



THE GEOLOGY
OF
D.A.R. STATE
PARK

MT. PHILO
STATE
FOREST PARK



SAND BAR
STATE PARK

Top: Shoreline at D.A.R. State Park looking south.

Middle: Panoramic view from west overlook on Mt. Philo. Adirondack Mountains in background. Lake Champlain and Champlain Lowlands in foreground.

Bottom: Sand Bar State Park on flat surface of Lamoille River delta. A part of extensive picnic area looking northwest.

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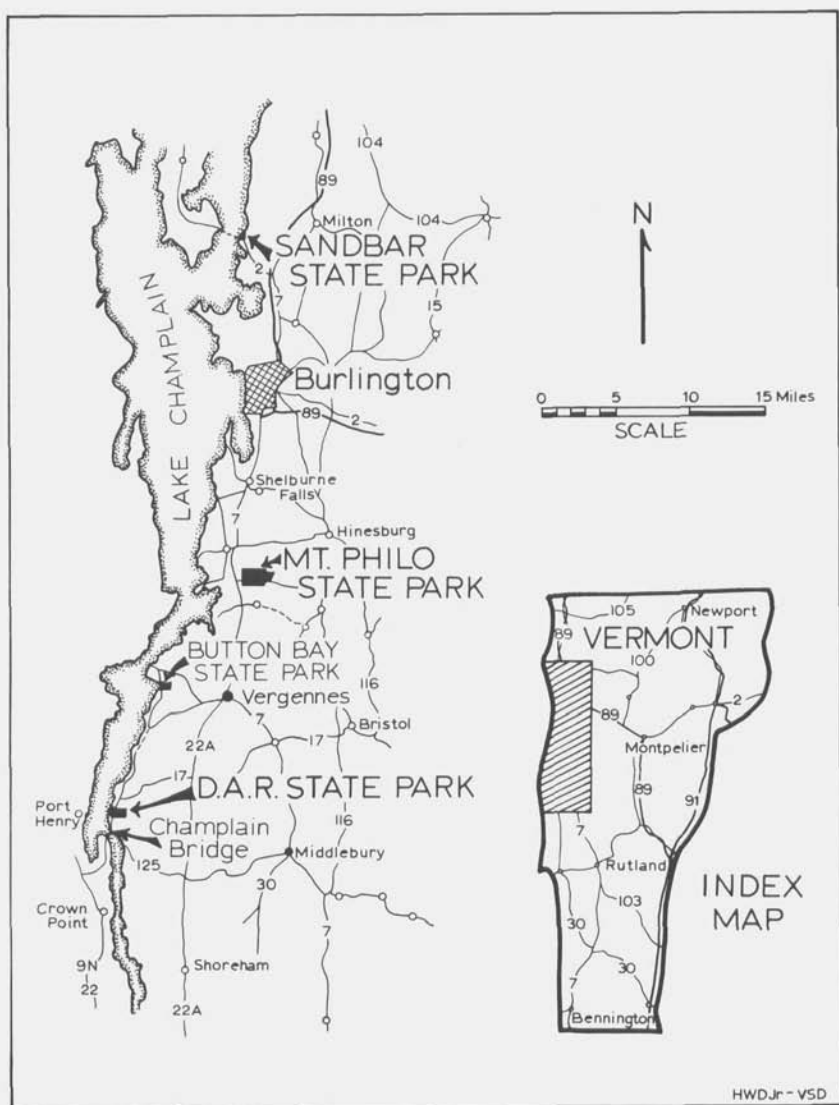


FIG. 1. Index Map.



FIG. 1A. Surface of marine terrace at D.A.R. State Park. Immediately to the left of shelter the land rises to a second terrace.



FIG. 2. View northwest along park beach. Illustrates dip of rocks toward northwest; strike, northeast.

THE GEOLOGY OF D.A.R. STATE PARK

INTRODUCTION

D.A.R. State Park is located in western Vermont on State Highway 17, approximately 1 mile north of Lake Champlain (toll) Bridge (see map, Fig. 1). The park, which fronts on Lake Champlain, contains undeveloped acres on the east side of the Highway. Tenting, leanto camping, picnicking and swimming are adequately provided for during the summer months.

This park, more than most others, not only awakens the visitor's curiosity about the past history of the Earth, but satisfies it. The story of an ancient sea and the life which existed in it can be read from the rocks exposed in D.A.R. State Park. You can read this story for yourselves. This Pamphlet is designed as an aid to a more complete understanding of the observations which you make. "Reading the rock record" is not difficult, but the geologist does have the advantage of possessing a certain trained scientific approach to these problems. This method of approach, the "tools of the trade," will now be passed on to you.

THE GEOLOGY OF THE PARK

The park beach is the ideal place to study the rocks of the park, for here the rocks are best exposed and can be easily examined at close range. The attitude of the rock layers can be seen on a walk down the ramp. By attitude is meant their relationship to an imaginary horizontal plane, which for our purposes is the level of the lake. Are the rock layers parallel to the surface of Lake Champlain or do they slant or dip into it? If the layers were parallel to the surface they would not "dip." The dip of the park strata (layers) is seen in Figure 2. Dip is expressed in the number of degrees *down* from the horizontal and here the dip is toward the west and is measured to be between 8 and 11 degrees. The dip is always measured perpendicular to an imaginary horizontal line on a rock layer called a "strike line." The average "strike," or compass direction of the "strike line" is 22 degrees east of *north*.¹

*Sedimentary rocks*² crop out on the park beach. These were originally lime mud resting on the sea bottom. Under continued pressure from the overlying sediments resulting from continued deposition and burial, the muds were slowly compacted and cemented into the hard limestones and limy shales which we see today. The many layers of rock were then tilted. Tilted layers tell the geologist of giant earth movements which took place since their formation. The story of these movements will be developed later in this pamphlet.

As you look at the tilted rock layers from the ramp, can you tell which layers are the oldest, that is, those first deposited as lime muds on the sea bottom? A basic geologic law, the Law of Superposition, states that if a series of sedimentary layers have *not* been overturned, the oldest is on the bottom and the youngest on top. Assuming that the

¹ A "strike" measurement is expressed as so many degrees east or west of north or south. For a diagram illustrating the dip and strike of a rock layer see Figure 3.

² This is one of the three major rock groups or families. The first consists of igneous rocks, including granite, syenite, and basalt, which were formed by solidification of molten rock-material. The igneous rocks are ancestors of the other two rock families; they form over 90 percent of the outer 10 miles of the Earth's crust. The second family, consisting of sedimentary or layered rocks including shale, sandstone and limestone, is composed of pieces and grains and other materials from all the families of rocks. In addition, sedimentary rocks are formed also from lime secreted by marine plants and animals or chemically precipitated from sea water, or by the accumulations of shells. The third family, metamorphic rocks, including gneiss, schist, slate and marble, were igneous or sedimentary rocks that have been subjected to heat and pressure in the presence of mineral-forming solutions. Metamorphic rocks generally look different from the rocks from which they formed, because the original minerals of the rock have been changed and reoriented.

