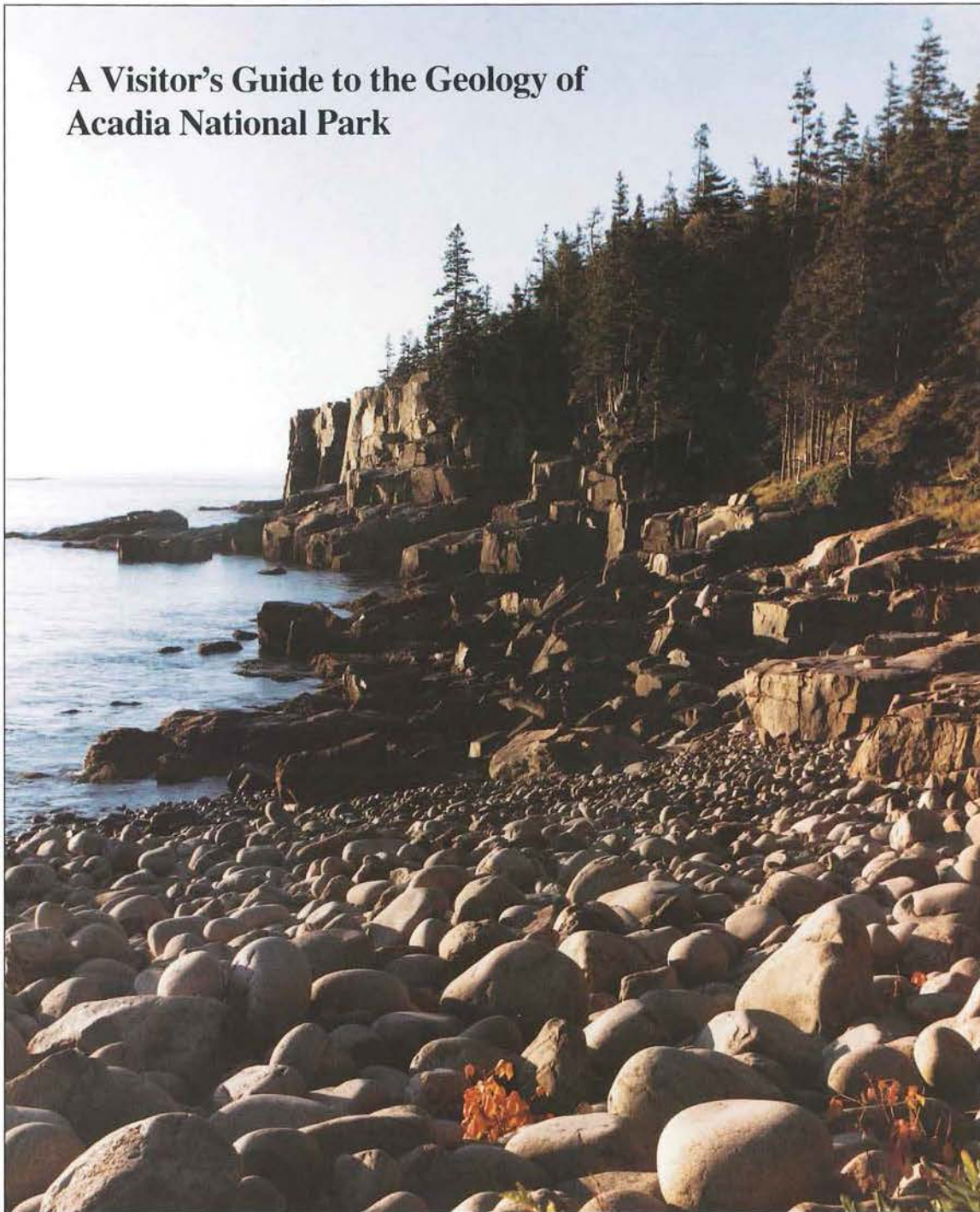


The Geology of Mount Desert Island

A Visitor's Guide to the Geology of Acadia National Park



Maine Geological Survey
DEPARTMENT OF CONSERVATION

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A Visitor's Guide to the Geology of Acadia National Park

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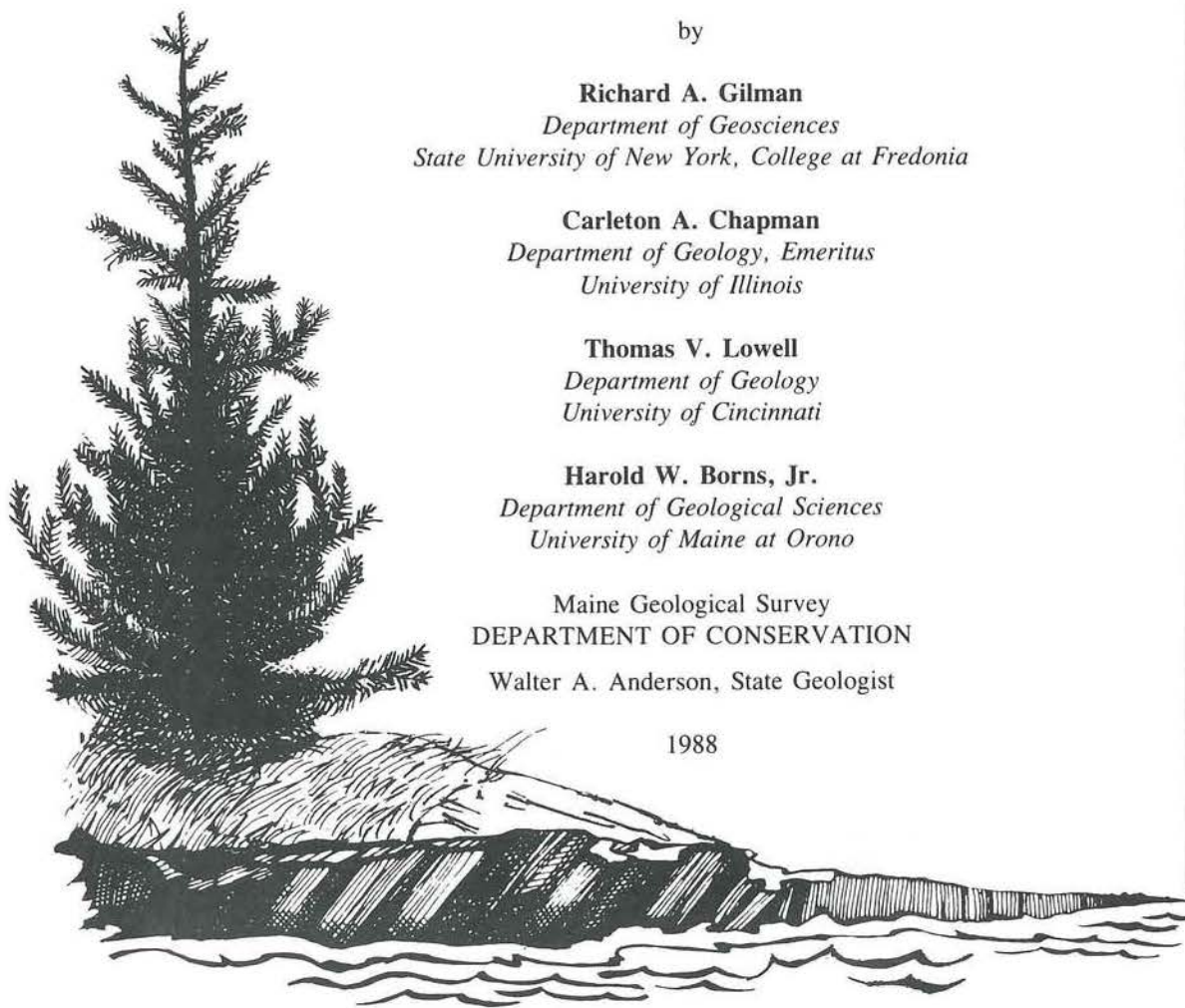
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Maine Geological Survey
DEPARTMENT OF CONSERVATION

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1988



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Note: The Surficial Geology map is superseded by: Braun, Duane D., Lowell, Thomas V. and Weddle, Thomas K., 2016, Surficial geology of Mount Desert Island: Maine Geological Survey, Open-File Map 16-1, map, scale 1:30,000.

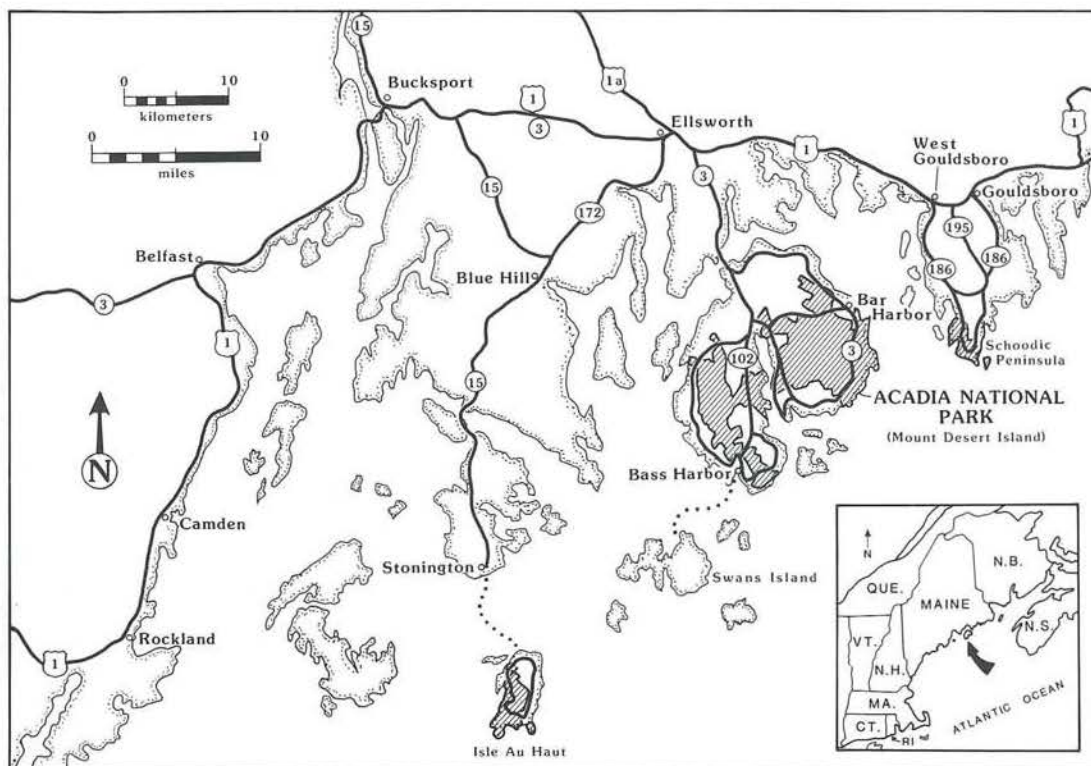


Figure 1. Map of mid-coastal Maine and Mount Desert Island. Acadia National Park is shown by ruled areas.



Preface

Maine has long been famous for the beauty of its coast. Mount Desert Island in particular has attracted numerous tourists and summer residents for well over a century. Visitors and residents alike enjoy the scenic vistas at Bar Harbor, Cadillac Mountain, Jordan Pond, Sand Beach, Thunder Hole, and many other places within Acadia National Park and elsewhere on the island. The purpose of this visitor's guide is simple: we hope that an understanding of the geologic processes which formed the island's spectacular scenery will leave the reader with a greater appreciation for both Mount Desert Island and the national park.

Mount Desert Island is the largest of the many islands located along the coast of Maine (Figure 1). Measuring almost 108 square miles in area, the island is located 150 miles northeast of the Maine-New Hampshire border and 70 miles southwest of the U.S.-Canadian boundary. Access to the island is via Maine Route 3 south from Ellsworth.

Named in 1604 by the French explorer Samuel de Champlain, the island and much of the adjacent coastal area were the site of continual skirmishing between the British and French during the French and Indian Wars. English colonists settled the island after the British victory over the French and the signing of the Treaty of 1763. Farming, lumbering, shipbuilding, and fishing were major industries for the new settlers, and fishing remains important today.

Although one of the nation's smallest national parks, Acadia is one of the most scenic and most visited. Much can be viewed from the state routes and park roads that wind around the island, or from the various hiking and carriage trails within the park. Unlike most other national parks, Acadia was not purchased with public funds or set aside from public lands. During the middle and late 1800's, the island became a summer colony for wealthy patrons from southern New England, Philadelphia, and New York. Concerned about the dangers of overdevelopment of the island, a number of prominent citizens, among them George B. Dorr, Charles W. Eliot (a former president of Harvard University), and John D. Rockefeller, Jr., together with many other Maine residents and summer visitors, worked to preserve the island's beauty. Out of their efforts came the donations of land that formed the nucleus of Acadia National Park. Legislation enacted by Congress in 1986 established permanent park boundaries, addressing concerns of adjacent towns that continued expansion of the park would hurt their economic growth.

This book summarizes the geologic history of Mount Desert Island and serves as a guide to geologic features located within and adjacent to the park. This history begins more than 500 million years ago with the formation of the oldest rocks on the island and continues today with the geologic processes that are presently shaping the face of the landscape. The accompanying geologic maps, used in conjunction with the text, allow readers to identify various geologic features on Mount Desert Island and understand how they came into being.

ACKNOWLEDGMENTS

Writing an interesting, understandable, yet scientifically accurate geologic summary for the non-geologist is a monumental task, much more difficult in many respects than writing a technical paper. We are grateful for the many helpful comments and suggestions and careful editing by Carolyn Lepage, Marc Loiselle, Sheila MacDonald, Bill Metzger, Ernest Muller, Woody Thompson, and Bob Tucker. Cathy Stultz's assistance with manuscript preparation is also appreciated, as are the illustrations drawn by John Poisson, and the photographs taken by John Poisson, Woody Thompson, and Joe Kelley.

The writers are also indebted to the staff of Acadia National Park for their assistance, especially Lois Winter, Park Naturalist, who read early drafts of the manuscript and offered many suggestions for making it more readable for park visitors.



Introduction

Not only is Mount Desert Island one of the most scenic places on the entire Atlantic Coast, it is also one of the most interesting from a geologic point of view. This short book will introduce you to the rock formations and glacial landscapes that record the more than 500 million years of earth history that went into the making of Mount Desert Island.

Maybe your imagination will be sparked by the fact that the location of the Acadia National Park Visitor Center was once part of a gigantic body of molten rock that cooled several miles below the surface of the earth, or that at another point in its history the same location was covered by hundreds of feet of glacial ice. And perhaps you'd find it intriguing to take a boat trip to the Cranberry Isles to see rocks that were spewed from volcanoes about 400 million years ago.

If these things interest you, read on; we will help you interpret the story that the landscape tells us. Part of this story is recorded in the bedrock exposed along the shore and on the mountain tops; other parts are recorded in the deposits of sand and gravel left by the glacier that once covered Maine's coast; and still other evidence is found in special features of the landscape that were carved by erosion over the past thousands of years.

The geologic history of the island can be conveniently divided into three parts: the period when the island's bedrock was deposited; the glacial period when many of the present day landforms were shaped; and the present day, when modern processes continue to modify the land. Two colored *geologic maps* of the island are included with this guide. One, the bedrock geologic map, shows the type and distribution of bedrock on the island as if all the overlying vegetation, soil, sand, and gravel were scraped off. The second, the surficial geologic map, shows the type and distribution of materials deposited during and immediately after glaciation, as well as materials formed in recent times. These maps will be referred to frequently in the descriptions that follow.

Note: Italicized words are defined in the Glossary of Geologic Terms at the end of the text.

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Bedrock Geology of Mount Desert Island

THE ROCKS OF MOUNT DESERT ISLAND

All three major kinds of bedrock, igneous, sedimentary, and metamorphic, are found on Mount Desert Island.

Igneous rocks are formed by the cooling and crystallization of molten rock, called *magma*, that forms deep within the earth's interior and then rises toward the surface. Some of this magma cools and solidifies before it reaches the surface, forming an *intrusive* igneous rock such as the granite on Cadillac Mountain. Other pockets of magma may reach the surface, erupting as *extrusive* igneous rock, perhaps forming a volcano. Much of the rock exposed on the Cranberry Isles is extrusive.

Layers of *sediment* form when small particles of rocks and minerals carried by a river are deposited in the ocean, a lake, or along the river bed itself. This material, if eventually buried by additional sediment, becomes compacted into *sedimentary rocks*. Sedimentary rocks are composed of layers, or *beds* as geologists refer to them, of different mineral composition or grain size. The Bar Harbor Formation, found along the shore path in the town of Bar Harbor, provides an easily accessible example of bedding in sedimentary rocks.

