The Geology of
Calvin Coolidge State Forest Park

by

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DEPARTMENT OF FORESTS AND PARKS
PERRY H. MERRILL, *Director*

VERMONT DEVELOPMENT COMMISSION

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

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Cover Picture. View of the entrance to Calvin Coolidge State Forest Park. Photograph was taken looking north along State Highway 100A.

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INTRODUCTION

Each summer hundreds of eager campers, picnickers, hikers and sportsmen visit the Pinney Hollow-Bradley Hill recreational area of the Calvin Coolidge State Forest Park. This area is located a few miles north of Plymouth, Vermont, and is easily reached via State Route 100A from either Plymouth or Bridgewater Corners (See index map of Vermont, geological map). The excellent camping and recreational facilities coupled with the natural scenic beauty of this region provide many visitors with an irresistible urge to return, summer after summer, to this same spot. This pamphlet is designed for all those who visit Coolidge Forest Park and especially for those who possess questioning minds and a general desire to learn more about the world around them.

GEOLOGY

Have you ever wondered why the present mountains and valleys are where they are and how and when they got there? Has the thought passed through your mind that the very rocks on which you stand or see nearby have a definite story to tell? The geologist not only wonders about such things, but through his training attempts to answer questions of this nature. His everyday job includes the reconstruction of ancient land and sea areas through a careful study of the rock record. He looks at the rock layers as you might the pages of a history book. The professional geologist, however, commands many basic geological principles and "tools of the trade" which permit him to read more accurately the records preserved in stone.

First, the basic geological principles will be explained and you will be given the proper "tools" for your adventure. Then, you are invited to travel back through 550 million years of time to see just why Coolidge State Forest Park is as it is today and what it was like in the distant past.

BASIC PRINCIPLES AND "TOOLS"

To many of you rocks are just "rocks" and very little thought has been given to any history which might be gained from their study. Probably even fewer of you realize that literally billions of years of Earth history can be derived directly from the rock record. Most geologists consider the Earth to be nearly four billion years old with man entering the picture a mere million or so years ago. No human was present to record the events of billions of years of changing land and seas, violent earth movements or the gradual evolution of life through the last 500 million years. The study of rocks and their contained evidence of past life offers the only clarification for the extremely long past history of the Earth. In order to unravel this past history the geologist accepts, with some reservations, three basic principles or laws.

The Law of Uniformitarianism provides an extremely important link with the past. This law states that the physical and chemical forces which are attacking or building up the surface of the earth today have operated in much the same way during past geological time. This means that our observations of present day environments, such as streams, deltas, lakes and oceans can be applied, after slight modification, to the past as recorded in the rocks. For example, study of present day deltas, such as the Nile or Mississippi River delta, has led to the discovery of many past deltaic deposits now preserved as layers and lenses of rock. This distribution pattern of sands and muds, the nature of the life forms within each environment and many other such criteria aid the geologist in his interpretations.

The Law of Superposition provides a physical order to the many layers of rock which form the geological record. Compare, for the moment, the vast numbers of rock layers (strata) with the layers of a layercake. As a layercake is built up each individual layer is placed one over another, with the bottom or base layer the first to be positioned and followed by successively overlying layers. If you think of the development of this cake in terms of time, the base layer is the oldest, the uppermost the youngest. The Law of Superposition follows this example and states that the lowermost stratum in a sequence of rock strata is the oldest or the first to form, while the stratum above is younger and formed at a later time. Some reservations do exist; however, in the Forest Park under immediate consideration this general law does apply.