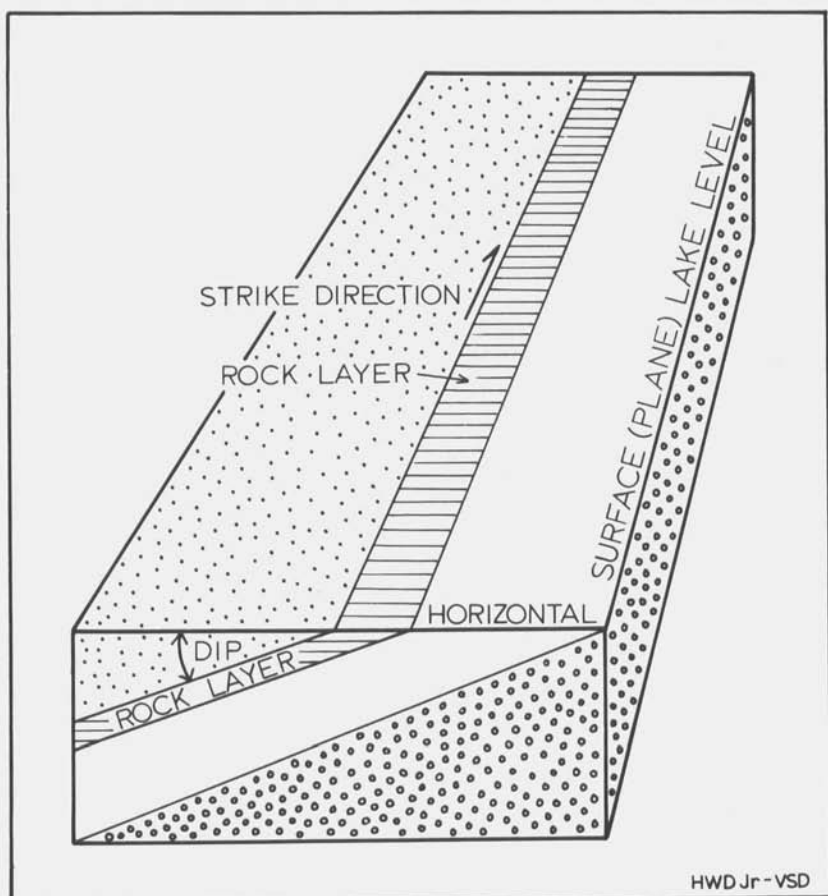


FIG. 3. Block diagram illustrating *dip* and *strike*.

layers which you are looking at have not been overturned, those on your left (south) are the oldest and those on your right (north) the youngest. Looking at Figure 2, taken from the ramp-bottom toward the north, the layers in the foreground are older than those in the distance. Let us take a close look at the individual layers of rock and delve deeper into the story that they have to tell.

Search the top of a few layers and you will notice many shell and other animal impressions. Do they represent animals which lived hundreds of millions of years ago or were they washed onto these rocks from present-day Lake Champlain? If you try to make a collection of the shell impressions you will see that they are a part of the rock and therefore must represent remains of animals that were buried in the

ancient lime muds. These preserved *remains*³ are called fossils. The geologist who specializes in the study of fossils is called a *paleontologist*. You may ask, "What can fossils tell me about the past?" In the first place, fossils tell us at what time in the past the sediments in which they are found were deposited. In this way, the *relative age*⁴ of the rock layers found in the Park can be learned. Secondly, the environment or surroundings in which these ancient sediments were deposited can be reconstructed from the types of fossils contained within them. Certain animals living today are quite similar to those in the Park rocks and their environment in today's sea can be used to reconstruct the environment of animals which lived in the past. The characteristics of the rocks and their relation to adjacent rocks are considered in any reconstruction of past environment. In the third place, the study of fossils is a mainstay of the theory of evolution. That is to say, changes in fossil forms collected from groups of successively younger rock layers document the theory that life has evolved little by little since its first appearance on Earth. Finally, it should be mentioned that some animals found as fossils are not living today and have not lived, to the best of our knowledge, for millions of years. Why did these forms of life die out? What set of circumstances led to their extinction? The answers to these questions are not easy to find and they are highly speculative.

³The actual remains are usually not preserved in their original state but are represented by molds and casts. Picture an ancient sea. The sea bottom mud slowly hardens around a shell. Water then seeps through the hardened mud and dissolves the shell leaving an open space where the shell once was. This open space is a mold. If the mold is filled a copy of the original shell is formed. This is called a cast.

⁴The relative rather than the absolute age of the rocks can be determined from a study of their fossil content. These fossils are compared with collections from various places in the world where the standard geologic time scale assigns them a place (see Fig. 4). The Park rocks were deposited during the Ordovician Period. How is a standard geologic time scale put together? Several geologists first worked out the sequences of rocks according to the Law of Superposition in Great Britain and neighboring parts of Europe. When systematic collections of fossils were made from these layers and arranged according to age it was found that certain fossils occurring in rocks in distant areas were identical and occupied the same relative age position. These fossils were considered to be of the same relative age. Fossils found in the Park can be compared with these reference fossils and a relative geologic age can be assigned to them. Absolute ages can be determined in some cases by the use of rates of decay of radioactive elements and in general these ages agree with the relative ages derived through the use of fossils.

