GEOLOGICAL SOCIETY OF MAINE
FIELDTRIP GUIDE FOR MOUNT DESERT ISLAND AND SCHOODIC PENINSULA
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Introduction

This trip provides an overview of the fascinating bedrock and surficial geology, and coastal marine processes of Mount Desert Island and Schoodic Peninsula. Hundreds of millions of years of complex geological processes (magmatic, tectonic, glacial, erosional) have interacted to produce the dramatic landscape of Maine's mid-coast. This landscape and the resources provided by it have attracted humans for millennia. In addition to traditional stops focused on geology, we will also explore this use of resources through granite quarrying and the construction of world-class carriage roads.

General Geology

The geology of Mount Desert Island is dominated by an igneous complex of multiple phases, which was intruded into a sedimentary and volcanic sequence at shallow crustal levels. The imposing edifice of Cadillac Mountain, which dominates the profile of the island from afar, is composed of the most abundant rock type here – granite. Once molten magma several kilometers within the crust, millions of years of erosion have now exposed it at the surface. Over the last million years or so, nature's most efficient agent of erosion – glacial ice – sculpted the classically rounded landscape of today.

Bedrock geology

This brief review of units begins with the oldest and is paraphrased from Gilman and others (1988).

Ellsworth Schist: (Cambrian) While not the subject of this fieldtrip, the Ellsworth rims the northwestern portion of the island and glacially distributed boulders of this unit can be found throughout the island. This is a strongly deformed green to gray schist with common thin quartz-feldspar layers or veins.

Bar Harbor formation: (Silurian) This unit of regularly bedded tan, gray, or lavender sandstone and siltstone is well exposed just southeast of the pier in Bar Harbor. Beds are generally a few cm to 20 cm in thickness and some are graded. Beds are gently inclined in most areas and lack the intense deformation of the Ellsworth, upon which this formation sits unconformably.

Cranberry Island volcanic series: (Silurian) The rocks that form the Cranberry Isles and the southwestern part of MDI are largely the result of volcanic eruptions that took place 424 +/- 1 million years ago (Seaman and others, 1995). Much of the series is composed of gray crystal and lithic tuffs, and other fragmental volcanics. There is an extensive section of light brown felsites and brown dacite flows southwest of Southwest Harbor. Some of these volcanics were probably contemporaneous with the Bar Harbor formation.

Gabbro-diorite: (Silurian) This rock represents the earliest phase of intrusive igneous activity and is found in a partial rim around the main body of granite. This dark gray, coarse-grained rock contains abundant black pyroxene and/or hornblende and gray plagioclase. Diorite has more abundant plagioclase, but the two rock types are often in a layered association with one another.

Granite of Southwest Harbor: (Silurian) Exposed in a belt west of Southwest Harbor, this granite is light gray to pinkish, fine-grained, and contains both biotite and hornblende.

Granite of Cadillac Mountain: (Silurian) Most of the island east of Somes Sound is underlain with this pink to greenish gray, coarse-grained granite. The feldspar in this granite is all pinkish perthite. Hornblende is a common accessory mineral in this granite. U-Pb dating of ziron by Seaman and others (1995) establishes a latest-most Silurian age, 419 +/- 2 Ma, for this granite. Gilman and others (1988) assigned this granite and others to the Devonian based on the best dating available at the time of their publication.

The contact of the Cadillac granite with the gabbro-diorite suggests that the magmas that cooled to these respective rock types where coeval. In numerous places at the contact, enclaves of gabbro float in a matrix of medium-grained granite. The rounded, cuspate margins of these enclaves, and frequent reaction rims around them are part of the evidence that the molten magmas commingled, much like water and oil. Wiebe and others (1997) provides more detail on this fascinating story.

Shatter zone: Gilman and others (1988) used this term for the spectacular zone of interaction between the Cadillac granite and the country rocks it intruded. The shatter zone likely resulted from severe fracturing of the country rock as the granite intruded. At Anemone Cave, the country rock is the only slightly older gabbro, while at other localities including Otter Point and Little Hunters Beach, the country rock is the Bar Harbor Formation. Within the shatter zone are wide variety of textures and shapes of blocks of country rock within a granite matrix.

Granite of Somesville: This fine- to medium-grained, pink to gray granite was mapped separately from the Cadillac, which it resembles, by Gilman and others (1988), but is lumped with the Cadillac on the generalized map of Mount Desert Island which accompanies this guide. In contrast to the Cadillac, this granite has both pink K-feldspar and light gray plagioclase.