Some rocks eventually become buried several miles below the earth's surface. High temperatures and pressures at these depths cause the minerals to recrystallize, forming *metamorphic rocks*. The changes that take place are collectively known as the process of *metamorphism*, and the product of these changes is a metamorphic rock such as the Ellsworth Schist, found along the north and west sides of Mount Desert Island.

The following sections describe the different kinds of bedrock found on Mount Desert Island and summarize the current interpretation of the island's geologic history. This text should be used in conjunction with the accompanying geologic map which shows the rock types and features that are found around the island. Each type of rock is identified by color on the map and described briefly in the map explanation. To use the map and text to best advantage, we suggest you first find your location on either the bedrock or surficial geologic map and determine the rock or sediment type by referring to the map explanation, then refer to this text for a more detailed description of the rock and an account of its history. Or, you may choose to read the text and examine the maps in some detail before visiting some of the sites of geologic interest marked on the maps.

Not all of the rocks on the island formed at the same time in the geologic past. They record the geologic history or sequence of events that took place in this part of the earth over a span of many millions of years. Before we turn to the rocks themselves, let's consider the vast span of time they represent. For most of us, ten years is a long time, a hundred years is longer than we expect to be alive, and a thousand years is ancient history. But all these lengths of time are but fleeting instants compared to the span of time over which the rocks of Mount Desert Island evolved. Figure 2 is a chart of *geologic time* detailing the last 600 million years, thus covering the ages of the rocks on the island. The earth is believed to be about 4.5 billion years old, so there is still a lot of earlier earth history (Precambrian Era) that is not represented by rocks in this area.

As you read the following descriptions, remember that each of the different rock types described below appears as a different color on the geologic map and each is identified and briefly described in the legend. The descriptions begin with a discussion of the oldest rocks on the island and proceed to progressively younger units.

Stratified Rocks

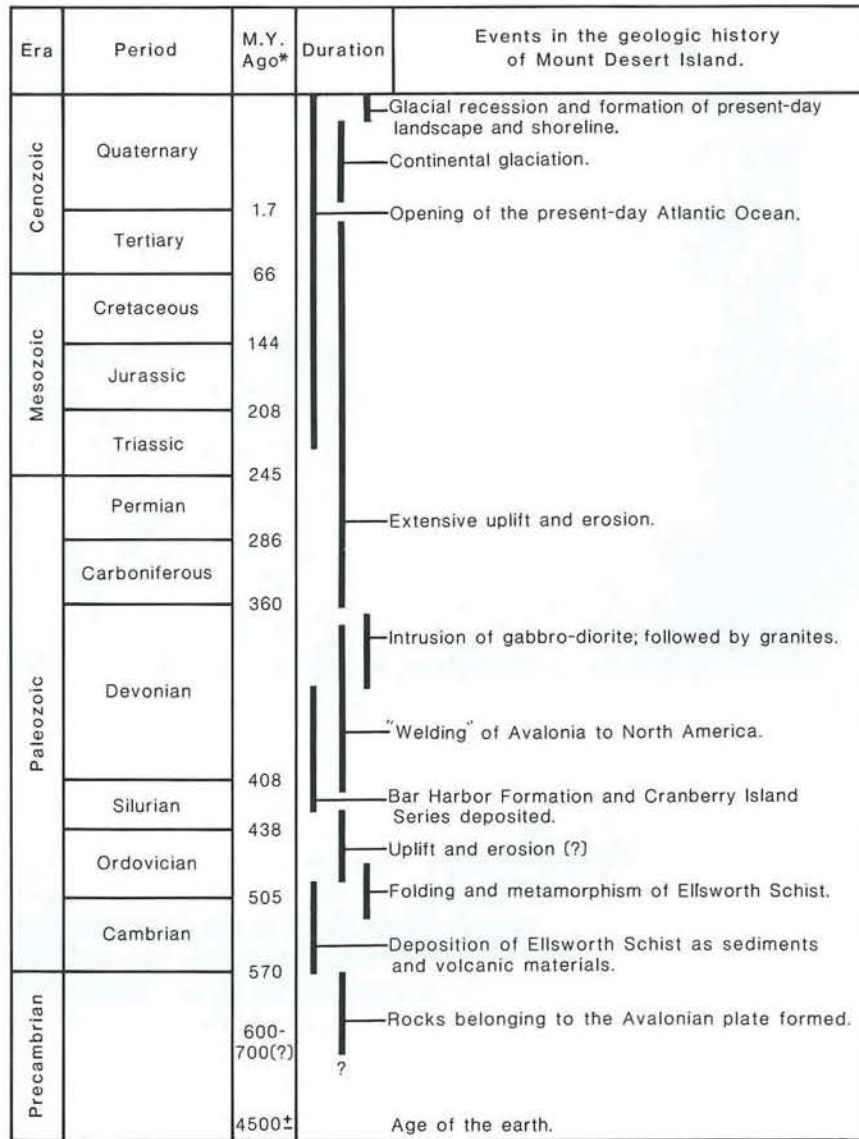
The older rocks on Mount Desert Island are *stratified* and include both sedimentary and volcanic types, the oldest of which have been substantially metamorphosed, while the younger ones are relatively unaltered.

Ellsworth Schist

The very first rock you see along the shore as you cross the bridge onto the northern end of Mount Desert Island is called the Ellsworth Schist (labeled "EOe" on the bedrock geologic map). It is the oldest rock exposed on the island. Large outcrops are found at the picnic area opposite the Acadia National Park information center on Thompson Island; on the northwest side of Mount Desert Island; and on the west side of Bartlett Island. The name *schist* refers to a type of metamorphic rock that is layered in appearance and that breaks along this layering. You may be more familiar with slate, another metamorphic rock that has these same properties. A schist, however, is more irregular in the way it splits than a slate. In addition, the mineral grains are larger in a schist, the grains of a slate being microscopic in size.

The Ellsworth Schist is commonly dark green or gray, and often has a distinctive streaked appearance caused by thin, lighter colored layers of quartz and feldspar mixed with darker layers consisting mostly of the mineral chlorite. The small barbed symbols on the bedrock geologic map show the orientation of this layering or *foliation*. The small wedge on the symbol points down the slope of the layers, in the direction water would drain. In many places you will find this layering folded into intricate patterns (Figure 3).

The complicated appearance of the Ellsworth Schist records its complex geologic history. The rocks originated over 500 million years ago as deposits of mud on a sea floor. Volcanic activity in the area at this time is indicated by the composition of certain layers within the schist that resemble modern day volcanic rocks. These sediments were subsequently buried several miles below the earth's surface where



*millions of years ago

Figure 2. Geologic time scale with major events in the geologic history of Mount Desert Island. Vertical bars indicate duration of each event.



Figure 3. Ellsworth Schist showing the complexly folded layering produced during metamorphism. Note the penny in the center of the photograph for scale.

higher temperatures and pressures brought about the changes of metamorphism including recrystallization and folding. We assume that the sedimentary layers were at one time more or less horizontal, so the complicated folds shown in Figure 3 indicate that the rock was deformed by forces acting within the earth. As a result, when erosion finally exposed the rock at the earth's surface millions of years later, it bore little resemblance to the original ocean-bottom sediments. But the rock contains clues that geologists learn to recognize and interpret in order to unravel the events that make up its history. Part of this history involves the startling idea that the Ellsworth Schist was not originally part of North America at all, but rather part of a small "continent" called Avalonia that became attached to North America during a time of continental collision between 350 and 400 million years ago. This is part of the theory of *plate tectonics*, which we will discuss in more detail under the section on geologic history.

Bar Harbor Formation

The Bar Harbor Formation (DSbh on the geologic map) is believed to be the second oldest group of rocks on the island. Notice in Figure 2 that it is more than a hundred million years younger than the Ellsworth Schist. This gap in the geologic record, called an *unconformity*, can be explained in two

ways. Either no sediments were deposited during the millions of years between the deposition of the sediments that make up the Ellsworth Schist and the Bar Harbor Formation, or, more likely, rocks younger than the schist but older than the Bar Harbor Formation were deposited and then eroded during periods of uplift between the Cambrian and the Late Silurian Periods. The unconformity between the Ellsworth Schist and the younger rocks is currently interpreted as evidence of uplift and deformation that occurred during this period.

Most of the Bar Harbor Formation consists of siltstone and sandstone beds measuring a few inches thick. Where exposed, the beds generally weather to a tan, gray, or lavender color but are typically dark gray on a freshly broken surface. These sediments were also deposited in an ocean environment, but possibly at shallower depths than the Ellsworth Schist sediments. Some volcanic material is also present. The Bar Harbor Formation takes its name from the excellent exposures along the shoreline at Bar Harbor where you can see the bedding inclined gently toward the ocean (Figure 4). The lack of complex folding and the gentle tilt of the beds indicate that these rocks were not subjected to the strong deformational forces that altered the Ellsworth Schist.

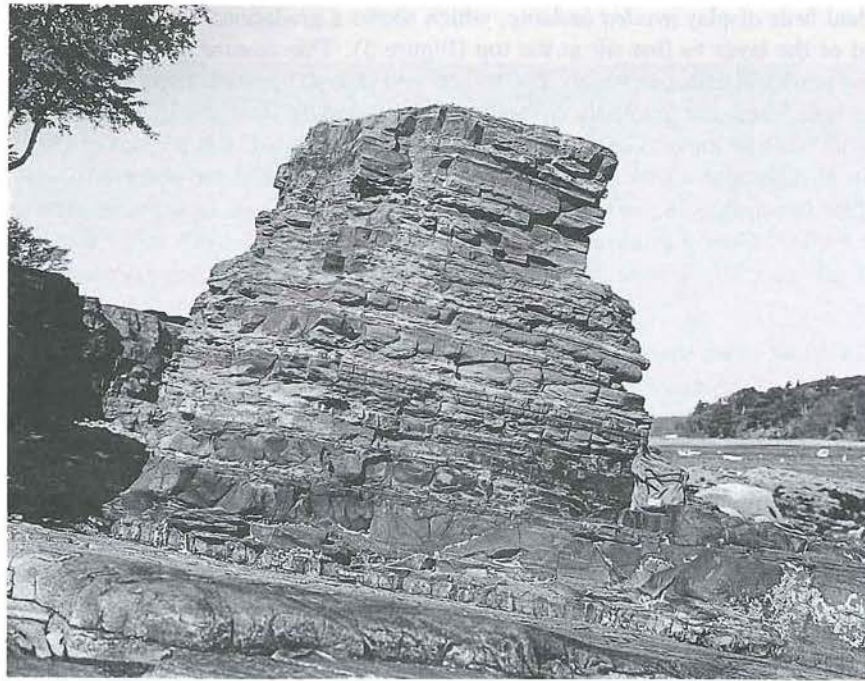


Figure 4. Bedding in the Bar Harbor Formation. This sea stack is about ten feet high and is located several hundred feet southeast of the pier in Bar Harbor. The bedding is inclined only slightly from the horizontal, indicating only minor deformation affected these rocks. Contrast these sediments with the highly metamorphosed Ellsworth Schist shown in Figure 3.

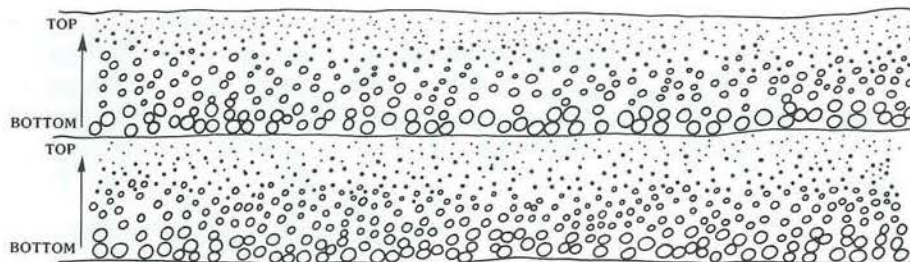


Figure 5. Drawing showing ideal graded bedding in sedimentary rocks. The coarser heavier material settled out of the water faster and is at the bottom of the bed. The size of the sand and silt becomes finer towards the top of the bed. Geologists use these and other features to unravel the deformation history of layered rocks.

Occasionally, the coarser-grained beds contain quartz pebbles up to 1/4 inch in diameter. In some cases individual beds display *graded bedding*, which shows a gradational change from coarse material at the bottom of the layer to fine silt at the top (Figure 5). This feature develops when a mixture of different-sized particles settles in water. The largest and heaviest particles settle out first, forming the bottom of the bed. These are gradually covered with increasingly finer and lighter particles. The cycle is repeated when another mass of sediments enters the water. Graded beds are one of the clues a geologist looks for to determine a rock's history. For instance, if the grains are observed to get finer downward rather than upwards as in Figure 5, a geologist infers that the rock layers have been turned upside down during folding. Graded bedding provides evidence that the rock strata in the Bar Harbor Formation are right-side-up with the same general orientation now as when they were deposited over 420 million years ago.

The rocks found along the shore at The Ovens and in the road-cuts along Route 3 at Ireson Hill on the northern side of the island also belong to the Bar Harbor Formation, but here the rock is flint-like and bedding is difficult or impossible to see. Some of these rocks are believed to be accumulations of ash that settled out of the atmosphere after a volcanic eruption.

Cranberry Island Series

The rocks that form the Cranberry Isles and the southwestern part of Mount Desert Island are largely the result of volcanic eruptions that took place along what is now southeastern coastal Maine about 380-400 million years ago. Three types of rock belonging to the Cranberry Island Series are shown on the geologic map: DScif, *felsites* and volcanic flows; DScit, *volcanic tuffs*; and DScis, interbedded volcanic and sedimentary rocks.

Rocks of the Cranberry Island Series are generally light gray or blue-gray and are most easily recognized by layers of volcanic tuff, a type of rock that formed as small pieces of rock debris settled after an explosive volcanic eruption. Good examples can be seen in front of the Seawall picnic ground parking

area (Figure 6). By looking closely, you will see that the rock is composed of a variety of angular fragments ranging in size from a fraction of an inch to a few inches in diameter.

Extensive exposures of volcanic tuff also occur along the west shore of Great Cranberry Island. The southern end of Great Cranberry Island has abundant layers of sedimentary rock with only occasional beds of tuff.

Along the ledges on the north side of Little Cranberry Island you will find excellent exposures of rock thought to be old lava flows. Its chaotic appearance is due to the continued flow of the lava as it cooled and solidified. Blocks of solid rock were engulfed in the molten lava which then crystallized around them.

The rocks described above (Ellsworth Schist; Bar Harbor Formation and Cranberry Island Series) all had their beginnings at the surface of the earth, either as accumulations of sand and mud in the case of the Bar Harbor Formation and Ellsworth Schist or as the products of erupting volcanoes in the case of the Cranberry Island Series. We now turn to the group of intrusive igneous rocks: the gabbro-diorite and granites that formed when magma intruded into the overlying rock, cooled, and solidified deep below the earth's surface.



Figure 6. Volcanic tuff at the Seawall picnic area. The larger angular fragments were incorporated with finer volcanic material during an eruption. Note the penny at the top of the photograph for scale.

Intrusive Igneous Rocks

Intrusive igneous rocks, primarily granites, make up the bulk of Mt. Desert Island. All of these rocks intruded and crystallized during the Devonian Period in a span of time from approximately 360 to 380 million years ago. The ages of these intrusive rocks can be determined in two different ways. First, since a granite can be no older than the rocks it intrudes, its maximum age can be determined if the age of the host rock is known. In this case fossils in rocks related to the Bar Harbor Formation and Cranberry Island Series indicate a Silurian-Devonian age; this, in turn, provides a Silurian-Devonian (or younger) age for the intrusive rocks (Figure 2).

The second way to obtain the age of intrusive rocks (and some volcanic rocks) is to use isotopic dating techniques. These techniques make use of the fact that naturally occurring radioactive elements (parent isotopes) decay to another element (the daughter product) at a fixed rate. By measuring the amount of daughter product in a rock relative to the parent isotope, it is possible to determine approximately how long since the intrusive rock cooled and crystallized. Based on these techniques, the best ages estimated for the granites on Mt. Desert Island range from approximately 365 million years old for the granite of Cadillac Mountain to 377 million years for the granite on Schoodic Point and 373 million years for the granite of Southwest Harbor. Thus these data indicate a Devonian age for the intrusive rocks.

Volcanic rocks of the Bar Harbor Formation on Mt. Desert Island have also been dated with isotopic techniques, and the age obtained (408 million years) agrees well with the Siluro-Devonian ages assigned to these rocks based on correlations with fossil-bearing formations elsewhere. The predominantly volcanic Cranberry Island Series has been dated by this method, and the age is determined to be 378 million years.

