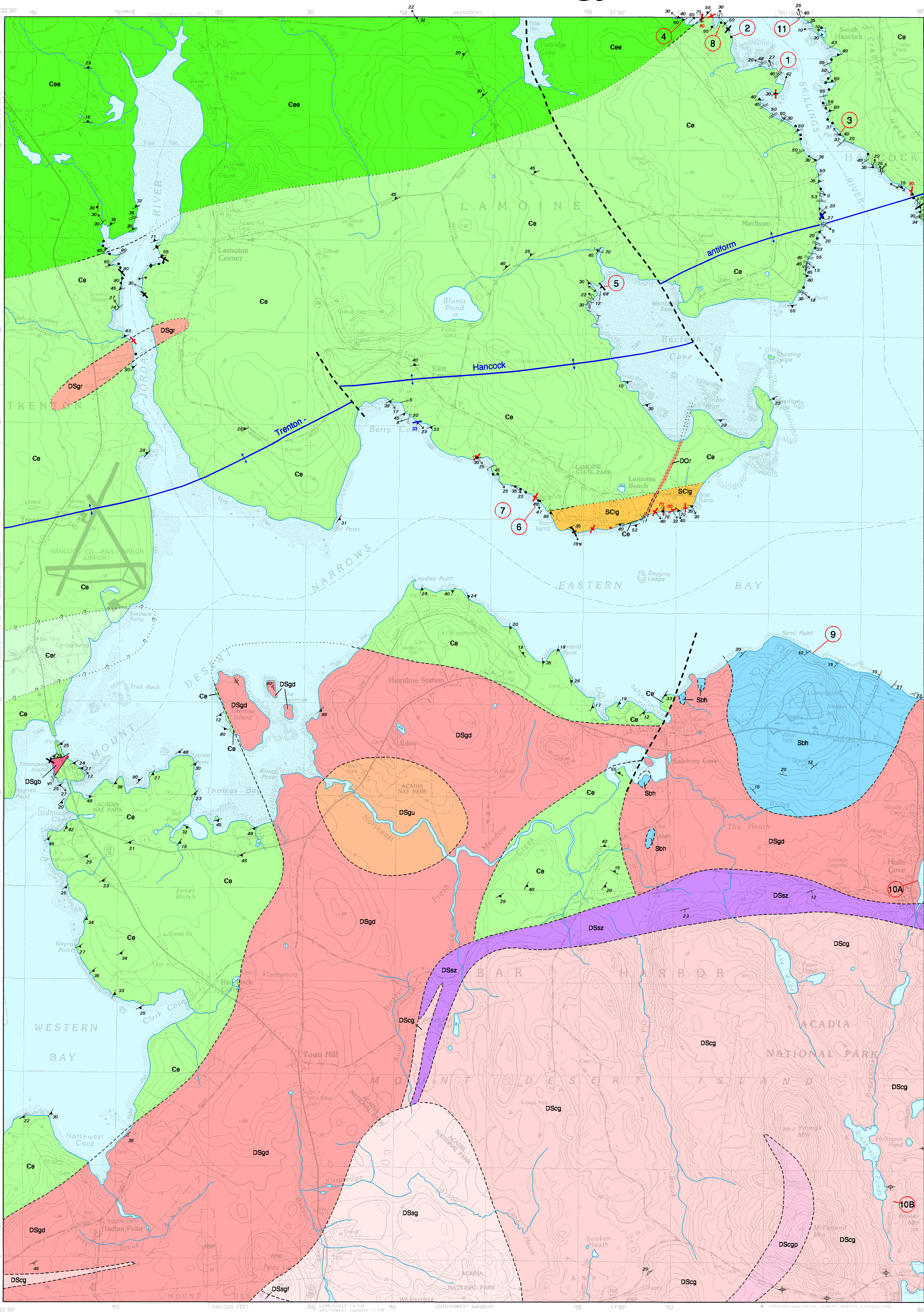
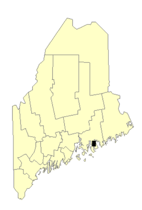
Bedrock Geology



SOURCES OF INFORMATION

Geologic mapping north of Eastern Bay by D.N. Reusch in 2001 and 2002. Geology south of Eastern Bay from Gilman and Chapman (1988).



Quadrangle Location

SCALE 1 : 24,000

1 — 0 — 1 MILE

1000 — 0 — 1000 — 2000 — 3000 — 4000 — 5000 — 6000 — 7000 FEET

1 — 0 — 1 KILOMETER

CONTOUR INTERVAL 6 METERS

TRUE NORTH

Topographic base from U.S. Geological Survey Salsbury Cove quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

Salsbury Cove Quadrangle, Maine

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* Geology of Mount Desert Island taken from Gilman and Chapman, 1988.

