The Geology of

Darling State Park

By

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VERMONT GEOLOGICAL SURVEY
CHARLES G. DOLL, *State Geologist*

DEPARTMENT OF FORESTS AND PARKS
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Cover picture: View of Burke Mountain (center, background). Picture taken toward the northeast from State Route 114, about 5 miles south of East Burke.

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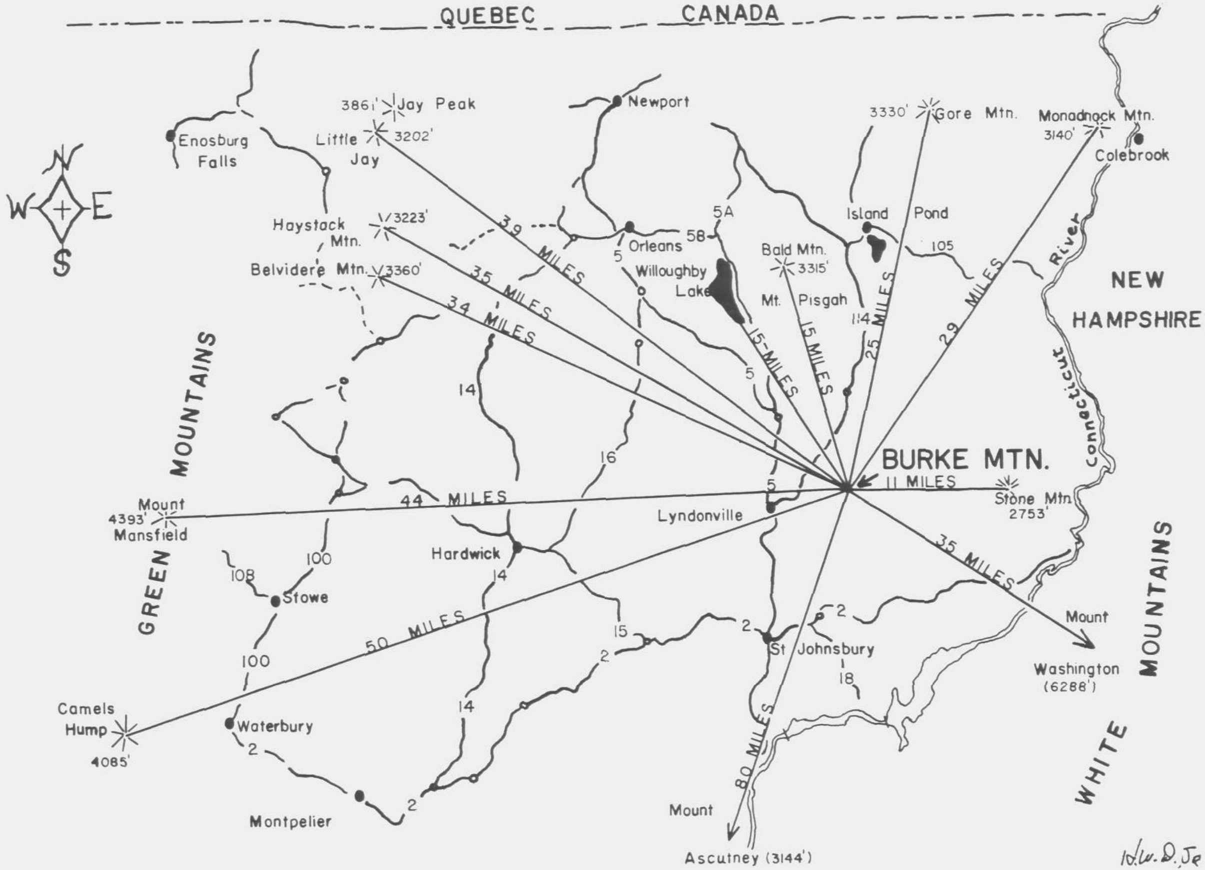

Figure 1. Map showing the location of Burke Mountain (Darling State Park), and mountain peaks which can be seen from the summit of Burke Mountain.

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INTRODUCTION

Darling State Park, located in northeastern Vermont (see map, "Burke Mountain," Fig. 1), offers outstanding opportunities to the camper, picnicker, hiker, view-seeker and winter sportsman. On a clear day the top of Burke Mountain offers a most spectacular view of northeastern Vermont and such distant points as Mount Ascutney (located on the Connecticut River, some 80 miles as the crow flies, to the south). Other prominent peaks that may be seen are Camels Hump (50 miles southwest), Mount Mansfield (44 miles west), Jay Peak (39 miles northwest), and Mount Washington (the highest Peak in the New England States and the northeast, which is located in New Hampshire some 47 miles southeast of Burke Mountain). For the traveler, the view from Burke Mountain reveals "where he has been" and where he might "next go." See Figure 1 for the location of points which can be seen from the overlooks atop Burke Mountain.

Both the professional and amateur naturalist will find Darling State Park extremely interesting. This pamphlet is devoted primarily to the geology of the park, but the fauna and flora of this area present the visitor with days of interesting studies. It is hoped that in the near future pamphlets describing these aspects of Darling State Park will be published.

THE GEOLOGY OF THE PARK

Before discussing the more detailed aspects of the geology of Darling State Park, certain basic geologic concepts must be explained. But, even before such a discussion, it might be best to clarify the position of geology among the many other, and oftentimes interrelated, sciences.

The basic reason for the science of geology might be said to be twofold; one is economic, the other related to Man's basic curiosity. In the first, the geologist through the use of his knowledge of the earth's rocks, locates those indispensable minerals and fuels without which our advanced society and technology could not exist. In the second, the geologist tries to unlock the many mysteries within the earth's crust merely to satisfy a thirst for knowledge and to pass such knowledge on to his fellow man. These two basic reasons complement each other and allow continued advancements in geology, both as a pure science and as a primary economic aid to the nation.