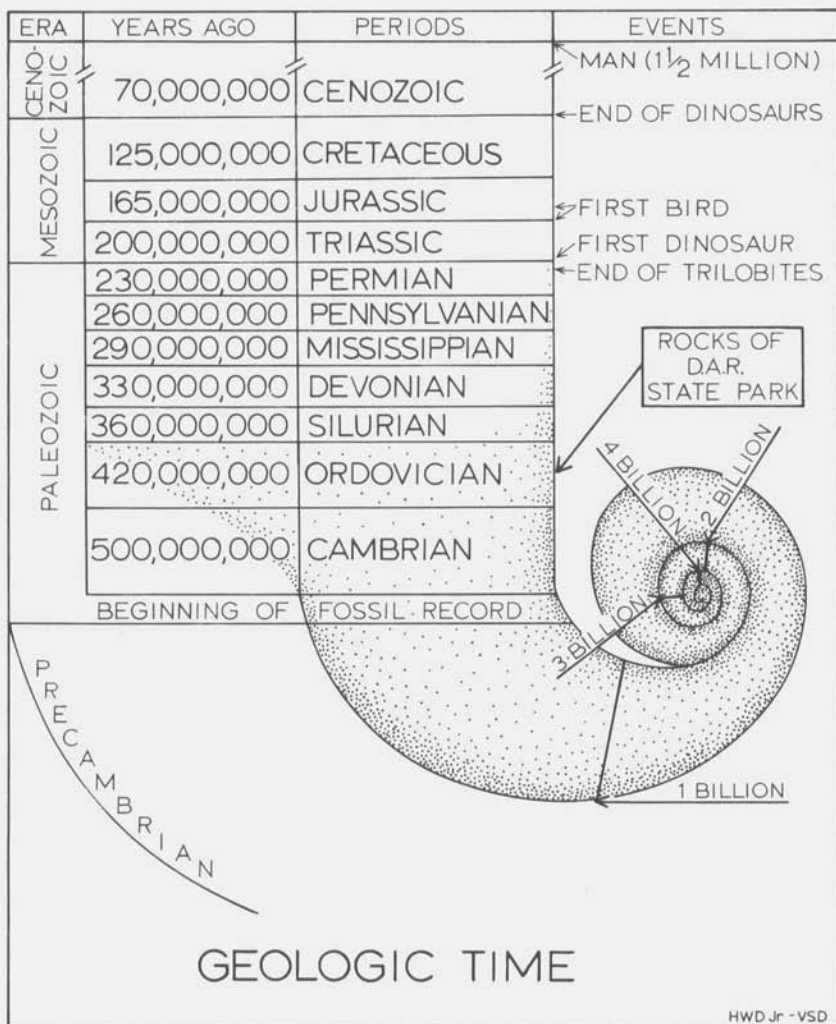


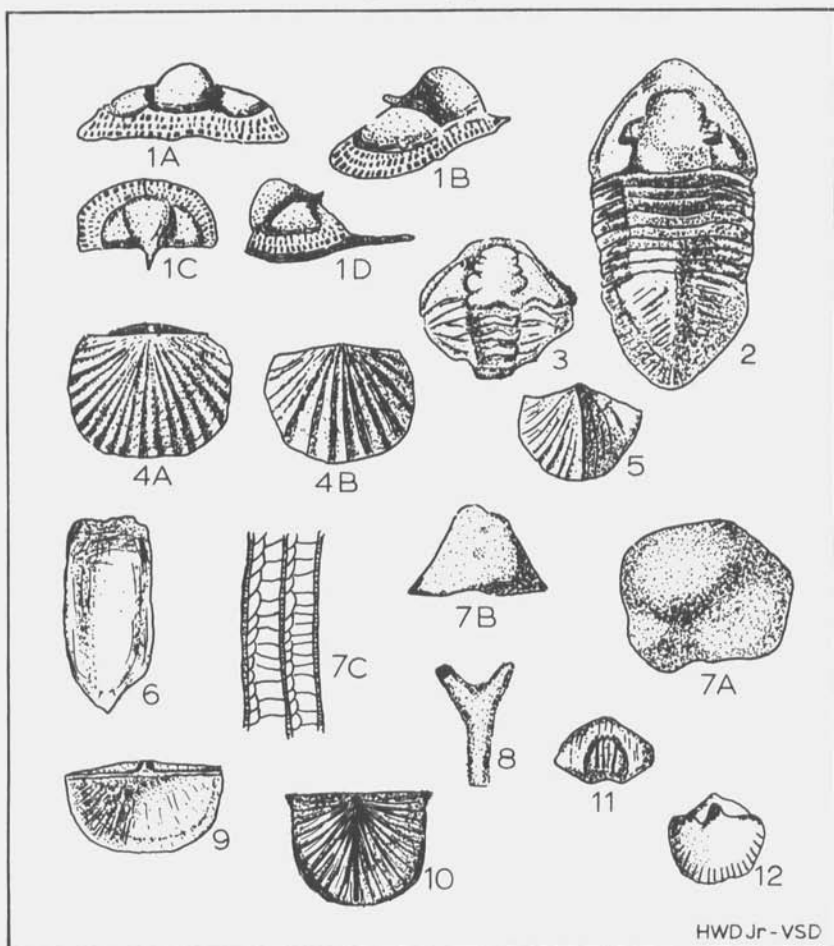
FIG. 4. Standard Geologic Time Scale.

THE FOSSILS

Many groups of invertebrates are represented in the fossils of D.A.R. State Park. Plate 1 will help you to identify these fossils. The name, phylum (major group) and age of each fossil are provided in the explanation of the plate. The following paragraphs describe each phylum represented in the Park rocks.

Arthropods. D.A.R. State Park rocks contain trilobites with the following imposing names: (*Cryptolithus tessellatus* (crip-toe-LITH-us tessell-AH-tus³), *Isotelus gigas* (ice-so-TELL-us GIG-us) and *Flexicalymene senaria* (flex-eye-cal-ah-Mean-ee sen-AREA). These fossils are figured on Plate 1, 1-A, B, C, D; 2; 3. Within the Park *Cryptolithus tessellatus* is very common wherever fossils occur. Generally only the cephalon or head portion of this trilobite is preserved. The cephalon is

PLATE 1. Typical fossils found in the Glens Falls Limestone. Explanation on opposite page.



easily recognized by three concentric rows of pits arranged around the brim. *Cryptolithus* is an excellent *index fossil*⁵ for the Park rocks. The

⁵ The capitalized syllable is the accented syllable.

⁶ An index fossil is used to date the rocks in which it occurs. A good index fossil must be abundant, widespread and easily recognized. Its vertical range is restricted to a small number of rock layers, therefore the geological span of life of a good index fossil is usually short.

Explanation for Plate 1

(all drawings are X1 unless otherwise indicated)

- 1-A. *Cryptolithus tessellatus*, ARTHROPOD (Trilobite), Middle Ordovician (Trenton Stage). Front view of the Cephalon or head. (X2)
- 1-B. *Cryptolithus tessellatus*, ARTHROPOD (Trilobite), Middle Ordovician (Trenton Stage). Oblique front-lateral view of the Cephalon. (X2)
- 1-C. *Cryptolithus tessellatus*, ARTHROPOD (Trilobite), Middle Ordovician (Trenton Stage). Top view of the Cephalon. (X2)
- 1-D. *Cryptolithus tessellatus*, ARTHROPOD (Trilobite), Middle Ordovician (Trenton Stage). Side view of the Cephalon. (X2)
2. *Isotelus gigas*, ARTHROPOD (Trilobite), Middle Ordovician. Top view of specimen.
3. *Flexicalymene*, ARTHROPOD (Trilobite), Ordovician to Silurian. Top view of an enrolled specimen.
- 4-A. *Dinorthis pectinella*, BRACHIOPOD, Middle Ordovician (Trenton Stage). Exterior view of the brachial valve.
- 4-B. *Dinorthis pectinella*, BRACHIOPOD, Middle Ordovician (Trenton Stage). Exterior view of the pedicle valve.
5. *Reuschella edsoni*, BRACHIOPOD, Middle Ordovician. Exterior view of the pedicle valve.
6. *Lingula*, BRACHIOPOD, Ordovician to Recent.
- 7-A. *Prasopora*, BRYOZOAN, Ordovician. Top view. (X0.5)
- 7-B. *Prasopora*, BRYOZOAN, Ordovician. Side view. (X0.5)
- 7-C. *Prasopora*, BRYOZOAN, Ordovician. Vertical thin section showing the nature and growth of part of a bryozoan colony. (X18)
8. BRYOZOAN, "twig-like" type, Ordovician to Devonian.
9. *Sowerbyella*, BRACHIOPOD, Middle and Upper Ordovician. Exterior view of brachial valve. (X2)
10. *Rafinesquina*, BRACHIOPOD, Middle and Upper Ordovician. Exterior view of the pedicle valve.
11. *Platystrophia trentonensis*, BRACHIOPOD, Middle Ordovician (Trenton Stage). Anterior or front view.
12. *Hesperorthis tricenaria*, BRACHIOPOD, Middle Ordovician (Black River and Trenton Stage). Interior view of the pedicle valve.



FIG. 5. The surface of a layer or bed of Glens Falls Limestone. Pen points to a colonial Bryozoan *Prasopora* "head." These "heads" are very common just south or to your left if walking down the ramp.

arthropod phylum is characterized by animals with jointed legs, segmented bodies and a jointed outer armour of *chitin*.⁷ For examples, the crabs, lobsters, spiders, scorpions and insects are arthropods. Trilobites appear early in the fossil record but they did not survive beyond the Paleozoic Era.