Diabase dikes: Schoodic Point is an excellent locality for study of younger diabase dikes within the magmatic complex that underlies most of Mount Desert Island and vicinity. Most of these fine-grained, gray basalt dikes are less than 10 feet wide, but some exceed 60 feet. Crosscutting relationships demonstrate several phases of dike intrusion. Several large dikes intrude the Cadillac granite on the southern flank of Cadillac Mountain, and others are visible in roadcuts on the Cadillac Mountain Road.

Glacial geology

Mount Desert Island has been profoundly affected by the last glacial period, with the last glacial advance reaching its maximum extent around 21,000 years ago. The glaciers scoured the landscape, eroding mountains into their characteristically rounded

shapes, and excavating lake basins along preexisting zones of weakness. Scoured and polished outcrops of granite are abundant throughout the park.

This area became ice-free around 14,000 years BP, when sea level was briefly higher due to isostatic depression of the crust by the weight of ice. Raised cobble beaches, sea caves, and sea stacks today attest to this former higher sea level. Glacial marine mud deposited during the higher sea drapes much of the bedrock in stream valleys and the lower elevations throughout the island. Slower rebound, which may still be underway (and possibly responsible for seismic activity?) has raised these features 70 meters above current sea level.

Earthquakes

On September 22, 2006, the morning routines of many Bar Harbor residents were disrupted by the rumbling and shaking of a Mn 3.4 earthquake with an epicenter in nearby Frenchman Bay. While few probably felt several sub-Mn 2.0 that preceded this event in the hours before, the succeeding series of more than two-dozen earthquakes drew considerable public, media, and scientific attention. The largest earthquake of this series, Mn 3.8, occurred on October 2, 2006 at around 8 PM local time. This ground-shaking event set off numerous rock falls and rockslides within the Park, notably on Champlain Mountain and Dorr Mountain, prompting Park officials to close several hiking trails.

Both Weston Observatory, manager of the New England Seismic Network, and the Lamont-Doherty Cooperative Seismographic Network responded with additional investigations. Following the October 2 event, Lamont installed portable seismographs around the region to record and better locate subsequent events. Weston personnel used information from the portable units to relocate the earlier events. The earthquake locations plotted on the accompanying map are the results of this work. Notably, the earthquakes in this series are oriented nearly north-south and parallel to the linear valleys gouged by glacial ice in fractured rock. Perhaps the north-south joint set that controlled this erosion also controls local release of seismic stress.

Stop 1. Anemone Cave

Schooner Overlook was previously called "Anemone Cave". The Park Service path leads to the former overlook site and rust marks still exist where a fence was built. The cave is not publicized now because of visitor damage to the anemones. Even at a distance, however, the cave is impressive by Maine standards. It is 5 m in height at its opening and about 15 m deep. Curiously, there is little loose material in the cave. Roof-fall rocks and other debris are apparently washed out by storm waves.

The cave is developed in rocks of the shatter zone of Gilman and others (1988) – the boundary between the massive Cadillac granite intrusion and older country rock. Here the shatter zone is unspectacularly developed in slightly older gabbro-diorite that partially rims the northern and eastern part of the granite. A few younger basalt dikes cut the older rocks. Several sets of gently and steeply dipping shear zones and joints combine to create a zone of weakness that has been exploited by waves and other processes to produce this impressive cave.

Stop 2. Sand Beach, Acadia National Park

Sand Beach (Figure 3-1-1) is one of the most visited beaches in Maine, yet it is also one of the most unusual. This pocket beach is surrounded by granite outcrops and isolated from any distant source of sand. The parking lot is developed on a terrace that contains till on the bottom and seaward-dipping outwash sands at the surface. The till is exposed just to the west of where the stairs enter the beach. A similar terrace exists across the valley containing the salt marsh behind the barrier.

Despite the ongoing erosion of these terraces, the beach contains up to 70% carbonate shell fragments (Leonard and Cameron, 1981; Brandes, 2000). The carbonate concentration varies spatially and temporally, with a greater abundance of shells nearshore and less in the backbarrier region. Cores through the dunes exhibit near-constant values of carbonate. The major organisms forming the carbonate fraction of the beach, in order of most to least abundant, are barnacles (*Balanus* sp.), bivalves (mostly *Mytilus edulis*), and echinoderms (mostly *Strongylocentrotus drobachiensis*)(Leonard and Cameron, 1981; Brandes, 2000). This is similar to offshore samples, except that echinoids are more abundant there then bivalves (Barnhardt and Kelley, 1995).