The third basic principle to command is known as the Law of Faunal Succession. In generalized form this law states that each stratum of

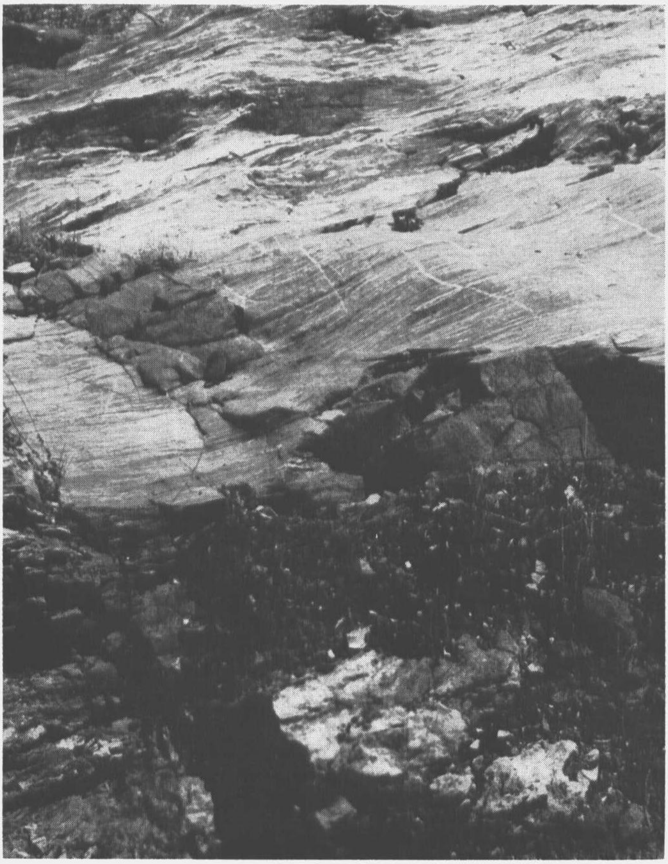

Figure 1. Igneous dike cutting the Pinney Hollow formation. The dike is the darker rock which trends toward the upper left of the photograph. This dike is located approximately 100 yards south of the Pinney Hollow Historical Monument and on the east side of State Highway 100A.

rock contains its own distinct group of animal or plant remains, termed fossils, and that these same remains can be recognized throughout the world wherever they occur. Since plants and animals changed through time and because their remains are found throughout the world, it is possible to erect a worldwide time scale based upon animal and plant evolution. In short, the fossils found in particular rock are characteristic representatives of the life at the time that rock originated and the fossils found could have been entombed only at that time. One stratum, therefore, would have a total fossil assemblage quite different from the stratum above or below. Without this time reference chart it would be impossible to reconstruct what did happen during any one time interval in the past.

In addition to these three basic laws it is necessary to mention the rudiments of rock classification. The geologist divides *rocks*[1] into three major groups which are termed Igneous, Sedimentary and Metamorphic rocks. Igneous rocks are those formed by the solidification of molten material. This molten material was thrust into the outer crust of the earth from below and after cooling became a solid igneous rock such as granite, or in other cases it flowed out over the surface of the earth in the form of volcanic lava. Some small igneous bodies, termed dikes, can readily be seen along State Highway 100A adjacent to Calvin Coolidge State Forest Park (See photograph, Fig. 1).

Sedimentary rocks are formed in quite a different manner and differ in general appearance. These are what might be considered second-hand rocks. They are composed of particles derived from other rocks, igneous, metamorphic or older sedimentary, which have been carried by streams, wind or ice to a place of rest and there cemented into rock. Perhaps you can visualize a river which, throughout its course, runs over rocks of many types. This river would pick up particles of rock from its bed and banks and transport these to a lake or perhaps the sea, where the various transported materials would settle to the bottom in distinct layers. The first layer deposited would become buried under thousands of tons of overlying layers of sediment whose weight and resultant pressure, together with the presence of adequate rock-cementing material such as calcium carbonate or silica, would cause the bottom layer to harden into rock. The layered appearance of sedimentary rocks is one of their most characteristic features and these rocks are said to be bedded or composed of many individual beds of sedimentary rock. Sandstone, composed of sand size particles; shale, originally mud; and limestone, once lime-rich mud, are examples of sedimentary rocks.