Brachiopods. Brachiopods are abundant in the Park rocks (see Plate 1, 4A, B; 5; 6; 9; 10; 11; 12). These invertebrates are small marine animals which generally live in waters no deeper than 600 feet. The two valves of their shell are joined at the back (posterior) end of the body along a hingeline of interlocking teeth and sockets. The shell of the brachiopod is opened or shut by muscles attached to the inside of each valve. Brachiopods are found in the oldest rocks containing definite and abundant fossils. Brachiopods are still living today.

⁷ Chitin is a colorless horny substance similar to the material which makes up fingernails.

Bryozoans. Bryozoans or "moss animals" are very small marine animals which live in colonies. The bryozoans construct their mutual home or colony of lime which is commonly preserved for the fossil record. Large colonies of the fossil *Prasopora* (prah-sop-OR-ah) are commonly seen on the weathered surfaces of many of the rock layers in the Park (see Plate 1; 7A, B, C; 8 and Figure 5). Individuals of one genus common here, can be recognized by their chocolate drop shapes. Bryozoans first appear in lower Paleozoic rocks and are still living today in clear well-circulated shallow to deep marine water. Considering all of the fossils found in the Park rocks, the past environment is thought to have been a relatively shallow and warm sea.

FIG. 6. This photograph shows the typical thickness of the Glens Falls Limestone beds in the Park area. Note the massive nature of the limestone bed. The 5-inch pen in the center of the picture is for scale.



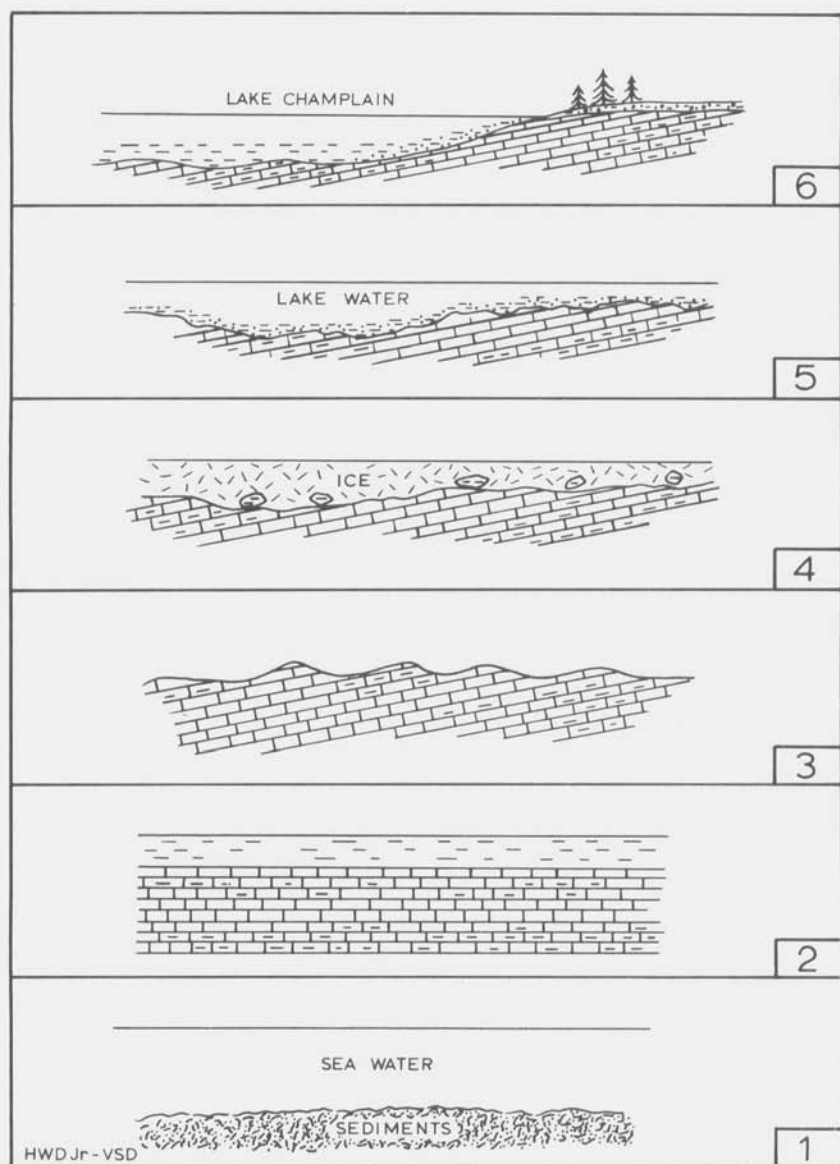


FIG. 7. Sections illustrating the geologic history of D.A.R. State Park.

THE ROCKS AND THEIR HISTORY

Approximately 75 vertical feet of the Glens Falls Limestone occur along the Park beach. The rocks are *black*^s or blue-black on a fresh surface, gray or grayish-white on a surface which has been exposed to

Explanation for Figure 7

1. Glens Falls and younger sediments were deposited on the Ordovician sea floor.
 2. Sediments hardened into Glens Falls Limestone and younger rocks.
 3. Rocks were tilted during the late Ordovician Taconic Disturbance and the younger rocks and part of the Glens Falls Limestone were removed by erosion. Erosion continued for some 350 million years.
 4. During the Pleistocene Epoch, which started some 1 million years ago, glacial ice overrode the beveled layers of the Glens Falls Limestone. Hard rocks frozen to the underside of the glacial ice produced scratches or striations in the exposed layers of the Glens Falls Limestone.
 5. Glacial lakes Vermont form as the glaciers retreat northward. In between the glacial lakes Vermont and present Lake Champlain, marine waters flooded the valley and formed an arm of the Atlantic Ocean. Clay, silt, sand and gravel were deposited on glaciated Glens Falls Limestone (Fig. 1a).
 6. Present-day Lake Champlain formed when relatively greater uplift in the north dammed the Champlain valley.
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the weather. Most of the individual beds or layers are 5 to 7 inches thick (see Fig. 6) with the thickest being just under 5 feet. The beds are separated by thin "partings" of rock, many of which contain abundant fossils. The beds consist of massive limestone, shaly limestone or limy shale; the partings are generally limy shale or shaly limestone.

The rock types found in the Park lead to certain conclusions regarding the environment which existed during their formation. Most of the rocks are composed of lime (limestone) or a mixture of lime, fine sand and mud (limy shale or shaly limestone). The mineral pyrite (FeS_2) is present in many of the rocks. Most of the rocks contain abundant amounts of organic matter. The sediments which make up these rocks were carried to the Ordovician sea by streams flowing primarily from the east. As these streams entered the quiet sea waters the larger followed by the smaller particles began to settle to the bottom. Lime was slowly precipitated from the warm sea water and pyrite formed under stagnant bottom conditions. Organic material accumulated on the bottom and intermixed with the sediments. The poor life-sustaining qualities of much of the bottom waters prevented rapid or complete bacterial action on the accumulated debris and the sediments remained "organic black" in color. Slowly, as the weight of overlying sediments increased, the lower layers were compacted and cemented into the hard limestone and shale which we see today.

^b The black color is due to an abundance of finely divided organic (plant and animal) material within the rock.

The tilt or dip of the Park rocks resulted from subsequent earth movements. When were these rocks tilted? From the evidence presented in the Park all that can be said is that they were tilted sometime after hardening and before the Pleistocene glaciers overrode the region during quite recent times (at least 10,000 years ago). Thus, there are some 350 million years of rock record missing in the Park. Can we tell what happened during these "missing" years through a study of only the Park rocks? The answer to this question is partially "yes," but we must look to the work done in adjacent areas for a more complete story.