Sand Beach exhibits classic summer/winter topographic profiles (Leonard and Cameron, 1981; Brandes, 2000), and the tidal inlet at the eastern end opens and closes frequently. During the Patriots Day Storm of 2007, significant retreat of the frontal dune occurred. The dune fence was destroyed and an old shipwreck appeared under the eroded dunes.

Stop 3. Monument Cove Acadia National Park

This boulder beach is a prime example of large, compact-shaped clasts developed from a granite source (Waag and Ogren, 1984). The source of material is the cliff surrounding the cove, including the 7-meter high sea stack at the north end of the beach. Note the steeply-dipping joint pattern and the well-developed sheeting fractures. The removal of blocks along these joint planes initially yields tabular blocks that become more spherical with time (Waag and Ogren, 1984). Clast long axes range upwards of 1 meter; the most spherical clasts are on the order of 30-50 cm. The larger clasts are rounded in place by the smaller clasts rolled about during storm events. Clast shape and rounding varies from the top of the storm berm at the uppermost storm-swash limit, less rounded and more compact in shape, down to spring low water and out onto the upper shoreface, better rounded and more disc-like. This beach is a great place to demonstrate variation in clast form and sphericity to students.

The steeply dipping joints here and elsewhere on Mt Desert Island strike generally to the north. In some places slickensides are visible in fractures with the same orientation. In other locations diabase dikes possess a similar attitude; many of these have been differentially eroded to produce sea caves and thunderholes such as those visible in Monument Cove and adjacent to it. On a regional scale the north-south oriented joints and faults were preferentially eroded by glaciers, resulting in the many deep valleys and gorges on the island. Late-stage hydrothermal alteration produced molybdenite and pyrite in some fractures. Note, also that what at first glance looks like a mat of green lichens on some joint surfaces is actually a thin coating of epidote, a product of late-stage hydrothermal processes.

Stop 4: Gorham Mountain, Acadia National Park

A short walk up Gorham Mountain leads to the Cadillac Cliffs trail. This trail at about 70 m asl marks the local, late-glacial highstand position of the sea. The trail follows along the base of a paleo-seacliff, with sea stacks, boulder beaches and at the end, a large sea cave. It provides an excellent higher-than-present analogue to the boulder beach setting at Monument Cove.

In the late 19th Century, Shaler (1874) described the location (and others like it) around what-is-now the National Park. His interpretation of the raised shoreline features was later challenged by Johnson (1925), whose model of Maine's coast as one of regional submergence disallowed higher-than-present sea-level positions. Johnson ascribed the raised shoreline landforms to glacial processes.

Stop 5: Little Hunters Beach, Acadia National Park

Little Hunters Beach is a pocket beach in a small cove. It is sourced by erosion of a till deposit at the rear of the beach. There are usually several storm berms in evidence on the higher parts of the beach, all of which usually possess beach cusps.

Beyond the beach on the right, the headland exposes one of the most spectacular sections of the shatter zone anywhere on the island (contrast with stop 1). The country rock intruded by the granite here is the Bar Harbor formation – regularly bedded siltstone and sandstone. Blocks mostly of the Bar Harbor formation in nearly randomly orientation and of variable size (several cm to several m) are surrounded by a matrix of light-colored granite. While many blocks are angular, others are rounded, hinting at the chemical 'erosion' of the blocks within the fluid granitic magma. Some show reaction rims which further attest to exchange of components between the country rocks and magma. A few blocks are more ghost-like – parallel wisps of biotite and quartz in mostly granitic material. Gilman and others (1988) suggest that close to the main body of the granite, the light colored matrix that surrounds the blocks is a mixture of recrystallized country rock and fine-grained Cadillac granite. Farther away, the matrix might be entirely recrystallized country rock. At this locality, near the contact with the granite proper, the matrix is probably a mix.