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For additional information, see Open-File Report 03-92.

GEOLOGIC HISTORY

ORIGIN OF THE ELLSWORTH SCHIST

The Ellsworth Schist (**€e**) originally formed as a thick accumulation of sedimentary and igneous rocks deposited in an ocean in Cambrian time (see Geologic Time Scale below). The volcanic materials included lava flows and deposits of rock fragments of various size. Most of the formation consists of thinly layered rocks which represent fine-grained sediments such as mud and silt that were eroded from a nearby volcanic region. Since they were deposited, all these rocks have been modified by heat and pressure at depth, a process called metamorphism, which somewhat obscures their original character. Though distorted, the thin layering of the rocks is widely preserved (**Photo 1**).

Thin sheets of igneous rock are common in the Ellsworth Schist. Igneous rocks originate from molten rock, or magma, that cools and solidifies. Most of the igneous rocks in the Ellsworth are of two types, a dark greenish gray rock called greenstone (**Photo 2**) and a white to cream-weathering rock called rhyolite (**Photo 3**). Most of the igneous rocks formed when lava erupted at the earth's surface, in some cases violently, during the time sediment was accumulating. A few igneous sheets probably solidified beneath the surface. The Lamoine Granite Gneiss (**S€lg**) may have intruded at this time. The Egypt Member of the Ellsworth (**€ee**) is a darker colored schist that contains greenstone but virtually no rhyolite. During metamorphism, distinctive white feldspar grains grew in the schist (**Photo 4**). The chemical composition of igneous rocks in the Ellsworth Schist suggests that they formed in a continental rift (Stewart, 1998).

Photo 1. Thinly interlayered white quartz-feldspar rock and grayish-green schist characteristic of the Ellsworth Schist (**€e**). Schist is a metamorphic rock that splits along flat surfaces. Folded layers are tilted up toward the northwest (left). (*Mosely Point.*)

Photo 2. Thin sheets of greenstone in schist. These are interpreted as volcanic layers that have been flattened during metamorphism. (*Ellsworth Schist. North of Mosely Point, Skillings River.*)

Photo 3. Two sheets of white volcanic rock (rhyolite) in the Ellsworth Schist (**€e**). Rhyolite is of the same chemical composition as granite, but has cooled rapidly from the molten state to form a hard, crystalline rock with very small mineral grains. (*Pecks Point, Skillings River.*)

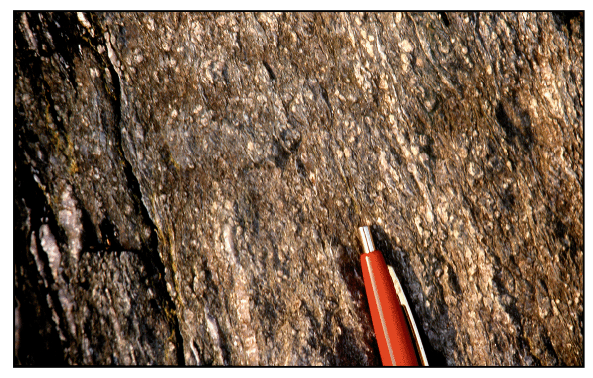

Photo 4. Dark colored, more uniform schist of the Egypt Member (**€ee**), with distinctive white feldspars. The feldspars grew in the rock during metamorphism. (*Skillings River, north edge of map.*)

DEFORMATION AND METAMORPHISM OF THE ELLSWORTH SCHIST

The Ellsworth Schist has been deformed at least three times producing a highly contorted rock structure. In the main stage of deformation, wet sediments and the interlayered volcanic materials were squeezed from the sides and shoved toward the northwest. Distorted thin layers show that the rocks were crumpled into abundant small folds whose shapes reflect the northwest motion (**Photos 1, 5**). This deformation affected the entire mass of Ellsworth Schist. The most pervasive feature of every outcrop is the main foliation, a microscopic alignment of flat mineral grains giving the rock an overall sheet-like structure. On foliation surfaces, mineral grains have been stretched to form lines that constitute a mineral lineation (**Photo 6**). In most places the lineation is oriented in a northwest-southeast direction, as symbols on the map indicate.