The mere fact that there are no rocks representing these millions of years tells us that the sea had withdrawn from the area and that the previously deposited rocks were undergoing erosion during most or all of the missing rock gap (the time not represented by rocks). Information from adjacent areas, however, tells us that the Park rocks were tilted during the Taconic Disturbance which occurred during the final stages of the Ordovician Period. East of the Park, Taconic earth movements are more dramatically exhibited. The rocks are tilted even more than in the Park and are broken by faults or cracks in the earth's crust. Some of these faults, known as thrust faults, positioned giant slabs of rock far from their original locations and placed older on top of younger rocks.

Following these earth movements there occurred a long period of erosion. Many of the rock layers were stripped off and carried piece by piece by rivers to other regions. Hundreds of millions of years passed and then, less than one million years ago the great glacial ice sheets slowly advanced southward over the Park area. Pieces of hard rock frozen to the underside of the ice sheets scratched and scraped the rock surfaces leaving these scratches or striations for us to see today (near the northern end of the Park beach these striations are common on the outcropping rock). The retreating glaciers created a series of lakes in which clay, silt, sand and gravel were deposited. Today these sediments are found resting on the beveled edges of the Park rocks.

Present-day Lake Champlain owes its existence to a general uplift of the earth's surface, greater in the north than in the south, perhaps due to the removal of the heavy glacial ice sheet from the area. The greater uplift in the north dammed the Champlain valley which slowly filled with water. For a diagrammatic picture of the geologic history of D.A.R. State Park, see Figure 7.

SUGGESTED READING

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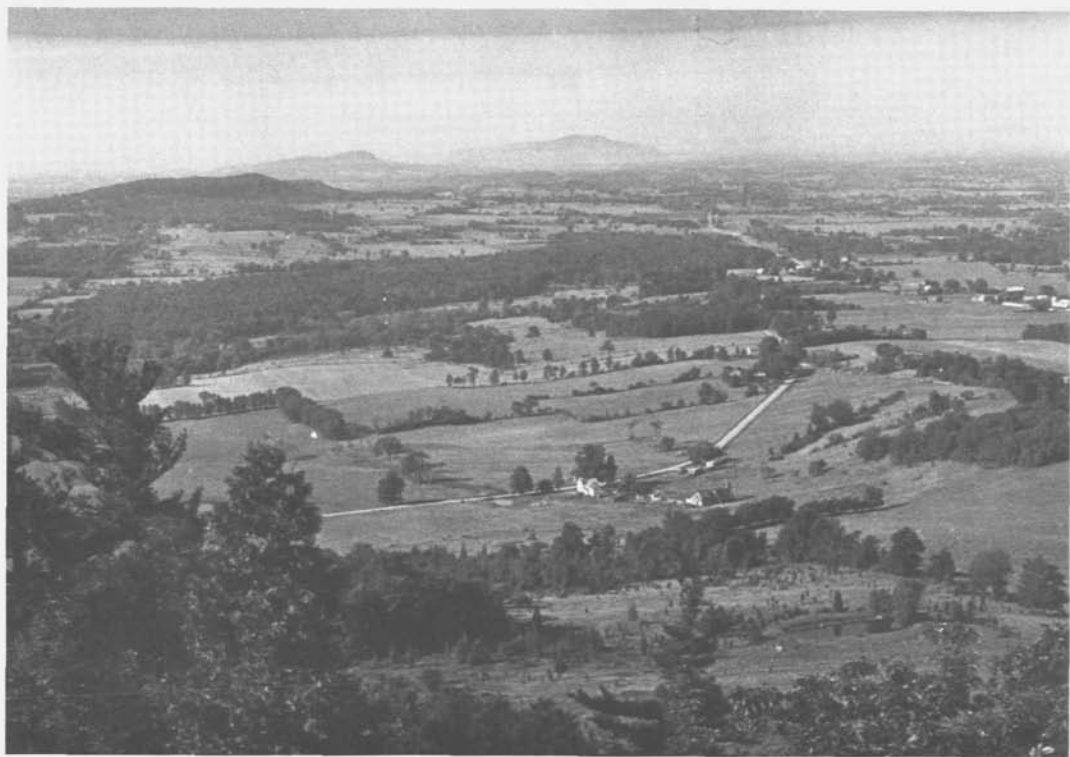


FIG. 7A. View south from Mt. Philo Overlook. Shellhouse and Buck mountains in the distance.



FIG. 8. View looking north at western Overlook in the summit area of Mt. Philo. Note Monkton Quartzite layers which are dipping toward the northeast.

THE GEOLOGY OF MT. PHILO STATE FOREST PARK INTRODUCTION

Mt. Philo State Forest Park, consisting of some 160 acres, is located about 15 miles south of Burlington and 1 mile east of U.S. Route 7 (see map, Fig. 1). This park is noted for its scenic views, especially of the broad Champlain Valley and the rugged Adirondack Mountains beyond (see cover picture and Fig. 7a). From a 46-foot high observation tower a panoramic view is easily gained. Picnic facilities, including stone fireplaces, fuel wood, piped spring water and sanitary facilities are available. A large rustic lodge with porch and portico provides protection from sudden showers. Tenting on the top of Mt. Philo is not allowed.

THE GEOLOGY OF THE PARK *The Rocks*

The rocks of the Park which will probably first attract your attention are those exposed at the main western Overlook which is located in the summit area. This Overlook is found just northwest of the Park lodge (see Fig. 8). These rocks are light to dark red or purplish in color, are

primarily *quartzite with minor dolostone*¹ dipping approximately 35 degrees to the northeast (for an explanation of dip, see Fig. 3 and text of D.A.R. State Park, page 6) and striking toward the northwest (for an explanation of strike, see immediately preceding reference).

A closer look at this Monkton Quartzite outcrop shows that it is made up of several layers of rock (see Fig. 8). These layers, strata, or beds are not all of the same thickness, but are generally from 1 inch to 1 foot thick. If an individual layer is traced over the extent of the outcrop, it is found that its thickness remains about the same throughout. It is therefore said to be regularly bedded. Thin laminations of dark red shale are abundant and commonly define individual layers. A magnified look at a specimen of this quartzite, under a hand lens, shows that it is composed of fine to coarse fragments of quartz. Some of these fragments have rounded edges, but others are quite angular. The spaces between the fragments are filled with silica (quartz). Therefore, the rock is said to possess a silica cement.

In many places where this Monkton Quartzite has been studied, features attesting to a shallow water origin have been found. Among these features are mud cracks, which form under alternating wet and dry conditions; ripple marks, which are usually found only on shallow water bottoms; and cross-bedding, which commonly forms in shallow water areas.

The Monkton Quartzite underlies approximately a third of the Park (see Geologic map, Fig. 9). This quartzite is between 250 and 300 feet thick on Mt. Philo; however, the lower 50 feet or so consist predominantly of white quartzite interbedded with dolostone. The age of the Monkton Quartzite is considered to be Lower Cambrian (see Standard Geologic Time Scale, Fig. 4).

