THE GEOLOGY OF
BAXTER STATE PARK
AND MT. KATAHDIN

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BULLETIN 12

DEPARTMENT OF FORESTRY
Augusta, Maine

1972
Revised Edition
Baxter State Park, containing 200,000 acres, was a gift to the State of Maine by former Governor Percival P. Baxter. It is a paradise for the naturalist, mountain climber, and hiker.

Governor Baxter expresses the spirit of the Park as follows:

*Man is Born to Die, His Works are Short Lived
Buildings Crumble, Monuments Decay, Wealth Vanishes
But Katahdin in All Its Glory
Forever Shall Remain the Mountain of the People of Maine.*

\[\text{Signature:}\]

Dedicated to Helon Taylor.

The Maine Geological Survey in cooperation with the Baxter State Park Authority is republishing the second of a series of State Park geologic reports—*THE GEOLOGY OF BAXTER STATE PARK AND MT. KATAHDIN*. This report, written in semi-popular style, describes the geology of the State Park area and vicinity. The detailed character of the bedrock, as well as the interesting surface features that were developed by the glaciers which once covered the entire State are discussed.

These reports are planned for use by tourists and campers who visit the State Parks, but may be of general interest to anyone who desires some knowledge of the geology of the State.
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Introduction

The poem of the late Governor Baxter printed on the previous page expresses a faith, that is shared by many people, that mountains are a fixed and permanent part of the landscape. We use the phrase “everlasting hills” as a symbol of permanence. The earth does not seem to change very much, except from season to season, in the years of a single life time. But if you look closely at the earth and you remember what you see, you can see that the earth does change. Mount Katahdin has changed and is changing, little by little. Anyone who has come to Katahdin for 20 years or more will know of some of these changes: new roads and trails have been cut where before there were trees and forest litter and old trails have become deeply eroded and worn. New landslides have scarred mountainsides and old scars have become overgrown. A hiker, by chance or design, kicks loose a stone which bounds and rolls to some lower place. Each year, little changes like these have taken place and have served to change the mountain by so much. These small changes and many, many more that have gone unnoticed, add up in the long run, to a mountain and a landscape that are everchanging. This is one of the basic concepts of geology: the earth is constantly changing by tiny amounts and these small changes in the long run of geologic time add up to almost incredible change.

In the Baxter Park region there is a record of some of the changes that this part of the earth has experienced. There is evidence here of primitive creatures who lived out their times in vast shallow seas which once covered this area. A vast change took place when these ancient seas were rocked by violent earthquakes and fiery volcanoes made huge piles of lava rock. Later in time, after the volcanoes had been quiet for nearly 300 million years, Mt. Katahdin and all the land for as far as the eye can see and farther, was covered by a vast sheet of glacial ice. It rasped and gouged and bulldozed the rocks, the ledges and the soil, changing the land and leaving an indelible mark on the landscape.
All of these changes in the past have left some kind of record and this record is the basis for the geology of the Mt. Katahdin region. The discussions which follow are an account of the geologic history of the Mt. Katahdin region as it is recorded in the rocks and in the landscape.

Along with Governor Baxter, we can be glad that Mt. Katahdin will belong forever to the people of Maine, but when we learn the lessons taught by its rocks and its scenery, we come to realize that Katahdin itself will not remain unchanged: it has seen many vast changes before and there is no reason to believe that it will not continue to change in times yet to come.
Bedrock Geology

Bedrock. Much of the basic information which a geologist uses in the interpretation of the geologic history of a region comes from his examination of bedrock outcrops. Bedrock is the solid rock which underlies loose material such as soil, sand and gravel. An outcrop* is exposed bedrock.

In a very general way, the descriptions and discussions of the bedrock geology of Baxter State Park will follow the procedure used by many geologists in presenting the results of their investigations. We will first consider the various kinds of bedrock which outcrop in Baxter State Park, showing how these rocks may be recognized. A geologic map is presented which shows the distribution of the most important rock types. Certain easily accessible outcrops which illustrate an interesting feature or have particular bearing on the geologic history will be described in some detail. With this background it will then be possible to discuss the geologic history recorded in the bedrock of Baxter State Park. Finally, at appropriate places in these discussions, the ways in which the rocks were formed will be considered.

Description and Distribution of Bedrock Types

Katahdin Granite

The bedrock in the southern half of Baxter State Park is granite (see geologic map, plate 1A). Two distinct types of granite occur: the more common grey granite which forms the bedrock at intermediate and lower elevations and the pink colored granite which forms the bedrock at many higher elevations, especially near the summit of Baxter Peak. Both varieties are called Katahdin granite, from which it may be inferred that the rock in the Katahdin region is somehow different from any other granite. Trained geologists familiar with the Katahdin granite may quickly identify it, but to the untrained eye, Katahdin granite looks very much like many other granites.

The distinct difference in appearance of the two varieties of Katahdin granite is a result of a difference in the minerals which make up the granite. All granites are composed primarily of light

*Italicized words are redefined in the Glossary of Terms.
colored minerals, feldspar and quartz, and contain minor amounts of such dark colored minerals as biotite (black mica) and hornblende. If the feldspar, which forms roughly 60 per cent of the rock, is white or cream colored, the granite has an over-all grey or white color, as in the case of the lowland variety of Katahdin granite. The presence of a pink or flesh colored feldspar produces a pink colored granite such as occurs at higher elevations on Mt. Katahdin.

This description of the Katahdin granite refers to its appearance in fresh, unweathered exposures. The granite in much of Baxter State Park, especially at high elevations, is covered with lichens which partly mask its true color. Many boulders of Katahdin granite on the Tableland and much of the bedrock along the Knife-Edge is colored greenish-grey, especially if viewed from a distance.

An interesting result of this lichen coloration may be seen on a sunny day along the trail which leads from the Saddle to Baxter Peak. Loose boulders of both pink and grey Katahdin granite cover the slopes along this trail from the Baxter Peak Cut-Off Trail to the summit, but the rocks are colored greenish-grey by lichens. In the trail itself, however, the boulders have lichen-free surfaces because either the lichens are worn by the traffic or are killed by the frequent changes in position of the boulders. When viewed from some distance, the trail is seen as a thin pink or grey strip in the general greenish-grey color of the boulder covered slopes.

Within the area of granite outcrops in the southern half of Baxter State Park, there are variations in appearance other than the general pink and grey color. Near Baxter Peak, the pink Katahdin granite has small holes lined with small crystals of a variety of minerals. The granite exposed near the summit of South Turner Mountain differs markedly in appearance from that exposed on Mt. Katahdin. This is because the individual mineral grains in the South Turner Mountain granite are much smaller than in the Mt. Katahdin rocks although the granites in both areas have about the same mineral composition. Because the mineral grains are smaller, the granite has a sugary appearance and it is difficult to distinguish individual minerals in outcrops of Katahdin granite on Turner Mountain.

In order to discuss the significance of the fine-grained granite of Turner Mountain, it is necessary to discuss briefly the origin of granites in general. Granite is one of the most common of the group which is called igneous rock, a term derived from the Latin, ignis, meaning fire. Many geologists believe igneous rocks have formed by
the solidification of a molten or partially molten material called magma. The origin of magma is a widely disputed subject among geologists, but most of them agree on what happens to magma after it forms.

For example, it is generally accepted that volcanoes are formed by magma which has somehow reached the surface of the earth from its place of origin, probably several miles below the surface. Magma which has reached the surface is called lava. Molten lava cools, and in that sense, freezes to form various kinds of extrusive igneous rocks, meaning the rocks form at the surface of the earth, rather than below the surface. The bedrock in the vicinity of Traveler Mountain in the northern part of Baxter State Park is the result of the accumulation of various kinds of extrusive igneous rocks.

Much of the magma which starts toward the earth's surface fails to get there but cools and becomes solid rock at some depth below the surface. Igneous rocks which form in this fashion are called intrusive igneous rocks.

Experiments with artificially melted rocks and various theoretical considerations indicate that the rate at which magma cools will in part control the size of the individual mineral grains of the rocks which form. Other things being equal, the more rapid the cooling of a magma, the smaller the mineral grains of the rock will be.

Thus the mineral grains of extrusive rocks, lava flows and the like, which cool at the earth's surfaces, are often so small that they cannot be seen without magnification. Intrusive rocks, cooling below the surface, lose their heat very slowly, some taking thousands or even millions of years to become completely solid. The greater the depth, the longer the cooling period during which the individual minerals may grow in size. This simplified picture does not account for all the variations in grain size which occur in igneous rocks, but it may be taken as a general rule which can explain grain size differences in many geologic situations.

Those outcrops of Katahdin granite which contain large, easily recognizable mineral grains probably cooled more slowly, at greater depths in the earth, than did the fine grained granite such as occurs on South Turner Mountain.