The minerals that comprise the main foliation, chlorite and white mica, form at elevated temperatures, typically 350 to 400 degrees Centigrade. It is due to this heat that the rocks could be deformed by folding rather than by breaking. Also during heating, milky white quartz veins formed throughout the schist. These veins were deformed along with the rest of the rock. The age of deformation and metamorphism cannot be determined precisely in this map area; it must be younger than the Cambrian age of the Ellsworth Schist which is deformed, and older than the Silurian Bar Harbor Formation, which is not affected by the main stage of deformation.

The main foliation and lineation of the Ellsworth Schist were themselves distorted by a variety of later folds (**Photo 7**). Some appear to indicate movement towards the southeast, in a direction opposite to the earlier main stage movement. The Hancock-Trenton antiform, indicated on the map, is a broad warp in the regional bedrock structure that deforms the earlier, main phase features.

Following the two stages of folding, brittle faults occurred. A few may be significant, shown by the heavy lines on the map, but most are minor features that are not very extensive (**Photo 8**). Some of the faults, particularly around the Cadillac Mountain Intrusive Complex, are related to intrusion of the large magma bodies. Other faults are probably of Mesozoic age.

Photo 5. Folded white quartz-feldspar layer displays effect of main phase deformation. View toward southwest. (*Raccoon Cove.*)

Photo 6. Streaks of quartz and feldspar on a rhyolite surface define a lineation (**L**) showing the rock was stretched. (*Lamoine State Park.*)

Photo 7. The main phase deformation fabric is overprinted by younger crenulation folds. Main phase fabric runs left to right along the bottom of the photo; crenulations run from upper right to lower left in center of photo. (*Shoreline west of Lamoine State Park.*)

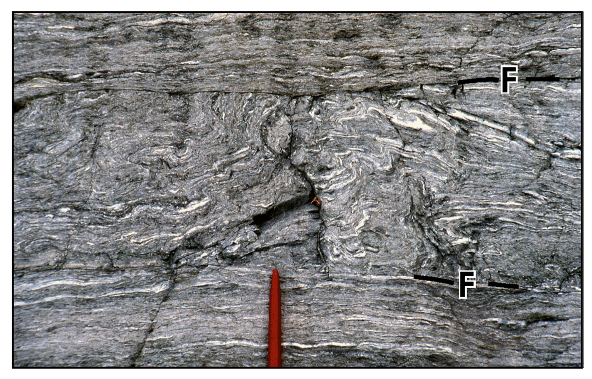

Photo 8. Two minor faults (**F**) cut the earlier metamorphic fabric. Rock layers are cut and have been displaced at the faults. This sort of small fault is common. (*Skillings River, north edge of map.*)

DEPOSITION OF THE BAR HARBOR FORMATION

Some time after the main phase of deformation in the Ellsworth Schist, it was gradually uplifted to the surface and eroded. In Early Silurian time, layers of silt and limy sand began to accumulate on the exposed Ellsworth rocks, in a warm, shallow seaway. The broad, thin layers of accumulated sediment comprise the Bar Harbor Formation (**Photo 9**). Layers of volcanic ash indicate that there were volcanic islands in the vicinity, perhaps related to volcanic rocks now preserved on southern Mount Desert Island and the Cranberry Isles.

INTRUSIVE ROCKS

Soon after deposition of the Bar Harbor sediments, melting of rocks at depth produced large volumes of magma that rose through the crust, intruded the Ellsworth Schist and Bar Harbor Formation, and slowly solidified. Three major batches of magma intruded to form the igneous complex. A dense magma rich in iron formed gabbro (**Photo 10A**); a lighter magma formed the Cadillac Mountain Granite (**DScg**) (**Photo 10B**). The gabbro (**DSgd**), solidified before, during, and after intrusion of the granite. The third major intrusion, the Somesville Granite (**DSsg**), is a mixture of late stage magmas with new intrusions (Wiebe, 1994).

Photo 9. Prominent, nearly horizontal layers typify the Bar Harbor Formation (**Sbh**). (*North shore of Mount Desert Island, east of Sand Point*)

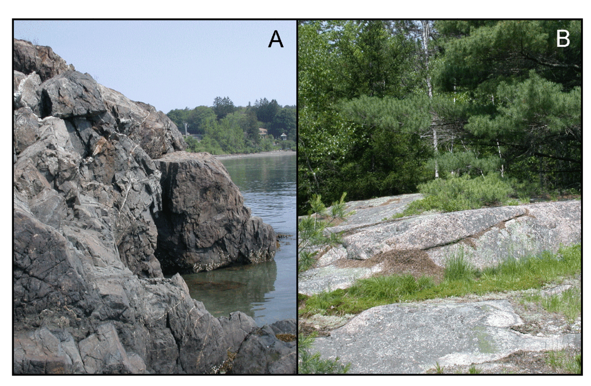

Photo 10. Rocks of the Cadillac Mountain Intrusive Complex. A. Dark gray diorite (**DSgd**) at Hulls Cove. B. Pink granite (**DSsg**) beside the carriage trail south of Breakneck Ponds.