Gabbro-Diorite

Gabbro and *diorite* are both igneous rocks that are poor in silica, alumina, sodium, and potassium, and rich in iron, magnesium, and calcium. They differ slightly in their composition, but this difference is difficult to distinguish visually in an outcrop. They are frequently intermixed over short distances and cannot be shown separately on a map of the size included with this book, hence the hyphenated term.

The gabbro-diorite (Dgd on the geologic map), found predominantly on the northwest side of Mount Desert Island, is the oldest of the intrusive rocks. It was intruded in turn by younger granitic rocks. The gabbro is a dark gray, coarse-grained rock in which you can see individual black and gray mineral grains (pyroxene and plagioclase feldspar crystals). If the rock is lighter gray due to the abundance of light gray feldspar, it is called diorite. Some exposures show an irregular layering of light and dark colored rock, indicating that the two types are closely related in origin. Good exposures of the lighter colored diorite are found along Route 3 just west of Salsbury Cove on the north side of the island. Gabbro-diorite can also be seen in Hulls Cove, three miles northwest of Bar Harbor, and on the summit of Great Head on the east side of the island. Gabbro-diorite is also exposed on the Porcupine Islands where it occurs as thick layers, called *sills*, which intruded into the Bar Harbor Series.

Granite of Southwest Harbor

In contrast to the dark gray to black gabbro-diorite, *granite* is a light-colored rock. It is rich in silica, alumina, sodium, and potassium, and poor in iron and magnesium, the chemical elements that make up many dark-colored minerals. Small differences in chemical composition and percentages of accessory minerals can produce significant differences in the color and texture of granites, however, and a number of different types can be distinguished on the island.

The Southwest Harbor granite (Dshg on the geologic map) is a fine-grained, light gray granite, commonly with a tan or pinkish hue. Outcrops are visible along the shore at Southwest Harbor and near West Tremont, but inland exposures are not abundant. Quartz and alkali feldspar are the major minerals in all granites, but due to their small size in this particular granite, the grains are usually not easily identified except with the aid of a magnifying glass. Rock similar to the Southwest Harbor granite makes up the southern end of Schoodic Peninsula and is beautifully exposed at Schoodic Point.

Granite of Cadillac Mountain

The bald ledges of Cadillac Mountain are made of a pink to greenish-gray, coarse-grained granite (Dcg on the geologic map). In contrast with the Southwest Harbor granite, individual grains of translucent, gray, glassy-looking quartz and pink or gray feldspar are easily seen. The black mineral is hornblende. The rock is uniform in appearance and you will recognize it easily as you hike the high ridges.

One of the most spectacular geologic features on the island is the shatter zone (Dsz) that surrounds the Cadillac Mountain granite on nearly all sides and ranges in width from a thousand feet to more than a mile. Within this zone, angular pieces of rock (in some cases gabbro-diorite, in other cases Ellsworth Schist or volcanic and sedimentary rocks from the Bar Harbor Formation) up to hundreds of feet across are surrounded by fine-grained "granite" (Figure 7).

Though the details of its formation are not fully understood, the shatter zone is undoubtedly related to the intrusion of the Cadillac Mountain granite. Close to the main body of granite the light colored *matrix* that surrounds the angular pieces appears to be a mixture of ground-up and recrystallized *country rock* plus fine-grained Cadillac Mountain granite. Farther away, the light colored matrix is believed to be exclusively ground-up and recrystallized country rock. This suggests that the shatter zone resulted from severe fracturing of the country rock as the granite was intruded. One theory, favored by C. A. Chapman, is that the shatter zone represents the outermost edge of a collapsed central region and that blocks of crushed country rock were intruded by the magma which crystallized to become the granite of Cadillac Mountain (Figure 8).

Excellent exposures of the shatter zone occur at Otter Cliffs and at Western Point south of Black Woods Campground. It is also well exposed on both sides of the entrance to Northeast Harbor; look for it as you leave the harbor on your way to the Cranberry Isles. Other good exposures can be seen at the east end of Sand Beach and near the parking lot for the overlook at Schooner Head.

Look closely at the map in the region where the Cadillac Mountain granite is exposed, and you will see small symbols similar to those used in the Ellsworth Schist. These show the orientation of tabular



Figure 7. The shatter zone showing angular blocks of older country rock in a fine-grained granite matrix.

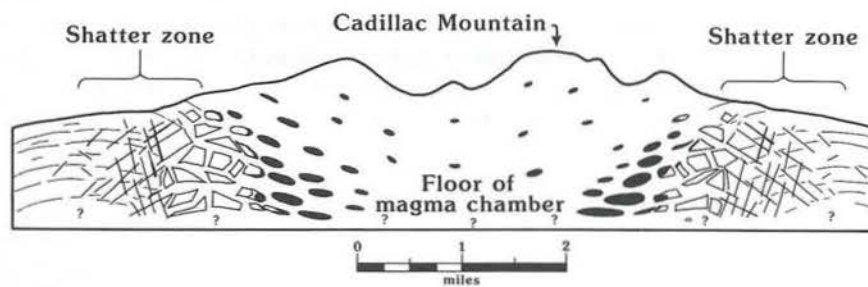


Figure 8. Schematic cross section through the Cadillac Mountain granite showing the shatter zone and the saucer-shaped distribution of inclusions.

shaped inclusions of older rock within the granite. Good examples of these inclusions can be found on the top of Great Hill, west of Bar Harbor. Study of these inclusions shows that they are essentially horizontal in the interior of the granite body, but toward the outside margin they tend to be tilted downward towards the interior. This, plus evidence from the shatter zone suggests that the magma filled the space left by the collapse of the roof above the magma chamber, a process geologists have called *cauldron subsidence*. As the magma crystallized, the inclusions apparently settled to the floor of the magma chamber producing a saucer-shaped arrangement as shown in Figure 8.

Granite of Somesville

The head of Somes Sound and the region to the west are underlain by a fine to medium grained, pink and gray granite, which at first glance may not look much different from the Cadillac Mountain granite. However, the Somesville granite (Dsg on the geologic map) has smaller mineral grains and a slightly different type of feldspar. The feldspar in the Cadillac Mountain granite is all pinkish *perthite* (greenish where fresh), whereas the feldspar in the Somesville granite is of two types: pink or cream colored *K-feldspar* and light gray *plagioclase*. Further, the black grains in the Somesville granite are biotite mica, not hornblende as in the Cadillac Mountain granite. This is not an easy distinction to make, so don't be surprised if you have trouble telling one granite from the other.

The map shows a separate type of granite in the center of the Somesville intrusion (Dsg₁). This fine-grained granite is probably closely related to the medium-grained granite that surrounds it. The difference between these two types is rather subtle but can best be seen at exposures along Route 102 south of Somesville. Here, north of Echo Lake, the ledges along the road are of the fine-grained type, and many show abundant *phenocrysts* (larger grains that are set in the fine-grained host rock). Farther south along the road, particularly near the southernmost of the two roads to the village of Hall Quarry, the granite is coarser grained and has no phenocrysts.

The relationships between the two varieties of the Somesville granite are not yet well understood, but it appears that the fine-grained variety is younger than the medium-grained type, and may even be a separate intrusion.

The Somesville granite was extensively quarried during the late 1800's and early 1900's. The Halls Quarry supplied large quantities of building stone to many major cities. Figure 9 shows Halls Quarry during the period of peak activity.

Other Granites

There are several other examples of granite on the island; all are pink, fine to medium grained, and contain black flakes of biotite mica. Examples of these granites are well exposed at Baker Island (Dg₁) and Bass Harbor Head (Dg₂). The Baker Island granite is distinctive because it has a faint "grain" or alignment of darker minerals in a northeasterly direction. The granite at Bass Harbor Head (also exposed at Wonderland) has a distinctive fine-grained granular texture similar to a lump of sugar.



Figure 9. The Halls Quarry during a major period of activity. (from Grindle, R., 1976, Tombstones and Paving Blocks: The History of the Maine Granite Industry, Courier-Gazette, Rockland, Maine, following p. 20)

Diabase Dikes

Features which may catch your eye are the stripes of fine-grained black rock, called *dikes*, that cut through all of the other rock types. Because of the color contrast, they are most readily noticed in the light-colored granites (Figure 10).

These dikes are composed of a fine-grained intrusive igneous rock called *diabase* and formed when magma was forced into fractures in the host rock. Diabase is very closely related to the black volcanic rock called *basalt*, and you may see black dikes referred to elsewhere as basalt dikes. Diabase and basalt are also very closely related to gabbro. Chemically, the three rocks are similar, but they represent different modes of origin. Whereas basalts erupt onto the surface, diabase dikes represent magma that did not reach the surface, but cooled quickly in fractures some distance below the surface. Diabase dikes are "transitional" between the deep-seated gabbros and extrusive basalts.

Most dikes in the park are less than ten feet wide, but some exceed 60 feet. Not all of these dikes formed at the same time, as evidenced on a small scale at Schoodic Point where dikes of a younger age cut across older ones. On a larger scale, an interesting relationship is found if the directions of the dikes are compared with the type and age of the rocks through which the dikes cut. Such a study reveals three general trends; (1) 45 to 75 degrees east of north, (2) due north to 30 degrees east of north, and (3)



Figure 10. Diabase dike intruding the Cadillac Mountain granite. Note the strong horizontal jointing in the granite.

10 to 30 degrees west of north. The first group (trending northeast to east-northeast) is found in rocks believed to be older than the Bar Harbor Formation and is, therefore, the oldest group of dikes. The second group (north to north-northeast trending) is found in all rocks except the Cadillac Mountain granite and the Somesville granite and therefore must have been intruded before these granites, but later than the gabbro-diorite and the Southwest Harbor granite. The last group (north-northwest trending) is found in all rock types and therefore must be younger than all of the other rocks of the area.

This study of the relative ages of the dikes presents an interesting contradiction. On one hand, the Cranberry Island Series is believed to be younger than the Bar Harbor Formation on the basis of radioactive dating. On the other hand, an abundance of east to northeast trending dikes in the Cranberry Island Series suggests that it is the older of the two series. Clearly the geologic history of the area is not completely understood and resolution of the problem will require more study.

Of the numerous places dikes may be found, two localities are especially good: Schoodic Point (to be discussed later) and Cadillac Mountain. At the hairpin turn 1.8 miles from the entrance gate on Cadillac Mountain Road, two five-to-ten foot wide dikes can be found cutting through the granite. This is a hazardous curve, but there is a small parking area just up the hill from the turn. These dikes are proba-

bly extensions of the ones that can be seen along the trail on the south side of the mountain that leads to Black Woods Campground. Exposures of the dikes along this trail are the best of any along the high ridges and will provide a hiker with excellent opportunities to study their features. The dikes can be traced from the south side of the road at Blue Hill Overlook to beyond the rock knoll just south of where the trail crosses the Canon Brook trail. In fact, the marker at the trail intersection is placed in granite with black dikes just a few feet away on both sides. Three major dikes and several smaller ones can be found on the rock knoll; in places they merge. The details of their margins are quite complex and tracing out their geometry should provide a challenge for the curious hiker.

Joints and Faults

As you walk over the ledges of Cadillac Mountain, look carefully at the surfaces of the granite. The many long, straight cracks in the rock that commonly form smooth surfaces are *joints*, natural fractures in rock along which there has been little or no movement or displacement (Figure 11). Many of these fractures are nearly vertical, and frequently there will be several of them close together and parallel to each other that are referred to as *joint sets*. Further examination will disclose that there are several joint sets on Cadillac Mountain, the most prominent ones having directions of east-west, 40 degrees east of north, and 25 degrees west of north.

In addition to the vertical joints, there are prominent, nearly horizontal joints which form the broad exposures of smooth, gently sloping rock on the high ridges. These *exfoliation* joints most likely formed as the weight of overlying rock was removed by erosion, and the rock beneath expanded and cracked parallel to the surface. The presence of both vertical and horizontal joints weakened and loosened the bedrock and allowed the glaciers to remove large blocks of rock.

Joints and faults are due to forces acting within the earth that have at times exceeded the breaking strength of the rock. Under some conditions the forces are great enough to not only fracture the rock but also to cause slippage along the fracture, forming a *fault*. Faults are not as easily found as joints and are not often seen in outcrops. There are several reasons for this: the limited amount of bedrock outcrop reduces the number of faults exposed at the surface; faults usually contain ruptured and broken rock which weathers easily; and many faults may lie in low areas, covered by soil or glacial material. The presence of a fault is usually inferred from other geologic evidence, such as the abrupt and unpredictable change in rock type or orientation.

Several small faults, recognized by an abrupt interruption of bedding, can be found in the Bar Harbor Formation along the north shore of the island in the vicinity of The Ovens. These are all nearly vertical and are too small to show on the geologic map; none can be traced inland.

A larger fault is inferred at Salisbury Cove where sheared and broken Ellsworth Schist terminates abruptly against the gabbro-diorite. While the actual fault cannot be traced inland, it is possible that the eastern boundary of the Ellsworth Schist south of Salisbury Cove is a continuation of this fault.

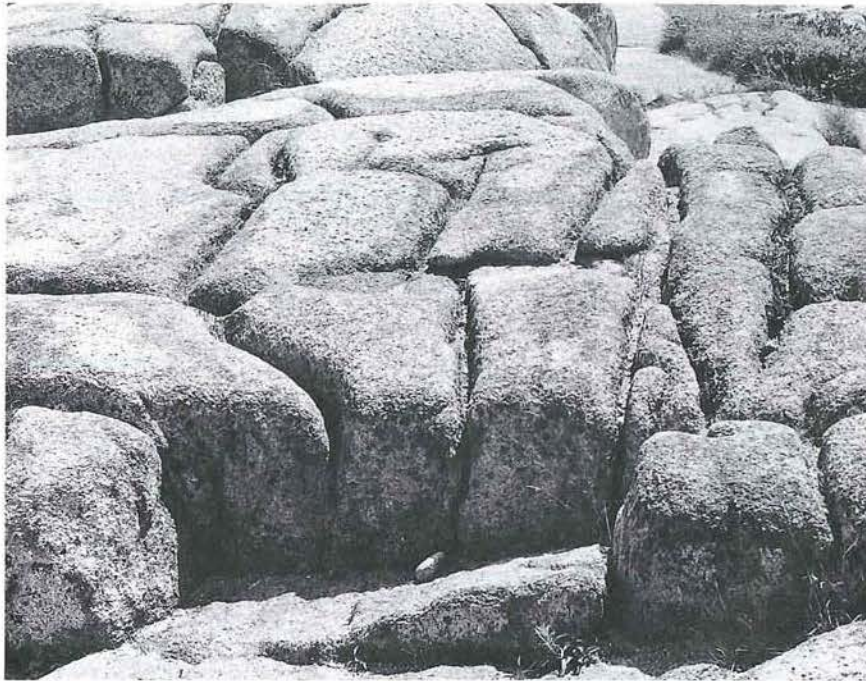


Figure 11. Jointing in granite on the summit of Cadillac Mountain. Two sets of joints are nearly vertical, and a third, which makes up the smooth top surface, is nearly horizontal. Also note the preferential weathering and removal of the granite caused by water percolating through the cracks.