A second type of rock is exposed in the south bank of the exit road approximately 0.7 miles from the summit area. This is the *black*² to

¹ A quartzite is either a metamorphic or sedimentary rock consisting of fragments of the mineral quartz (SiO_2) which are cemented together by silica (quartz). The combination of quartz fragments held together by quartz cement creates a very hard rock which oftentimes will break across the fragments rather than around them. The quartzites of the Park area are primarily of a sedimentary origin. For a description of the three major rock groups, of which the sedimentary and metamorphic groups are two, see footnote, D.A.R. State Park, page 6. A dolostone is a sedimentary rock composed of fragmental, concretionary, or precipitated dolomite (a mineral of chemical composition, $\text{CaMg}(\text{CO}_3)_2$) of organic or inorganic origin.

² The black color is due to the inclusion of finely disseminated carbonaceous material (animal and plant remains) within the rock.

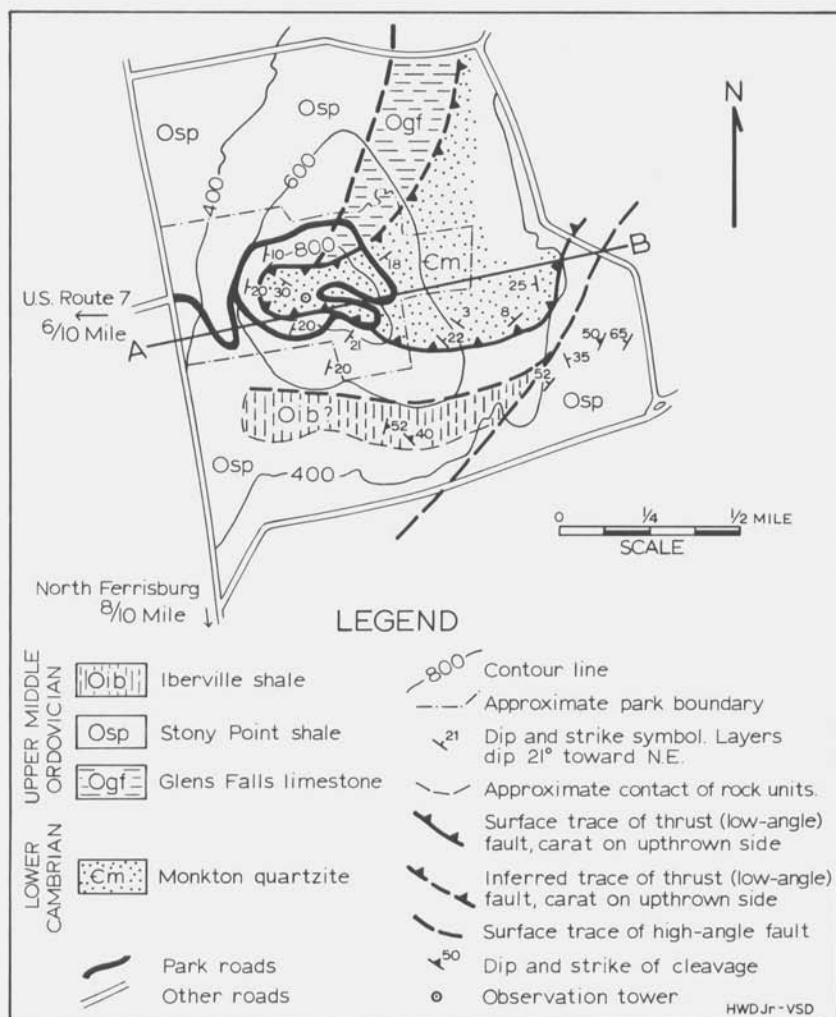


FIG. 9. Geologic Map of Mt. Philo State Forest Park (after C. W. Welby, 1961). Because Ogf and Oib were not definitely identified by the author of this pamphlet and for the sake of simplicity, these rock units have not been discussed in the text of the pamphlet. Some dip and strike symbols have been added to Welby's original map.

bluish-black Stony Point Shale (see Fig. 10), which underlies the Monkton quartzite. This shale, or hardened limy mud, is thinbedded and shows abundant *cleavage*³ parallel to the layers or beds. At this outcrop the

³ This splitting or cleavage was produced after the layers had hardened into rock. The cleavage planes were produced when the rocks were subjected to pressures too great to withstand. In some places these cleavage planes do not parallel the layers.



FIG. 10. View looking south of cut-bank, south side of exit road, about 0.7 miles down from the summit parking area. Here the layers dip 20 to 40 degrees toward the southeast and strike in a northeast direction. Note that the shale is thin-bedded and contains numerous cleavage planes parallel to the layering. The handle of the geologic pick is about 1 foot long.

layers strike to the northeast and dip 20 to 40 degrees toward the southeast. The dip and strike of the Monkton Quartzite (see above) is not similar to the dip and strike of the underlying Stony Point Shale. It follows, that the layers of the Monkton Quartzite are not parallel to those of the Stony Point Shale.

The fact that these two units are not parallel could mean that the Stony Point Shale was deposited, hardened into rock, uplifted, folded and eroded, all prior to the deposition of the Monkton Quartzite. But, first, what is the age of the underlying Stony Point Shale? If the story is as listed above, the Stony Point Shale *must be older*⁴ than the overlying Monkton Quartzite. From the fossil animal remains found in the Stony Point Shale, geologists have dated the Stony Point Shale as upper middle Ordovician (see Standard Geologic Time Scale, Fig. 4). And so, here we have older rocks (Lower Cambrian) resting on younger (upper middle Ordovician).

⁴ According to the basic geologic law, the Law of Superposition, younger rocks (those deposited last) are always found resting on older rocks (those deposited before the younger). The only time that this is not true is when either breaks (faults) or folds in the earth's crust place the layers in an inverted order, as in the case here cited.

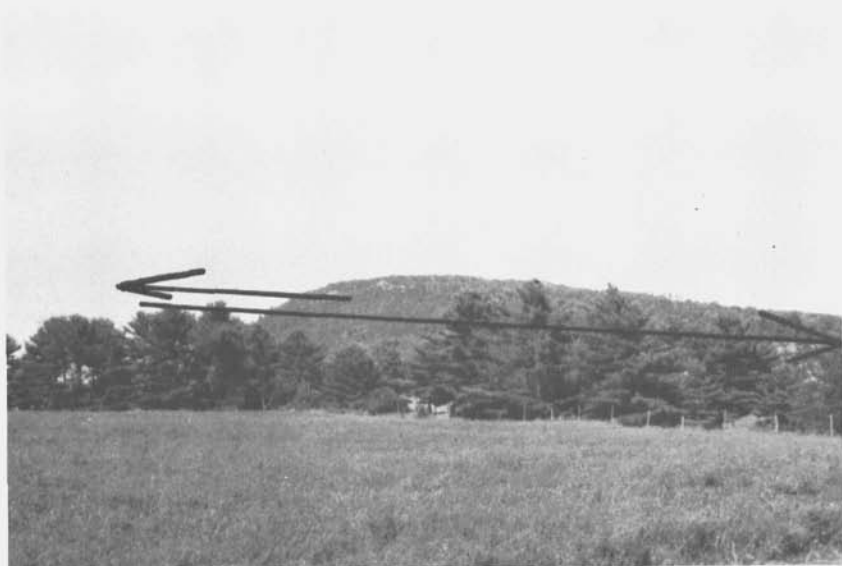


FIG. 11. View of Mt. Philo, looking toward the northeast. The black line approximates the position of the thrust fault. The Monkton Quartzite, which is above the line, was thrust westward over the Stony Point Shale (note the arrow). Line A-B, Fig. 9, approximates the section.