Stop 6: Hunters Brook

This stop presents some of the glacial deposits that drape the bedrock landscape of Mount Desert Island. A small slump occurred at this locality several years ago, exposing glacial marine sediments. The brook is mostly underlain with marine clay, which occupies many of the lower elevation drainages on the island. The upper portion of the slumped bank exposes coarse-grained glacial sand. This outwash deposit formed at the outlet of a meltwater channel that follows the valley NNW of here toward Eagle Lake.

Stop 7. Maine Granite Industry Historical Society Museum.

At this stop, museum director Steve Haynes will show us tools and artifacts of the stone cutting industry and demonstrate cutting.

Stop 8. Hall quarry

(From Dale, 1923): The Hall or McMullen Quarry opened about 1880. In 1905 the quarry measured 250 feet north to south by 250 feet from east to west. The quarry had a depth of 50 feet at the west side. Transport of the granite was by track 800 feet to the wharf, which was accessible to schooners of 20 feet draft. The operator was the Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York. The granite was reportedly a light-buff grayish color with a coarse to medium texture. Accessory minerals: Apatite and a little secondary calcite within the oligoclase.

Stop 9. Duck Bridge and Duck Quarry

An excellent example of the local use of granite from Mount Desert Island.

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GEOLOGICAL SOCIETY OF MAINE SUMMER FIELD TRIP 2008
SUNDAY JULY 27, ANP SCHOODIC SECTION

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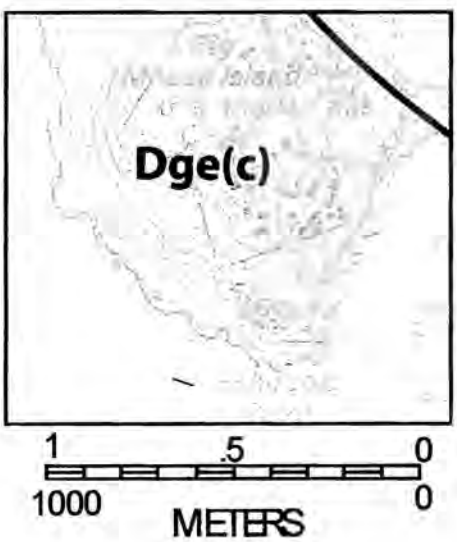
Introduction

The ~419 Ma Gouldsboro pluton is a bimodal pluton that extends south from the ~366 Ma Tunk Lake pluton (Gylling and Seaman, 2001), at the northernmost portion of the Schoodic peninsula, south toward related volcanics at the southern end of the Schoodic peninsula and east toward the town of Steuben. The pluton appears to have been constructed by repeated discrete intrusions to generate a series of south dipping sheets with the most mafic units, 2 pyroxene + olivine rhythmically layered gabbros, exposed in the northeastern portion of the peninsula. Evidence of complex mechanical and physical mingling of mafic and felsic materials is exposed in the eastern central portion of the peninsula, and the most felsic, volatile rich exposures in the south. The Gouldsboro pluton intrudes a greenschist facies meta-volcanic unit to the northwest and the meta-sedimentary units of the Bar Harbor formation to the west. A very texturally diverse dioritic portion of the Gouldsboro system is in turn intruded by a younger hypersolvus unit of the Tunk Lake pluton to the northeast.

The regional pattern of exposure is that of a plutonic system exposed roughly in a cross-sectional view (Koteas and Seaman, 2007.) Recent studies have revealed a pattern of gradients in water concentration from the base of the system to the top of the system where units appear to have devolitalized, likely in the process of eruption (Koteas and Seaman, 2008). Overall, the Gouldsboro pluton is best characterized as a fine to medium grained K-feldspar, quartz, plagioclase, hornblende +/- biotite +/- epidote granite; however, textural and compositional heterogeneity are very common in areas of the pluton where nearly contemporaneous mafic and felsic magmas have interacted to generate either mechanical mixtures or compositional hybrids.

Stop 1. Schoodic Head parking area

This parking area is the southern terminus of the Acadia National Park Schoodic section loop road. Excellent exposures can be viewed in all areas south, east, and west of the parking area.