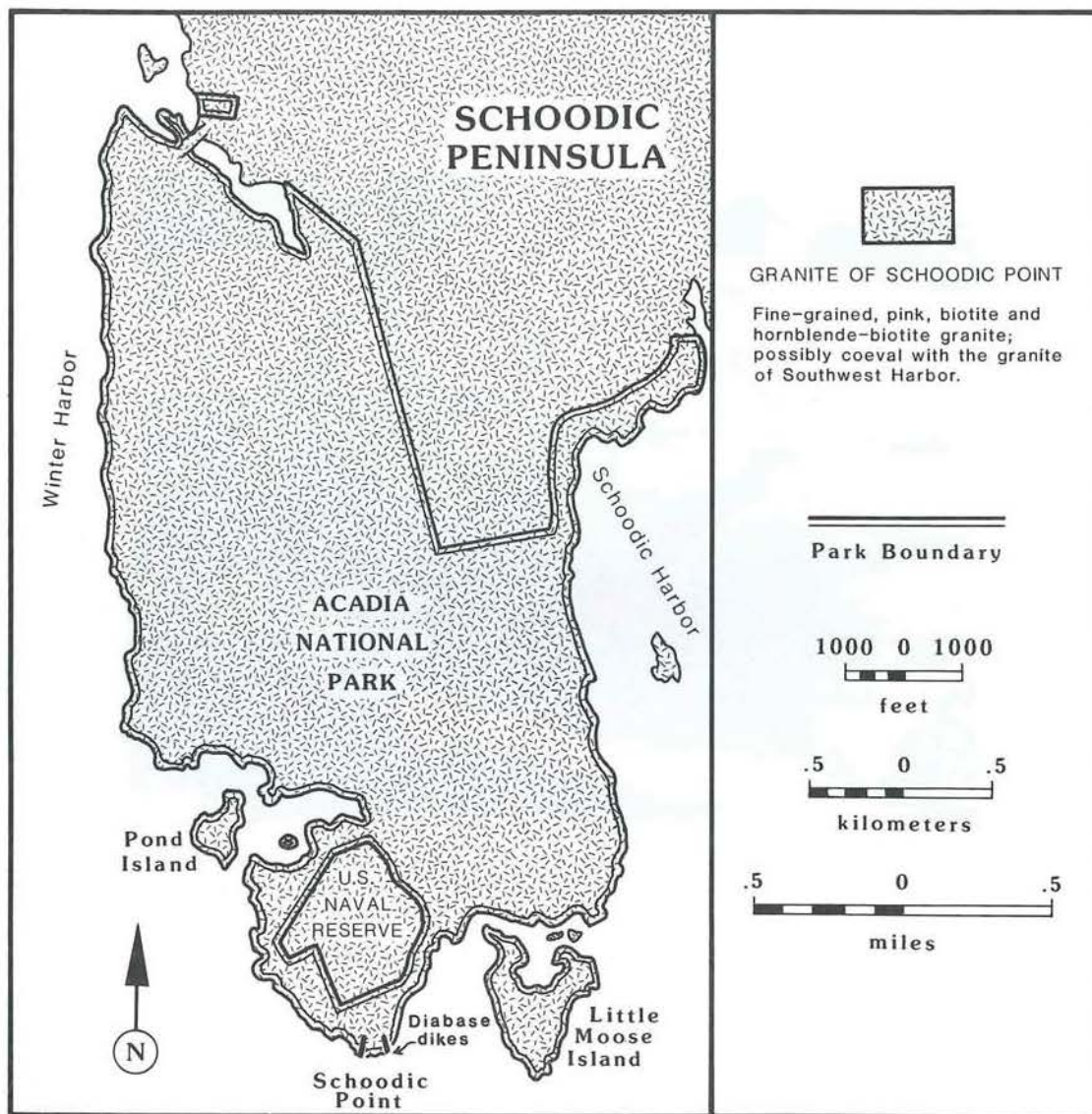


Figure 12. Bedrock geologic map of Schoodic Peninsula. Excellent exposures of diabase dikes are present next to the parking lot at Schoodic Point.

SCHOODIC PENINSULA

The southern end of Schoodic Peninsula, also part of Acadia National Park, is made up almost entirely of a fine-grained granite that is similar to that of Southwest Harbor (Figure 12).

Beautiful exposures of diabase dikes that cut the granite are present on the southern end of the peninsula. An excellent place to study the details of these dikes is at the parking area at Schoodic Point. The shore ledges are particularly interesting because you can see evidence for more than one episode of dike intrusion; you will find younger dikes cutting across older dikes, as well as fragments of older dike rock enclosed by the younger dikes. You can also see how the cracks filled by the magma taper and eventually end (Figure 13). This is one of the best places in the park to see how dikes are formed by fracturing of solid rock followed by the intrusion of magma.



Figure 13. Detail of diabase dike at Schoodic Point. Small dikes taper along fractures in the lighter colored granite (just left of the hammer) and a fragment of granite is enclosed in the dike (just to the right of the hammer handle).

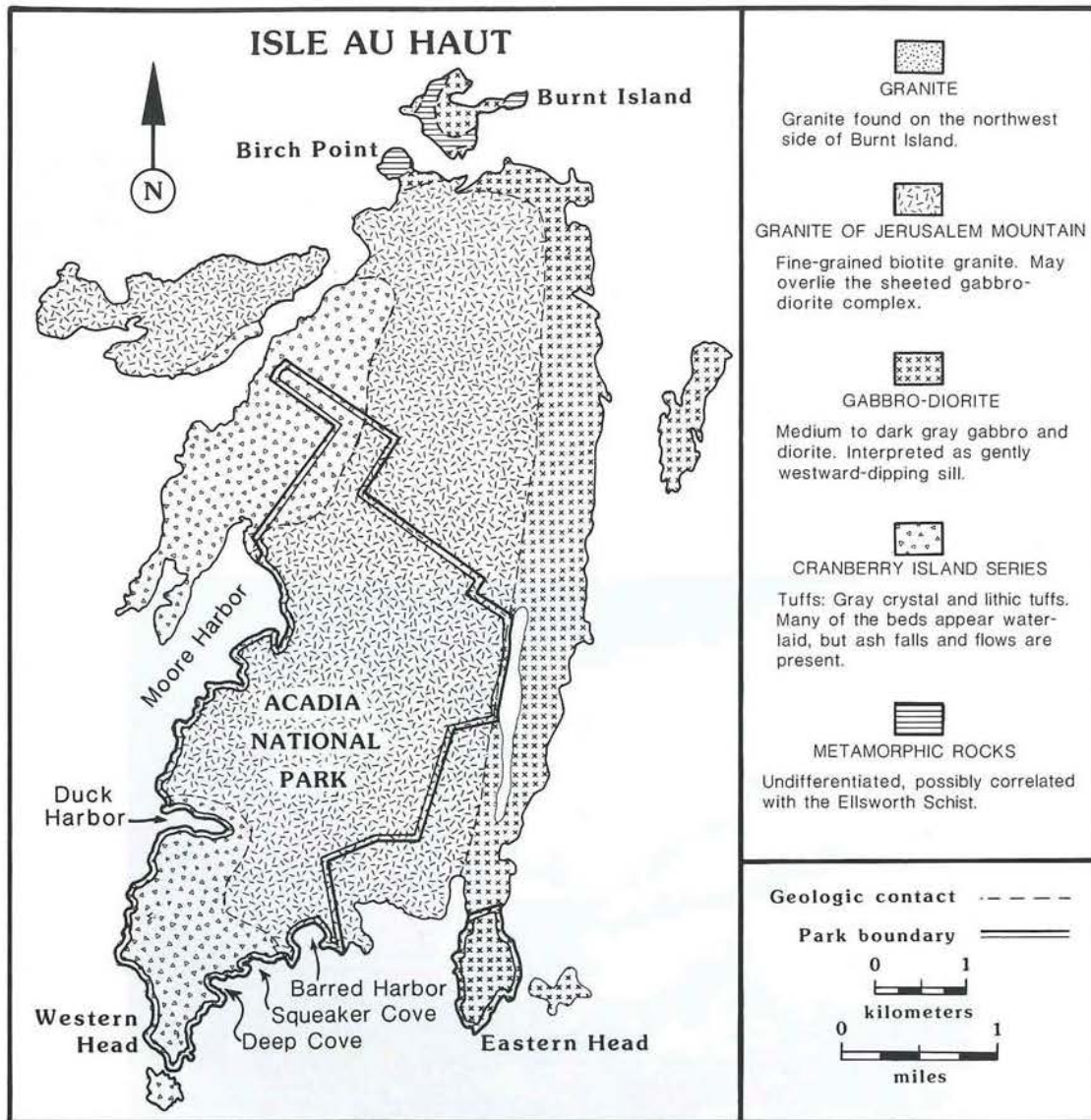


Figure 14. Bedrock geologic map of Isle au Haut.

ISLE AU HAUT

Isle au Haut is composed for the most part of rocks similar to those on Mount Desert Island: gabbro-diorite, fine-grained granite, and volcanic rocks similar to the Cranberry Island Series. Since all of these rock types have been discussed earlier, we will simply point out some of the best places for you to see them (Figure 14).

As a summertime day visitor to Acadia National Park on Isle au Haut, the part of the island you will most likely explore will be the southern end, south of the park landing at Duck Harbor. From Duck Harbor, follow the Western Head Road (used for hiking, not driving) south to Deep Cove. This trail crosses several areas of ledges, but the rock is difficult to study because of the lichen and moss cover. But the exposures at the shore are excellent. From the head of Deep Cove you have a choice of two shore trails to follow, either south toward Western Head and then back to Duck Harbor, or easterly along the Goat Trail toward Squeaker Cove. In either case you will find exposures of rock believed to be related to the Cranberry Island Series.

Following the trail to Western Head, you will see almost continuous exposure of light gray volcanic tuff containing angular fragments, similar to rock seen at the parking area at Seawall picnic area on Mount Desert Island. This rock represents the settling of ash and rock fragments that were blown into the air at the time of an explosive volcanic eruption. In some cases you will find that the rocks are bedded, some beds having more fragments than others, and that these are consistently inclined toward the west at a fairly steep angle (see Figure 15).

If you take the Goat Trail toward Squeaker Cove you will also see excellent exposures of volcanic tuff. Just before you reach Barred Harbor you will cross the contact of tuff with the fine-grained granite. Near this contact you will be able to find several large pieces of the volcanic rock enclosed in the granite, proving that the granite is younger than the tuff. The trail then leads north from Barred Harbor where it joins the main road. Taking this road to the left brings you back to Duck Harbor, whereas a turn to the right will take you to Eastern Head. This central part of the island is underlain by fine-grained granite, and a hike along the trail leading from the main road to Moore Harbor crosses excellent exposures of this rock.

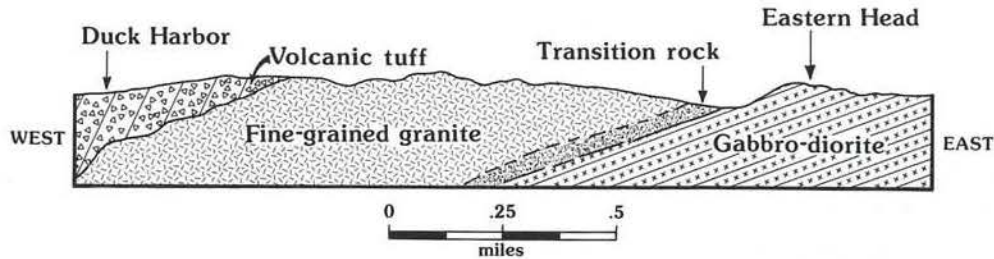


Figure 15. Geologic cross section across the south end of Isle au Haut showing the inferred relationship between the gabbro, the granite, and the volcanic rock. This is what you would see if you could cut a deep (200 feet) vertical trench along the road and look at its north side.

Gabbro-diorite is best seen along the eastern shore of the island, particularly at Eastern Head. Here the ledges offer excellent views of gabbro-diorite which in some instances show lighter colored layers gently inclined toward the west. These layers have led geologists to the conclusion that the gabbro-diorite, and probably the fine-grained granite as well, form a large sheet of intrusive rock that was injected into the volcanic rocks seen on the west side of the island (Figure 15).

A mixed or transitional type of rock is found in a narrow zone between the gabbro-diorite and the granite. Geologists interpret this to mean that the gabbro-diorite and granite on Isle au Haut are related to the same episode of magma intrusion.

These rock types can be traced over the remainder of the island. Birch Point, at the island's extreme northern end, consists of a metamorphic rock that is of uncertain relationship to other rocks in the area; it may be related to the Ellsworth Schist seen on Mount Desert Island. Burnt Island, just north of Birch Point, consists of the same metamorphic rock and gabbro-diorite, as well as granite that is part of a very large body believed to underlie most of the bay between Isle au Haut and Stonington.

SUMMARY OF THE BEDROCK GEOLOGIC HISTORY OF MOUNT DESERT ISLAND

Our story of the bedrock of Mount Desert Island covers only a small part of the history of the earth: the Cambrian, Ordovician, and parts of the Silurian and Devonian Periods (see Figure 2). What transpired here at other times in the geologic past is not clear because there are no rocks of those ages on the island to preserve the geologic record. As a result, a complete history must be pieced together by examining rocks elsewhere along the Atlantic coast.

The earliest history recorded in the rocks of the park dates back perhaps 550 million years, to the Cambrian Period. At this time the region was part of an ocean floor. Mud, some of which formed from explosive volcanic ash falls, accumulated on the sea floor. Continued deposition of sediments buried the mud well below the earth's surface where it was squeezed and heated by forces acting within the earth. Eventually, uplift and erosion exposed this material at the earth's surface once again, not as mud but as the metamorphic rock we now call the Ellsworth Schist.

Approximately 400 million years ago, during the Silurian and Devonian Periods, sediment once again accumulated on an ocean floor, some as silt and sand, which became the sedimentary rock known as the Bar Harbor Formation, and some as deposits of volcanic ash and lava flows now known as the Cranberry Island Series. Both of these rock units have been folded to some degree, but neither shows evidence of strong metamorphism.

The youngest rocks found on Mount Desert Island are the intrusive igneous rocks. The gabbro-diorite, diabase dikes, and the various granite bodies were emplaced between 360 and 380 million years ago during the Devonian period.

It was mentioned earlier that part of the history of the Ellsworth Schist involved the theory of plate tectonics. In this theory the crust of the earth is conceived as being composed of rigid "plates" which float on the underlying, partially molten *mantle*. These plates, some of which include the continents, are in constant motion relative to one another. It is the movement of continents as part of these plates that gives rise to the more popular phrase — *continental drift*.

As a result of detailed geologic studies along the coast of the northeastern United States and the Canadian Maritime Provinces, it appears that the Maine coast as we now know it was not part of North America until the middle of the Paleozoic Era, sometime in the Early Devonian. Maine's coastal region is believed to have been part of another continent, called Avalonia, that collided with North America during the Devonian Period. Evidence for this collision comes from the major differences in rock type, age, fossil assemblages, and structure between portions of coastal Maine and the interior. Very little is actually known about Avalonia. Other remnants of this land mass are found in eastern Massachusetts and in Maritime Canada, where it was first recognized. Avalonia may have been related to the larger continent of Eurasia, or existed as an isolated continental fragment for some time prior to collision with North America.

When two continents collide, they become joined together. In Maine, the Ellsworth Schist, with its long history of metamorphism and folding, was part of the Avalonian continent that was joined to the eastern edge of North America. It is probable that the Bar Harbor Formation and the Cranberry Island volcanic rocks were deposited on top of the Ellsworth Schist, perhaps at about the time the collision was taking place. Thus, the Ellsworth Schist, Bar Harbor Formation, and Cranberry Island volcanic rocks were all added to what previously had been the eastern edge of North America.

This collision of continents accompanied the closing of an ancient ocean basin called the Iapetus Ocean — the forerunner of the Atlantic Ocean. Final closure of the ocean involved the collision of Eurasia with North America in the Late Paleozoic. The present day Atlantic Ocean, on the other hand, started to form a little over 200 million years ago as North America broke away from Eurasia. But this split did not take place precisely at the point where the continents were joined, and a small part of what was once Avalonia was left behind, "welded" to the eastern margin of North America. This sequence of events is diagrammed in Figure 16. Keep in mind that this interpretation is only one of several possibilities, and that there is currently much debate among geologists as to the details of the geologic history. In addition, the history of Mount Desert Island is but a small segment of a larger story that accounts for the development of the entire Appalachian Mountain chain that extends from Newfoundland to Georgia. Geologists use the term *orogeny* to refer to the process of continental collision and resulting folding and metamorphism of rocks, and, in some cases, the generation of long chains of mountains.

Igneous activity commonly accompanies orogeny, and the region around Mount Desert Island illustrates this well. The process of continental collision must have generated sufficient heat at depths tens of miles below the surface to melt some of the rock there, creating pockets of molten rock. This magma rose toward the surface of the earth, and was injected into the Ellsworth Schist, Bar Harbor Formation, and Cranberry Island Series about 360-380 million years ago. The rock exposed on the bare ledges of the highest mountains on the island, for example Cadillac Mountain, owes its existence to this period of earth history. Several different types of igneous rocks formed during this time. Listed in order of their intrusion, they are (1) the gray to black, coarse-grained gabbro-diorite; (2) the granite near Southwest Harbor; (3) the granites on and near Cadillac Mountain; and (4) the granite near Somesville. Diabase dikes also formed during this same period of igneous intrusion.