Metamorphic rocks result when igneous or sedimentary rocks are

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[1] A rock, for those desiring a more technical definition, is any relatively hard, naturally occurring, combination of minerals which form an essential part of the earth. Minerals are composed of one or more chemical elements, such as oxygen or silicon, that form in nature.

subjected to abnormal heat and pressure. Folding or *faulting*[1] of rocks within the earth's crust or deep burial beneath overlying rocks or sediments commonly produce metamorphism. The introduction of hot fluids during folding and faulting greatly increase the speed and degree of metamorphic conversion. When igneous or sedimentary rocks are subjected to metamorphism they tend to lose their original appearance as some minerals are completely changed or altered into new minerals and most of the original minerals are oriented in one or more preferred directions. The degree of heat and pressure, type and amount of hot fluids provided and the type of rock undergoing metamorphism will determine the nature of the metamorphic rock to develop. Perhaps the most unfortunate effect caused by the metamorphism of sedimentary rocks, especially when considering the history recorded in the rocks, is that in the majority of cases all fossils originally present are either destroyed or distorted beyond recognition. The absence of fossils makes age determination quite difficult and hinders definition of previous environments.

The rocks seen in and adjacent to Coolidge State Forest Park, with very few exceptions, are metamorphic rocks which were originally sedimentary rocks. Luckily the metamorphism is slight and several pages of geologic history can still be read. Schists, phyllites and *quartzites*[2], all metamorphic rocks, are well displayed in the Forest Park region.

The parallel arrangement of mica plates and segregation of the darker minerals into distinct layers in the schists and phyllites together with the inherited sedimentary layering in the quartzites, impart a distinctly visible orientation to the rocks seen in the Forest Park. The parallelism

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[1] A fault is a break or fracture in the rocks of the earth's crust where one side of the fracture moves in some direction relative to the other side. Some recent earthquakes in California and Nevada have produced visible faults where, for instance, roads were cut and one side displaced several yards from the other.

[2] Most of the mineral grains which make up a schist, a metamorphosed shale or sandy shale, can be seen with the naked eye, and the parallel to subparallel arrangement of platy or flaky minerals, such as the abundant mica, is the most obvious feature. In bright sunlight a schist presents a very shiny, almost silvery appearance which is caused by the reflection of sunlight from the many parallel mica plates. A phyllite has much the same mineral composition as that of a schist; however, the individual mineral grains are too small to be seen without the aid of a magnifying glass. As with the schist, a phyllite when viewed in direct sunlight, appears shiny. Quartzites are metamorphosed sandstones which have been fused into great hardness through the application of heat and pressure.

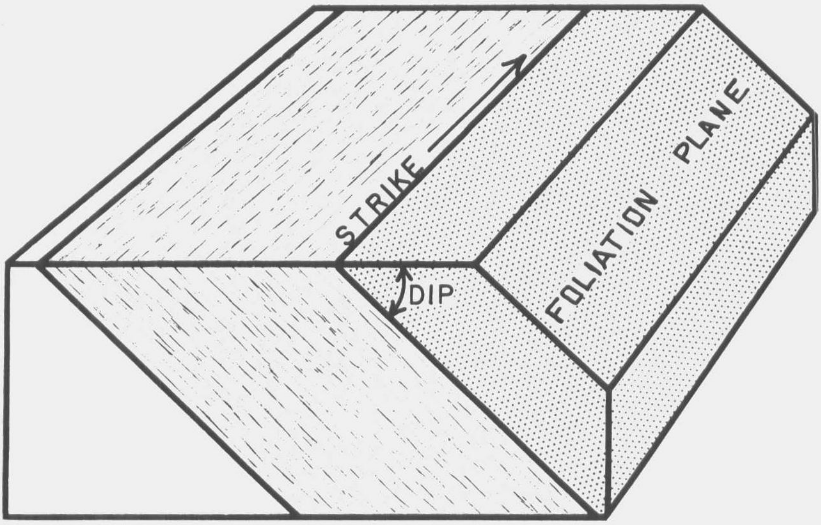

Figure 2. Block diagram illustrating the dip and strike of foliation. The top of the block is considered an "imaginary horizontal plane."

of the mica and segregation of the darker minerals in the schists and phyllites is directly related to metamorphic processes and the measurable orientation is called foliation. The original sedimentary layering of the quartzites, little changed through the metamorphism, is referred to as bedding. From all indications the foliation and bedding are practically parallel in this region and since most of the rocks represented are of the metamorphic type, all orientation features will be referred to as foliation.