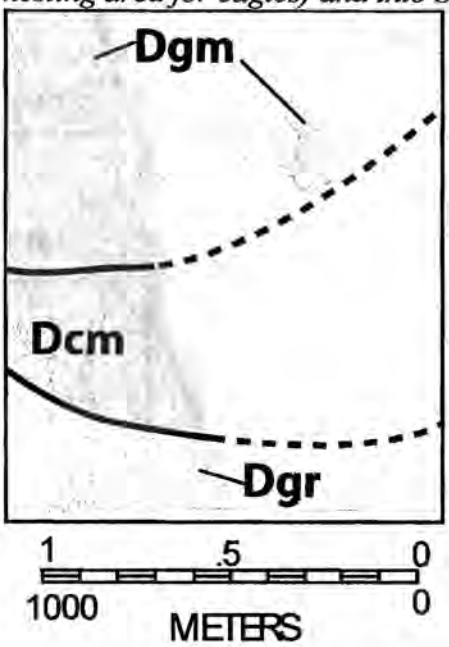
Granitic rocks exposed in this area are very K-feldspar rich and quite fine grained. This "sugary" unit is hypothesized to be close to the roof of the ~419 Ma (Waight et al., 2007) Gouldsboro pluton. Granite here is cross-cut by both 3-20 meter wide mafic dikes as well as less common rhyolitic dikes. Previous interpretations suggested that most mafic dikes in this region were Mesozoic and rift related; however, there appears to be significant compositional heterogeneity preserved within dikes as well as clear differences between very straight and more anastomosing dikes that display much

more irregular margins. These observations suggest that some mafic dikes intruded the host granite before final solidification of the pluton such that there are at least two distinct generations of mafic dikes preserved in this region.

The rhyolite dike preserved ~70 meters south and west of the parking area at Schoodic Head is an excellent example of a layered dike that is likely related to some of the latest pulses of magma active within the bimodal Gouldsboro system. Evidence from exposures further north and east on the Schoodic peninsula reveal a compelling case for multiple episodes of mafic and felsic reinjection during the construction of the Gouldsboro pluton (Koteas and Seaman, 2007b). Rhyolitic dikes as well as felsic and intermediate enclaves preserved at higher levels (south) in the Gouldsboro pluton are likely related to melting induced by thermal influx from late mafic reinjections.

Stop 2. Minx Den parking area, eastern Schoodic section ANP loop road

This parking area is not designated by park service signage; however, it is the second pull-off after the Blueberry Hill parking area on the eastern portion (northbound) of the loop road. The parking area provides a nice view east to Rolling Island (a common nesting area for eagles) and into Schoodic Harbor.

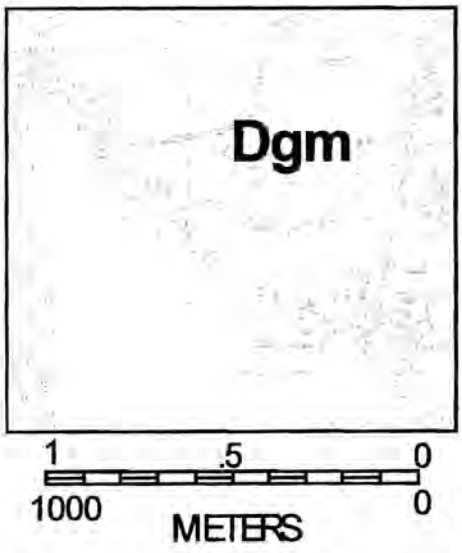


Felsic and intermediate centimeter to meter scale enclaves are very common in this area and make-up 200-300 meters of coastal exposure. Subrounded to subangular enclaves exhibit vesicles that are often filled with quartz, alkali feldspar, chlorite and less commonly hornblende and epidote. There have been multiple interpretations related to the origin of felsic enclaves such as collapsed roof material (Didier, 1991), crystal rich mush brought from the lower portion of a fractionally crystallizing magma chamber during later mafic injections (Wiebe and Adams, 1997), and late felsic magma injections from foreign crustal sources (Waight et al., 2007).

Coastal exposures just northeast of this area preserve composite dikes that preserve evidence of both basaltic and rhyolitic magmas using the same conduit even at these relatively high levels of the system (Wiebe and Ulrich, 1997).

Stop 3. Coastal exposures within Inner Harbor (west of Prospect Harbor Point)

In the town of Birch Harbor (MJ's market will be on the right), make a right on Route 186 and follow the road through the village of Prospect Harbor. Make a right on Route 195 and continue for ~400 meters then bear right and continue to the sharp bend in the road adjacent to NAVSEC DET Alpha. The best coastal exposures in this area are on the SSW facing portion of the point.