In nearly every outcrop of Katahdin granite there are cracks which are called joints. Some of the joints are the result of contraction of igneous rocks during cooling; others are caused by the extreme
stresses produced by the rock surrounding the intrusion. In many outcrops there are numerous joints, some differently oriented, and as a result rock breaks from the outcrop in angular blocks with flat smooth surfaces. Katahdin granite exposed at Ledge Falls on Wassataquoik Stream breaks into extremely large blocks because the joints are widely spaced (figure 1), whereas much smaller blocks of granite occur on the Tableland and the slopes leading from the Tableland to Baxter Peak (figure 2). Well developed joints have produced large, nearly flat outcrops of granite along the Cathedral Trail and on the trail leading to the Pamola Caves. The Cathedrals themselves were formed by the erosion of granite which has prominent, closely spaced, vertical joints.

Figure 1. Widely-spaced joints in Katahdin granite at Ledge Falls, Wassataquoik Stream, showing development of large joint blocks.

The presence of joints has weakened the granite to the extent that climbing over the granite is at best a nuisance and in many places on the Cathedral Trail, Saddle Trail, on the Knife-Edge and in the Chimney, care should be exercised in climbing lest a foothold give way. Well developed jointing also promotes more rapid weathering, which further weakens the granite.

Most of the trails on Mt. Katahdin cross many outcrops of granite and close examinations of the rocks along such trails as the
Cathedral Trail or the Knife-Edge offer a convenient excuse for unscheduled rests. Remember, though, that there is not a great deal of variation in granite from one place to another, and too frequent "geologic" stops may cause the rest of the party to become suspicious of the motives for stopping.

![Blocks of Katahdin granite on the Tableland, Mt. Katahdin. The smaller blocks are bounded by the smooth surfaces of former close-spaced joints.](image)

**Figure 2.** Blocks of Katahdin granite on the Tableland, Mt. Katahdin. The smaller blocks are bounded by the smooth surfaces of former close-spaced joints.

**Traveler Rhyolite**

North of the Katahdin granite area in the State Park, the bedrock consists of rocks of volcanic origin which may conveniently be called Traveler rhyolite. Rhyolite is an extrusive (see discussion of origin of granite) rock, and therefore composed of very small mineral grains. It has the same mineral and chemical composition as granite.
In appearance, Traveler rhyolite has a uniform dark grey or black groundmass which comprises the bulk of the rock, with a few larger light-colored mineral grains of quartz or feldspar. Thin, wavy bands of light-colored material occur throughout the rhyolite.

The weathered surfaces of outcrops of rhyolite may be nearly white, light grey, blue-white, or stained brown or red by iron, but freshly exposed surfaces are generally dark in color.

Outcrops of Traveler rhyolite occur along much of the two most commonly used trails in the Traveler Mountain area, the North Traveler Mountain Trail and the trail which leads along the shore of Lower South Branch Pond to the potholes on Howe Brook. The potholes on Howe Brook are formed in rhyolite. The geologic map, Plate 1A, shows the area of Baxter State Park in which the bedrock is Traveler rhyolite.

According to Douglas Rankin who has studied the volcanic rocks in the Traveler Mountain area in great detail, the Traveler rhyolite consists of many separate lava flows, one on top of another, which have a total thickness of several thousand feet. Rankin has found that besides the lava flows, deposits of volcanic ash, now firmly bonded into solid rock called tuff, also occur as part of the Traveler rhyolite. The hills and mountains in the Traveler Mountain area are not the peaks of volcanoes which once were active in this region, but probably the eroded roots or remnants of the volcanoes. Rankin estimates that some 80 cubic miles of rhyolite lavas formed in the Traveler Mountain area, making this one of the largest piles of this kind of volcanic rock in the world.

From a consideration of some rocks formed by the erosion of the Traveler rhyolite, Rankin visualizes the active volcanoes, if such there were, as a group of volcanic islands in a part of the ocean which covered this part of Maine more than 350 million years ago. More will be said of these islands and the rocks which were formed by their erosion in the section dealing with the geologic history of the State Park area.

One of the most interesting features of the Traveler rhyolite is the occurrence of columnar jointing in many outcrops. Columnar jointing, as the name suggests, causes the rock to break into long columns which usually have a more or less definite five or six-sided pattern, and is occasionally so perfectly developed that the columns
seem to have been cut. Figure 3 shows columnar jointing on an unnamed hill in the headwaters of Gifford Brook. Jointing of this type forms as the result of contraction of lava during cooling.

![Figure 3. Columnar jointing in Traveler rhyolite near summit of unnamed mountain in headwaters of Gifford Brook.](image)

Well known examples of columnar jointing in other parts of the world are the Giants Causeway in Northern Ireland and the Palisades along the Hudson River in New Jersey.

Unfortunately the blazed trails in the Traveler area do not cross outcrops which display well developed columnar jointing and the writer hesitates to suggest that anyone should leave the beaten path to search for geologic phenomena. The base of the first steep knob along the North Traveler Trail, about one-half mile from the South Branch Pond campground, is a vertical cliff formed by columnar joints, but these may be most easily seen from the south shore of the lower pond, or from a boat in the pond. Several easily accessible outcrops of columnar-jointed rhyolite occur on Dry Brook (Traveler Mountain quadrangle map, United States Geological Survey) less than a mile upstream from the Patten road. Columns in this area are smaller in diameter than those shown in Figure 3, but many are several feet long. Fragments of these columns have been carried down Dry Brook.
to its juncture with Trout Brook and careful examination of the gravel bed of Dry Brook should reveal some recognizable fragments of the columns.

**SEDIMENTARY ROCKS**

As can be seen from the geologic map, the bedrock in most of Baxter State Park is igneous rock, either granite or rhyolite. In the northern part of the State Park and in the vicinity of Nesowadnehunk Lake the bedrock consists of various kinds of sedimentary rocks. Sedimentary rocks are formed by the accumulation, compaction, and cementation of sand, gravel, and mud. It will be recalled that a major difference between granite and rhyolite is the difference in the size of their mineral grains. In the same fashion, many sedimentary rocks are classified by the size of the rock and mineral fragments of which they are composed. A sedimentary rock composed of rock and mineral fragments about the size of sand grains is sandstone, whereas gravel-sized fragments form a rock called conglomerate. Shale is a sedimentary rock formed from mud, in which the rock and mineral fragments are much smaller than sand grains.

The origin of most sedimentary rocks is not as much of a problem as the origin of intrusive igneous rocks. It is possible to observe the present day accumulation and compaction of sedimentary rock-making materials, but it is doubtful that any geologist ever has or ever will be able to watch a granite form. One need only to travel along the Maine coast to find bays and harbors in which mud and sand is accumulating. The mud in the clam flats will someday be converted to shale, and the long sandy beaches in southwestern Maine are potential sources of sandstone.

A common characteristic of sedimentary rocks is stratification, in which occur alternating layers of rock and mineral fragments of different sizes, commonly the result of variations in the strength of the waves and currents which transport the sediments. For example, a bed of mud may accumulate in the quiet recesses of a bay, to be covered by sand particles swept in during a storm. The rocks formed from these two sediments would consist of a layer of shale overlain by a layer of sandstone. Repetition of these conditions could form many horizontal layers. The illustrations on subsequent pages (figures 5, 6 and 7) of sedimentary rocks exposed on South Branch Pond Brook show good examples of layering or stratification. Later, we will discuss the stratification found in certain glacial sediments.
Many sedimentary rocks contain features which suggest how the rock was formed. For example, *ripple marks* are preserved which do not differ in the least from ripple marks which may be seen on ocean and lake bottoms and in stream channels. The ripple marks indicate the size, strength and direction of the waves and currents which made them. By these and similar studies the geologist learns about conditions which prevailed when the rocks he is studying were formed. He is able to visualize the beaches, tidal flats, streams, oceans, lakes, swamps, and other features of some pre-historic landscape and thus reconstruct the long dead past.

Fossils

One of the most interesting and instructive features of sedimentary rocks are the *fossils* which occur in many of them. A fossil is any recognizable trace of life which existed before historic times. It may consist of a complete skeleton of an animal or a fragment of a tooth, a footprint or a worm hole, a perfectly preserved clam shell or only a faint impression of a shell, a petrified log or the carbonized impression of a leaf.

The geologist uses fossils in many ways to aid in the reconstruction of geologic history. For example, sharks now live in the ocean. Therefore, a fossil shark preserved in a rock would be good evidence that the rock was formed in the sea. Similarly, the fossil pine trees in the Petrified Forest, Arizona, indicate that the rocks in which the petrified wood is preserved were formed on land.

Many groups of animals and plants have not survived the changes of climate, the shifting of oceans and continents, and the periods of intense volcanic activity which have occurred in the geologic past. Their fossil remains are useful in dating sedimentary rocks, as well as suggesting the conditions that existed when the rocks were formed. For instance, it has been found from studies of rocks in many parts of the world that dinosaur fossils occur only in those rocks which were formed between roughly 225 and 70 million years ago. Thus if a geologist is studying a group of rocks of unknown age and finds some indication of dinosaurs, he knows those rocks are between 225 and 70 million years old.

The fossils which occur in the sedimentary rocks in Baxter State Park and vicinity may not be as spectacular as some famous dinosaur bone beds or the Petrified Forest, but they are nevertheless of great importance to the understanding of the geologic history of this part
of Maine. There are few easily accessible outcrops of rocks containing fossils in Baxter State Park, yet fossils may be found in the gravels of beaches and streams in nearly every section of the State Park, especially in the vicinity of the South Branch Pond campsite.