As found in most spheres of present-day scientific endeavor, the geologist relies heavily on other related sciences for insight into problems at hand. A basic knowledge, and oftentimes an advanced knowledge, of physics, chemistry, mathematics and zoology, to name only some, are needed before the geologist can approach many of his own problems. It might be obvious to you by now, but a geologist will be certainly included in the first scientific party to journey to the moon and planets.

Within the general science of geology are several branches, to name only a few; paleontology, sedimentology, mineralogy, petrology, stratigraphy, petroleum geology, and structural geology. Each of these branches or specialty-areas contributes basic data for the overall interpretation of the past geologic history of any given geographic area. The historical geologist takes all these clues and attempts to fit the pieces of information together into a picture of past events.

The concept of Geologic Time must be understood before the history of Darling State Park can be unraveled. Usually we think of time in terms of minutes, hours, days, weeks, months and years. The geologist thinks and talks in terms of millions or even billions of years. Time units as short as hundreds of years are impossible to distinguish in the past history of the Earth. When it is realized that the earth is probably 4 to 6 billion (4,000 to 6,000 million) years old, and the record of these years is incomplete, it is easy to understand why the geologist speaks in terms of millions of years instead of years. With modern methods of radioactive dating the geologist hopes for finer time definitions in the future.

In short then, the geologist interprets and puts order into millions of years of history which can only be "read" as recorded in the rocks beneath our very feet. Of course, just looking at the rocks does not magically open the book of geologic history. This pamphlet is designed to sharpen your powers of observation and to help you in your interpretation of these observations.

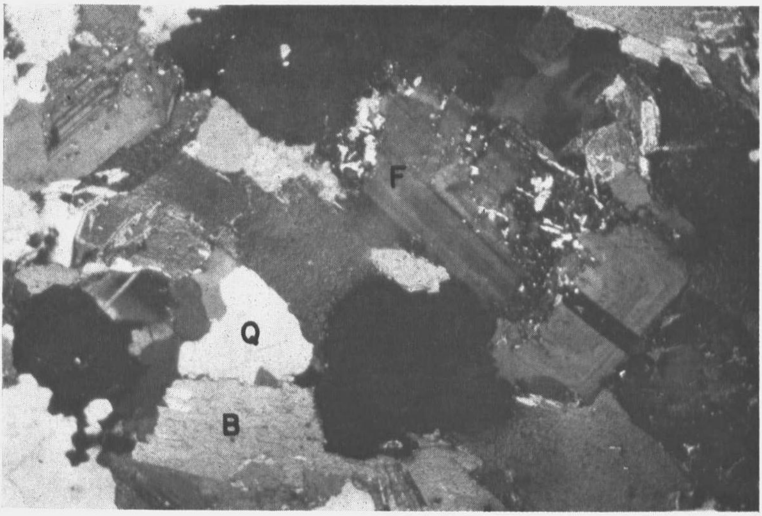

Figure 2. Thin-section of granite from Burke Mountain. The main minerals seen in this photograph are feldspar (light gray center right, marked with "F"); quartz (whitish, marked with "Q"); biotite (light gray, speckled appearance, marked with "B"). Note the interlocking nature of the minerals which make up this rock. Magnified 15 times, under crossed nicols.

THE ROCKS AND THEIR HISTORY

The most conspicuous rock found in the park is *granite*.[1] Along the road which winds to the summit of Burke Mountain you will see several outcrops of the white or pinkish biotite granite (Fig. 4). This granite is well displayed in the summit parking area and along the trail to the observation tower (Figs. 3 and 5). A walk down the Bear Den Ski Trail also shows an abundance of granite outcrops (Figs. 6, 7, and 8).

[1]The granite found in Darling State Park is white or pinkish in color and most times is speckled with shiny black mica flakes. On close inspection, grains of smoky to clear color are seen within the rock. The white and pink grains are the mineral, feldspar; the shiny black flakes, biotite mica; the smoky to clear grains, quartz or silica. A magnified picture of a slice of granite (see Fig. 2) shows the individual mineral grains and their interlocking nature with each other. Granite belongs to a major family of rocks, termed *Igneous rocks*. Igneous rocks are formed through the hardening or lithification of molten rock-material when subjected to the cooler temperatures at or near the earth's surface. The molten rock material formed at some depth beneath the surface of the earth, where temperatures were many hundreds of degrees hotter than at the surface.

Figure 3. Speckled granite with inclusion of metamorphic rock. Black specks in granite are flakes of black biotite mica. Metamorphic inclusion, located just above the hammer head shows some reaction with the invading granite. Pieces of metamorphic rock were undermined by and dropped into the granite as it worked its way upward into these rocks. Picture taken a few yards west of the tower on top of Burke Mt.

While looking at some of the above-mentioned photographs, a second family of rocks is discovered (Figs. 3, 5, 6, 7, and 8; also, Figs. 9, 10, 11, and 16). In many places these rocks have a layered or banded appearance and in other places large lath-like crystals are common in some of the layers. In some areas these rocks are very heterogeneous in appearance and display distorted layers and profuse development of lath-like crystals (Figs. 12 and 13). These rocks belong to the second major family of rocks, the *Metamorphic* rocks. The metamorphic rocks[1] seen in the park were

[1]Metamorphic rocks are either sedimentary (this, a third major family of rocks which is characterized by a layered appearance that has been retained by many of the altered park rocks) or igneous rocks (the granite) which have been under the influence of pressure, heat, and chemically active fluids, oftentimes resulting in chemical and structural changes. Most of the metamorphic rocks seen in the park are either schist, phyllite, slate or quartzite. For the benefit of the more advanced student, the rocks of the park area are considered a granite-hornfels complex (see Bertram G. Woodland's paper of 1963, "A Petrographic study of Thermally Metamorphosed Pelitic rocks in the Burke Area, Northeastern Vermont," in the American Journal of Science, volume 261, pages 354 to 375).