Photos 1-8 and 11 by D. R. Reusch. Photos 9,10 by H. N. Berry.

PRESENT EXPOSURE

All the metamorphic and intrusive bedrock in the map area was once at depth in the earth. For these rocks to be exposed at the surface now, a significant amount of overlying rock must have been eroded in the hundreds of millions of years since the Devonian Period. The latest increment of erosion occurred during the last Ice Age, when a continental glacier extended across Maine and ground down some of the bedrock surface. The different types of bedrock have eroded differently, to produce the present varied landscape (**Photo 11**). The last glacier melted from the Maine coast about 14,000 years ago, leaving a blanket of sediment that covers most of the bedrock in the area.

Photo 11. Ellsworth Schist (foreground) is easily eroded to low outcrops. The mountains of Mount Desert Island (distance) are made of granite, more resistant to erosion. Bedrock controls the major landforms. (*View looking south along the Skillings River toward Cadillac Mountain.*)

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INTRUSIVE ROCKS

Mesozoic(?) or Devonian(?)-Silurian(?)

Dikes of intrusive rock. Mainly dark gray diabase but also some light gray rocks of intermediate composition. Not metamorphosed. Typically less than a few meters thick, with fine-grained margins. Some dikes near Lamoine Beach are porphyritic, with plagioclase and pyroxene phenocrysts (Inclined, Vertical, Orientation not specified).

Devonian(?)-Ordovician(?)

DOr — **Rhyolite.** Mottled pale yellow-green to pink, massive to flow-laminated rhyolite exposed at Timber Point.

Devonian(?)-Silurian(?)

DSgr — **Granite.** Medium-grained granite south of Crippens Brook. Not well exposed. Size and shape of body unknown.

DSgb — **Gabbro to diabase of Thompson Island.** Interior of pluton is medium-grained (around 5 millimeter grain size).

Early Devonian-Late Silurian

Cadillac Mountain Intrusive Complex

DSsg — **Somesville Granite.** Pink and gray, medium-grained to coarse-grained biotite granite containing pink or cream-colored alkali feldspar and light gray plagioclase. Hornblende is scarce to absent. Age of 424 ± 2 Ma reported by Seaman and others (1995) from U-Pb zircon analysis. Field relations clearly indicate that the Somesville Granite is younger than the Cadillac Mountain Granite (Wiebe, 1994).

DSsgf — **Fine-grained granite.** Variety of Somesville Granite.

DScg — **Cadillac Mountain Granite.** Pink to greenish-gray, coarse-grained granite. The individual grains of translucent, gray quartz and pink or gray feldspar are easily seen in outcrop. The principal black mineral is hornblende with minor biotite. Age of 419 ± 2 Ma reported by Seaman and others (1995) from U-Pb zircon analysis.

DScgp — **Porphyritic granophyre.** Fine-grained granophyre with variable proportions of coarse quartz and feldspar crystals. The large equant quartz and feldspar crystals resemble individual grains in the Cadillac Mountain Granite. Interpreted by Chapman (1970) as a zone in which Cadillac Mountain Granite was largely recrystallized by late-stage hydrothermal alteration. Alternatively interpreted by Wiebe (1994) as disrupted silicic dike that intruded partially solidified granitic mush.

DSgu — **Unnamed granite.** Pink, medium-grained granite with scattered larger grains of light lavendar alkali feldspar. Not well exposed.

DSgd — **Gabbro-diorite.** The gabbro is a dark gray, coarse-grained rock consisting of black pyroxene and/or hornblende, and gray plagioclase feldspar. The diorite is lighter gray due to the greater abundance of plagioclase.

DSsz — **Shatter zone.** Zone of intensely shattered country rock surrounding the Cadillac Mountain Granite. Near the granite contact it consists of angular blocks of dark country rock in a light gray matrix of granite or hybrid igneous rock. The blocks include rock from the Bar Harbor Formation, Cranberry Island volcanics, and gabbro. Interpreted to be an intrusion breccia (Chapman, 1970).

Late Cambrian(?)

Greenstone. Little-deformed, metamorphosed, massive dikes. Possible feeders for Castine Volcanics (Inclined, Vertical).

Silurian(?)-Middle Cambrian(?)