The geologist uses the terms dip and strike to describe foliation and uses conventional symbols for plotting purposes (See geologic map). The dip of the foliation is the angle between an imaginary horizontal line and the tilt or downward slope of the foliation. The strike is the compass direction of a line formed by the dipping foliation plane and its intersection with an imaginary horizontal plane (See block diagram, Fig. 2). A glance at the geological map will show that the rocks of the Park area consistently strike north to northwest and dip to the east. If you look at the foliation symbols which are plotted on the geologic map, the straight line of the symbol indicates the strike and the black triangle points in the direction of the dip. The angles of dip have not been included on the map; however, they average forty-five degrees down from the horizontal and toward the east or right margin of the geological map.

THE ROCKS OF CALVIN COOLIDGE STATE FOREST PARK AND THE STORY THEY TELL

The rocks of Calvin Coolidge State Forest Park can be divided into four distinct units or *formations*[1]. The geologic map shows these formations as distinct bands, each band representing a different formation and its intersection with the ground surface. Each formation is, so to speak, stacked upon the next older with the oldest forming the western band and the youngest on the east. Remember that these metamorphic rock formations were originally sedimentary in nature and were deposited in a nearly horizontal position on the floor on an ancient sea. The fact that they are now tilted indicates that earth movements have taken place sometime after the sedimentary rocks hardened but before the present time.

The *Pinney Hollow formation,* the oldest formation of rocks seen in the Forest Park, was named for the excellent exposures of this formation in Pinney Hollow, a valley located along the western border of Coolidge Forest. You can readily see this formation, in its most typical development, along State Highway 100A about three-tenths of a mile south of the Park entrance road. Here, a historical monument which commemorates the naming of Pinney Hollow, is embedded in this formation (See photograph, Fig. 3). The lean-to, tent platform and picnic areas are situated on this formation and its rocks are easily observed. It is interesting to note that some of the Pinney Hollow rocks seen in these camping and picnicking spots differ from the typical rocks seen along State Highway 100A. In fact, some of the rocks which are dark and are classed as phyllites, can be confused with the overlying Ottauquechee rocks. A transition zone, several hundred feet wide, exists between these two formations and in which the two distinct rock types are intermingled. This "mixture" zone indicates that there was no break in the original deposition of these two formations and therefore the rock record during this time is complete.

The Pinney Hollow formation, which is an estimated 2,300 or more feet thick, is primarily composed of pale-green *schist*[2] with abundant white quartz layers and lenses sandwiched between the dominantly greenish colored rock. Originally these metamorphic rocks were sand,