The occurrence of these fragments of fossiliferous sedimentary rock in areas where the bedrock is granite or rhyolite is a result of the work of glaciers which covered this part of Maine, along with all of northeastern North America, several times during the past million years of Earth history. Glaciers ripped fragments from bedrock outcrops several miles northwest of where they are found today, carried them southward and redeposited them in areas where no fossils could possibly have originally occurred. This relocation of rocks and boulders illustrates why a geologist mapping bedrock geology must study only the real bedrock outcrops, rather than gravel and boulder occurrences, the source of which is uncertain.

![Figure 4. Brachiopod fossils.](image)

The most common fossils in these glacially transported gravels are *brachiopods*, a type of marine animal which superficially resembles the clam, but is not even remotely related. Many rock fragments
contain as many as ten different kinds of brachiopods, which are differentiated by the ridges and grooves on their shells, their general shape, their size, or some other feature of their shells. Figure 4 shows a rock containing various kinds of brachiopods.

Plant fossils occur in the shales exposed in downstream portions of Trout Brook. Some easily reached fossil occurrences are at Ripogenus Dam and along the north shore of Ripogenus Lake. Rocks in this area are sandstone and limestone and contain, in addition to brachiopods, fossil corals, bryozoa (a coral-like marine organism), and cephalopods (a marine mollusc, of which the chambered nautilus is the best known living representative).

![Figure 5](image)

**Figure 5.** Conglomerate exposed on South Branch Pond Brook. Pebbles and cobbles in conglomerate are composed of Traveler rhyolite. Layer of sediments overlying conglomerate is till, a glacial deposit described on Page 37.

*A recommended geologic field trip.*

Sedimentary rocks are dramatically exposed in the valley of South Branch Pond Brook between the pond and Trout Brook. The hike down this brook offers one of the most instructive and interesting geological excursions in Baxter State Park. But before attempting this trip one should consult the Ranger at the South Branch Pond campsite and examine the maps of the area, for there is no marked trail. It is recommended that South Branch Pond Brook be followed.
downstream to its juncture with Trout Brook and thence east along
the south bank of Trout Brook to the Patten Road, a walk of slightly
less than 3 miles. The trip from the campsite to the Patten Road will
take about three hours.

The bedrock along the first mile of this trip is Traveler rhyolite
(see geologic map, plate 1A), and excellent exposures occur in several
spectacular gorges, some of which cannot be passed without a refresh-
ing swim. Several exposures have well developed columnar jointing,
especially at a point about three-quarters of a mile downstream from
the campsite.

Approximately one mile downstream from South Branch Pond
the bedrock changes from Traveler rhyolite to conglomerate, a type
of sedimentary rock described above. One of the best exposures is
shown in Figure 5.

Careful examination of the geologic relations where the first
exposure occurs will reveal the pebbles and cobbles in the conglomer-
ate to be fragments of Traveler rhyolite, deposited upon bedrock of
the same material. This very simple but important relationship de-
serves further mention, for it is a demonstration of one of the basic
methods for interpreting geological phenomena.

It is clear that the conglomerate must have been formed after
the lava flows of Traveler rhyolite were laid down; first, because the
conglomerate is on top of the rhyolite and, further, because the gravel
in the conglomerate contains pebbles eroded from the rhyolite. In
other words, the conglomerate is younger than the rhyolite. Simply
knowing the relative ages of two rocks, as in this case, can form the
basis of understanding the geologic history of an area.

This example of relative rock age which is so clearly revealed in
the rocks exposed along South Branch Pond Brook is, in the writer's
view, the highpoint of the geology of Baxter State Park, worthy of
mention with any exciting or dramatic geologic situation anywhere
in the world.

Downstream from the initial outcrop of conglomerate the particle
size of the sedimentary rocks gradually becomes smaller. Near the
junction of South Branch Pond and Gifford Brook, the conglomerate
contains small pebble-size particles and thin layers of sandstone (figure
6). A few hundred yards farther downstream the exposed bedrock
consists of even finer-grained sedimentary rock: sandstone and layers
of shale (figure 7). In the outcrop shown in Figure 7 and in several other outcrops downstream, there are thin layers of impure coal.

The decrease in particle size from conglomerate at the initial outcrop (figure 5) to shale (figure 7) is an interesting and important feature of the sedimentary rocks in the Trout Brook valley. In order that the geologic interpretation of these rocks may be presented as clearly as possible, a series of diagrams representing various stages in the formation of the rocks is shown in Figure 8.

Following the formation of the Traveler rhyolite lava flows and volcanoes, streams began to erode the rhyolite and in time an extensive gravel deposit accumulated along the lower slopes of the volcanoes (figure 8A). Gradually the volcanic peaks became eroded to low hills and the streams attained gentle slopes over which only sand and fine gravel could be transported. Sand and gravel deposited in the stream channels covered the older, coarser, gravel deposit and formed a
sandy plain (figure 8B). During the final stages of sedimentation (figure 8C) this became a low, swampy, plain, where accumulated mud and organic sediments formed shale and coal-bearing rocks. These now occur in the downstream portion of South Branch Pond Brook, while sand and gravel deposits have formed the sandstone and conglomerate which are exposed in the upstream portion. The older rocks occur upstream and are progressively younger downstream.

A moment's consideration of diagram C, Figure 8, will indicate that something has happened to the rocks between the stage represented by diagram C and the present. Sometime following the deposition of the sedimentary rocks they, with the underlying Traveler rhyolite, were tilted, and the various layers which were originally essentially horizontal (diagram C, figure 8) became inclined downward toward the north. The stage shown in diagram D, Figure 8, occurred long after the tilting of the rocks, following a long period of stream erosion.

Also, the landscape represented in diagram D is not exactly that of the present, because various kinds of glacial erosion and deposition have modified the preglacial landscape. The geologic cross-section, Plate 1C, shows the geologic relations between the Traveler rhyolite and the sedimentary rocks in Trout Brook valley, and gives a more complete picture of the tilting, or folding of the rocks.

**Geologic History of Baxter State Park Area**

With the background provided by discussion of the bedrock types in Baxter State Park, it is now possible to outline the geologic history recorded in these rocks.

**Relative Age and Absolute Age of the Rocks**

Various kinds of evidence make it possible to determine the relative ages of two or more types of bedrock which occur in a given region. It has been mentioned previously that the conglomerate in the Trout Brook valley is younger than the Traveler rhyolite because the conglomerate rests on the rhyolite and because pebbles of rhyolite occur in the conglomerate. A third line of evidence by which relative age may be determined involves intrusive igneous rocks. A moment's reflection on the formation of granite will show that it (or any intrusive igneous rock) must be younger than the rock it intrudes,
A. Coarse gravel mantling lower slopes of volcano.

B. Sandy alluvium overlying coarse gravel. Volcano greatly reduced in size by erosion.

C. Muds accumulate on flat, swampy plain. Locally coal beds form. Presence of land plants indicated by fossils in shale.

D. Traveler rhyolite and sediments tilted toward the north. Erosion strips away much of sedimentary cover, exposing rhyolite in south.

Figure 8. Stages in the development of sedimentary rocks in the Trout Brook valley.
because there must be rock already formed into which or through which the granite can intrude.

But relative ages tell us only this rock was formed before that rock, and although such information is very important, we still want to know when. How unsatisfactory a history book would be if it told us only that Columbus discovered America after the Norman Conquest of England, but sometime before the Civil War!

Fortunately, some rocks contain certain minerals which record time as precisely as any calendar. Thus it is possible to determine with some accuracy how long ago the mineral and therefore the rock was formed. These minerals are termed radioactive minerals, the most familiar of which contain the highly active element uranium. Radioactive elements spontaneously change to some new element at a very definite rate of time, thus if the rate of time of this change is known, very accurate measurement of both the radioactive mineral remaining and the percentage of the new element present will indicate how long the radioactive change has been going on.

For example, starting with 1 gram of uranium, at the end of about 4.5 billion years (termed the half-life of uranium) there will remain $\frac{1}{2}$ gram of uranium, the other $\frac{1}{2}$ gram of uranium having changed to lead. Similarly, at the end of about 9.0 billion years, half of the remaining uranium will have turned to lead so that only $\frac{1}{4}$ gram of uranium is left.

By measurements of the amounts of uranium and lead and several other pairs of elements, the absolute ages of many rocks have been determined. Such techniques are most useful in dating igneous rocks.

**Geologic time scale**

The accumulation of evidence bearing on the relative ages of rocks from all over the world has resulted in a generally accepted measure of geologic time called the Geologic Time Scale. Geologic time is divided on geologic and fossil evidence into Eras, whose names characterize the stage of evolutionary development represented by fossils. "Paleozoic" Era means time of ancient life, "Mesozoic" Era means time of middle life, and "Cenozoic" Era means time of recent life.