Figure 4. Outcrop of biotite granite located on the summit road between the second and third turns from the summit of Burke Mountain and on the right side of the road if descending. Note the "sheeting structure" or flat joint surface which slopes or dips into the road. This flat break in the rock was probably caused by the release in pressure of the overlying glacial ice when it melted from this region.

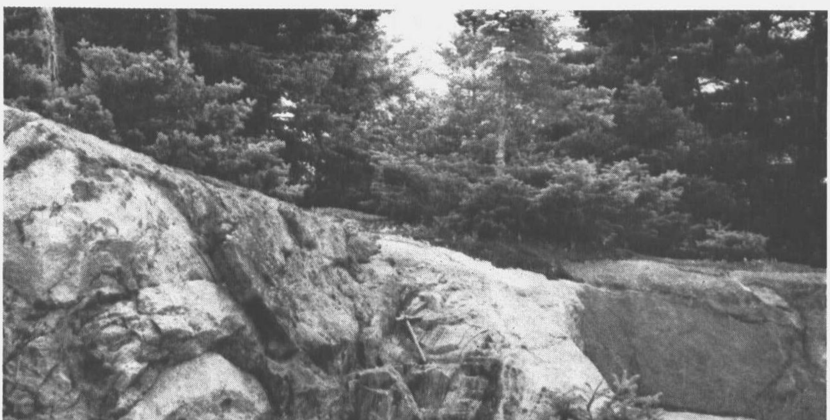

Figure 5. East side of parking area, summit of Burke Mountain. Outcrop of granite with many metamorphic rock inclusions (hammer, center of picture, rests on large inclusion). Layering or banding in the inclusions is almost vertical.

Figure 6. Outcrop located about midway down the Bear Den Ski Trail. Alternating metamorphic quartzite and phyllite invaded by lighter colored and speckled biotite granite. Note how the granite cross-cuts the layered or banded metamorphic rocks. This cross-cutting points out the fact that the layering or banding was present prior to the invasion of the granite.

originally *sedimentary*[1] rocks. These rocks belong to the Gile Mountain *Formation*[2] which was deposited during the *Devonian Period* some 300 million years ago (see Geologic Time[3] scale, Fig. 14). So much for the two major families of rocks present in the park, the igneous and metamorphic

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[1] Sedimentary or layered rocks, the third major rock family, are composed of pieces, grains and other materials from older metamorphic, igneous and sedimentary rocks, These fragments have been carried by rivers and streams to some resting place at the bottom of a sea, lake, or stream channel. This mud, sand and gravel, under the weight of steadily increasing overburden, and the presence of cementing materials, slowly hardened into rock which we now call limestone shale, sandstone, and conglomerate.

[2] A geologic formation consists of a sequence of rock layers which were deposited under essentially the same conditions, or a series of alternating conditions, and which can be easily distinguished and mapped as a unit by geologists in the field.

[3] Geologic time is divided into four Eras which are designated from oldest to youngest: Precambrian, Paleozoic, Mesozoic, and Cenozoic. Each of these Eras is divided

Figure 7. Outcrop located about midway down the Bear Den Ski Trail. Metamorphic quartzite and phyllite (darker color) and invading biotite granite (light speckled appearance). Here the granite has a more or less conformable relationship to the layers or bands in the metamorphic rock. Compare this relationship with the cross-cutting relationship in Fig. 6. For scale, the handle of the geologic hammer or pick is about 12 inches long.

rocks, and how to distinguish one from the other. Let us assume that you can now distinguish between the granite and the metamorphic rocks.

Now, what is the relationship of one to the other? That is, where you can see both of these rock types exposed together in one outcrop, can you describe the physical contact of one with the other? For instance, look at Figure 6, which was taken about midway down the Bear Den Trail, here you see the granite (the white speckled igneous rock which cuts horizontally across the picture) cutting across the distinctly layered or banded metamorphic rocks. The granite is said to have a cross-cutting relationship to the metamorphic rocks. In some outcrops the granite is

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into geologic periods of time. The Devonian Period is in about the middle of the Paleozoic Era and began some 330 million years ago and ended approximately 290 million years ago (see Geologic Time Scale, Fig. 14).

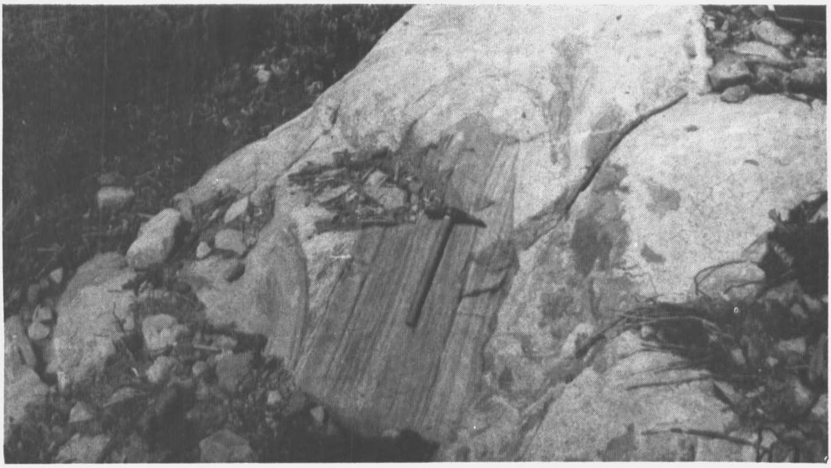

Figure 8. Inclusion of layered or banded metamorphic rock (hammer is resting on this inclusion) in lighter colored biotite granite as seen along the Bear Den Ski Trail. The metamorphic rocks were invaded and undermined by the granitic rocks, with the result that pieces of the metamorphic rock were surrounded by granite. For scale, the handle of the geologic hammer or pick is about 12 inches long.