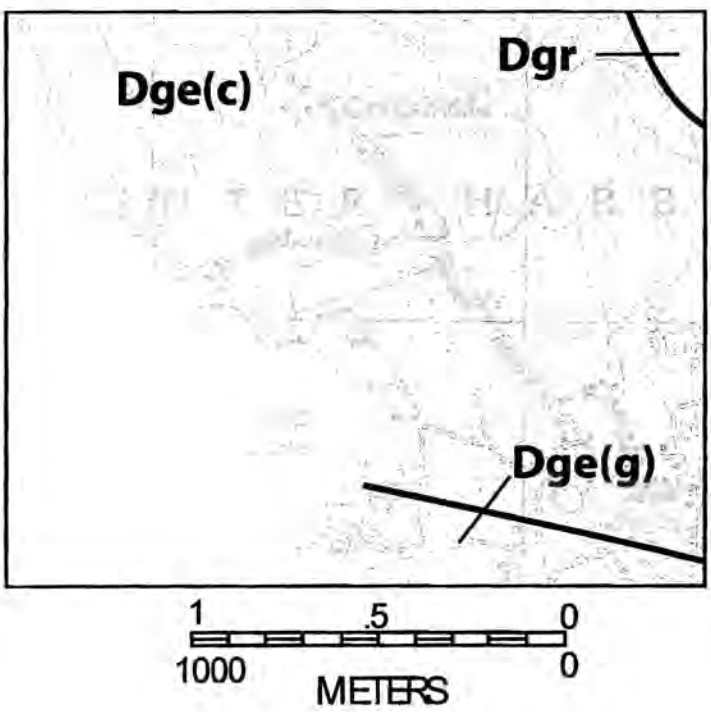


Exposures at this locality display the compositional and textural heterogeneity common within the fine to medium grained, miarolitic cavity rich granite (Dgm) unit of the Gouldsboro pluton. This unit is characterized by subtle hornblende rich clusters as well as fine to very fine grained irregular intermediate to mafic enclaves. At this locality, the clean coastal exposure shows the subtle complexity of two discrete but compositionally distinct felsic magmas that are mingling. This style of interaction is quite common within the central (middle) portion of the pluton where only rare direct evidence of mafic magma interaction is apparent in sharp contrast to exposures to the northeast where evidence of chemical and mechanical mingling between mafic and felsic magmas is very clear.

Both chatter marks and glacial striations are evident on this well polished surface. Rocks present on this beach also provide a nice breakdown of the regional geology with rounded cobbles from the Dublois, Tunk Lake, and Corea granites as well as the Ellsworth schist and assorted mafics.

Stop 4. Granite near Jordan Harbor on the west side of the Schoodic Peninsula

Return to the village of Prospect Harbor by making a left hand turn on Route 186 and continue back through Birch Harbor and through the town of Winter Harbor. Continue straight through the town center as the road curves to the north and becomes the Summer Harbor road. Continue for ~1.7 km and then make a right turn on the Gray road. After ~500 meters the road will curve to the right with a parking area immediately to follow on the left facing a large cobble beach.



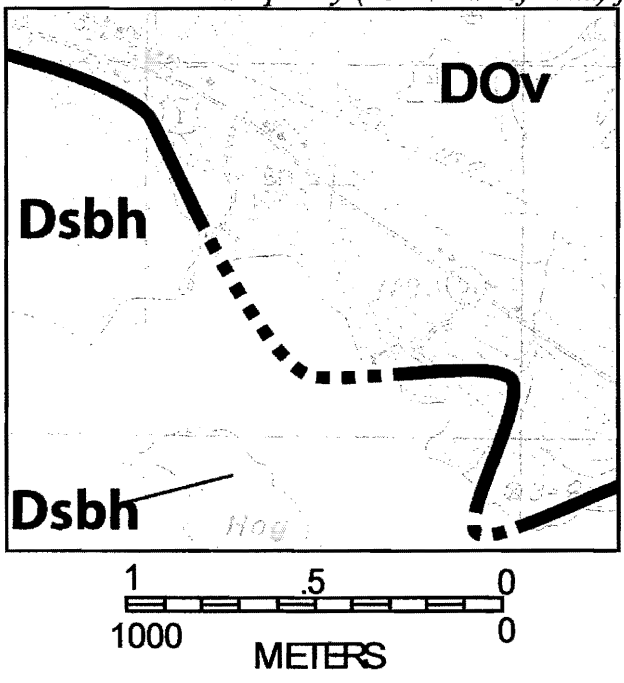
The granite here is relatively homogeneous and best characterized as fine to medium grained and K-feldspar rich. This granite acts as a transitional phase between more complexly mingled units, that become increasingly mafic to the north and east, and homogenous, fine grained, felsic granitoids to the south. Dge(g) is very similar compositionally to this unit (Dge(c)); however, Dge(g) is characterized by zones with high