Eras are divided into Periods, the names of most of which refer to the geographic location of rocks first described as being formed during the period of geologic time in question. For example, rocks
formed during the Devonian Period were first described by geologists working in Devonshire, in southwest England. The name, Devonian, is applied to rocks formed during that period whether they occur in Texas, New York State, or Maine.

A simplified geologic time scale is shown in Table 1. Besides the subdivisions of geologic time, a few absolute dates are included, from which a perspective of the lengths of some of the Eras and Periods may be gained. Certain aspects of the fossil record of plant and animal life are also shown. It should be noted that nearly all of the rocks in Baxter State Park are assigned to the lower and middle part of the Devonian Period of the Paleozoic Era.

**Older sedimentary rocks**

The oldest rocks in the Mt. Katahdin area are the sedimentary rocks which form the bedrock in the lowlands surrounding Baxter State Park on the east, north, and west. These rocks are sandstone, shale, and limestone which range in age from Cambrian to Lower Devonian. The fossils which occur in these rocks are the principal evidence by which their age has been determined and because the majority of the fossils are remains of such marine organisms as brachiopods, corals, and molluscs, it must be assumed that these rocks were formed from marine sediments. For approximately 200 million years during early Paleozoic time the ocean covered nearly all of eastern North America, along with what is now northern Maine.

The distribution of these older sedimentary rocks is shown on the map of the bedrock geology, Plate 1A.

**Traveler rhyolite**

During the Lower Devonian Period, approximately 400 million years ago, volcanic islands were formed in an ancient sea by the accumulation of lava flows and beds of volcanic ash. The flows and ash beds form the Traveler rhyolite. Except for a brief time at the end of the Ordovician Period, this part of Maine was under the ocean during the early Paleozoic; however, the geologic evidence suggests that no important marine submergence occurred after the Lower Devonian Period.

**Younger sedimentary rocks**

The sedimentary rocks formed by the erosion of the volcanic islands are the conglomerates, sandstones, and shales which form the
bedrock in much of the lower Trout Brook valley (see geologic map, plate 1A). Thus, there are two main groups of sedimentary rocks in the Baxter State Park area; the older group, Lower Paleozoic in age, on which the Traveler rhyolite was deposited and the younger group, Lower Devonian in age, in part derived from the erosion of the Traveler rhyolite.

The formation of these sedimentary rocks, and their relation to the Traveler rhyolite, was discussed in detail above (see figure 8).

An interesting feature of the younger sedimentary rocks is the presence of fossil land plants. Fossil evidence from many parts of the world indicates that few land plants, other than lichens, existed before the Devonian Period. Devonian age sedimentary rocks the world over contain abundant land plant fossils, as do all younger sedimentary rocks formed on or near land. Prior to the Devonian Period, the earth must have been a bleak place, indeed, with treeless, grassless, and flowerless landscapes. It is apparent from the fossil record that the earth became clothed in green for the first time in the Devonian Period. Undoubtedly it is no accident that the most primitive land-dwelling vertebrate animals (Amphibians) made their first appearance at this time.

KATAHDIN GRANITE

The youngest rock in Baxter State Park is the Katahdin granite, which forms the bedrock in roughly the southern half of the State Park and in the lowland area south of the State Park. At the power plant below Ripogenus Dam on the West Branch of the Penobscot River, there are several bedrock outcrops which indicate the Katahdin granite has intruded, and is therefore younger than the older sedimentary rocks described above. At the northwest end of Wassataquoik Lake the geologic relations indicate that the Katahdin granite has intruded the Traveler rhyolite also, and therefore is younger than the volcanic rocks in Baxter State Park. The somewhat more involved evidence which indicates that the Katahdin granite is also younger than the youngest sedimentary rocks, those exposed in the Trout Brook area, is discussed in the following section dealing with structural geology.

Radioactive age determinations of certain minerals in the Katahdin granite indicate it formed approximately 360 million years ago in the middle of the Devonian Period. Many other granites in New England were formed during the Late Devonian Period, although
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<th>Characteristic form of life</th>
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PRECAMBRIAN  Origin of Earth – 5 billion years before present
there is a wide range in age, from as great as 400 million years for some granites in Maine and Nova Scotia to about 350 million years for some Devonian granites in New Hampshire and Massachusetts.

**Structural Geology**

The branch of the subject called structural geology is partly concerned with the positions and conditions of rocks, such as the jointing and layering which have been previously discussed, and the interpretation of these structural features as they relate to geologic history. In the discussion of the sedimentary rocks exposed on South Branch Pond Brook, it was shown that the present attitude of these rocks is the result of tilting and erosion of originally horizontally layered rocks. The geologic cross-section, Plate 1C, shows that to the north, just south of Wadleigh Mountain, these same rocks are tilted toward the south, forming a fold or bend in the rocks. Many geologists consider that such folds are the result of compressive forces in the earth’s crust which accompany the formation of mountains. Layering, originally horizontal but now inclined, is shown in the exposures at the gorge below Ripogenus Dam and along the road north of Wadleigh Mountain in the Grand Lake Matagamon area.

If the compressive forces which produce folds in layered rocks exceed the strength of the rocks, the rocks are broken along faults. Active or recently active faults, such as the San Andreas fault in California, may be recognized by the obvious displacement of such surface features as streams, roads, and fences and by earthquakes which are produced by the release of energy along the faults. Ancient faults, however, are often difficult to recognize, and their existence may be shown only after careful geologic field work. The work of Rankin in the area north of Trout Brook indicates that the sedimentary and volcanic rocks exposed there are broken by several faults, two of which are shown on the geologic cross-section, Plate 1C. It may be assumed that the forces which produced the folded structures in the layered rocks were also responsible for the faults in those same rocks.

The folding and faulting of the rocks in the Mt. Katahdin area evidently occurred before the intrusion of the Katahdin granite, because microscopic examination of the mineral grains in the granite indicates that no great compressive force has acted on the granite. Had the granite been subjected to the same force which produced the folds and faults in the nearby layered rocks, mineral grains such as quartz in the granite would be crushed and strained. The lack of
evidence of strain in the granite indicates the intrusion of the Katahdin granite occurred after the folding and faulting of the layered rocks.

**SUMMARY OF BEDROCK GEOLOGY**

Three principal types of rocks form the bedrock of Baxter State Park: granite, and volcanic, and sedimentary rocks. Geologic and fossil evidence indicates that the oldest rock in the area is sedimentary; the youngest is the Katahdin granite, and the volcanic rock is intermediate in age. The layered rocks are folded and faulted by compression acting in the earth's crust. The compression occurred before the intrusion of the Katahdin granite.

The distribution of various bedrock types in Baxter State Park is shown on the geologic map (plate 1A). This geologic map shows only the surface orientation of bedrock; it does not show the structural relations of the various rock types. Detailed mapping of surface structural features of the bedrock yields information which can be used in the construction of a structural geologic cross-section. Such a cross-section is shown as part of Plate 1. It shows the underground structural relations of the various rocks in the State Park. The section lies along a line which extends from Grand Lake Matagamon to Baxter Peak and along to the southern State Park boundary. Much of the cross-section is highly generalized, but is substantially accurate.

**Glacial Geology**

**INTRODUCTION**

The record of the geologic history of Baxter State Park between the Devonian Period and the Pleistocene or Glacial Period, which began about one million years ago, is for all practical purposes blank. Probably for at least 99 percent of the approximately 350 million years between the Devonian Period and the Ice Age the area under consideration was out of water and no bedrock younger than Middle Devonian in age has been found. During this great span of time, streams and rivers slowly eroded the bedrock formed during the Lower Paleozoic Era, carrying it away to the ocean as gravel, sand, and mud. Perhaps as much as 10 thousand feet of rock was eroded.
The harder, more resistant types of bedrock were eroded more slowly than the softer rocks. The igneous rocks, Katahdin granite and Traveler rhyolite, being more resistant, form the mountains in Baxter State Park; whereas the softer sedimentary rocks have been reduced by erosion to low hills. The general features of the landscape are the result of erosion of different types of bedrock. The mountains are high because they are formed of more resistant bedrock types and the lowlands are low because the bedrock in these areas consists of weak sedimentary rocks.

The present elevation of Mt. Katahdin and the other mountains in Baxter State Park above the surrounding lowlands represents the result of nearly 300 million years of erosion probably attained during the Middle or Late Cenozoic Period, but before the Ice Age. The landscape in the Katahdin area at the beginning of glaciation was approximately that of today and the results of glaciation have merely modified the preglacial landscape.

The answer to the often asked question, "How old is Mt. Katahdin?" must be given in three parts. In the first place, the rocks which form the mountain are old, about 360 million years old. Secondly, the general shape of the mountain, and especially its relief above the lowlands, is the result of a long period of erosion and was probably attained in essentially its present form about 2 to 5 million years ago. And finally, the details of the landscape, such as the Knife-Edge, the basins on Mt. Katahdin, and many features of the streams and rivers, are the result of glaciation which occurred during the past one million years.

It is tempting to speculate about what might have happened in the Katahdin region during the nearly 300 million years of its unrecorded history. But even though comparisons could be made with other parts of the world which have records dating from these years, the result would be a story bordering upon science fiction. The record of glaciation in Baxter State Park, however, is well preserved and is the subject of the following section of this paper.