Structural Geology

How can we explain this inverted order of rock units? The geologic evidence presented in the Park does not indicate that folding of the rocks was responsible. From the surface distribution of the two rock types (see Geologic map, Fig. 9) and the nature of their contact with each other, a fault relation is envisioned, in which older rocks were thrust westward over the younger and thus to rest upon them (see Fig. 11).

We know the ages of both rock units involved in this thrust fault but what is the geologic age of the actual thrust movement? Both the Stony Point Shale and the Monkton Quartzite were hard rock when this thrusting took place, therefore, the thrusting would have occurred later than upper middle Ordovician time, but before late Silurian time. Two other fault systems are recognized in or near the Park (see Geologic map, Fig. 9). They are *high angle*⁵ faults which formed later than the thrust fault, but still preceding late Silurian time.

⁵The fault plane of a high-angle fault forms a large angle (generally from 30 to 90 degrees) at its intersection with an imaginary horizontal plane. The plane of a thrust fault, or low-angle fault, forms a small angle (generally less than 30 degrees) at its intersection with an imaginary horizontal plane.

The Iberville Shale (this is not described in the section on "The Rocks," but is seen on the Geologic map, Fig. 9), which is questionably exposed on the south side of Mt. Philo, would be the youngest rock found in the Park. This shale is about 390 million years old. The most recent faulting took place no later than about 340 million years ago. There are no rocks in the Park which give us any positive geological clues to the Park's history from the last episode of faulting to the Pleistocene glaciers less than 1 million years ago. However, the fact that rocks representing this interval of time are not present does indicate that the area was above water during most of these 339 million years (this number of years is very approximate). If any rocks were deposited during this "rock-gap" period, they have since been washed away.

The Pleistocene Deposits

Beginning between 60,000 and 70,000 years ago two glacial advances and retreats took place in the Champlain Valley. This was during the most recent or the Wisconsin Stage of the Pleistocene Epoch. Scratches or striations were cut into the overridden rock by rock debris carried along at the base of the ice as it advanced (note the arrow in ("br") area at overlook in Fig. 12; this shows striation orientation, therefore, the direction in which the glacier advanced). The glacial sediments found on Mt. Philo were deposited during the final retreat of glacial ice, which took place from 11,000 to 12,000 years ago. Most of the Park is covered with these glacial deposits and by more recent soils.

Most of the glacial deposits found on Mt. Philo are classified as glacial *till*⁶ (see Map of Glacial Deposits, Fig. 12), but other glacial deposits are also mapped. A *kame*⁷ (designated "K" in Fig. 12) is a glacial feature found in the southern part of the Park.

With the slow retreat of the glacial ice front from the Mt. Philo region, deposits were left which indicate that a series of lakes formed in front of the wasting ice mass. There is also evidence just west of Mt. Philo (see "bgm" in Fig. 12) which indicates that just prior to the formation of present-day Lake Champlain, an arm of the Atlantic Ocean

⁶This is the Burlington till (Stewart, 1961) and was deposited from the Burlington Ice Lobe during its period of wasting. The till is a hodge-podge mixture of clay, sand and pebbles and is usually brown in color.

⁷A kame is a mound or ridge of poorly sorted (sometimes well-sorted, that is, made up of all the same sized particles) water deposited materials. Most kames are ice-contact features; that is to say, the materials which make up the kame were deposited in contact with a glacial ice surface. The Mt. Philo kame may be the filling of an ice-free area during the final melting of the glacial ice.

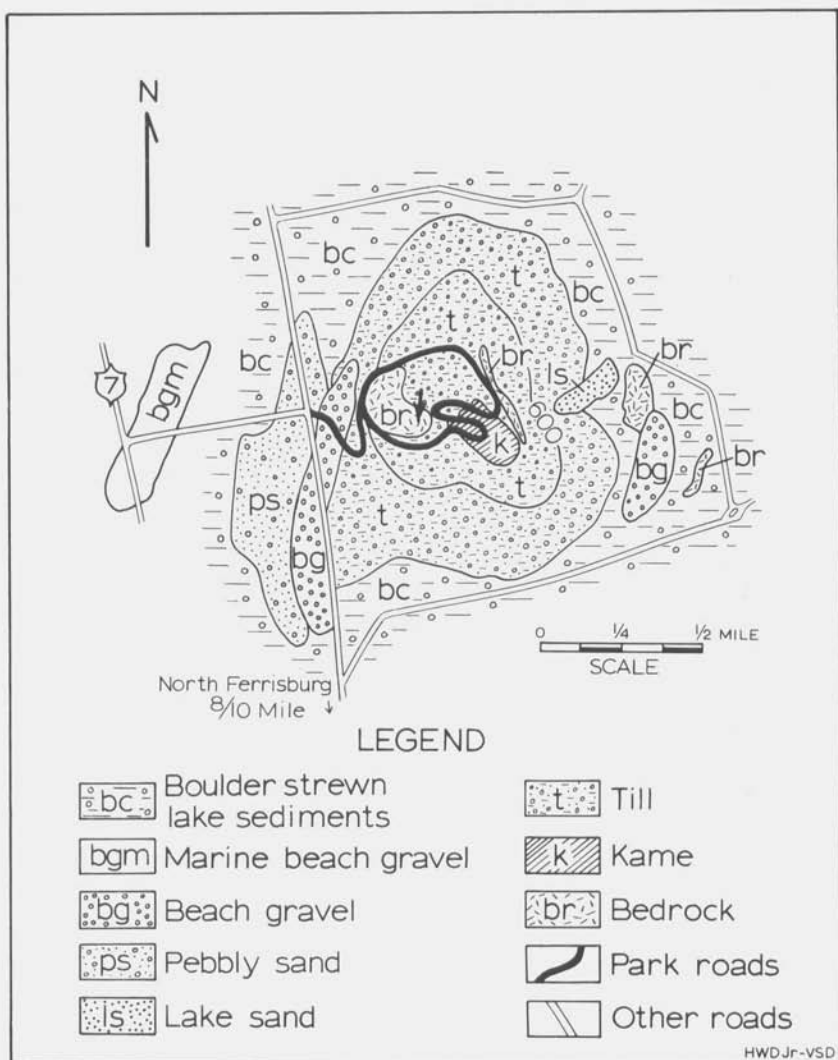


FIG. 12. Map of the Pleistocene deposits of Mt. Philo State Forest Park (after D. P. Stewart, 1961).

reached into the Champlain Valley from the St. Lawrence River region. Lake-beach gravels (designated "bg" in Fig. 12) are found on both the east and west slopes of Mt. Philo. The interesting fact about these beach gravels is that they occur almost 500 feet above the present-day level of Lake Champlain. Lake sand (designated "ls" in Fig. 12) is found some 450 feet above Lake Champlain. This means that during a

good portion of its recent geologic history, Mt. Philo was an island surrounded by lake water. From the distribution of marine beach gravel (designated "bgm" in Fig. 12), it appears that the invasion of sea water from the St. Lawrence region did not isolate Mt. Philo as an island.

The complete story of the lake series is still not known, but, for the most up-to-date treatment of this subject see D. P. Stewart's paper entitled "The glacial geology of Vermont": Vermont Geological Survey Bulletin 19 (1961). Suggested also is C. H. Chapman's article entitled "Late glacial and postglacial history of the Champlain valley" in the American Journal of Science, 5th series, volume 34, pages 89-124 (1937). Looking out over the Champlain lowlands from the summit of Mt. Philo leaves little doubt in the visitor's mind as to the prior existence of lakes which surrounded Mt. Philo in the not too distant past (see Cover picture).

