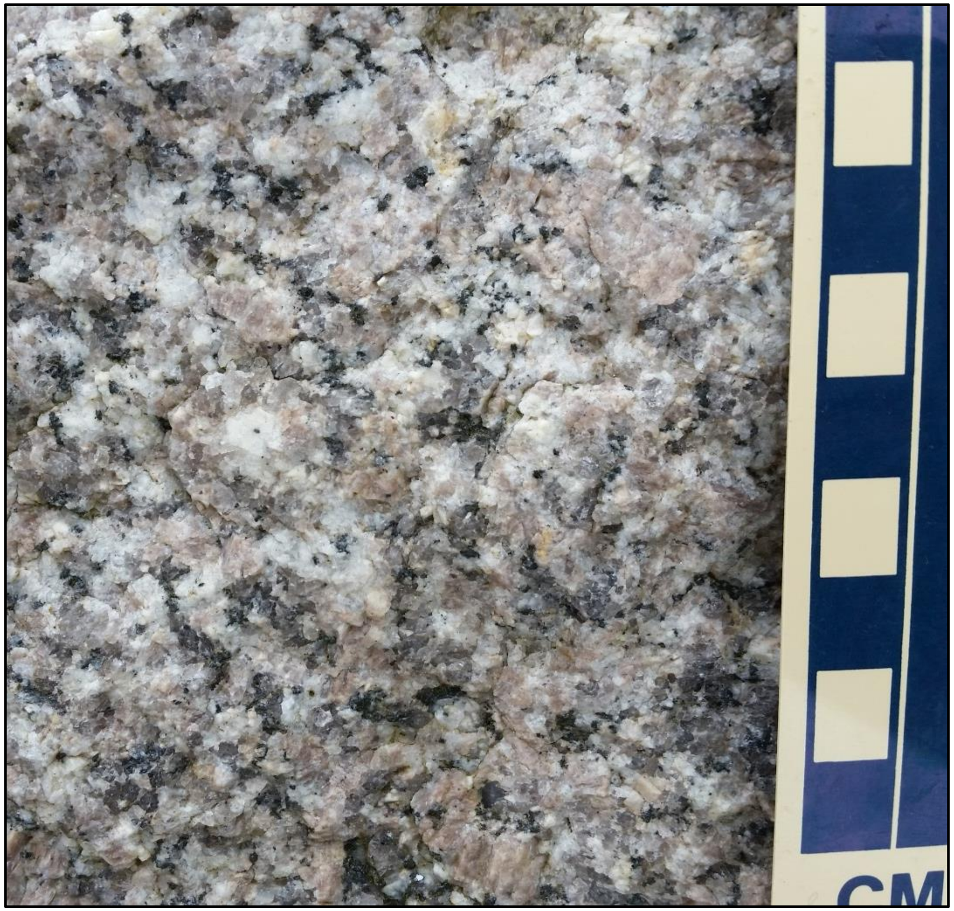


Figure 17. Close-up view of individual crystals within the granite. Bring a hand lens to get a good look at quartz, feldspar, and mica crystals.

The Beavertail

The Beavertail is a bit of land, exposed during low tide, that extends out into the river. Joseph Williamson's book, *History of Belfast, Maine,* says the feature was once more extensive, but the whole landform was removed during construction of the railroad.