**Glaciers and How They Form**

A glacier is a mass of ice on land, which is moving or shows some evidence of having moved in the recent past. Glaciers form wherever more snow falls during a series of winters than melts during the intervening summers. Such conditions are met at high latitudes, near the North and South Poles, where the largest glaciers now exist, as in
Greenland, Iceland, and Antarctica. Small glaciers occur today at high elevations at middle and even low latitudes, as in the Rocky Mountains, the Alps, the Andes, and the Himalayas. For reasons yet undiscovered by geologists, climatic conditions at several times during the past one million years were such that glaciers formed at much lower latitudes and elevations than they do today. Glacial ice is produced by the weight of accumulated snow.

If accumulation occurs in a valley, when the ice reaches a sufficient thickness, probably about 100 feet, it moves slowly down the valley, partly for the same reason that water flows downhill: it is pulled downhill by gravity. Also partly responsible for the movement of glacier ice is the squeezing force produced by the accumulation of ice and snow upstream. Glacier motion has been measured in many parts of the world and ranges from less than an inch to more than 100 feet per day.

There are two principal types of glaciers; continental glaciers and valley glaciers. A continental glacier; also termed an ice sheet or ice cap, is so large that it completely covers the landscape, burying valleys and mountains alike. The ice in continental glaciers moves essentially outward from the center, radiating in all directions. Because continental glaciers are tremendously thick, over 1000 feet in most cases and sometimes exceeding a mile or more in thickness, motion is but locally hindered by hills and mountains, and these glaciers are able to flow over whatever may be in their paths.

Valley glaciers, on the other hand, are confined by the valley walls and can move only down the valley. Valley glaciers are sometimes called mountain glaciers, because they occur only in mountains. The well known glaciers of Switzerland and Alaska are mostly valley glaciers.

The movement of glaciers carries ice to lower elevations or latitudes, where it is eventually melted. A glacier can advance to a point where the rate of forward motion just equals the rate at which ice is melted, so that the downstream margin of the glacier remains stationary. Boulders, gravel, mud, and other debris is dumped at the margin of the glacier in the form of a moraine. In many valleys such moraines record the former positions of glaciers where glaciers no longer exist.

The former margins of continental glaciers also are recorded by moraines. The presence of prominent moraines in such places as
Long Island in New York, Cape Cod in Massachusetts, and in much of the Midwest is evidence that continental glaciers once covered North America north of these moraines.

![Glacial scratches (striations) on sandstone outcrop on Patten Road.](image)

The glacier which produced these striations moved in the direction indicated by the thin bar at end of compass.

Studies of moraines and other glacial features, principally in the Midwest, have indicated that continental glaciers have formed and melted several times during the past one million years. Following each glacial episode the glaciers melted, perhaps completely, which would indicate that the climate was warmer than it is today. The most recent major advance of the continental glacier started about 30,000 years ago and continued, with minor fluctuations, until about 9,000 years ago, at which time general melting occurred. Even though
glaciers are at present melting rapidly the world over, historic records in the Alps and geologic evidence from many other mountain areas indicate that glaciers are now more extensive than they were some 3,000 to 7,000 years ago. From this it may be inferred that the climate of these areas is colder than it once was, but is becoming warmer.

**RESULTS OF GLACIATION IN BAXTER STATE PARK**

**FEATURES PRODUCED BY GLACIAL EROSION**

**Striations.** Gravel, boulders, and other debris lodged in the base of a moving glacier scrape and abrade bare bedrock surfaces, producing outcrops which have a smooth polished surface and grooves and scratches called *striations*. If the compass directions of the striations are recorded on a map as a series of lines, a picture of the direction of glacier motion may be gained. Figure 9 shows an outcrop with well developed striations.

In Baxter State Park many outcrops of sedimentary rocks have striations, whereas Katahdin granite and Traveler rhyolite have weathered surfaces on which striations are commonly not preserved. Bedrock surfaces of igneous rocks which have been buried by glacial sediments and only recently exposed have well preserved striations, as in the vicinity of Ripogenus Dam. Several outcrops of sedimentary rocks along the Patten Road show striations, especially on the north side of the road at Hurricane Deck. A few outcrops near the Patten Road just north of Horse Mountain are striated as are several outcrops of sedimentary rocks along the road from Trout Brook Farm northward to Second Lake Matagamon.

**Striations measured in northeastern North America indicate a general northwest to southeast glacier motion originating somewhere near Hudson Bay in Canada.** The direction of glacier motion in Baxter State Park evidently diverged somewhat from this general direction, probably as a result of the obstruction of the mountains in the area.

**U-shaped valleys.** Glaciated valleys have a characteristic shape which distinguishes them from stream eroded valleys. Looking up or down glaciated valleys, they are seen to have a broad U-shape, with steep valley walls and broad valley bottoms. Figure 10 shows such a valley which leads from the Northwest Basin. Nearly all the large valleys in Baxter State Park have the same shape, as, for example, the valley of Nesowadnehunk Stream east of Doubletop Mountain, With-
erle Ravine, and the long valley leading from the Roaring Brook campground to Russell Pond and on to the South Branch Pond campground.

Cirques. The most spectacular result of glaciation in Baxter State Park are the many well developed and well preserved *cirques*, which were the source areas of valley glaciers. All of the well known basins, North Basin, Great Basin, Northwest Basin, and so forth, are cirques, each of which nourished a valley glacier. A cirque differs from the head of a normal valley in that it does not become narrower upstream, but rather broadens into a semi-bowl shape. This difference may be seen in Figures 11A and B, which shows the typical cirque-shape of North Basin and the narrow headwaters of Howe Brook on Traveler Mountain.

![Image of a U-shaped glacial valley, Northwest Basin.](image)

*Figure 10. U-shaped glacial valley, Northwest Basin.*

Many of the cirques in Baxter State Park are shown in Figure 12, a high level aerial photograph, and the rounded shapes of the heads of the cirques are apparent. Also clearly visible in Figure 12 is the long U-shaped valley, shown in Figure 10, which leads from the Northwest Basin cirque.

Cirques are formed principally by a form of weathering which is called frost-wedging. Water from melted snow trickles down to the
**Figure 11A.** North Basin cirque. Notice steep headwall and boulder moraine in foreground.

**Figure 11B.** Head of valley of Howe Brook, Traveler Mountain in background. Notice difference between the shape of this valley and the North Basin cirque. Dark patches near summit are remnants of virgin forest.
underlying bedrock. When it freezes in joints and other openings in the rock, the expansion dislodges a fragment of rock which becomes incorporated into the moving ice of the glacier and is carried down the valley, eventually ending as part of the moraine at the end of the glacier. A continuation of this process widens the valley, producing the characteristic cirque shape. The result is a very steep headwall which retreats as long as an active glacier exists in the cirque. The cirque is deepened by the ice as it moves down the valley, ripping off fragments of bedrock from the whole valley floor, and carrying them to the end of the glacier.

An interesting feature, which may be a very small cirque, occurs on the west side of South Turner Mountain, nearly at the summit. Much smaller than other cirques in Baxter State Park, the South Turner cirque gives a picture of the larger cirques as they may have appeared many thousands of years ago. Perhaps the feature is not a cirque at all, but may be the result of some kind of landslide.

As mentioned above, present day glaciers occur at middle and low latitudes where elevations are sufficient to provide the necessary climatic conditions. For the same reason, cirques in Baxter State Park, source areas of former glaciers, occur only at high elevations, and most of them are found in Katahdin granite. The principal exceptions to this general statement are a few poorly preserved cirques in the Traveler Mountain area.

Aretes. Probably the single most spectacular feature of the scenery of Baxter State Park is the Knife-Edge, another type of erosional feature which is the result of valley glaciation. Such narrow, irregular ridges are called aretes, and are formed by the widening of valleys by valley glaciers. The retreat of the headwall and valley walls of a cirque because of rapid weathering and erosion results in the formation of an arete if the high lands above the cirque are narrow. Assuming that North Basin now contained a valley glacier, an arete would not form until the headwall had retreated westward across the Tableland and the Tableland was reduced to a ridge as narrow as the Knife-Edge.

Hamlin Ridge also is an arete, formed between the two valley glaciers which existed in North Basin and the Great Basin cirques. Few other aretes occur in Baxter State Park because the cirques are too widely spaced and the higher elevations in Baxter State Park consist mainly of broad uplands, such as the Tableland (see figure 12).
Roches moutonnee. An interesting product of glacial erosion is a group of smoothed, sometimes straited, ridges of bedrock which are similar in size and shape to a whale’s back. Such features have been called roches moutonnee, because they bear some resemblance to a herd of sheep, especially if seen from a distance. The Northwest Basin Trail follows a large roche moutonnee between Lake Cowles and Davis Pond. Several smaller “sheeprocks” occur in Northwest Basin.