The first section of this guide has outlined the geologic evolution of the bedrock in the Acadia National Park region over a span of about 150 million years. But what of the time from 350 million years

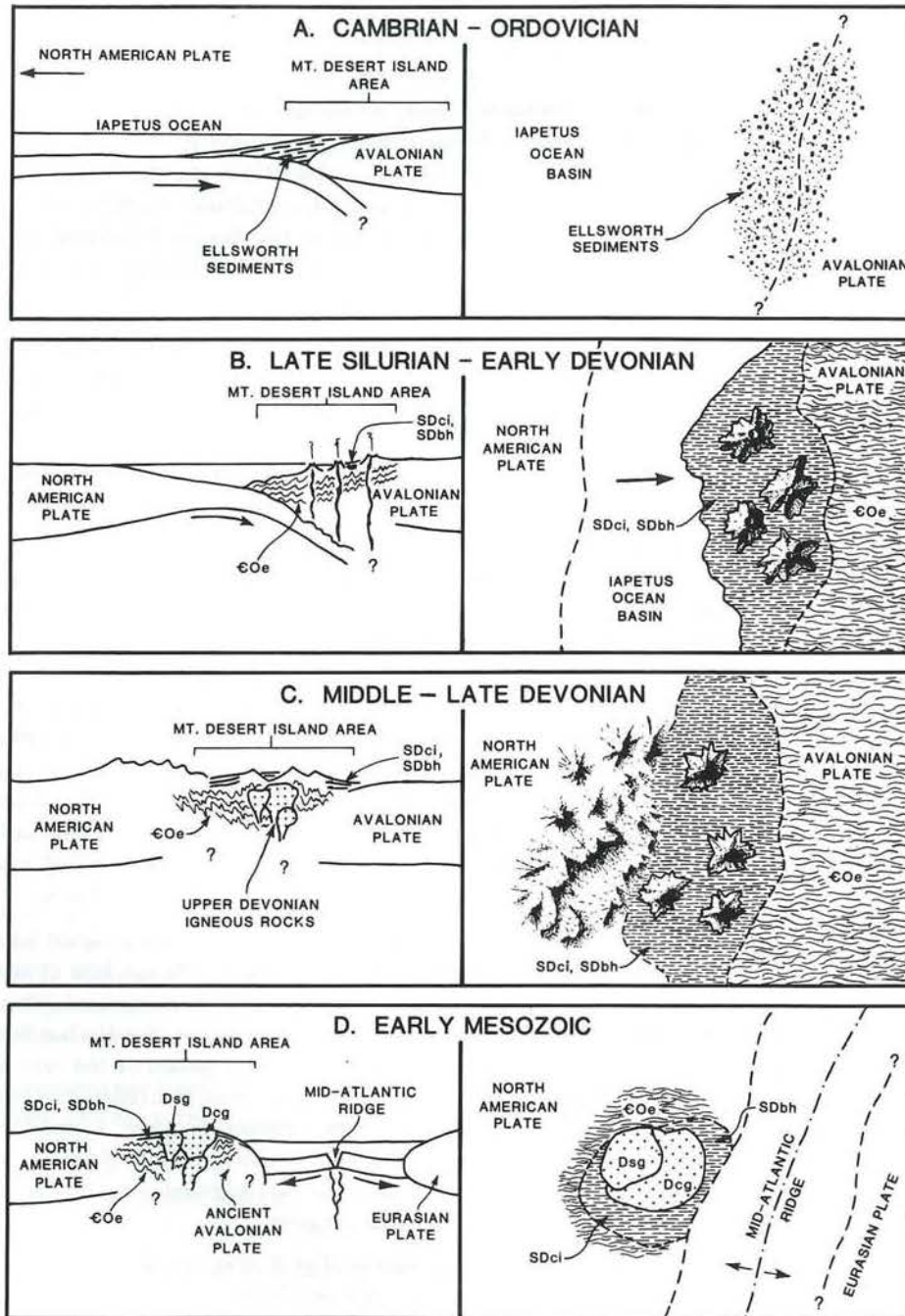


Figure 16.

ago until the comparatively recent Ice Age? Unfortunately, there are no rocks in the area to record events that occurred during this interval of time. As mentioned above, present theories suggest that the Atlantic Ocean developed during the last 200 million years or so. It continues to widen at the rate of about one inch per year. We also know that extensive erosion took place on land because the granites now exposed on Mount Desert Island could only have cooled and formed several miles below the surface. Any rocks that might have been deposited after the intrusion of the igneous rocks have all been worn away.

The latest major event of earth history that affected the entire park region was glaciation. Thick glacial ice flowed southward across Mount Desert Island a number of times during the last few hundred thousand years, sculpting the landscape that we see today. The remainder of this book will discuss the history of the island during the Ice Age, as well as the geologic processes that have modified the region since the retreat of the last glacier.

Figure 16. Schematic maps and cross sections of a possible plate tectonic interpretation of the geologic history of Mount Desert Island. Cross sections (left-hand diagrams) are drawn from left to right through the map views (right-hand diagrams).

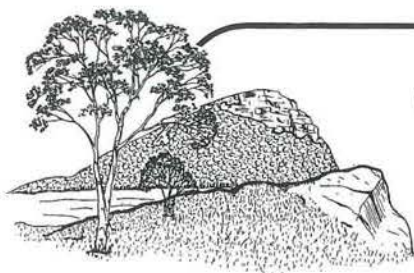
A. Cambrian-Ordovician. Sediments of the Ellsworth Schist (EOe), mud and ash, were deposited in the Iapetus Ocean along the leading edge of the Avalonian plate. At this time the crust of the Iapetus Ocean began sliding beneath the Avalonian plate. The Ellsworth Schist was then metamorphosed, folded, and uplifted.

B. Late Silurian-Early Devonian. The crust of the Iapetus Ocean continued to be destroyed beneath the Avalonian plate. The Cranberry Island volcanic rocks (SDci) resulted from partial melting of the oceanic crust; sediments of the Bar Harbor Formation (SDbh) were deposited unconformably on top of the Ellsworth Schist.

C. Middle-Late Devonian. The North American and Avalonian plates collided as the Iapetus Ocean was completely eliminated. Heat generated by this process caused some rocks in the collision zone to melt, resulting in large igneous intrusions at depth.

D. Early Mesozoic. The two plates separated along a fracture which was southeast of the line where the plates joined during collision, leaving part of the Avalonian plate attached to North America. This separation began the development of the present-day Atlantic Ocean. The mountains formed during the collision were subsequently eroded to the level of the Ellsworth Schist and granites.

Note: Details of the earlier history of the North American and Avalonian plates have been omitted.



Glacial Geology of Mount Desert Island

INTRODUCTION

As you travel around Mount Desert Island you can see the effects of glaciation in many places: deep valleys carved into the bedrock; boulders that have been transported far from their original locations; and a patchy veneer of glacially-derived sediments ranging from clay to boulders. Before taking a closer look at some of the glacial features on the island, we will briefly consider the Ice Age so that we can better understand the events on Mount Desert Island.

The last Ice Age began some 1.7 million years ago at the beginning of the Quaternary Period as the worldwide climate cooled by 3-6° C. Because of this cooling, more snow fell in the winter than melted during the summer. Continued accumulation and compaction of the snow formed great masses of ice, called *continental glaciers*, over large portions of the earth. The level of the oceans dropped because of the vast amount of water frozen in these glaciers, and the land beneath the glaciers was pushed downward by the weight of the ice. The Ice Age included several periods of cold, glacial intervals that were separated by warmer, nonglacial times (Figure 17). We now appear to be in one of the warm phases, but cooling and another expansion of continental glaciers may occur within the next few thousand years. Maine probably experienced several major glacial episodes during the Ice Age, but the last episode obliterated most of the evidence of earlier glaciations.

Here in North America, the most recent continental glacier covered most of Canada and the northern United States. This ice sheet advanced across New England from the northwest prior to 25,000 years ago, and at its maximum extent about 21,000 years ago covered all of the land area of New England, including the highest mountains. The ice expanded into the Gulf of Maine in the Atlantic Ocean and terminated on the continental shelf almost 370 miles southeast of the present Maine coast. Sand and gravel deposits on the present sea floor mark the former position of the glacier's margin in this area. The continuation of the ice margin to the southwest of the Gulf of Maine is revealed by the thick accumulations of glacial sediments that form Cape Cod, Nantucket Island, Martha's Vineyard, and Long Island. The withdrawal of the last ice sheet started about 18,000 years ago as the glacier thinned and the ice margin began to recede generally northward. The high mountains of New England protruded from the glacier between 14,000 and 12,000 years ago, and lowland areas became ice free during the next 2,000 years.

This latest period of glacial activity is called the Wisconsin glaciation, named after Wisconsin where its effects are especially prominent. Along with several earlier glaciations, it took place during the geologic time interval called the Pleistocene Epoch, the scientific term for the Ice Age. The subsequent in-

| Period | Epoch | Climate | Years before present | Events in the glacial history of Mount Desert Island |
|------------|-------------|--|----------------------|--|
| Quaternary | Holocene | Warmer period | | Holocene beach, talus, and wetland deposits |
| | Pleistocene | | 10,000 | Crustal rebound complete |
| | | Wisconsin glaciation | 13,000-14,000 | Deposition of marine clay Development of end moraines, deltas, and raised shoreline features Ice retreat from Mount Desert Island begins |
| | | Warmer period | 80,000 | Sculpting of bedrock landforms by glacial ice Beginning of Wisconsin glaciation |
| | | Illinoian glaciation | 130,000 | } Sculpting of bedrock landforms during periods of glaciation |
| | | Earlier glaciations alternating with warmer periods. | 300,000 | |
| | | | 1,700,000 | |

Figure 17. Geologic time scale for the past 1,700,000 years showing major glacial episodes in North America.

terval is called the Holocene Epoch, which extends from 10,000 years ago to the present day. Together, the Pleistocene and Holocene Epochs make up the Quaternary Period (Figures 2, 17). On Mount Desert Island the Wisconsin ice sheet covered the highest hills and modified the earlier landscape through glacial erosion. The thin veneer of materials left as the glacier retreated are collectively called *drift*. On the surficial geologic map included with this book, deposits are prefixed either with a "W", indicating deposition during the Wisconsin glaciation, or an "H", indicating deposition in the modern Holocene Epoch. The next two sections of the book describe the processes that occurred during these intervals and examine their effects on Mount Desert Island.

SHAPING OF THE LANDSCAPE BY GLACIAL EROSION

A *glacier* is a mass of snow and ice that has accumulated on land and is large enough to move under its own weight. Glaciers form where there is a net buildup of snow over many years, and the more deeply buried snow layers become compacted into ice. Glaciers develop in various sizes and shapes. The rivers of ice that occur in high mountain valleys are called *alpine glaciers*, and the huge pancake-like masses covering nearly all of Greenland and Antarctica are continental glaciers.

Glacial ice expands outward like a pool of cold molasses (but much more slowly), to eventually dissipate because of melting or the breaking away of icebergs into lakes or the ocean. The ice in a continental glacier constantly flows from the center toward its outer margin. The location of the ice margin may advance or retreat depending on the balance between ice accumulation in the glacier's source area and the rate at which it melts away near the margin. It is interesting to note that even when the edge of a glacier is "retreating," the ice may continue to flow forward from the source area toward the glacier margin. At its maximum extent, the margin of the Wisconsin glacier was in the Gulf of Maine, but later ice margin positions indicate retreat of the glacier as ice wastage exceeded ice accumulation during deglaciation.

Erosion by glacial ice flowing in a southerly direction was responsible for the major landforms that we see today in Acadia National Park. The Wisconsin ice sheet flowed over Mount Desert Island for at least 10,000 years, eroding bedrock by two processes: *abrasion* and *plucking*.

Let's consider abrasion first. Rock fragments carried along under the base of the glacier acted like the grit on sandpaper, abrading and scratching the underlying bedrock. This abrasion was stronger on the north sides of hills, which faced against the southward-flowing ice. We cannot say just how much rock was removed by abrasion during the last glaciation, but the average bedrock surface was probably lowered one or two yards by this process.

Today if you visit the north-facing bedrock slopes you'll find the effects of glacial abrasion. Close examination of ledges where soil has recently been removed is likely to reveal a polished and scratched bedrock surface. These scratches are called *striations*, and plotting their orientations on a map shows us the direction of glacial movement over Mount Desert Island. A large bedrock ledge located across Maine Route 3 from the north end of The Tarn (a pond south of Bar Harbor) provides an excellent place to examine glacially quarried, polished, and striated bedrock (Figures 18 and 19). On ledges where soil



Figure 18. Granite ledge near the Tarn showing brightly polished surface resulting from glacial abrasion. Note two people for scale.

was never present, or has been removed for a long time, the rock surface is usually weathered to the extent that striations are not preserved. This is especially true for areas of granite.

Because of weathering, none of the other striations plotted on the surficial geology map are as pronounced as those near The Tarn. Most of the striations occur in very small patches, especially where the drift has just been removed. One might notice striations along hiking trails such as the one leading to South Bubble.

The second type of glacial erosion, plucking, removed large amounts of rock and produced many of the spectacular cliffs that we see in the park today. This process occurred because the ice at the base of the glacier at times required only a slight increase in pressure to cause it to melt. The movement



Figure 19. Close-up of polished bedrock surface seen in Figure 17 showing striations and arc-shaped fractures (chatter marks) produced by pressure of glacial ice. Note pen for scale. Striations are parallel to the pen.

of the ice sheet over the hills on Mount Desert Island produced a slightly higher pressure on the north side of the hills which melted the ice at the bottom of the glacier and allowed water to seep into fractures in the bedrock. This meltwater would freeze again as it moved into zones of lower pressure on the south sides of hills where the ice was no longer riding up over the slope. As the water refroze in rock fractures, it expanded with tremendous pressure and forced the rock apart. After blocks of bedrock were pried loose in this manner they were then frozen into the glacier and carried away. The southeast side of The Beehive (Figure 20) shows prominent cliffs that were produced by the plucking process.

The combination of glacial abrasion on the north slopes and plucking on the south slopes caused many of the hills and mountains in Acadia National Park to have a distinctively asymmetric profile: gentle and smooth on the north side facing into the ice flow, and steep and rugged on the south side. These hills also tend to be elongated and streamlined in a north-south direction as a consequence of glacial flow and erosion. Such glacially sculpted bedrock hills are called *whalebacks* or *roches moutonnées*. The Bubbles, located north of Jordan Pond, are a fine example of these features (Figure 21).

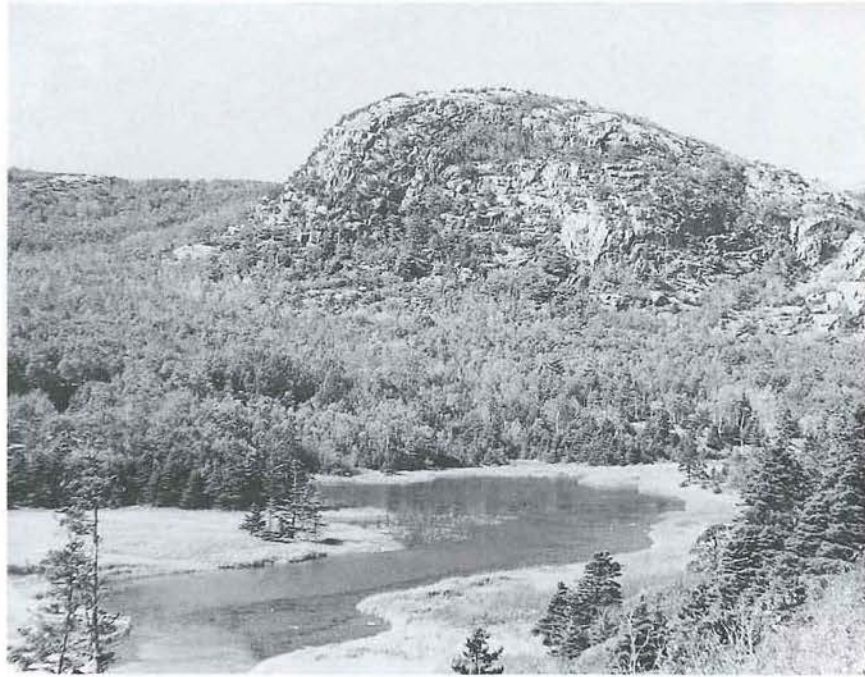


Figure 20. Cliffs produced by glacial plucking of large granite blocks on The Beehive. Foreground shows tidal inlet and salt marsh located behind Sand Beach.