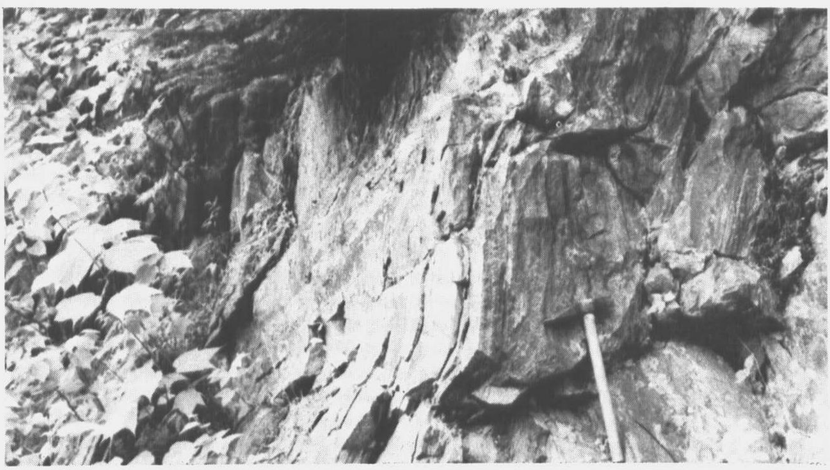

Figure 9. Picture taken along the Burke Mountain summit road of typical Gile Mountain metamorphic rock. Here the rocks dip almost vertically. For those more advanced in geology, note the pillow-like segments or boudinage structure about one foot to the left of the chisel point of the hammer. This structure is due to a stretching of the rock. For scale, the hammer handle is about 12 inches long.

Figure 10. Banded or layered metamorphic rocks with inter-squeezed granite (lighter colored material). This outcrop is located on east side of the Bear Den Ski Trail and quite close to the Burke Mountain summit road. The hammer handle, center of picture, is about one foot long.

more or less parallel to the layers of metamorphic rock (Fig. 7). Here, the granite is said to have a conformable relationship with the metamorphic rocks. Still another relationship between the granite and the metamorphic rock is seen in Figure 8. Here, blocks of metamorphic rocks are inclosed by granite. These inclosed blocks are called inclusions and are pieces of invaded rock which fell into or were encircled by the invading granite.

From these relationships, what can be said about the relative ages of

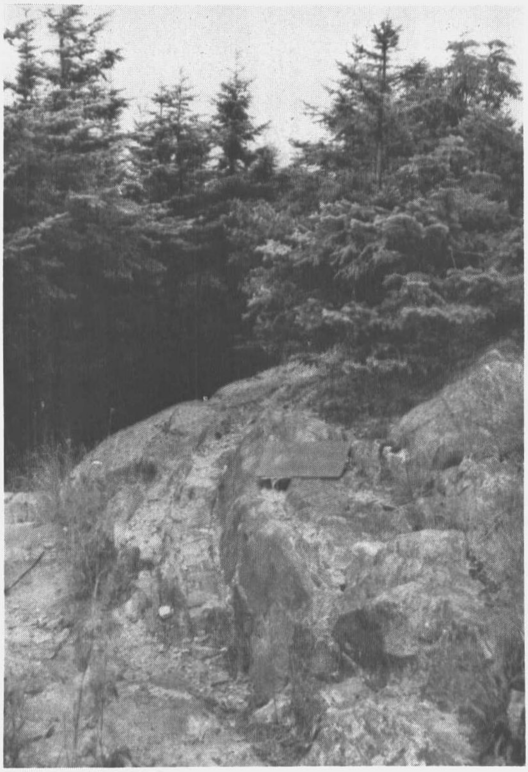

Figure 11. Picture taken only a few yards from the Burke Mountain observation tower, along the path to the summit parking lot, looking northwest. Here you see metamorphic rocks (quartzite and phyllite) with some inter-squeezed granite. Note how the nearly vertical metamorphic rock layers bend or "wrap-around" to the right. The highly resistant inter-squeezed granite actually holds Burke Mountain up, or to be more scientific, it prevents these rocks from being worn down as fast as the surrounding rocks. For scale, see the clip board in the center of the picture.

the two rock types? Which is the older, or first formed? Which is the last formed? If you study the above relationships for a minute or so, it will become obvious that the layered rock had to be formed *prior* to the emplacement of the granite. Some of the minerals now seen in the layered or banded metamorphic rocks were formed at the time of granite intrusion, but the basic "stuff" or partially metamorphosed sedimentary rock was present before the granite entered the area from beneath. So, the

Figure 12. Outcrop on south Lookout, summit of Burke Mountain. Distorted layers of Gile Mountain metamorphic rock. Lath-like crystals developed along some of these layers during the second period of metamorphism, that is, when the granite invaded the metamorphic rocks. For scale, the hammer handle is about one foot long.

knowledge of the two rock types present and an understanding of their relationship to one another tells us a story of at least two events which occurred in the park area hundreds of millions of years ago.