**Features Produced by Glacial Deposition**

An active glacier is not composed wholly of ice and snow, but contains a great deal of rock fragments, sand, and mud, especially near the base of the glacier. This material may be deposited directly by a glacier, left scattered about the countryside after a glacier melts, or be reworked by streams formed by melting ice and deposited as sand and gravel. All types of glacial deposits are called glacial drift, a term handed down from the 18th and early 19th Centuries, when glacial deposits were considered to be the result of icebergs drifting in the Biblical flood. There are two types of drift deposits: unstratified drift, or material deposited directly by a glacier, and stratified drift, or sediments washed from glaciers into meltwater streams and deposited as sand and gravel. The terms “stratified” and “unstratified” refer to the presence or absence of layering in the sediments, as discussed previously in the section dealing with sedimentary rocks. Stratified or layered glacial sediments have been in part transported and deposited by water.

Unstratified drift deposits. Erratics. Near the summit of Baxter peak are boulders of sandstone, shale, and other rock types different from Katahdin granite, the underlying bedrock. These rock fragments are called glacial erratics and are the principal evidence indicating that Mt. Katahdin was once covered by a glacier. If the possibility that some energetic climber carried these rocks to the summit is eliminated, there is no conceivable way, other than by means of a glacier, that these rocks could get to the summit of Baxter Peak. The term erratic is usually applied to rock fragments lying free at the surface, but is also applicable to any foreign material, in gravel deposits and the like. Some erratics composed of distinctive rock types whose bedrock source is known, indicate glacial transport of many miles, even several hundred miles in extreme cases. For example, some erratics on Mt. Katahdin are similar to bedrock which occurs in Canada north of the St. Lawrence River.
Till. The most widespread type of glacial deposit is *till*, a sediment popularly called hardpan. Till is composed of all sizes of rock fragments, from mud to boulders, which are carried in the basal part of a glacier. As a glacier moves its great weight of ice, it may plaster this unsorted material onto the underlying bedrock to the extent that it becomes firmly compacted, especially if the till contains a great deal of fine particles.

Excellent exposures of till occur in the vicinity of the South Branch Pond campground in the banks of streams in that area. Some of the most easily accessible exposures are along South Branch Pond Brook where till overlies many of the bedrock outcrops of rhyolite and sedimentary rock (see figure 5). At a point where the auto road is very close to the stream, about one-half mile north of South Branch Pond campsite, the high bank between the road and the stream exposes more than 50 feet of till. In fresh exposures this till is blue-grey in color and so firmly packed that it is nearly impossible to dig. Most of the larger rock fragments in this till are sandstone and shale, many containing fossils, although there are fragments of Traveler rhyolite near the base of the till.

The map of glacial geology shows the principal till deposits in Baxter State Park.

Moraines. A moraine is a ridge of bouldery material which accumulates at the end or temporary margin of a glacier. As mentioned previously, the deposition of a moraine occurs when the rate of ice melting at the terminus equals the rate of forward motion of a glacier. The actual terminus of the glacier is stationary; the ice within the glacier, however, is continually moving. As a result, fragments of rock are carried by the inner ice down to the terminus and deposited there. In areas of valley glacier development in a given region, several moraines may be formed at the end of a valley glacier at the same time if climatic conditions are the same throughout the region. A warming trend causes a glacier to retreat from the position marked by its terminal moraine, with retreat continuing as long as warm weather prevails. After the development of one series of moraines, a cooling trend causing the glacier to advance once again, will override and probably destroy any previously formed moraines. Most moraines record only a general warming period which is punctuated with short periods of stable climate.

The most prominent moraine in Baxter State Park is the irregular ridge east of Basin Ponds on the Chimney Pond Trail, which is over
50 feet high and more than 2 miles long. The Basin Ponds owe their existence to this moraine, the ponds having formed in the depressions behind the moraine. Part of this moraine is visible in Figure 12.

Valley glaciers flowed from South Basin, Great Basin, North Basin and Little North Basin and merged along the line marked by the Basin Pond moraine. Following the deposition of the Basin Pond moraine, these glaciers retreated for approximately one mile and the North Basin glacier became separated from the combined glacier coming from Great Basin and South Basin. Smaller moraines in North Basin at Blueberry Knoll and in Great Basin at Dry Pond on the Chimney Pond Trail record a halt in the general retreat from the Basin Pond moraine. The typical hummocky morainic topography near Blueberry Knoll is shown in Figure 13.

![Figure 13. View of moraines in North Basin cirque, looking east. Katahdin Lake in background. Boulders are composed of Katahdin granite.](image)

At the very head of North Basin there is an irregular deposit of boulders which records the position of either a very small glacier or more likely, a permanent snowbank, over which boulders falling from the headwall above rolled (see figure 11A).

Ground moraine. Deposits of unstratified drift marked by irregular topography but lacking pronounced linear features such as end moraines, are termed ground moraine. Ground moraine occurs in nearly all the lowland area south of Mt. Katahdin, in several of the large valleys in the central part of Baxter State Park, and on the floors of the cirques (see plate 1B). These deposits have a similar appearance, although they were likely formed in different ways.
Stratified drift deposits. The lowland valleys in Baxter State Park contain deposits of stratified drift which were formed by the melting of the final remnants of the ice sheet which last covered this area. Melting glaciers lose most of their volume by thinning, rather than by the retreat of their margins. During the wasting away of a continental glacier, the glacier eventually becomes so thin that hills and ridges protrude through the ice, leaving detached masses of ice in the valleys. The melting of these stagnant ice blocks produced the deposits of stratified drift which characterize the valleys in Baxter State Park, as in much of New England. Nearly all of the valuable sand and gravel deposits of New England consist of one kind of stratified drift or another.

Eskers. The most easily recognized of the stratified drift deposits are eskers, which are long, sinuous ridges of sand and gravel. These features are commonly called “horsebacks” or “whalebacks” in Maine.

Many geologists believe that eskers are formed in tunnels at the base of melting glaciers, tunnels bored by meltwater streams from the melting glacier. In time, deposits of sand and gravel from the melting ice build up in the tunnel, and when the ice finally disappears a ridge of this material is left upon the ground to mark the bed of the subglacial stream. Esker ridges range in width from about 20 feet to more than 600 feet, in height from 10 feet to more than 150 feet, and in length from less than 200 feet to more than 100 miles. Portions of some of the longest eskers in the world occur in the vicinity of Lincoln and Bangor, Maine.

Four principal groups of esker ridges occur in Baxter State Park and the nearby lowlands and are shown on the map of the glacial geology. The most conspicuous esker occurs between Togue Pond and Abol Pond, a portion of which is shown in Figure 14. The subglacial stream which formed this esker apparently flowed toward the West Branch of the Penobscot River down what is now the Abol Stream valley.

Another esker system starts in the vicinity of Slaughter Pond, crosses the Nesowadnehunk Stream valley, and follows the lower part of the Katahdin Stream valley. It is characteristic of many esker systems that they show little regard for present drainage systems. Many occupy portions of several stream valleys. The esker system in the Wassataquoik Stream valley is one of those which diverges somewhat from the present drainage lines (see map of glacial geology). In the valley between Billfish Mountain and Trout Brook and Horse Moun-
Figure 14. Esker ridge near Togue Ponds. The park road from Togue Pond to Abol and Nesowadnehunk campsites, which was built after the photo was taken, follows the crest of the esker exactly.

...there is an esker which may be part of a long esker which follows the valley of the East Branch of the Penobscot River (see map of glacial geology). This esker runs between High Pond (elevation 936 feet) and Long Pond (elevation 926 feet) and it is difficult to under-
stand why the water does not seep through the esker so that both ponds have the same elevation. Perhaps this esker has some impermeable material buried under the surface sand and gravel which prevents seepage.

Kames, kettles, and kame terraces. In addition to eskers, other types of stratified drift deposits occur in the valleys in Baxter State Park, but they are not as well developed and are generally difficult to recognize.

Small mounds of stratified drift are called kames and are commonly associated with eskers. It is believed that kames are formed by the settling of sand and gravel at the base of vertical pipes or wells in a melting glacier.

Kettles or kettleholes are depressions formed in deposits of stratified drift, caused by the melting of a large block of ice which had been buried in the sand and gravel. Many of the small, nearly circular lakes and ponds in the Katahdin region are kettleholes partly filled with water, as, for example, Russell Pond, Abol Pond, and Rat Pond (see frontispiece and figure 14).

Kame terraces are accumulations of sand and gravel which occur at the sides of valleys and represent the deposits of meltwater streams that flowed along the margins of melting ice blocks. Terraces of this sort are present at Trout Brook Farm campsite in the northern part of Baxter State Park, and a gravel pit between the State Park road and the former Trout Brook Farm exposes typical stratified drift.