The amount and rate of erosion of any landscape vary depending on the eroding agent (e.g. glaciers, rivers, or waves), the resistance of the bedrock, and time. In the case of Mount Desert Island, the Cadillac Mountain granite has proven to be more resistant than the surrounding rock types and consequently forms the highest terrain on the island. Within this granite there are zones of relative weakness (for example, areas where jointing is especially strong) that have been preferentially eroded by glacial ice. The glacier removed larger volumes of rock from these zones, producing deep valleys with a distinctive U-shape when viewed along their length. Like the whalebacks described above, the *U-shaped valleys* have a preferred north-south trend, parallel to the direction of former ice flow. They may have developed where preglacial streams had already eroded channels into the weaker parts of the bedrock. These valleys, modified and deepened by concentrated glacial flow, are called *dorrs* after George B. Dorr, who was instrumental in the founding of Acadia National Park. G. H. Chadwick named these features and suggested that Somes Sound was an ideal example of a dorr. A number of lakes on Mount Desert Island are located in such valleys (Figure 22). The profile of the island's mountains and valleys is especially well seen on any of the boat trips along the south side of the island.

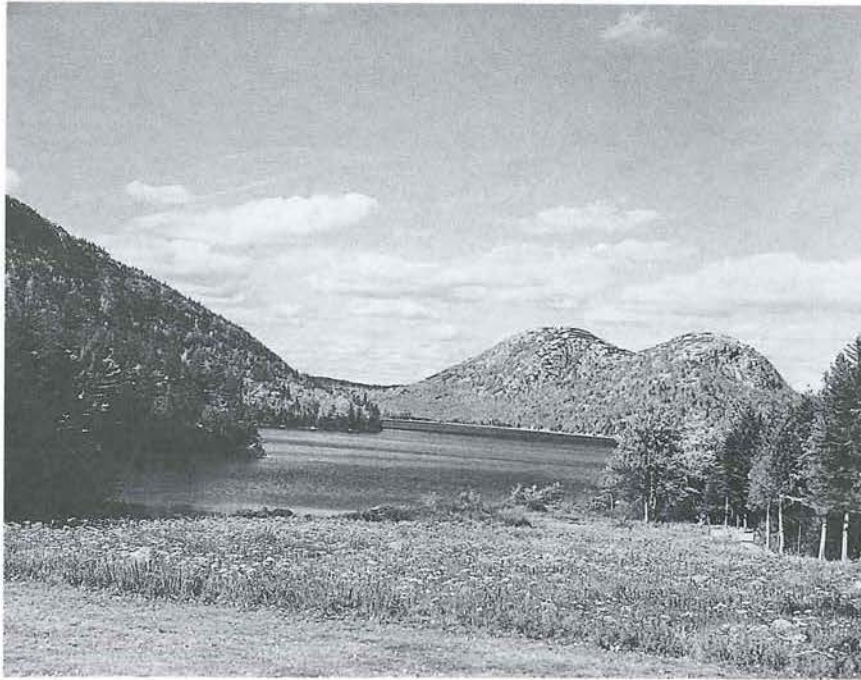


Figure 21. View of The Bubbles looking north across Jordan Pond. Erosion by glacial ice flowing southward (toward the viewer) along the Jordan Pond valley produced the rounded profile of these mountains.

GLACIAL TRANSPORTATION AND DEPOSITION OF ROCK DEBRIS

Most of the rock fragments that are eroded, incorporated into the ice, and transported at the base of a glacier are deposited less than two miles from their source. However, fragments eroded from hill-sides or hilltops in areas of high relief, such as Cadillac Mountain, are often incorporated high in the ice as the glacier moves away from the side or top of the hill. This material may travel for tens or even hundreds of miles before being deposited. Many of the glacially plucked rocks from Mount Desert Island can still be found on the island today, although they have been displaced to the south from their original positions. Others were carried out into the Gulf of Maine. By the same token, we find foreign rock fragments on the island, carried there by ice from the mainland north of Mount Desert. For example, numerous gray granite boulders which contain large rectangular white crystals of feldspar are found on top of Cadillac Mountain. These boulders were transported to that and other locations on the island from outcrops of Lucerne granite, located 19 miles to the north. The famous balanced boulder called Bubble Rock on South Bubble, just north of Jordan Pond, is the best known of these far-traveled *erratics* (Figure 23).



Figure 22. Glacially sculpted U-shaped valley between Dorr Mountain (right) and Huguenot Head, on east side of Mount Desert Island. The Tarn is the pond in the foreground.

Glacially transported boulders are commonly mixed with silty to sandy rock debris released from melting ice, forming a deposit called *till*. Most of the rock debris carried by the glacier was concentrated near the base of the ice, where it was subjected to intense grinding and crushing. Some of this pulverized rock material was deposited beneath the moving ice sheet. The resulting *basal till* is generally a compact, fine-grained sediment containing many striated stones. Elsewhere, the material carried by the glacier was released into nearby water (see the description of deglaciation below) where it flowed as a slurry. Glacial sediment deposited in this manner may appear very similar to basal till, so both types are combined into a single “till” unit on the map. Appreciable thicknesses of till occur only in a few low areas of Mount Desert Island (Wt on the geologic map).

DISAPPEARANCE OF THE GLACIER

As the earth’s climate warmed, Mount Desert Island became ice-free by a process called *deglaciation*. In some parts of the world, glaciers simply melted under the influence of sun and rain, but in areas such as Mount Desert Island the glacier withdrew in a more complex fashion because it was partly in contact with the sea. The deglaciation history of the island can be divided into three parts which will

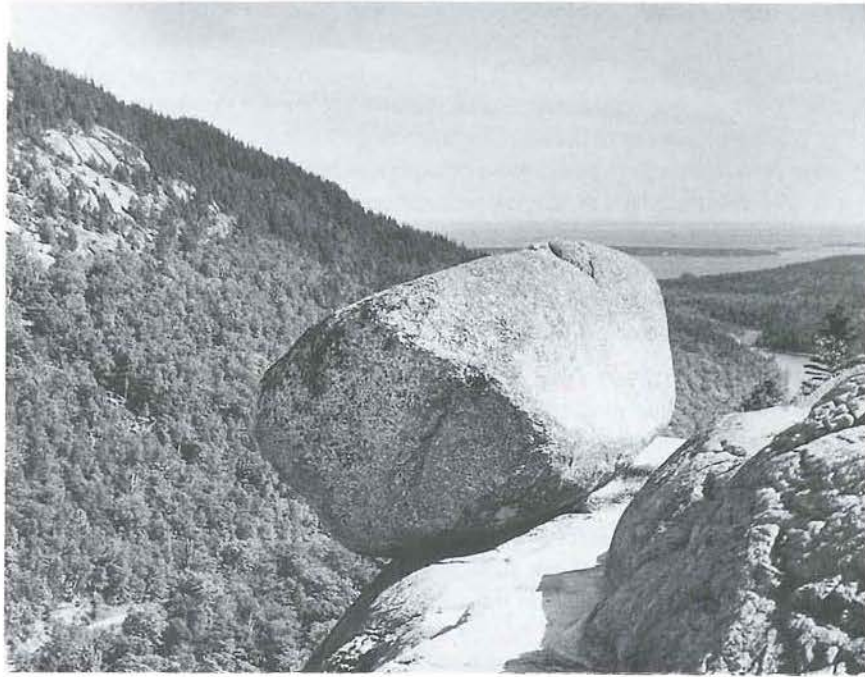


Figure 23. *Bubble Rock, a large glacial erratic over 10 feet tall, is perched high on the side of South Bubble Mountain.*

be described separately: 1) glacial downdraw into the sea, 2) melting of glacial ice on land, and 3) uplift (rebound) of the Earth's crust as the weight of the ice sheet was removed. As we consider these individual aspects of deglaciation, it should be remembered that they are all interrelated.

Glacial Downdraw into the Sea

When the last ice sheet was at its greatest extent, sea level was about 330 feet below its present level. By about 18,000 years ago, however, the climate had warmed enough to begin melting the ice. The melting of the continental ice sheet returned water to the oceans, causing a rise in sea level.

As the sea rose against the edge of the ice sheet, the water eventually became deep enough to float the seaward edge of the ice up off the bedrock. Since it was no longer slowed by friction with the underlying ground, the floating ice began to flow rapidly into the sea and disintegrate into icebergs. This process, called *downdraw*, may have increased the speed of the glacier in marginal zones by a factor of ten and probably removed large volumes of ice from coastal Maine. However, the downdraw stopped when the ice margin retreated to a position above sea level. On Mount Desert Island this occurred about 13,000 years ago. The ice remaining in areas above sea level was land-based, and deglaciation proceeded in a different manner.

Melting of Glacial Ice on Land

As the climate continued to warm during late-glacial time, the ice surface melted and produced vast amounts of water. Some of this meltwater flowed directly off the surface of the glacier, but a sizable amount found its way to the bottom of the ice. The internal meltwater carved channels within the glacier. We can partly trace these channels because some of them reached the hills beneath the glacier and eroded into the bedrock. The resulting trough-shaped features are called *meltwater channels*. Glacial streams were able to carve these channels because the strong currents carried abundant sediment, which abraded the bedrock surface. Meltwater channels exist high on the sides of all the mountains on the island. One of the best examples forms the gap between Cadillac Mountain and Dorr Mountain and can be seen from the Park Loop Road where it crosses Otter Cove. These channels were cut prior to the deglaciation of the land.

As the surface of the melting glacier steadily dropped, Cadillac Mountain and other peaks became exposed as islands of bedrock in the ice. However, the ice still flowed around the flanks of the emerging mountains as deglaciation progressed. Lobes of ice extended southward along the major valleys that occur in the central part of Mount Desert Island, such as those now occupied by Long Pond, Somes Sound, and Jordan Pond. The sea was in contact with the ice lobes where they extended from the southern ends of the valleys, but the water depth was not sufficient to float them. Therefore, the ice in these valleys still rested on the ground, and it continued to transport rock debris. The freshly exposed mountain peaks also contributed to the debris load. All of this rock debris was carried along by the flowing ice, as if on a conveyor belt, and was released to form mounds and ridges at the front edge of the ice. These glacial dump piles, called *end moraines*, can be seen in the southern portions of several valleys (Wm on the geologic map).

The best-known end moraine in Acadia National Park forms a natural dam at the south end of Jordan Pond, and the Jordan Pond House was built on its crest. The till that makes up this moraine consists of sediment ranging from clay to boulders (Figure 24). The melting ice also supplied water that transported and sorted some of the dumped sediment into a sand and gravel mixture known as *outwash*. Boulders moved little, if at all, in the meltwater streams, while the tiny silt and clay particles washed away into the ocean. One of these areas of outwash extends from Bubble Pond southward along Hunter Brook (Wgo on the geologic map). In some places the sand and gravel entering the ocean built up to the water surface, forming flat-topped deposits called *deltas* (Wgd on the geologic map). The tops of these deltas, such as the one just south of the Jordan Pond moraine, mark the approximate position of sea level when the deltas were formed. At times the glacier advanced a little and overrode the outwash, causing the sand and gravel layers to be pushed and folded. Several folded gravel layers have been exposed in a gravel pit near Southwest Harbor.

Rebound

A third process that occurred during deglaciation was *rebound* of the land surface. The crust of the Earth is flexible and floats on the denser, slightly plastic mantle beneath. Any weight added to the crust will push it down. For example, 3,000 feet of ice will cause the underlying bedrock to sink about 1,000

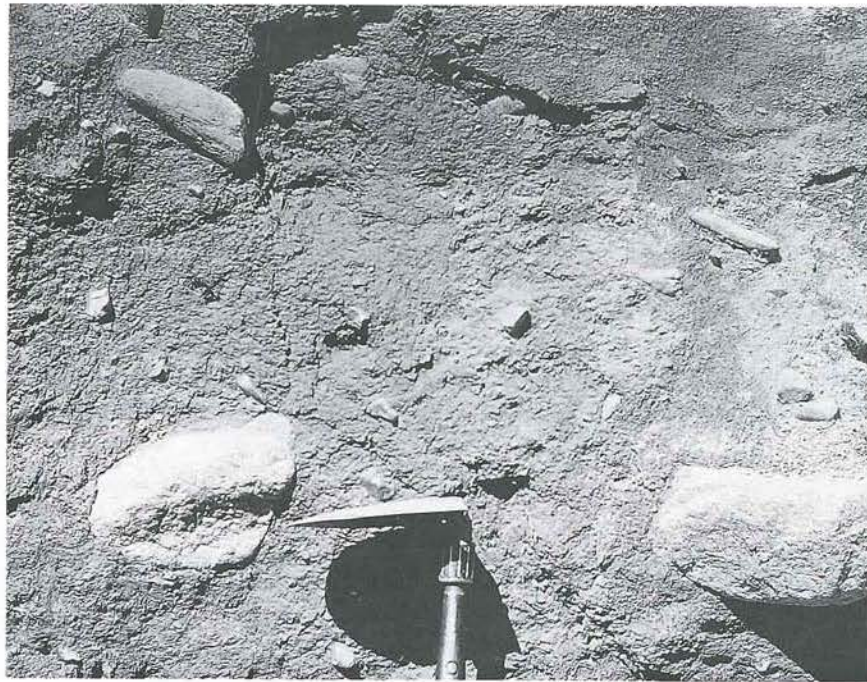


Figure 24. Glacial till exposed in excavation during construction of the Jordan Pond House. Shovel blade is 7 inches across.

feet. However, when the ice melts, the crust will rise slowly back to its original level. The uplift of the land that takes place during this rebound process may continue for several thousand years following deglaciation.

The solid line in Figure 25 shows the changes in elevation of the earth's crust during a full cycle of glaciation, including the rebound phase described above. The dashed line in this figure shows the worldwide changes in sea level caused by the growth and shrinkage of continental ice sheets. During the cycle of glacial advance and retreat, the relative positions of these curves show whether sea level was higher or lower relative to its present position. For example, during the period of rapid glacial retreat following maximum glaciation, sea level was relatively higher than the present-day land surface, and today's coastal lowlands were drowned by the sea. During the period following rapid crustal rebound, sea level was *relatively* lower than at present, and today's offshore areas were above sea level. The important conclusion to be drawn from this illustration is that the *relative* positions of the land surface and sea level — not their absolute elevations — determine whether the coastline was higher or lower than its present position.

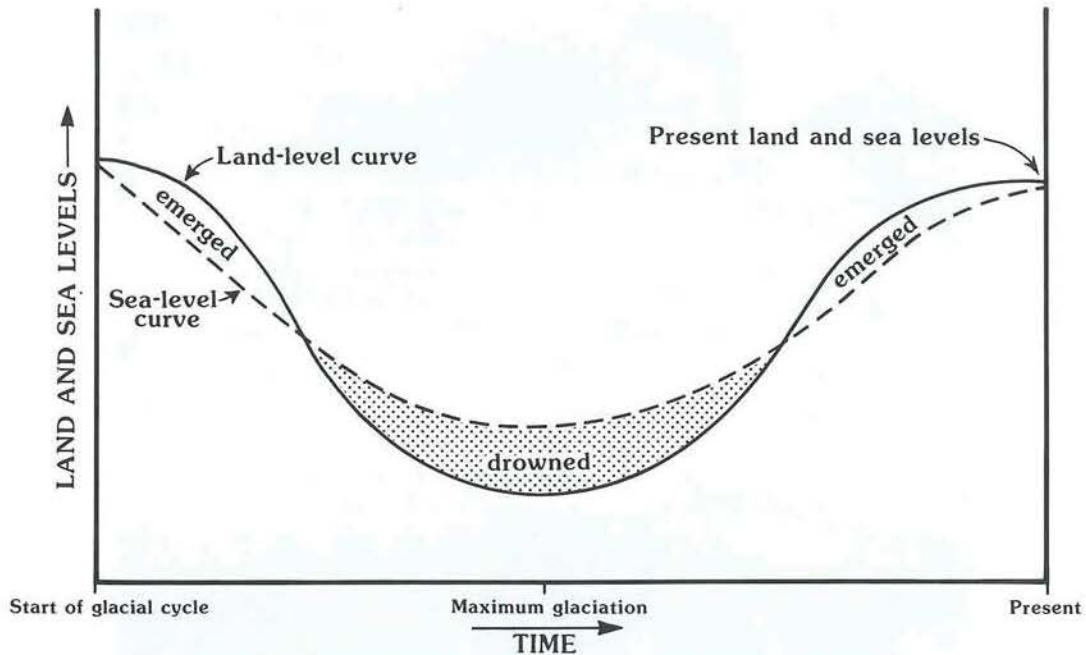


Figure 25. Graph showing relative positions of worldwide sea level and the earth's crust in the vicinity of Mount Desert Island during the last cycle of glacial advance and retreat.

It is evident from Figure 25 that even though global sea level was lower as the last ice sheet retreated, the land (which hadn't rebounded yet) was even lower than the ocean. This circumstance allowed the sea to flood much of coastal Maine, including low-lying portions of Mount Desert Island. Elevated shoreline features on the island, such as the delta south of Jordan Pond, indicate that the relative position of sea level was about 230 feet higher during late-glacial time. This raised sea level allowed water to follow the ice margin onto the island, and the sea extended well into lowland areas of central Maine before rebound forced it to withdraw.