Can we find other facts in these rocks which might add to the above-mentioned events? The answer to this question is, yes! The types of minerals found in the metamorphic rocks coupled with the inherited layered structure so common in these rocks, tells us that they were once sedimentary rocks. There is other evidence which indicates that these sedimentary rocks were slightly metamorphosed and folded prior to the invasion of the granite. Added information indicates that these same rocks were subjected to increasing temperatures with the invasion of the granite and another metamorphic mineral change took place. Thus far, the rocks have told us about four distinct events; the deposition and hardening of the Gile Mountain Formation of sedimentary rocks, the first period of wide-spread metamorphism, accompanied by broad folding, the invasion of the granite, and a second phase of metamorphism

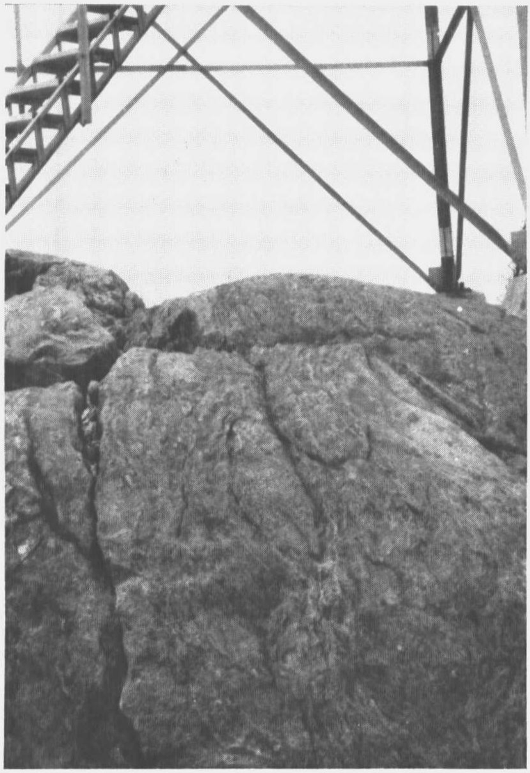

Figure 13. Photograph of the outcrop beneath the observation tower, summit of Burke Mountain. Note the heterogeneous appearance of the granite-infiltrated metamorphic rock. Here the metamorphic rock approaches granite itself in composition and if the process had progressed a bit more, it would be said to be granitized rock. Large lath-like crystals are very prominent in the rocks of this outcrop.

with the increased temperatures produced by this invasion (see cross-sections illustrating the geologic history of the park area, Fig. 17).

The four events which are mentioned in the preceding paragraph took place hundreds of millions of years ago. What has happened in the park since these events? Take a look at Figure 15, which was taken along the road to the summit of Burke Mountain (coming down from the summit, this outcrop is located on your right, midway between the second and third turns in the road). Here the granite exhibits linear scratches or striations which trend about 40 degrees east of south (general direction in

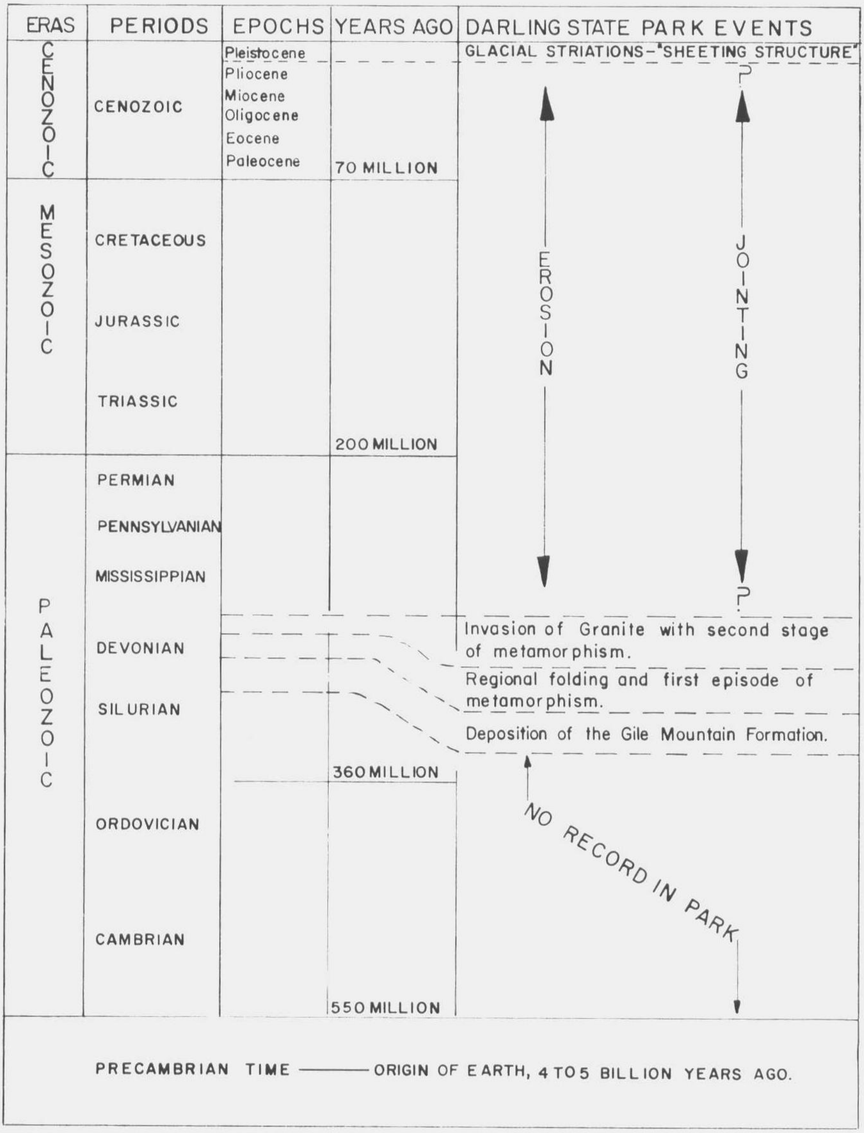

Figure 14. Geologic Time Scale. The main Darling State Park geologic events are noted on the right, opposite the approximate geologic time when each occurred.