concentrations of felsic to intermediate volcanics that are completely absent in this unit. Miarolitic cavities are less common here than in exposures to the south around Schoodic Head; however, isolated miarolitic cavities can reach diameters greater than 4 centimeters and are often filled with late quartz, hornblende, or epidote.

Frenchman Bay can be seen to the west from this location, which provides an excellent view of landslides on the east face of Champlain mountain from earthquake activity during the fall of 2006. Also in this view is Jordan Island that preserves the intrusive contact of the Gouldsboro pluton into the Bar Harbor formation (DSbh), on its west side, as well as Ironbound Island that is supported by a dioritic sill underlying DSbh.

Stop 5. Flander's Bay greenstone exposed in Ashville

Return to the Summer Harbor road and make a left turn (northbound). This road will junction with Route 186 in ~4 km. Go northbound on Route 186 to the junction with US Route 1 in West Gouldsboro. Make a left on US Route 1 (westbound) and continue ~3 km to a small roadside quarry (north side of road) just before Young's Market.



The Flander's Bay greenstone has been interpreted to be a greenschist facies basalt-andesite by Gilman and Lash (1988) whose work focused on the erosional unconformity between this unit and the overlying DSbh. Ongoing work reported in Arnost and Koteas (2008) confirms the general interpretation of Gilman and Lash (1988) but recognizes the importance of contact metamorphism and deformation due to the intrustion of both the Gouldsboro system as well as the Tunk Lake pluton to the north. Bulk rock geochemisty suggests that the unit is best characterized as having an island arc affinity. Petrographic studies and electron microprobe work also have shown that the unit transitions to an epidote amphibolite grade gneiss approaching the contact with the Tunk Lake pluton in the north. At this location weathered exposures reveal a clear foliation with sigmoidal quartz veins as well as flattened plagioclase crystals indicating a top-to-the-northwest sense of shear. The dominant south dipping planar fabric in this area roughly mimic the poorly exposed erosional contact with DSbh in the area of the slope break beneath US Route 1.