In Acadia National Park, the most widespread evidence of submergence by the sea is the discontinuous blanket of *marine clay* that covers some of the low areas on Mount Desert Island (Wef on the geologic map). This clay consists of very small mineral particles (*rock flour*) that were derived from glacial abrasion and washed out of the melting ice. Marine clay was once called *cove clay* because of its concentration in the coves and near-shore valleys of the island. If you look closely, you can see these clay deposits in eroded banks around the coves along Ocean Drive. Marine clay deposits are also exposed on the east side of Otter Cove where it is crossed by the Park Loop Road and at the east end of Sand Beach. Although the clays were originally gray or bluish-gray, most have been weathered to a brown or brownish-gray.

In places the marine clays contain well-preserved shells of clams, mussels, and other mollusks. Some of the fossil shells belong to species that now live only in cold, subarctic waters. These fossils indicate that the late-glacial marine environment of coastal Maine was similar to that of southern Greenland today. The shells can also be used to determine the time of glacial retreat and invasion of the sea. For example, a clay deposit on the shore of Goose Cove on the west side of the island contains shells determined to be approximately 12,250 years old by the carbon-14 dating method.

Other evidence of former marine submergence is the wave-worked boulders, gravels, and sands that mark ancient shorelines well above present sea level. Look at any of the coves along the Park Loop Road and you will see modern beach deposits consisting of boulders, cobbles, and perhaps sand lapped against the bedrock cliffs. Similar deposits can be seen at higher elevations in the park, documenting sea levels of the past (Wec on the geologic map). On the east side of Day Mountain, east of the village of Seal Harbor, there are several emerged beaches containing well-rounded boulders (Figure 26). Near this former beach there are also steep, wave cut cliffs such as those found along the present shoreline.



Figure 26. Emerged beach on the side of Day Mountain. Note the concentration of boulders which were tossed about and rounded in the former surf zone when sea level was approximately 210 feet above the present level.

Rebound of the earth's crust soon outpaced the rising sea and forced the shoreline to drop. The ages of fossils from the marine clays mentioned above reveal that Mount Desert Island and the rest of coastal Maine rose above sea level between 12,000 and 11,000 years ago. Rebound continued until the relative position of sea level was about 215 feet lower than it is today. No evidence of this minimum sea level is visible on land, but drowned stream channels and deltas are present offshore in the Gulf of Maine. Continued melting of glaciers worldwide eventually raised sea level to its present elevation.

SUMMARY OF GLACIAL HISTORY

Perhaps the best way to relate the wide-ranging topics discussed here is to take another look at the area around Jordan Pond House. From this vantage point we can easily examine glacial features that illustrate most of the concepts that we have talked about. Figure 27 is a series of maps and sections illustrating the various stages in the evolution of the landscape.

Looking north from the Jordan Pond House, we see the striking effects of glacial erosion during the main onslaught of the Wisconsin ice sheet: the deeply scoured U-shaped valley now occupied by Jordan Pond and the rounded profiles of The Bubbles at the north end of the pond (Figure 21). High on the southeast shoulder of South Bubble, you may also be able to see Bubble Rock, an erratic which was left in its seemingly precarious position after traveling for miles within the ice sheet (Figure 23).

Right around Jordan Pond House is a low ridge of glacial till, the Jordan Pond moraine, which forms a natural dam containing the lake. A short walk in this area will reveal some of the boulders that melted

Figure 27. Schematic maps and cross sections of the Jordan Pond valley from late-glacial time until the present. Cross sections (left-hand diagrams) are drawn from top to bottom through the map views (right-hand diagrams).

A. 14,000 years ago. A continental glacier covered the entire region. Glacial plucking removed bedrock blocks from hillsides.

B. 12,500 years ago. The continental glacier had receded from the area, leaving only a tongue of ice in the Jordan Pond valley. The ocean covered the depressed land surface. Debris carried by the ice formed the Jordan Pond moraine and a delta. Marine clays were deposited on the ocean floor.

C. 11,000 years ago. The ice had completely disappeared from the Jordan Pond valley. The moraine at the southern end of the valley formed a natural dam for Jordan Pond. Sea level continued to drop and the delta began to emerge.

D. 10,000 years ago. The rebound of the land surface caused the sea to recede from the area.

E. 2,000 years ago to present. Rising sea level has once again inundated part of the area, and modern beach deposits are being created. The Jordan Pond House was built on top of the moraine. The surficial units are shown here as they appear on the surficial map.

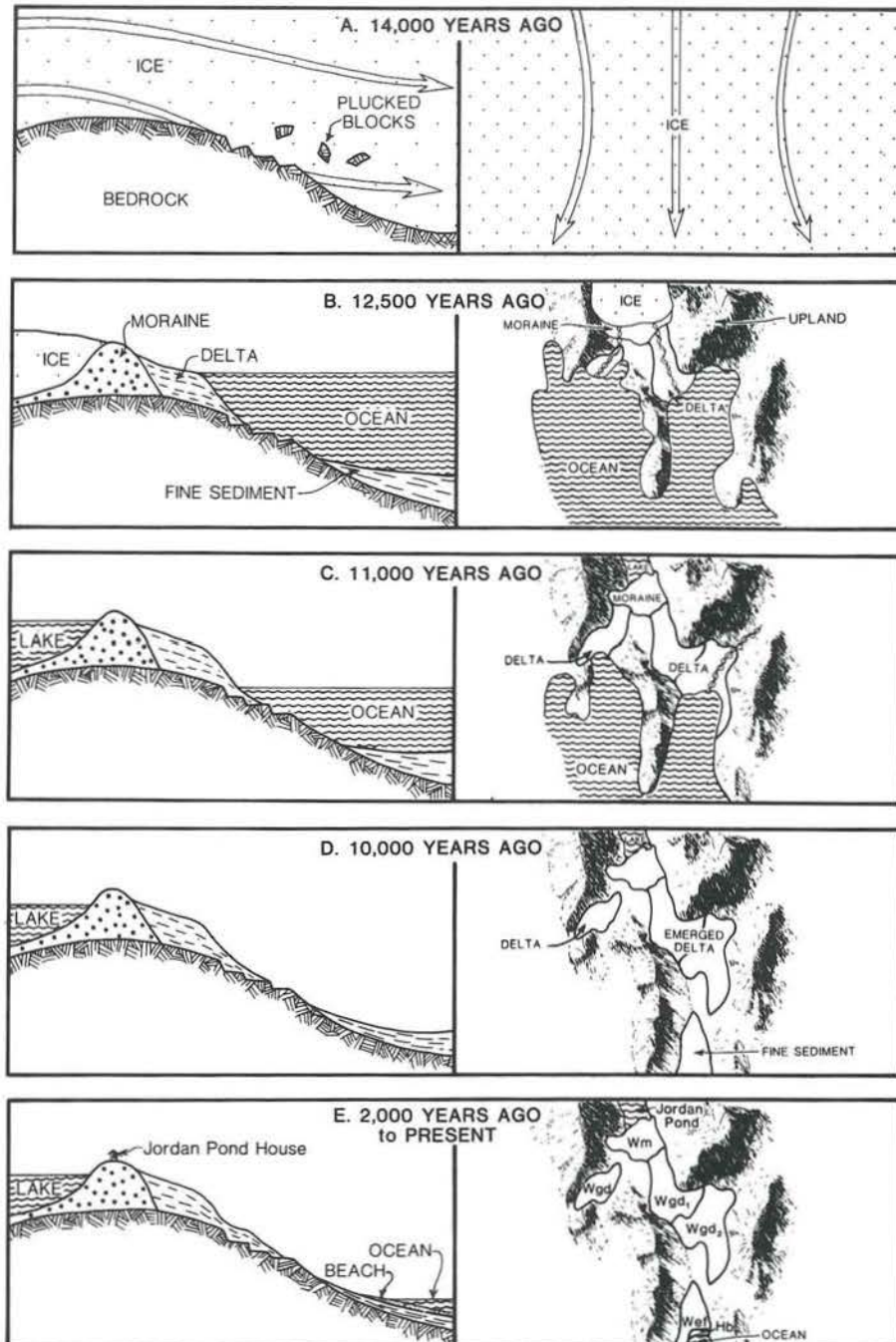


Figure 27.

out of the glacier as the moraine accumulated. Narrow lobes of ice extended down the Jordan Pond valley and other neighboring valleys of Mount Desert Island during deglaciation, and moraines such as the one seen here accumulated at their southern ends.

If we walk or drive down the road to a point about one-half mile southeast of the Jordan Pond House (heading toward Seal Harbor), we find ourselves on a flat surface. This is the top of a delta composed of sand and gravel that washed southward into the ocean when the ice margin stood right behind the Jordan Pond moraine. This delta is complex and in part received some of its sediment from meltwater that flowed into Jordan Valley from the east (Wgd₁ and Wgd₂ on the surficial map). The Jordan Pond delta began to form at a time when the relative position of sea level was 230 feet higher than today. Depression of the Earth's crust under the weight of the glacier allowed the sea to encroach to this high level and submerge much of the low-lying coastal terrain.

The lack of erosional modification or clay deposits higher than the Jordan Pond delta suggest that the sea never rose above the delta top. However, the presence of beach features at lower and lower elevations to the south reflects the drop in sea level during rebound. As the sea retreated, streams flowing from Jordan Pond began to cut into the delta and reduce it to its present size.

Most of the events shown in Figure 27 occurred in a fairly short time. The longest time span, from about 10,000 to 2,000 years ago, is not well represented here because the sea level was much lower (Figure 25) and no evidence exists for it on Mount Desert Island.



Recent Geologic Processes on Mount Desert Island

Changes to the landscape, both along the ocean shore and at higher elevations, have by no means stopped since the glacier which covered Mount Desert Island receded. Following the postglacial uplift of the Maine coast, worldwide sea-level rise caused a gradual encroachment by the ocean which continues today. The sea continually attacks the shore, eroding dikes and other weaker rocks to form chasms such as Thunder Hole, and cutting cliffs, caves, and sea stacks. Eroded rock material is carried away from these high-energy zones and deposited either as coarse beaches, or in mud flats in areas of quiet water. The coarser beach deposits (sand and gravel; Figure 28) are shown as Hb on the geologic map.

While the sea works on the shoreline, the interior areas of Mount Desert Island are continually worn down by other processes. Glacial erosion left steep, jagged cliffs along the valley sides. Although the rock in these cliffs is strong, it is so fractured that it will not stand for long in a vertical position. Water seeping into the fractures and freezing, together with gravity, causes blocks of the bedrock to break away and fall or slide down the slopes. At the bottoms of the cliffs they join other fallen blocks in a pile of rubble called *talus* (Ht on the geologic map). One of the largest talus piles occurs on the west side of Huguenot Head, along Route 3 south of Bar Harbor.

There is not a great deal of modern sediment accumulation on Mount Desert Island, partly because there are no major rivers to erode and re-deposit the glacial materials. However, there are significant wetland areas in which organic-rich sediments are being deposited. These areas include salt marshes along the coast (Hs on the geologic map) and freshwater wetlands (Hw). Some of the freshwater deposits are *peat* bogs, such as The Heath on Great Cranberry Island.



Figure 28. Gravelly beach ridge near the Seawall picnic area, south end of Mount Desert Island. The raised gravel ridge forms a natural seawall along this portion of the island.



Conclusion

Having seen the effects of glacial ice and modern processes on Mount Desert Island, our geological overview of the region is now complete. The geologic history of Mount Desert Island is a long one; rocks over 500 million years old present evidence for the island's beginnings on the bottom of an ancient ocean floor. "Younger" rocks, approximately 400 million years old, show that the island was once the site of volcanic activity. A large part of the geologic history is unknown — no geologic evidence is present for the period from 350 million years ago until late-glacial time (approximately 15,000 years ago).

A wide variety of geologic processes have affected the island in the past: deep burial and metamorphism at high temperatures and pressures altered sediments to form the Ellsworth Schist; magma rose and intruded the sedimentary and volcanic rocks to form the granites that make up the core of the island; thick ice sheets sculpted the bedrock and pushed the land below the sea. Geologic processes, principally erosion, continue to alter the island's form today.

These processes affected more than just the island's landscape. Granite quarrying was a major industry on Mount Desert Island and continues to play a small role in the economy of the greater Penobscot Bay region. The good harbors sculpted by ice provide shelter for the region's fishermen and boating enthusiasts. And today, the spectacular scenery of Acadia National Park is the largest economic factor in the area.

We hope that this description of the area's geology has contributed to your understanding of the events that shaped this scenic part of the Maine coast, and that you can use this information to enrich your travels on the island. If you wish to study the development of the island's landscapes in more detail, you should consult the publications mentioned in the supplementary reading list at the end of this bulletin.

For anyone contemplating an extended tour of Mount Desert Island, a large topographic map, "Acadia National Park and Vicinity, Hancock County, Maine", is most useful. This may be obtained at the Acadia National Park Visitor Center and in local book and outdoor supply stores. Topographic quadrangle maps of the Mount Desert Island area are available from the latter sources, as well.

More casual visitors can obtain a copy of the map of Acadia National Park from the Visitor Center, Thompson Island Information, or Nature Center. Trail maps of Mount Desert Island are also available from the Park information centers and in local book and outdoor supply stores.



Supplementary Reading

The following articles are suggested for those interested in further studies on the geology of Acadia National Park:

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- Chapman, C. A. and Rioux, R. L., "Statistical study of topography, sheeting and jointing in granite, Acadia National Park." *American Journal of Science*, vol. 256 (1958), p. 111-127.
- Hodge, D. S., and others, "Gravity studies of subsurface mass distribution of granitic rocks in Maine and New Hampshire." *American Journal of Science*, vol. 282, no. 8 (1982), p. 1289-1324.
- Metzger, W. J., "Stratigraphy and geology of the Bar Harbor Formation, Frenchman Bay, Maine." *Geological Society of Maine, Bull.* 1 (1979), p. 1-18.
- Metzger, W. J., and Bickford, M. E., "Rb-Sr chronology and stratigraphic relations of the Silurian rocks, Mt. Desert Island, Maine." *Geological Society of America Bulletin*, vol. 83 (1972), p. 497-504.
- Raisz, E. J., "The scenery of Mount Desert Island, its origin and development." *Annals of the New York Academy of Science Annual*, vol. 31 (1929), p. 121-186.
- Shaler, N. S., "The geology of the island of Mount Desert, Maine." *U.S. Geological Survey Annual Report*, no. 8 (1889), p. 987-1063.



Glossary of Geologic Terms

Abrasion: The grinding or wearing away of rock surfaces caused by the scraping action of rock fragments frozen into the base of a glacier.

Albite: Sodium-rich (Na) *feldspar*, $\text{NaAlSi}_3\text{O}_8$.

Alpine glaciers: A medium to small glacier that forms in a mountain range and flows down valleys.

Basal till: A compact mixture of *sediment*, ranging in size from clay to boulders, deposited directly from the bottom of a glacier.

Basalt: A dark, fine-grained *igneous rock* that is erupted onto the surface as a lava flow.

Beds: Individual layers of a *sedimentary rock*.

Cauldron subsidence: The process in which a more or less cylindrical block of rock above a magma chamber collapses into the space left as the *magma* moves toward the surface.

Continental drift: The theory suggesting that rigid continental and oceanic plates move over the surface of the globe, producing many of the large scale geologic features (such as mountain ranges) we see today.

Continental glaciers: A glacial ice sheet of considerable thickness which covers a sizable portion of a continent and obscures most of the underlying terrain. The modern Antarctic ice sheet is a good example.

Correlative: A term applied to two or more rock units of similar age and possibly similar origin.

Country rock: The rock into which a mass of *igneous rock* was intruded.

Crust: The outermost, least dense layer of the earth. Includes continental crust and oceanic crust.

Deglaciation: The disappearance of an ice sheet through melting or by breaking off of icebergs.

Delta: A deposit of sand and gravel, often triangular and fan shaped, formed at the mouth of a river or stream where the current becomes too slow to carry the *sediment*.

Diabase: A dark gray to black rock with the composition of *basalt* that solidifies beneath the surface as thin *dikes* or *sills*.

Dike: Thin, tabular *igneous rock* body that cross-cuts the bedding of the rock that it intrudes.

Diorite: A coarse-grained *intrusive igneous rock* intermediate between *granite* and *gabbro* in silica and iron and magnesium content.

Drift: A general term applied to all rock material transported by glacial ice and deposited either directly from a glacier or by meltwater streams.