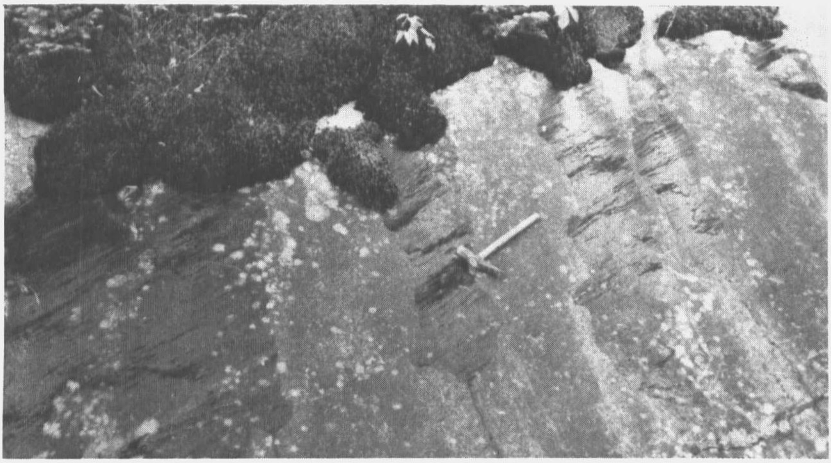

Figure 15. Glacial striations or scratches on outcrop midway between the second and third turns in the road down from the summit area of Burke Mountain. Striations trend about 40 degrees east of south or in approximately the same direction that the hammer handle is pointing. Hammer handle is about one foot long.

Figure 16. Midway between the second and third turns, descending on the Burke Mountain summit road. Metamorphic quartzite and phyllite showing at least two prominent joints. Layers are vertical and parallel to the front joint (one which hammer handle touches). For the more advanced student of geology, note the lineations parallel to the hammer handle and on the front surface. For scale, hammer handle is about one foot long.

which the hammer handle points). Again, just down the road from the midway picnic and camping area, and on your right, striations can be seen. Here they trend about 45 degrees east of south or approximately in the same direction as the first series of striations mentioned. These scratches or striations occur in many places throughout the park, and in most cases their orientation is about the same. What caused these numerous striations?

Since they are still preserved in the rocks for us to see, they must have been formed quite recently, that is, geologically speaking. What can explain these striations and their common orientation? Did you ever hear about the Great Ice Age, or the Pleistocene Epoch? Less than one million years ago, in fact, some 12,000 years ago, an ice sheet many thousands of feet thick rode over Burke Mountain in a southeastward direction. The many boulders frozen to the underside of the ice sheet tended to scratch the rocks over which they rode. The scratches or striations seen in the park rocks were caused by these attached boulders. The ice sheet also plucked and rounded Burke Mountain into the shape it possesses today.

A look at Figure 4 shows still another event which occurred during recent geological time. The prominent smooth fracture-surface seen to slope or dip toward the road is called "sheeting structure" which has its origin in post-glacial time. It is thought by many geologists that these flat surfaces or *joints*[1], which are generally parallel to the ground surface, were formed with the release of the weight of the overlying glacial ice when the glacier retreated northward. So, here we have evidence displayed in the rocks which tells of still another event in the park's history. It should be mentioned here, while still on the subject of joints, that other joints do occur in the park rocks. Figure 16 shows joints which were formed earlier than the "sheeting" and which are not parallel to the surface of the ground. These joints were probably formed as a result of the removal of the overlying rocks through erosion, thus releasing long-continued pressures produced by the weight of the overlying rocks, and movement of the earth's crust. We now have the story of two main episodes in the park's geological history; one took place many millions of years ago, the other within the last 12,000 years. What happened between these two rock-documented episodes?

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[1] A joint is a break in a rock mass which interrupts its physical continuity. A group of more or less parallel joints is known as a joint set.