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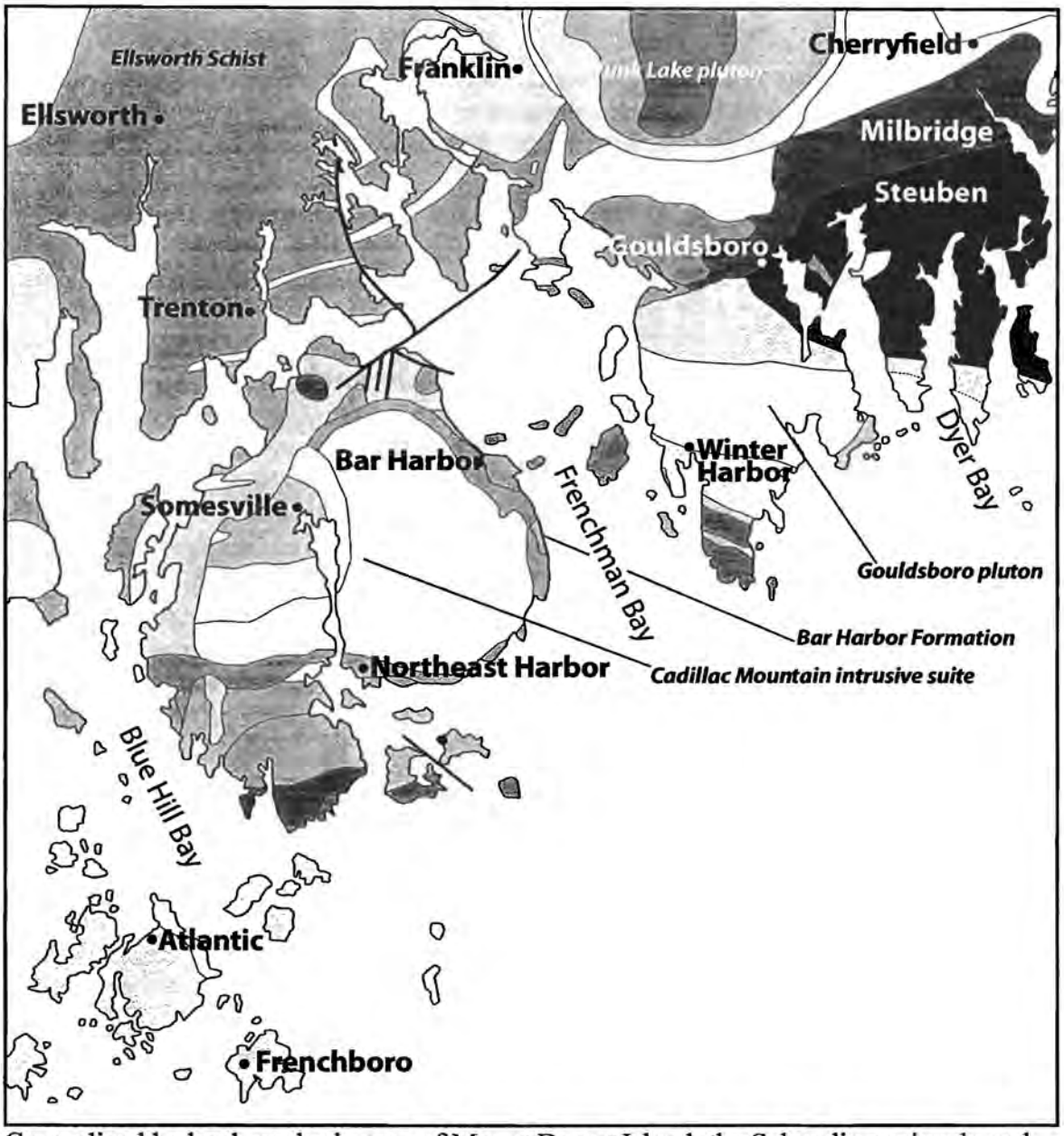
Bar Harbor FormationCadillac Mountain intrusive suiteTunk Lake plutonEllsworth



Generalized bedrock geologic map of Mount Desert Island, the Schoodic peninsula and surrounding region with major country rock and plutonic units labeled.


Western Bay
Frenchman Bay
Schoodic Peninsula
Mount Desert Island
Winter Harbor
Bar Harbor
Somesville
Somes Sound
Eagle Lake
Cadillac Mtn
Dorr Mtn
Champlain Mtn
Sargent Mtn
Hall Quarry
Long Pond
Echo Lake
Western Mtn
Anemone Cave
Sand Beach
Schoodic Point
Gorham Mtn
Monument Cove
Hunters Brook
Seal Harbor
Little Hunters Beach
Otter Cove
Northeast Harbor
Southwest Harbor
Blue Hill Bay
Bass Harbor
Cranberry Isles
N
0 0.5 1 2 3 4
Miles
Bedrock Units
Other granite (D? S?)
Cadillac Granite (S)
Southwest Harbor granite (S?)
Gabbro-Diorite (S)
Shatter zone (S)
Bar Harbor Fm (S)
Cranberry Island Volcanics (S)
Ellsworth Schist (OZ)
Fall 2006 Earthquakes
1 - 1.9 Mn
2 - 2.9
3 - 3.9
4 - 4.9
Rock Slides from 4.2 EQ
Mapped Fault


MOUNT DESERT ISLAND
Hulls Cove
Start of Park Loop Road
Hulls Cove Entrance
Hulls Cove Visitor Center
X 2. Duck Brook Bridge
X Duck Brook Quarry
Cadillac Mountain Entrance
Park Headquarters
Wild Gardens of Acadia
Nature Center
Abbe Museum
Cadillac Mountain
Somesville
X 1. Maine Granite Industy Museum
X 3. Quarry at Jock William's Boat Yard
Hall Quarry
Ikes Point
Jordan Pond Nature Trail
Town Hill
Indian Point Road
Pretty Marsh Road
Long Pond Fire Road
Beech Hill Road
Crooked Road
Eagle Lake
Cadillac Mountain Road
Duck Brook Road
Somes Pond
Echo Lake
Jordan Pond
Bar Harbor

Distribution List Name: GSM Field Trip

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