Downdraw: The process by which the ice flow of a glacier accelerates and the surface of the ice drops rapidly.

End moraine: Ridges of *till* and/or sand and gravel formed at the margin of a glacier.

Erratic: A glacially-transported rock that has been deposited some distance away from its point of origin and now rests on bedrock of a different type.

Exfoliation: The process by which horizontal to near-horizontal fractures cut rock into sheets, due to pressure release caused by erosion of overlying rock material. Very common in *granites*.

Extrusive: Term applied to *igneous rocks* that erupt onto the surface as flows or into the air as ash.

Fault: A fracture in rock along which there has been substantial movement, either horizontally or vertically.

Feldspar: A family of common silica and alumina rich rock-forming minerals. Includes *plagioclase* (calcium-feldspar), *albite* (sodium-feldspar), *K-feldspar* (potassium-feldspar), and *perthite*.

Felsite: A fine-grained, generally light-colored intrusive or extrusive *igneous rock* forming *dikes*, *sills*, or flows.

Foliation: A general term for the sub-parallel, planar arrangement of platy minerals such as micas. Typically best developed in *metamorphic rocks* such as the Ellsworth Schist.

Gabbro: Silica-poor, iron and magnesium rich intrusive igneous rock. Generally coarse-grained and dark in color.

Geologic map: A map which shows the distribution of rocks or surficial materials and geologic structures of a region as if all soil and vegetation were stripped away.

Geologic time: The time extending from the beginning of the earth as a separate planetary body to the beginning of written history; implies extremely long duration or remoteness in the past: approximately 4.5 billion years.

Glacier: A large mass of ice formed by the compaction and recrystallization of snow and showing evidence of past or continuing flow.

Graded bedding: Sedimentary layering which displays a gradual change in particle size from coarse particles at the base of the *bed* to fine particles at the top. At the top of each bed there is an abrupt change back to the coarse particles of the next bed.

Granite: A silica-rich, iron and magnesium poor *intrusive igneous rock* of medium grain size composed primarily of quartz and *feldspar*. Generally light in color.

Igneous rock: Rock that solidified from molten rock material or *magma*.

Intrusive: An *igneous rock* that solidified from *magma* that was injected into older rocks below the earth's surface.

Joints: Planar fracture surfaces in rock along which there has been little or no movement.

Joint sets: Sub-parallel joints oriented in clearly definable directions.

K-feldspar: A type of feldspar containing potassium (K), an essential mineral in granites.

Magma: A mixture of molten rock and mineral grains which may be erupted as volcanic material or cool slowly at depth to produce *intrusive* rocks (such as *granite*).

Mantle: The middle layer of the earth, lying below the *crust*. Denser than the crust, rigid plates of oceanic and continental crust move over a partially molten zone in the mantle. See *plate tectonics*.

Marine clay: A deposit of very fine rock and mineral particles that accumulated on the ocean floor.

Matrix: The finer-grained part of an igneous rock in which larger crystals (*phenocrysts*) occur. Also the light colored rock that encloses the dark blocks in the shatter zone.

Meltwater channels: Gulleys cut into bedrock by water flowing beneath or from a glacier.

Metamorphic rocks: Rocks whose original mineral composition or texture has been changed by recrystallization at high temperatures and pressures, but have not melted.

Metamorphism: A process where rocks are recrystallized by heat and pressure in the earth's crust. Metamorphism is a process that usually accompanies *orogeny*.

Orogeny: The process whereby mountain belts are formed.

Outwash: Stratified sand and gravel deposited by meltwater streams in front of a glacier.

Peat: A deposit of partially decomposed plant remains that accumulates in a wetland environment such as a marsh or heath.

Perthite: A mineral made up of intergrown *albite* (sodium-feldspar) and *K-feldspar* (potassium-feldspar). A common constituent of *granites*.

Phenocrysts: Large, conspicuous crystals surrounded by fine-grained material in a volcanic rock or a *dike*.

Plagioclase: Calcium (Ca) *feldspar*, $\text{CaAl}_2\text{Si}_2\text{O}_8$.

Plate tectonics: The theory and study of the formation, movement, and interaction of the rigid plates that make up the earth's crust and upper mantle.

Plucking: A glacial erosion process in which fragments or blocks of bedrock are first loosened by the expansion of freezing water in fractures and *joints* and then picked up and removed as the overlying glacial ice advances.

Quarrying: Same as *plucking*.

Rebound: The rise of the earth's crust in response to the removal of substantial thicknesses (and weight) of ice.

Roche moutonnée: An elongate bedrock knob or hill with a distinctive asymmetric profile. The up-ice surface (which faced into the flowing ice) is gently inclined and rounded, and the down-ice side is steep and rough.

Rock flour: A glacial sediment composed of finely ground rock formed by *abrasion* at the base of the glacier.

Sea stack: A pillar-shaped bedrock pinnacle resulting from wave erosion along the ocean shore.

Schist: A coarse-grained, mica-rich *metamorphic rock* characterized by aligned mica flakes.

Sediment: Unconsolidated deposits of sand, silt, clay, etc., deposited and transported by water, ice, or wind.

Sedimentary rocks: Rocks formed by the accumulation and cementation of mineral grains transported by water (and less commonly by wind or ice), or by the precipitation of minerals from water.

Sills: Thin, tabular sheets of *igneous rock* parallel or sub-parallel to the bedding in the sedimentary rocks they intrude.

Stratified: A term describing rocks formed or arranged in layers or beds.

Striations: Parallel grooves on bedrock surfaces produced by the abrasive action of rock fragments frozen in the base of an actively moving glacier.

Talus: Angular rock fragments of any size (usually boulders) lying at the base of a steep rock cliff.

Till: A glacial deposit consisting of a mixture of clay, silt, sand, gravel, and boulders that was deposited directly from glacial ice.

Unconformity: A gap in the geologic record, resulting from a period of erosion or non-deposition between an older rock unit and the younger, overlying rock strata.

U-shaped valleys: A valley whose cross-sectional profile is similar to the letter "U". It has steep sides and a relatively flat bottom. This type of profile is typical of glacially carved valleys where the long axis of the valley is parallel to the former direction of ice flow.

Volcanic tuff: A term describing rocks composed of volcanic ejecta, such as broken pieces of volcanic glass, *phenocrysts*, rock fragments, etc.

Whalebacks: Same as *roche moutonnée*.

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44°27'30"

25'

20'

15'

10'

25'

25'

20'

15'

10'

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Bulletin 38

BEDROCK GEOLOGY OF MOUNT DESERT ISLAND

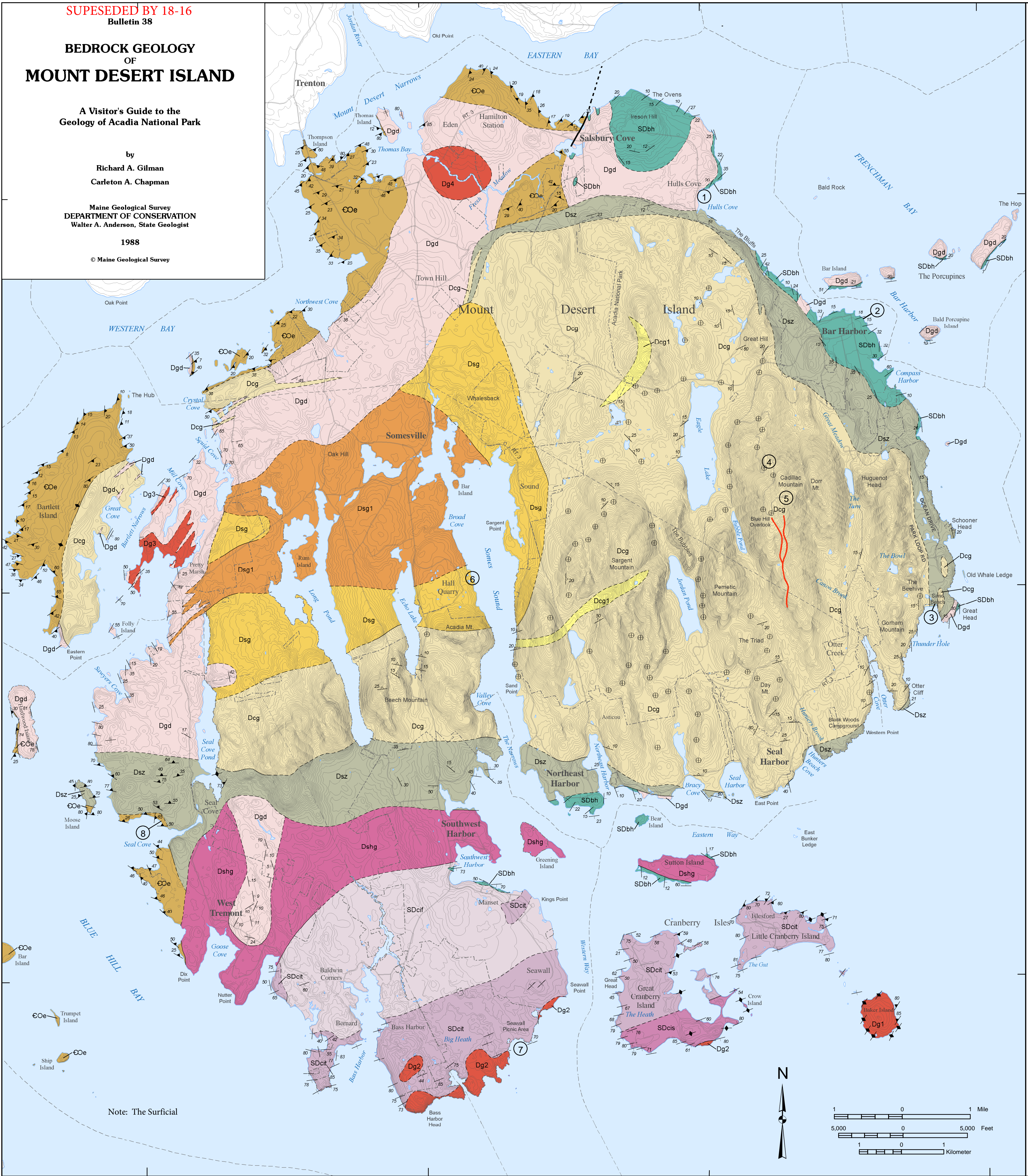
A Visitor's Guide to the
Geology of Acadia National Park

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EXPLANATION

INTRUSIVE ROCKS

Granite - Miscellaneous small granite bodies. All contain biotite mica. Subscripts do not indicate relative ages.

Dg1 (Baker Island): Pink, medium-grained granite with a faint northeasterly 'grain' due to parallelism of biotite grains.

Dg2 (Seawall to Bass Harbor): Pink, fine-grained granite with a distinctive sugary texture. Contains abundant veins of coarser quartz and feldspar.

Dg3 (Pretty Marsh Harbor): Pink, medium-grained granite occurring as dikes in the gabbro-diorite.

Dg4 (Northeast Brook): Pink, medium-grained granite with scattered larger crystals of light lavender alkali feldspar.

DEVONIAN

Dsg **Granite of Somesville** - Pink and gray, medium-grained biotite granite containing pink or cream-colored alkali feldspar and light gray plagioclase.

Dsg1 Fine-grained variety of the Somesville granite.

Dcg **Granite of Cadillac Mountain** - Pink to greenish-gray, coarse-grained granite. The individual grains of translucent, gray, glassy-looking quartz and pink or gray feldspar are easily seen; the black minerals are hornblende and occasionally biotite.

Dcg1 Recrystallized zones within the Cadillac Mountain granite.

Dshg **Granite of Southwest Harbor** - Light gray, fine-grained granite, commonly with a tan or pinkish hue. Contains both biotite mica and hornblende.

Dgd **Gabbro-diorite** - Gabbro: dark gray, coarse-grained rock consisting of black pyroxene and/or hornblende, and gray plagioclase feldspar. Diorite: lighter gray color due to the greater abundance of light gray 'granite' feldspar.

Diabase dikes on Cadillac Mountain: dark gray, fine-grained rock.

SHATTER ZONE

DEVONIAN

Dsz **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 embedded in light gray 'granite.'

STRATIFIED ROCKS

Cranberry Island Series

SDcif Felsites and flows: Blue-gray to light brown felsites and gray to brown dacite flows.

SDcit Tuffs: Gray crystal and lithic tuffs. Many of the beds appear water-laid, but ash falls and flows are present.

SDcis Interbedded volcanic rocks and contact metamorphosed siltstones and slates, including hornfels and gray, lavender, or cream-colored spotted slates.

SILURO-DEVONIAN

SDbh **Bar Harbor Formation** - Siltstones and sandstones displaying regular beds a few inches thick. The beds weather to a tan, gray, or lavender color but are typically dark on a freshly broken surface.

-----UNCONFORMITY-----

CAMBRO-ORDOVICIAN

COe **Ellsworth Schist** - A dark green or gray schist, often with a distinctive streaked appearance caused by thin, lighter colored layers of quartz and feldspar. The dark layers consist mostly of the mineral chlorite.

SYMBOLS

----- Geologic contact between adjacent map units.

----- Fault

73 35 Orientation of bedding in volcanic and sedimentary rocks (inclined and vertical)

55 35 Orientation of compositional layering in gabbro-diorite (inclined and vertical)

15 35 Orientation of metamorphic foliation (parallel alignment of platy minerals (inclined and vertical)

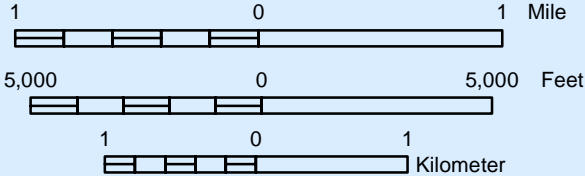
20 35 Orientation of inclusions in the Cadillac Mountain granite (inclined, vertical, and horizontal)

SITES OF GEOLOGIC INTEREST

① Location of site

- Gabbro and diorite.** Park on the shoulder of the road overlooking the beach at Hulls Cove. The 15-foot cliff along the center of the beach is composed of well-jointed, dark gray gabbro (nearest the water) grading to lighter gray diorite towards the road. At least three sets of joints are visible: a vertical set running into the cliff, a set dipping 45° towards the water; and a third set dipping approximately 80° inland. The thread-like white lines on the surface of the rock are quartz veins occupying old joints. The several rusty-colored zones are due to the weathering of iron sulfide minerals that were deposited along joints. This exposure has several excellent examples of 'boxwork veining'.
- Bar Harbor Formation.** From the pier in Bar Harbor, walk southeasterly along the shore path overlooking the beach. The rocks along the water below the motor inn and restaurant are Bar Harbor Formation. Notice the bedding in the rocks and how it tilts toward the ocean. Approximately 200 yards south there is a good example of a sea stack, formed by wave erosion. See Figure 4.
- Shatter zone surrounding the Cadillac Mountain granite.** From the parking lot at Sand Beach walk to the eastern end of the beach. The large angular inclusions in the cliffs at this end of the beach are country rock (gabbro/diorite and metasediments) engulfed in the shatter zone. See Figures 7 and 8.
- Diabase dike.** Park in the turnout approximately 1.7 miles from the entrance to the summit road (immediately past the hairpin turn). About 60 yards downhill from the turnout there are excellent examples of near vertical diabase dikes cutting the Cadillac Mountain granite. The dikes are bluish-gray in color, and can be seen on both sides of the roadcut. Compare the dikes on the north side of the roadcut with their extensions on the south side and note how the dikes vary considerably in thickness over this short distance. Look closely at the edges of the dikes on the north side of the road and observe the chilled margin, about 2 inches wide, where the mineral crystals are much finer-grained. See Figure 10.
- Cadillac Mountain granite.** Park at the top of Cadillac Mountain and walk on the paths that lead toward the summit. Several sets of joints are well displayed in the granite, and the rock has weathered preferentially along the joints emphasizing the fractures. See Figure 11.
- Quarries in the Somesville granite.** Several abandoned quarries are visible in and around the village of Hall Quarry. See Figure 9.
- Volcanic tuff of the Cranberry Island Series.** Next to the parking area west of the Seawall picnic area there are a number of good exposures of light gray volcanic tuff. Notice the fragments of volcanic ejecta included in the rock. This texture is very typical of 'air fall' tuffs. See Figure 6.
- Ellsworth Schist.** From route 102 just north of Seal Cove take the road 0.5 miles west to the public boat access. Approximately 100 yards beyond the boat launch area the ledges contain excellent examples of complexly folded gray and white banded Ellsworth Schist jutting into the water. See Figure 3.

Note: The Surficial



44°12'30"
68°27'30"

25'

20'

15'

10'