Drainage channels. Meltwater streams, besides forming the various kinds of stratified drift deposits described above, may also erode channels, which by their size and location may be distinguished from modern stream channels. In the valley of Trout Brook there is a complex system of meltwater drainage channels, most of which are now completely dry, although some are used by the modern streams. Because of the thick second growth forest which covers this part of Baxter State Park, it is difficult to see these features except from above, either from one of the nearby mountains, such as North Traveler, or from an airplane. Several of these channels are clearly visible at the upper left of Figure 15, a high level aerial photograph. Many channels, also visible on the Traveler Mountain quadrangle map, are shown as black arrow lines on the map of the glacial geology of Baxter State Park (plate 1B).
SEQUENCE OF EVENTS INFERRED FROM THE GLACIAL GEOLOGY OF BAXTER STATE PARK

It has been mentioned that studies of glacial geology in other parts of the world indicate that there have been several, probably four, major episodes of continental glaciation in the past one million years, and that present climatic conditions are part of the waning stages of the last major glaciation which probably began about 30,000 years ago. Nearly all of the glacial deposits in New England are a product of this
last continental glacier, but it is difficult to determine for any particular area when this glacier finally melted. It would be safe to say, however, that the last continental glacier to cover the Baxter State Park area was here somewhere between about 9,000 to 15,000 years ago.

The erratic boulders near the summits of many of the mountains in Baxter State Park were left by the last continental glacier, although most moraines of similar material have been removed from the valleys by stream erosion. However, just east of the Basin Pond moraine is a smaller belt of moraines which, because of the boulders and cobbles of sandstone and other erratic material in them, probably were formed by a continental glacier. The Basin Pond moraine, on the other hand, is composed almost entirely of Katahdin granite, which indicates that it was formed by valley glaciers which had only bedrock sources of Katahdin granite available to them. Because the Basin Pond moraine extends more than a mile south of the cirques which produced the valley glaciers, these valley glaciers likely ran into the mass of continental ice and were carried southward by it. An attempt to reconstruct the distribution of the glaciers at this time is shown in Figure 16.

Other evidences of the last continental glacier in Baxter State Park are the stratified drift deposits and meltwater drainage channels of the till, principally in the South Branch Pond area.

Small valley glaciers lingered in the cirques on Mt. Katahdin following the final melting of the continental glacier. The present rugged landscape of Mt. Katahdin, including such features as the Knife-Edge and the steep headwalls of the cirques, was formed by erosion by these valley glaciers. Much, if not most, of the erosion represented by the cirques themselves was performed by the combined efforts of older valley glaciers which accompanied older continental glaciers. The most recent erosion, however, which produced the Knife-Edge and other details of the landscape that we see today, is the result of the latest valley glaciers to occupy the cirques. The presence of moraines associated with these cirques indicates that there may have been several periods of stable climate following continental glaciation, although in general the climate has become warmer following continental glaciation. Because no evidence has been found by which the beginning or, indeed, the end of the valley glacier stages can be dated, it is not known for how long valley glaciers lingered in the cirques on Mt. Katahdin. The relatively unweathered condition of such moraines as Blueberry Knoll compared with the deeply
Figure 16A. Mt. Katahdin as it may have appeared during the late glacial times. The glacier in the foreground is part of the last continental glacier and extends across the Sandy Stream valley to Basin Ponds where the remnant of the continental glacier merged with the combined valley glaciers issuing from North Basin, Great Basin, and South Basin.
B. Mt. Katahdin as it appears today. The moraines which extend southward from Basin Ponds mark the zone along which the continental glacier merged with the valley glaciers shown in Figure 16A.
weathered Basin Pond moraine suggests a long time, perhaps several thousands of years, elapsed between the formation of these moraines.

Valley glaciers did not form in most of the valleys in the Traveler Mountain area following continental glaciation, apparently because there was not sufficient elevation. It is interesting to note that several geologists have interpreted the evidence on Mt. Washington in New Hampshire to mean that no important valley glaciers existed on that mountain following continental glaciation. Lack of prominent moraines in the cirques and the relatively subdued appearance of the cirque headwalls on Mt. Washington indicate that the cirques probably were formed during some older stage of glaciation; that the cirques were overridden by the ice sheet and somewhat eroded, and that important valley glaciers were not present after the ice sheet melted.

The pile of rubble at the head of North Basin is probably the youngest glacial feature in Baxter State Park and may have formed during a period of several hundred years preceding the mid-nineteenth century. Since about 1850, glaciers in many parts of the world have been melting, whereas during the five hundred or so years which preceded 1850, glaciers advanced in the Alps and other mountain regions.
Miscellaneous Geologic Features In Baxter State Park

Several features, not clearly related to either bedrock geology or glacial geology deserve mention.

**Potholes**

Bedrock outcrops in streams are often worn by pebbles and cobbles caught in swirling eddies. After many years of such wear a deep, smooth-sided hole, called a *pothole*, is worn in the bedrock. The best developed and most easily accessible potholes in Baxter State Park occur on Howe Brook, near South Branch Pond campground. These potholes, reached by a clearly marked trail, afford some of the most exciting, and undoubtedly, the coldest swimming in the State Park. Potholes are present on nearly every stream in the State Park (see figure 1).

**Streams and Rivers**

Parts of the courses of several streams in Baxter State Park are different from the courses used by those streams before the Katahdin area was glaciated. Some streams now flow in entirely different directions than they did prior to glaciation and some have taken over parts of other stream valleys. These changes may have been produced by glacial erosion, which opened new valleys through bedrock, or by glacial deposition which dammed the drainage, causing the stream to seek a new valley in which to flow; or by a combination of both glacial erosion and deposition. It will not be possible to mention all streams so affected, but the changes thought to have taken place in the Nesowadnehunk Stream valley will serve as a good example with which the interested reader may make his own reconstructions of drainage changes in other streams.

The small tributary stream just west of Doubletop Mountain flows northward until just above its juncture with Nesowadnehunk Stream, where it bends sharply to the south (see plate 1). Such an orientation strongly suggests this tributary was once part of a northflowing stream system and that it may once have drained into what now is Howe Brook. It is probable that this stream system comprised what is now the upper part of Nesowadnehunk Stream, Little
Nesowadnehunk Stream, and the above mentioned tributary; that is, the part of the present drainage basin which is roughly north of Doubletop Mountain. Erosion by continental glaciers eroded the deep narrow valley east of Doubletop Mountain and glacial deposits blocking the former northerly outlet of the stream forced the drainage southward into the present course of Nesowadnehunk Stream. In other words, the present course of the stream from Doubletop Mountain northward is postglacial in origin, and now flows approximately in opposite direction of its preglacial course.

From the vicinity of Foster Field southward, Nesowadnehunk Stream flows in the valley of a smaller stream which probably flowed in much the same direction in preglacial times that it does now. Minor drainage changes which are mostly the result of glacial deposits may be noted in the downstream portion of Nesowadnehunk Stream. For example, Katahdin Stream probably used to be tributary to the preglacial lower Nesowadnehunk Stream, but has been diverted from the course by the prominent esker which occupies the valley in the vicinity of the Katahdin Stream campground.

Another characteristic of many streams in the Katahdin area which is related to glaciation is the presence in the stream channels of large numbers of extremely large boulders. Many of these boulders were transported to their present positions by glacier ice and even at highest flood stages the streams are incapable of moving them. Perhaps some boulders were deposited in the channels by streams having a great deal more water, and therefore possessing greater ability to transport large boulders. Such streams likely existed during the final melting of glacier ice and perhaps at times following glaciation during periods of greater rainfall than now prevails in the Mt. Katahdin area.

**South Branch Pond Delta**

A *delta* is a deposit of sediments at the mouth of a river or stream. Between Upper and Lower South Branch Ponds there is a large, fairly level deposit of gravel and boulders which is a delta formed by Howe Brook (see figure 15). Prior to the formation of this delta, the South Branch Ponds were one large lake.

The forested condition of the delta and the probability that the present Howe Brook, even at highest flood stage, is unable to transport most of the boulders on the delta, indicate that the delta was formed a long time ago. A good guess would be that it formed during the melting of the final remnants of the last continental glacier, when the
glacial drainage channels (see figure 15), which also indicate greater flow of water than presently occurs, also were probably formed.

LANDSLIDES

On many steep bedrock slopes which have a thin cover of till, the slopes have prominent landslide scars (see figure 18). Landslides occur where loose material rests on slopes which are too steep, and are aided by heavy rain and meltwater from snow. Landslide scars on O.J.I. Mountain approximate the shape of those letters, but continued landslide activity has nearly destroyed the letters. Especially prominent scars occur on the east side of Doubletop Mountain.

FEATURES RELATED TO CLIMATIC CONDITIONS

Above 4,000 feet elevation on Mt. Katahdin, the mean annual temperature is below 30°F. and the climatic conditions are comparable to those found in the Arctic zone, 400 miles north of Mt. Katahdin. This severe climate has resulted in several interesting geologic and biologic phenomena.

PATTERNED GROUND

Curious rings of stones and bands of stones occur above timber line along many trails in Baxter State Park. These stone rings and stripes are called patterned ground and are formed by the expansion and contraction of the soil by freezing and thawing. Large stone rings, 20 feet or more in diameter, with boulders and cobbles on the margin, occur on the Tableland of Mt. Katahdin (figure 17). Perhaps these rings formed during the severe climate when valley glaciers existed in the cirques below the Tableland. Miniature rings, a few inches in diameter, and composed of small pebbles, are visible in the early spring along the Dudley Trail on Pamola but are destroyed by summer traffic, proving that miniature patterned ground features can form under the present climatic conditions. Other miniature patterned ground may be seen near the summits of many mountains in the Traveler Mountain region and along the shore of Grand Lake Matagamon at low water. Patterned ground is commonly associated with permanently frozen ground and occurs in such places as Siberia, Northern Alaska, and Northern Canada.