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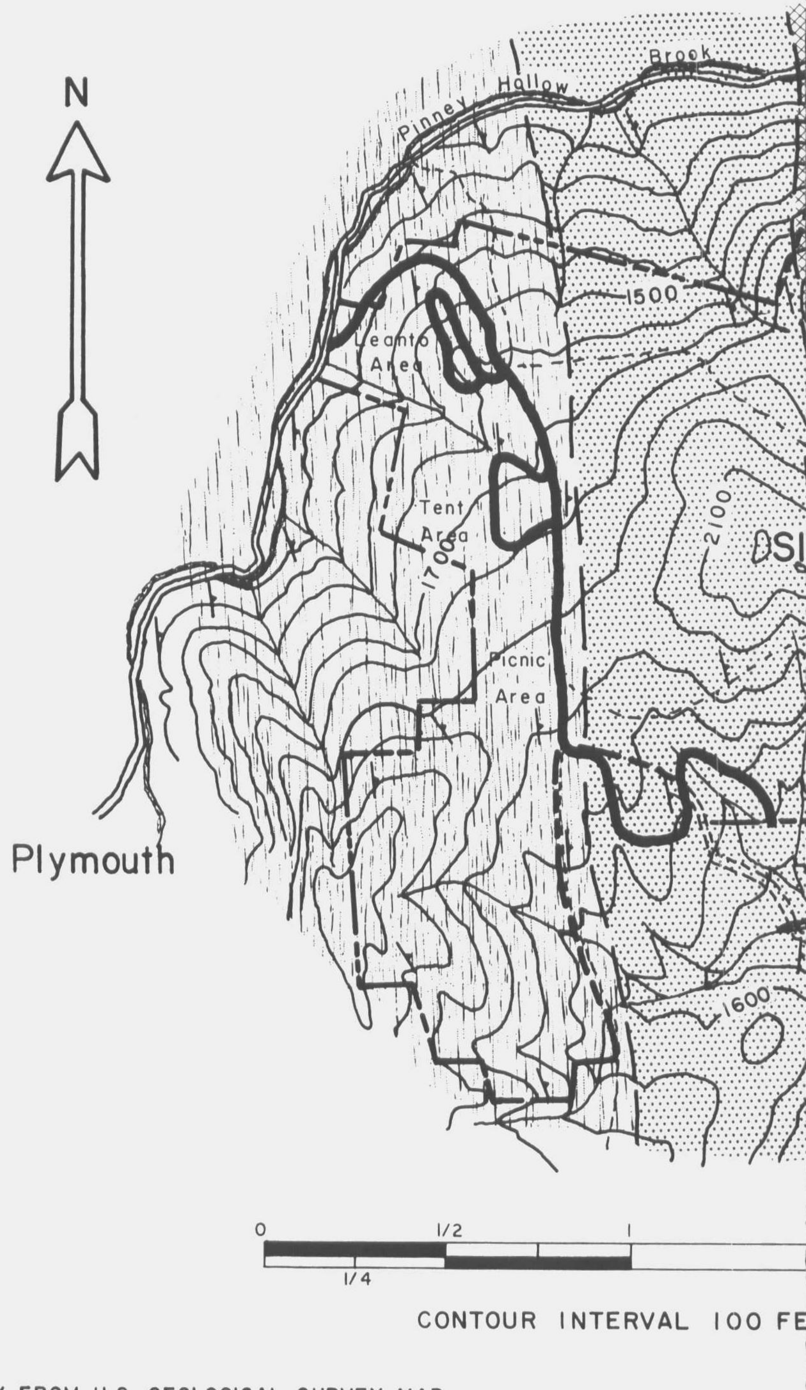
[1] A geologic formation consists of a group of similiar rocks, or sequence of rocks, which can be easily distinguished from adjacent rocks and whose distribution can be plotted on a map.

[2] More technically this schist is termed a chlorite-sericite-quartz schist.