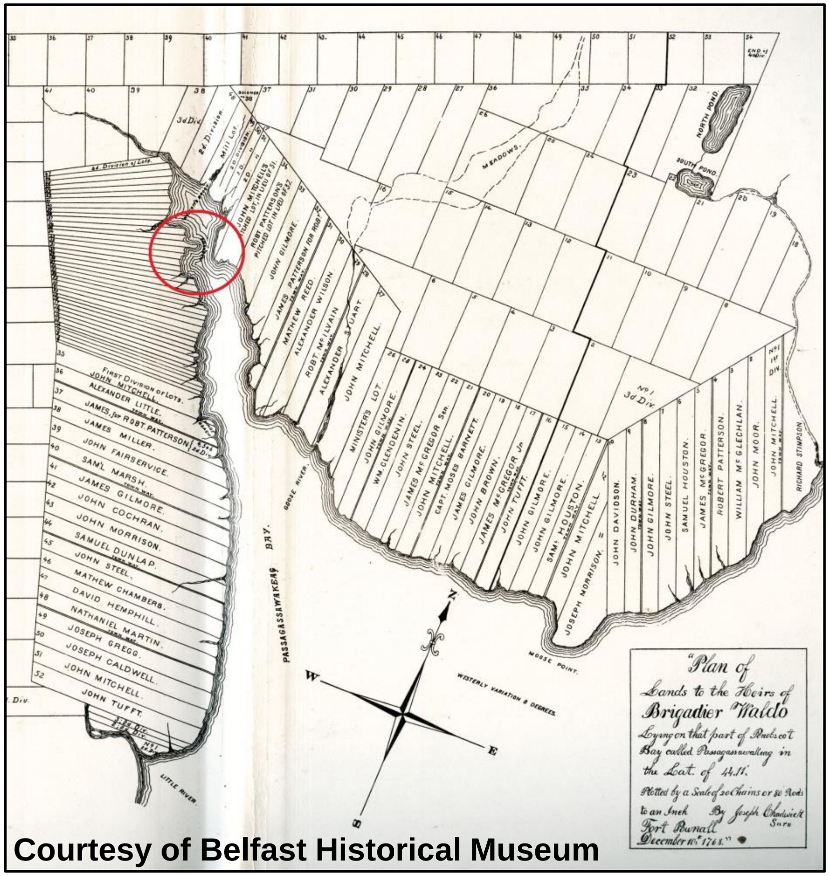


Figure 18. (from left to right) A sign on the rail trail marks the location of the Beavertail; The 1768 original plan of Belfast shows a large cape at a place labeled "narrows"; an aerial photo showing the Beavertail today..

The Estuary

Estuaries are places where fresh water and salty ocean water meet. The amount of dissolved salt in the water, or the salinity, determines the boundaries of an estuary, but this boundary changes with the tides and the seasons. Sea water has a salinity of 30 to 35 parts per thousand (ppt), and fresh water has a salinity near 0.5 ppt or less, so an estuary generally has salinities that fluctuate between 0.5 and 30 ppt (Ruffing, 1991). Estuaries are classified by the relative amounts of fresh water input and sea water (water balance), by their shape (geomorphology), and by the vertical distribution of salinity in the water column. In temperate climates like Maine, estuaries generally have a positive water balance, meaning that the amount of fresh water contributed from the river and runoff is greater than the amount of freshwater lost through evaporation. Fresh water, which is less dense than sea water, is able to flow out to the ocean by “floating” on top of the denser sea water.

Estuaries are unique habitats in the transition zone between the land and the sea. Many shellfish and fish use the sheltered environment to feed or as nurseries. Estuarine plants provide food and also slow flood waters, reducing erosion and allowing sediments to settle out. Land animals use the banks and shoreline to forage or hunt for food in the rich estuarine system.

The Passagassawakeag Estuary

The Passagassawakeag funnel-shaped estuary extends from Belfast Bay approximately 3 miles inland to the head of tide at the gorge past City Point (Maine Coastal Program, 1991). A survey in 1979 by Larsen and Doggett found that the salinity in the estuary defined a long smooth gradient, and the State Planning Office found that the estuary salinity was stratified (layered) above the Route 1 bridge, and partially mixed below the bridge.

The mud flats support abundant shellfish, but are closed to harvesting due to discharges from the Belfast Wastewater Treatment Plant and other sources of pollution.

Figure 19. View to the north from the Upper Bridge parking lot. The beavertail is visible on the left.

References

List of Internet Resources:

Belfast and Moosehead Lake Railroad: http://belfastandmooseheadlakerail.org/joomla/index.php
Belfast bay Watershed Coalition: http://belfastbaywatershed.org/
The Belfast Historical Society and Museum: http://www.belfastmuseum.org/
Belfast Rail Trail map: http://www.hartdalemaps.com/uploads/5/1/7/6/51765423/belfast_railtrail_092516.pdf
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Maine Geological Survey interactive web map: http://www.maine.gov/dacf/mgs/pubs/#webmaps

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