ROCK STREAMS

The boulder strewn slopes on the Tableland are not completely stable. The irregular streams of boulders indicate some slow move-
ment downhill has occurred in the past and perhaps is still occurring on a small scale. The Saddle Trail from the Saddle to Baxter Peak and the upper part of the Cathedral Trail cross several of these rock streams (see figure 2). Movement of boulders in these rock streams is a result of the steep slopes and is aided by the expansion and contraction of water as it freezes and thaws. Some material is carried by these rock streams to the steep cirque headwalls where rock slides and rock falls occur.

![Figure 17. Crude stone rings on Tableland, Mt. Katahdin, along Baxter Peak Cut-Off Trail. Dark vegetation in middleground is windstunted spruce forest.](image)

**Arctic Plant and Animal Life**

Mention of the present plant and animal life of Baxter State Park may be stretching the geologic nature of this paper, but as plants and animals are sensitive indicators of climate, the nature of such life
above timber line in Baxter State Park deserves mention. Many species of shrubs, grasses, and heath plants which live on the Tableland are native to the Arctic zone and exist on Mt. Katahdin because of its severe climate. Several species of rodents and insects (not the ubiquitous black flies and no-seeums) which live on the Tableland are also natives of the Arctic zone.

Biologists feel that these plants and animals could not survive at lower elevations and it is an interesting problem as to how they got to Mt. Katahdin. Geologic evidence indicates that with each advance of the ice sheets the Arctic plants and animals migrated southward with the cooler climate. For example, reindeer and the wooly mammoth migrated as far south as Texas, where their fossil remains are now

![Figure 18. Patterned spruce and fir growth on north side of the Owl. Witherle Ravine in foreground. Notice landslide scars on Mt. Coe in distance.](image-url)
occasionally found. The melting of the ice allowed northward migration and those plants and animals which could not survive the warmer climate were killed off. Some plants and animals, however, had migrated to such areas as Mt. Katahdin, where the climate suited them and where they survive to this day — living remnants of a glacial climate. Mt. Washington and other of the White Mountains are also refuges for Arctic plant and animal life.

**PATTERNED SPRUCE AND FIR GROWTH**

On the slopes leading down into the large swampy area called the Klondike the spruce and fir growth has a curious striped pattern. This pattern is easily visible from almost anywhere on the Tableland or higher, but is especially prominent when viewed from the vicinity of Thoreau Springs, as shown in Figure 18 (see also figure 12). In the original edition of this paper, following the consensus of local opinion, I described this pattern as blowdown formed during the 1938 hurricane. Several readers, including Dr. A. E. Brower of the Maine Department of Forestry, called my attention to several inconsistencies in this interpretation, not the least of which being that they had seen and photographed these features long before 1938. Dr. Brower also correctly pointed out that many of the trees in what appear to be areas of blowdown are still standing, although dead.

Although I still have no better explanation for this pattern than my original erroneous one, I have examined several of these bands of dead trees in detail. It appears that the trees in these patterns reach a certain age (between 50 and 100 years) or perhaps a certain height, then for some reason they die. Some time following their death, the trees are blown over and are systematically replaced by new growth. When this new growth reaches a certain height or age, it is killed in turn and replaced by other new growth. Thus this pattern is not the result of a single event, such as a hurricane, but is a constant process of death and replacement. But I have yet to find a reasonable explanation of how this whole process begins and why it should take the form of such well defined stripes.

It is well to leave this discussion of the geology of Mt. Katahdin with an unanswered question. Despite all that is known about the earth, there is probably much more that is not known. And the mystery of the curious striped pattern in the high spruce forests on Katahdin is only the most obvious of many questions yet to be answered.
Acknowledgments

This paper was commissioned by the Maine Geological Survey and the writer is indebted to several other organizations and individuals who assisted in many ways in the preparation of the paper. Most of the information concerning the glacial geology of the State Park is taken from the writer’s Ph.D. thesis, based on three summers’ field work in the State Park. Field work was supported by grants and scholarships from Harvard University and Wellesley College. The hospitality of Helon Taylor, Baxter State Park Supervisor, the State Park rangers, and their wives made the stay in Baxter State Park a comfortable and enjoyable experience.

Andrew Griscom and Douglas Rankin of Harvard University and The U. S. Geological Survey made available their hard won knowledge of the bedrock geology of Baxter State Park. They also read a preliminary draft of this paper, and made many valuable suggestions which are incorporated in the paper in its present form. This writer, however, accepts full responsibility for any errors, misconceptions, or misinterpretations he may have introduced into the excellent work of Griscom and Rankin.

The geologic map was drafted by the late Linwood Partridge, Maine Department of Economic Development. The manuscript was typed by Mrs. Margaret Steele and Mrs. Gale Marr.
Glossary Of Geologic Terms

arete. A sharp, rugged crest of a mountain range or mountain spur formed by weathering and mass wasting between two or more cirques.

bedrock. Solid rock or ledge which underlies loose gravel, soil, etc.

biotite. Black mica.

brachiopod. A phylum of marine, two-shelled animals. Also called lampshells.

bryozoa. A phylum of coral-like animals also called moss-animals.

cirque. A steep, deep valley head caused by glacier erosion.

columnar joint. Joints in volcanic rocks which break the rock into five or six-sided columns.

continental glacier. Glacier which is not confined to a valley. Also called an ice sheet or ice cap.

conglomerate. A sedimentary rock composed of rock and mineral fragments the size of pebbles or larger.

delta. A deposit of sediments at the mouth of a river.

drift. A general term used to describe any type of glacial deposit.

era. The largest division of geologic time. The names refer to the stage of development of life which characterize the eras.

erratic. A glacially transported rock which is different from the bedrock on which it lies.

esker. A long ridge of gravel and other stratified drift which formed in a tunnel at the base of a melting glacier.

extrusive rock. Igneous rock which cools at the surface of the earth, also called volcanic rock.

fault. A break or rupture in bedrock along which there has been differential movement.

feldspar. A mineral composed of soda, lime, or potash and alumina and silica. The most abundant mineral constituent of granite.

fossil. Any indication of prehistoric life which has some recognizable form.

glacier. A mass of ice and snow, on land, which is now moving or has recently moved.

hornblende. A dark-colored mineral of complex composition, which occurs in many granites.

igneous rock. Rock formed from molten material called magma. Either intrusive (formed below earth's surface) or extrusive, such as volcanic, in origin.

intrusive rock. Igneous rock which cools beneath the crust of the earth. Granite is the most common intrusive igneous rock.

joint. A crack or fracture in a rock.

kame. A small mound of stratified drift.

kame terrace. A terrace deposit of stratified drift formed at the margin of a melting glacier.

kettlehole. A depression in stratified drift formed as the result of the melting of a buried ice block.

lava. Magma which has reached the earth's surface. Volcanoes are made of lava.

magma. The molten or partially molten material, originating within the earth, from which igneous rocks are formed.

mineral. Any naturally occurring inorganic element or compound.

outcrop. Bedrock exposed at the surface of the earth.

patterned ground. Rings, stripes, and other patterns formed in loose surficial deposits by frost.

period. Subdivision of an era.
pothole. A smooth-sided deep hole in bedrock formed by the abrasion of pebbles and boulders caught in eddies in streams.
quartz. A mineral composed of silicon and oxygen. Characteristic of such igneous rocks as granite and such sedimentary rocks as sandstone.
radioactive mineral. Any mineral which contains some radioactive element such as uranium or thorium.
rhyolite. An extrusive igneous rock having the same chemical composition as granite.
ripple mark. Small ridges formed in sandy or muddy bottoms of streams, lakes, and oceans by currents and waves.
roches moutonnee. A smoothed, rounded bedrock outcrop formed by glacial erosion. Several of these features occurring together bear a fancied resemblance to a flock of sheep, hence the name, "sheeprock."
rock stream. A crude stream of rocks which moves as a slow-moving landslide.
sandstone. Sedimentary rock composed of rock and mineral fragments the size of sand grains.
sedimentary rock. Rock formed from the accumulation of sand, mud, or gravel.
shale. Sedimentary rock formed from mud.
stratified — layered. Refers to layering in sedimentary rocks and certain kinds of glacial deposits.
striation. A scratch on bedrock formed by debris lodged in base of overriding glacier.
till. Glacial sediment composed of rock fragments of all possible sizes. Popularly called hardpan.
tuff. Rock formed from volcanic ash.
unstratified. Without layering. Refers particularly to such glacial deposits as till.
valley glacier. Glacier confined to a valley. Also called a mountain glacier or an ice stream.
volcanic ash. Small cinders and dust-sized particles produced by the explosive eruption of certain volcanoes. This material may be carried in the air for long distances from the volcano which formed it. The settling of this material results in beds of volcanic ash.
Selected References Dealing With The Geology Of The Mount Katahdin Area


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