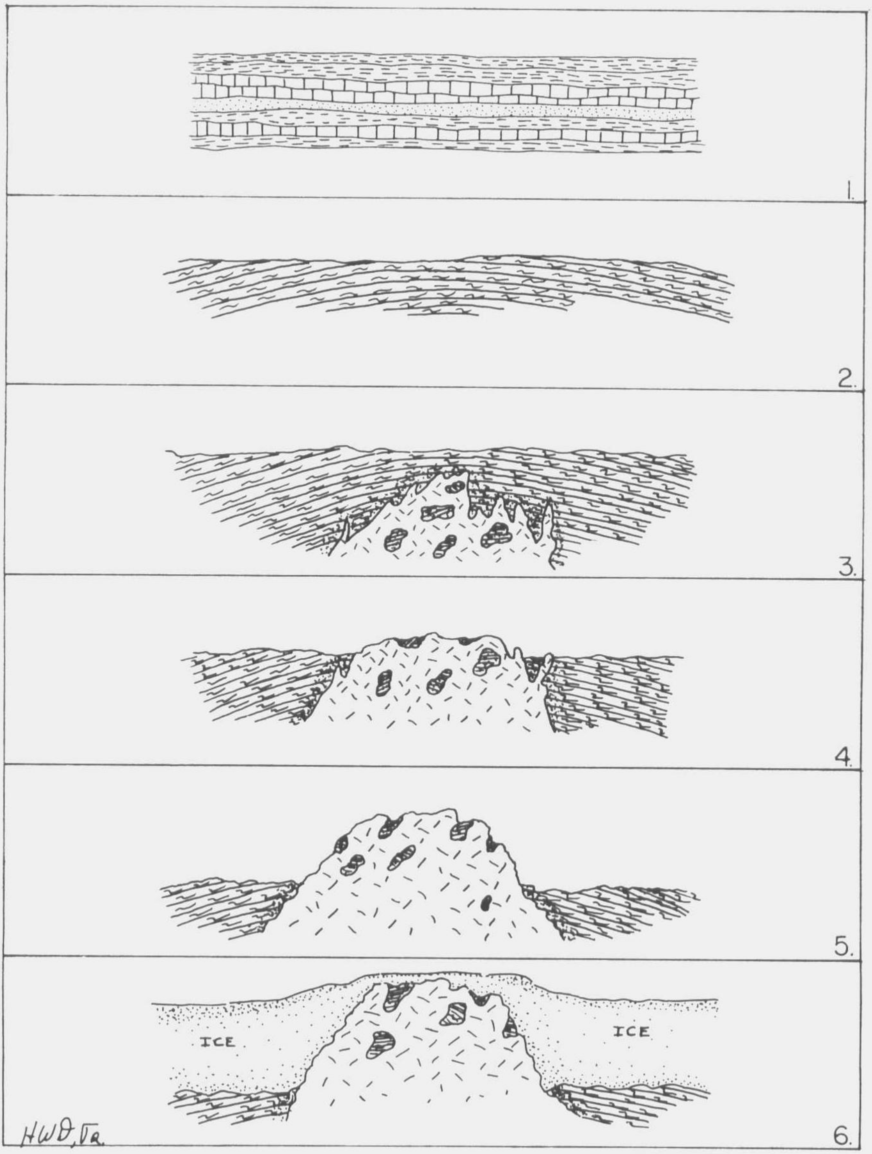

Figure 17. Geologic cross-sections illustrating the geologic history of Darling State park. (For explanation of cross-sections see top of page 19.)

1. Deposition and hardening of the Gile Mountain Formation. At this stage the layers of rock were more or less horizontal.
2. The horizontal and parallel layers of the Gile Mountain Formation were gently and broadly folded and regionally metamorphosed. This is the first stage of metamorphism in the park area.
3. Invasion by granite. This invasion was accompanied by local metamorphism of the invaded rocks. This is the second stage of metamorphism in the park area. Note the inclusions of first stage metamorphosed Gile Mountain rocks in the granite.
4. Many millions of years of erosion took place, the forces of nature finally exposing the granitic rocks at the surface of the earth.
5. Continued erosion caused the metamorphically reenforced Gile Mountain rocks to wear down more slowly than the surrounding weaker rocks. For this reason, these strengthened rocks stand higher than the weaker rocks.
6. Less than one million years ago the glaciers advanced over the park area. The glacial ice plucked and scratched (striated) the underlying rocks as it slowly advanced southward. During the retreat (northward) certain deposits were left. Present-day Burke Mountain is much the same as it was when the glaciers left, but, some added erosion has taken place and, because of uplift, the Mountain stands a bit higher than it did some 10,000 years ago. Some soil, much of which has removed by the glaciers, has since formed on the mountain.

There are no rocks present in the park which were deposited during this interval of time, therefore, no rock record. If no rocks representing this time interval are present, one of two reasons must be responsible. Either the park area was undergoing active erosion (wearing down) during this period, or sediments were deposited during part or all of this time interval and subsequently completely removed by erosion. Most probably, the intervening time found the park area above the depositional environment of the sea, when its rocks were being worn away by the erosional forces of nature. Again, see Figure 17 for a diagrammatic representation of the geologic history of the park.

WHY IS THERE A BURKE MOUNTAIN?

Granite is a very resistant rock, that is, it wears away very slowly under the forces of nature. The granite is worn down more slowly than the metamorphic rocks which it has intruded. The granite has been squeezed between and across the layers (bands) of the metamorphic rocks (previously sedimentary rocks) now found on Burke Mountain. In a very true sense, the granite forms a skeleton framework for the metamorphic rocks of Burke Mountain. In other words, it holds these metamorphic rocks up above the surrounding area of metamorphic rocks.

HIKES TO TAKE

A very interesting hike, both geologically and for nature hunting in general, is the old fire road which begins just above the old CCC camp and the present Bell Gardens. This trail cuts off to the right, if ascending the summit road, and runs completely around the mountain. Shortly after the fire trail intersects the Bear Den Ski Trail, and on the left, granite with obvious drill holes is seen (Fig. 18). Most of the granite used as curb stones, culvert headers, and islands along the park summit road was obtained from these small quarries. A few miles walk along this trail proves quite rewarding to the adventurer; an old lean-to demonstrates what a bear can do while sharpening his claws.

The Devil's Den Trail leads down the east side of Burke Mountain from the observation tower at the summit. This trail is rather poorly marked past a certain point, but if you wish to strike off on your own and see some wonderful country, a hike down this trail with a swing to the north will bring you back to the summit road.

The several ski trails on Burke Mountain are all walkable during the summer, but they will not appear as smooth as when covered with snow, and the trip down will take considerably longer on foot than on "boards." The Bear Den Ski Trail is especially good for geological sightseeing.

NEARBY AREAS TO VISIT

While at Darling State Park a visit to Lake Willoughby is well worth the trip (Figs. 19, 20). A glance at Figure 1 will show you its general location. Once you visit this lake, you might ask "why so beautiful a Lake Willoughby?" There is still some question as to the origin of the lake basin, but a combination of oriented joints and recent glacial movement seems to fit the picture. Deeper and faster weathering along parallel joints together with glacial movement and scour in the same direction as the joints probably dug the elongated trench which, when filled with water, became Lake Willoughby.

It is hoped that this pamphlet has given you the desire to enlarge your knowledge of the science of geology. Geology is all around you wherever you might travel and a knowledge of geology will open new roads even while traveling old ones. Here's luck to you in your travels; try to *see* what you look at.