S€lg — **Lamoine Granite Gneiss.** Light gray, white-weathering, medium-grained to fine-grained foliated and lineated granite exposed on the shore at Lamoine Beach. Foliation is defined by anastomosing planes of muscovite and chlorite. Fracture surfaces are commonly rusty.

STRATIFIED ROCKS

Silurian

Sbh — **Bar Harbor Formation.** Typified by dark gray siltstone and sandstone in regular beds several centimeters thick. The beds weather to a tan, gray, or lavender color. East of Sand Point, the formation includes massive, light greenish-gray to bluish-gray flinty tuff. The Bar Harbor Formation is interpreted to rest unconformably on the Ellsworth Schist (Chapman, 1970).

Cambrian

€e — **Ellsworth Schist.** Quartz-feldspar-muscovite-chlorite schist interstratified with lesser metamorphosed bimodal igneous rocks. The schist is typically dark green and light-weathering and consists of anastomosing, variably thick (1-20 mm), fine-grained, equigranular quartz and feldspar-rich laminations and muscovite-chlorite lenses and films. Most outcrops are generally massive, without discernable bedding, and compositions range from phyllosilicate-rich through quartz-rich. Medium-bedded quartz-feldspar sandstones and impure quartzites are rare. Ubiquitous sheets of metamorphosed igneous rocks, 10-200 cm in thickness, comprise greenstones (metamorphosed basalts) and metamorphosed rhyolites inferred to be pyroclastic deposits and rare flows rather than sills. Abundant greenstone sheets are typically fine-grained, massive, and contain sparse feldspars and patches of epidote. Rhyolites range from aphanitic to feldspar- and quartz-phyric, and contain pyrite cubes up to a few millimeters across.

€ee — **Egypt Member.** Dark green schist with feldspar porphyroblasts. Fine-grained biotite is reported in thin section (McGregor,1964). The Egypt Member appears to overlie the Ellsworth Schist to its south, so it may be stratigraphically higher. Alternatively, if the concealed contact is a cryptic thrust fault, the Egypt Member may be allochthonous. A fault is suggested by a possible metamorphic discontinuity at the southern contact of the Egypt Member, since metamorphic biotite has been reported only from the Egypt Member. Additional study is needed to assess the metamorphic contrast and the validity of this fault hypothesis.

€er — **Rhyolite of Goose Cove.** Inferred to underlie the western edge of the map, though not exposed in this quadrangle. Projected from the adjoining Newbury Neck quadrangle to the west (Reusch and Hogan, 2001).

EXPLANATION OF LINES

Stratigraphic or intrusive contact (well-defined, approximately located, inferred, conjectural).

High-angle fault contact.

Axial trace of Trenton-Hancock antiform in bedding and foliation.

EXPLANATION OF SYMBOLS

Outcrop

Strike and dip of bedding in volcanic and sedimentary rocks (Horizontal, Inclined).

Strike and dip of igneous sheet. Most are inferred to be pyroclastic deposits with some rare flows rather than sills (Inclined).

Strike and dip of igneous compositional layering in gabbro-diorite (Inclined, Vertical).

Strike and dip of enclaves or xenoliths in the Cadillac Mountain Granite (Horizontal, Inclined).

Strike and dip of main metamorphic foliation, defined by preferred orientation of phyllosilicates and parallel alternating quartzofeldspathic and phyllosilicate laminations (Inclined, Vertical).

Trend and plunge of mineral lineation, defined by elongate quartz, train of broken feldspar or pyrite, or phyllosilicate streaks (Horizontal, Plunging).

Main generation folds (flexural flow folds of McGregor, 1964). Generally asymmetric, tight to isoclinal folds typically a few centimeters in wavelength.

- Hinge line, rotation sense unknown (Horizontal, Plunging).
- Hinge line, rotation sense indicated (Clockwise, Counterclockwise).
- Strike and dip of of axial plane.

Late generation folds (flexural slip folds of McGregor, 1964). Symmetric to asymmetric folds that deform the main foliation and lineation. Generally more open than main generation folds.

- Hinge line, rotation sense unknown (Horizontal, Plunging).
- Hinge line, rotation sense indicated (Clockwise, Neutral).

Strike and dip of crenulation cleavage, spaced 1-3 mm (Inclined, Vertical).

Strike and dip of kink band (Inclined).

Strike and dip of quartz veins (Vertical).

Strike and dip of minor fault, motion unspecified (Inclined, Vertical).

Strike and dip of minor normal fault (Inclined).

Trend and plunge of slickenline on fault surface (Plunging).

Location of photograph in sidebar.

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-145
	Jurassic Period	145-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-544
Precambrian time		Older than 544

* In millions of years before present. (Okulitch, 2002)