Summary of the Geologic History

During lower Cambrian time, the Monkton Quartzite and dolostone followed by the Winooski Dolostone (not seen in the Park) were deposited east of Mt. Philo State Forest Park. During late Cambrian and early Ordovician, thick dolostones were deposited from the sea water which covered the Mt. Philo area (not seen at the surface in the Park).

During middle Ordovician time, a series of shale, calcareous shale and limestone was deposited from the sea water. Then, sometime between the beginning of late Ordovician and late Silurian time, the eastern lower Cambrian sequence was thrust westward over the middle Ordovician rocks. This low-angle thrusting was succeeded by high angle faulting.

The Park rocks were subjected to weathering and erosion for over 300 million years or until glaciers advanced over the area less than 60,000 to 70,000 years ago. Advancing glaciers scoured the rock; retreating or wasting glacial ice left deposits of clay, sand and gravel in the Park. A series of lakes formed south of the northward wasting glacial ice and deposits of beach-gravel and lake-sand formed along the slopes of Mt. Philo, which was then an island. An arm of the sea next advanced southward into the Champlain Valley leaving marine beach-gravels just west of Mt. Philo. The marine waters retreated and present-day Lake Champlain came into existence. The formation of the present soil cover and the deposition of recent alluvium from presently flowing rivers and streams concludes this brief summary of the Park's geologic history.

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(in addition to the general references listed for D.A.R. State Park)

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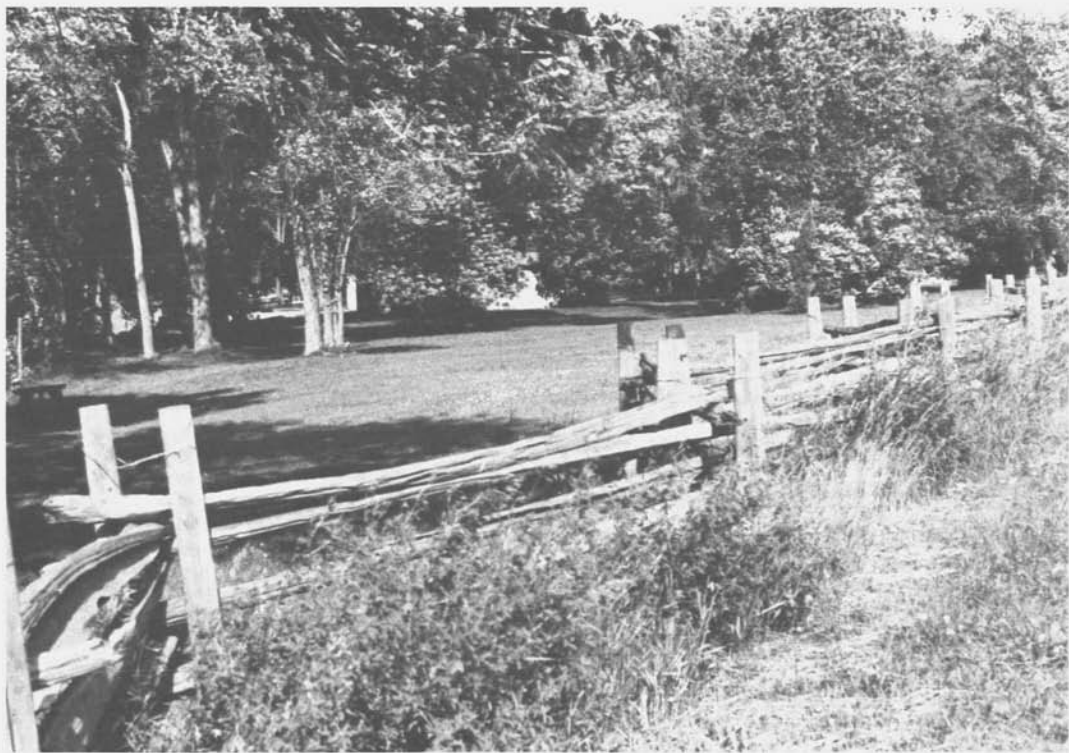


FIG. 12A. Over a typical Grand Isle split-rail fence at Sand Bar State Park.



FIG. 13. A portion of the beach at Sand Bar State Park looking east. The escarpment in the left distance marks the trace of the Champlain thrust fault.

THE GEOLOGY OF SAND BAR STATE PARK

INTRODUCTION

Sand Bar State Park is located in northwestern Vermont on U.S. Route 2, approximately 14 miles north of Burlington and near the east approach to Sand Bar Bridge which leads to South Hero Island in Lake Champlain (see map, Fig. 1). Tenting, picnicking and swimming are the Park's main attractions (Fig. 12a). The swimming beach is on the north side of U.S. Route 2 and fronts on Lake Champlain. Its shallowness makes the beach safe for children (Fig. 13). The tenting facilities are located on the south side of U.S. Route 2 on a south-facing shoreline.

THE GEOLOGY OF THE PARK

The geologic history of Sand Bar State Park is recent, geologically speaking, especially when compared with that of the other Parks treated in this pamphlet. The sediments of the park are blue and brown clay which were deposited throughout the Champlain Valley less than 10,000 years ago. This clay, which can be seen in many places along the bathing beach, was deposited from marine waters which flooded the Champlain Valley just prior to the formation of present-day Lake Champlain. No bedrock crops out in Sand Bar State Park.

The blue clay is covered with deposits brought downstream by the Lamoille River during very recent times and deposited as a *delta*¹ into Lake Champlain. This delta has shifted its distributary channels frequently and continues to grow southwestwardly into Lake Champlain. Much of the finer material (sand) brought into Lake Champlain by the Lamoille River has been shifted and concentrated by lake currents into ridges or bars; one sand bar stretches to South Hero Island and forms the foundation for the causeway named Sand Bar Bridge. Prior to the building of Sand Bar Bridge (causeway was started in 1849, opened to travel on December 5, 1850), this sand bar was fordable and was used as a link between South Hero Island and the mainland.

Most of the sand now found north of the Park bathing beach and which is responsible for the extensive "shallows" in the swimming area, was supplied by the now abandoned northern channel of the Lamoille River. It is interesting to note that most of the sand now seen on the bathing beach has been imported from nearby areas of Vermont. Since the northern distributary channel of the Lamoille River is no longer supplying sand, and sand from the active southern channel cannot work its way northward because of the Sand Bar Bridge causeway, there is a lack of sand for the beach.

The extensive swamp areas near the east end of Sand Bar Bridge are a wildlife sanctuary. The north-trending prominent escarpment east of the Park marks the trace of the Champlain thrust fault (Fig. 13). In a quarry at the east end of Sand Bar Bridge may be seen the fault contact between the younger, Middle Ordovician, Stony Point Formation, and the older, Lower Cambrian, Dunham Dolomite.

¹ Delta is the name of the fourth letter of the Greek alphabet, the capital form of which is an equilateral triangle. The triangular-shaped tract of land formed by the deposit of river sediment at river mouths is named for the triangular shape of the capital Greek letter delta.

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- ERWIN, R. B., 1957, *The Geology of the Limestone of Isle La Motte and South Hero Island, Vermont*, Vermont Geological Survey, Bull. 9.
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