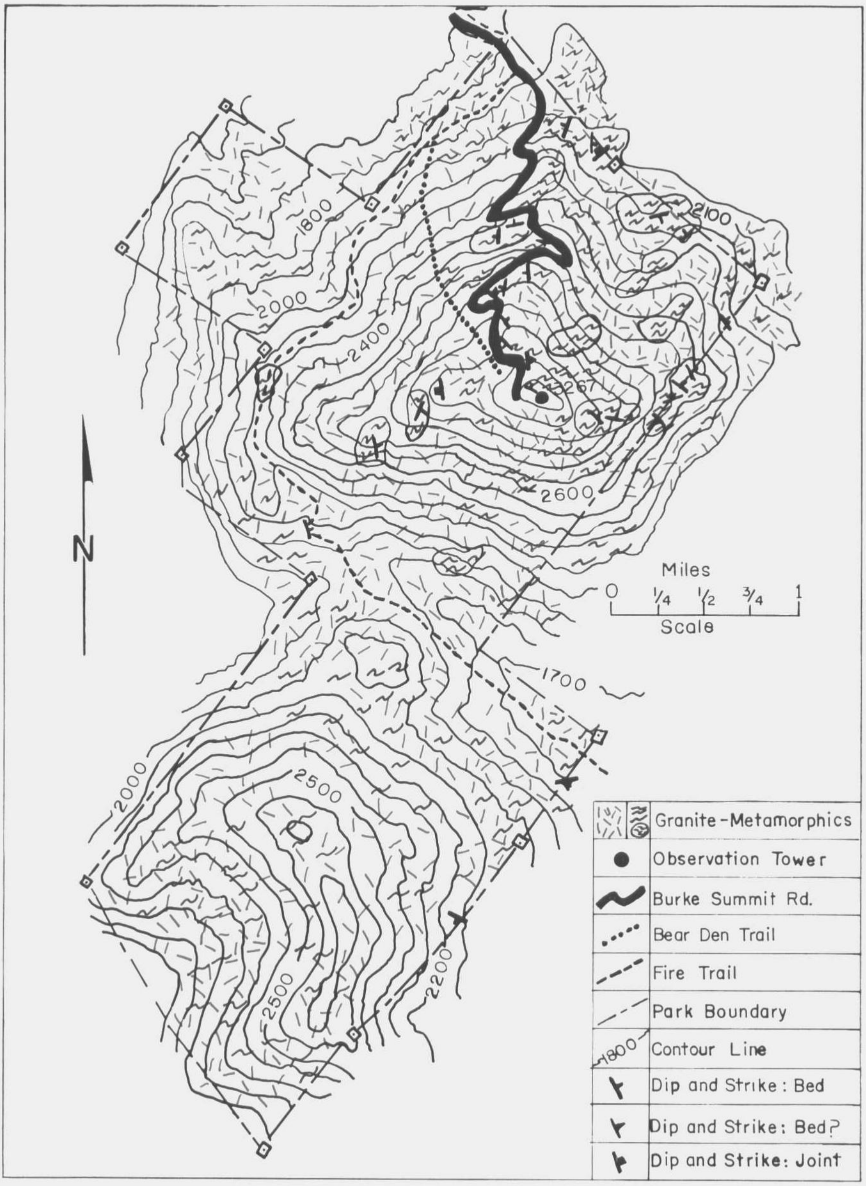

Figure 18. Geologic map of Darling State Park.

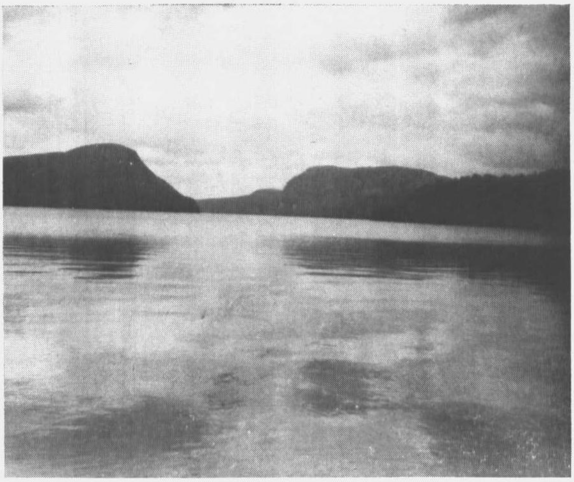

Figure 19. View of Lake Willoughby, seen from its north shore. Mount Pisgah on the left, Mount Hor on the right. The Lake Willoughby trough was produced by preferential erosion of a joint system accentuated by glacial movement and erosion in the same general direction. The lake bottom opposite Mount Pisgah is 210 feet deep.

Figure 20. Northwest view from the Burke Mountain summit road. Picture taken just above the old C.C.C. Camp and the present location of the Bell Gardens. Note Lake Willoughby trough in the distance. Mount Pisgah is on the right and Mount Hor on the left. Lake Willoughby lies in this trough.

SUGGESTED READING

Leet, L. Don and Judson, S., 1965, *Physical Geology*, 3rd Edition, Prentice-Hall, Inc., Englewood Cliffs, New Jersey. This is a starter for the geology student.

Dunbar, C. O., 1959, *Historical Geology*, John Wiley and Sons, New York. Also a beginning book, read after above book.

Dennis, John G., 1956, *The Geology of the Lyndonville Area, Vermont*, Vermont Geological Survey Bulletin 8. This is for the more advanced student and relates the geology of the area adjacent to Burke Mountain and Darling State Park.

Jacobs, Elbridge C., 1941–42, *The Great Ice Age in Vermont*, Report of the State Geologist, Vol. 23; pp. 27–47.

Stewart, David P., 1961, *The Glacial Geology of Vermont*, Vermont Geological Survey, Bulletin No. 19.

Woodland, B. G., 1963, *A Petrographic study of Thermally Metamorphosed Pelitic rocks in the Burke Area, Northeastern Vermont*, American Journal of Science, volume 261, pages 354–375. For the advanced student.

Woodland, B. G., 1965, *The Geology of the Burke Quadrangle, Vermont*, Vermont Geological Survey Bulletin No. 28. This is a comprehensive study of the Burke Mountain area and a must for those interested in Darling State Park.