GEOLOGIC MAP OF CALVIN COOLIDGE STATE FOREST PARK



TOPOGRAPHY FROM U.S. GEOLOGICAL SURVEY MAP

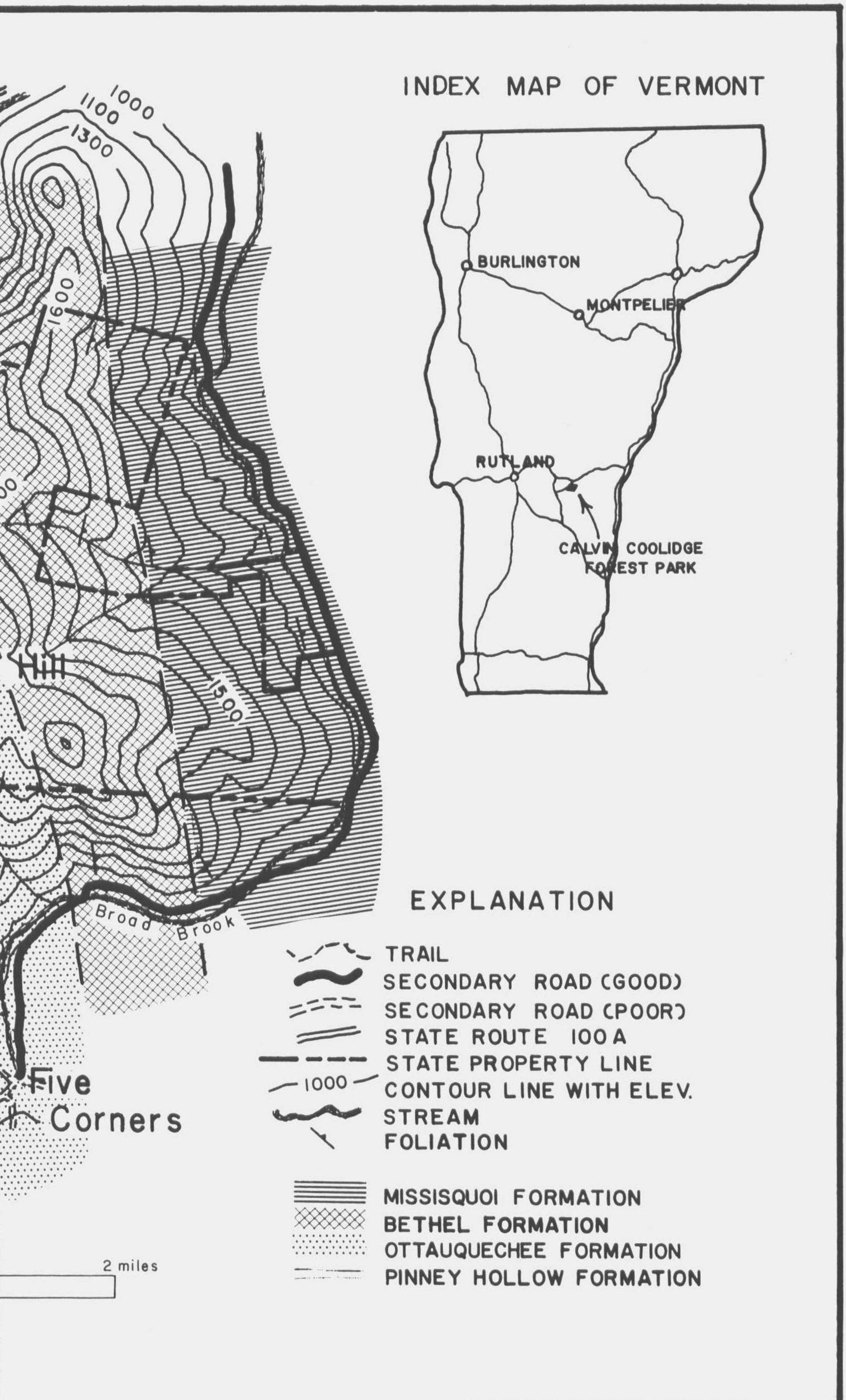

INDEX MAP OF VERMONT
BURLINGTON
MONTPELIER
RUTLAND
CALVIN COOLIDGE FOREST PARK
1000
1100
1300
1600
1500
Hill
Broad Brook
Five Corners
2 miles
EXPLANATION
TRAIL
SECONDARY ROAD (GOOD)
SECONDARY ROAD (POOR)
STATE ROUTE 100 A
STATE PROPERTY LINE
1000
CONTOUR LINE WITH ELEV.
STREAM
FOLIATION
MISSISQUOI FORMATION
BETHEL FORMATION
OTTAUQUECHEE FORMATION
PINNEY HOLLOW FORMATION
GEOLOGY BY H. W. DODGE, JR.

Figure 3. The Pinney Hollow Historical Monument embedded in the Pinney Hollow formation. The darker rock consists of pale-green schist and the white areas are quartz layers and lenses.

mud and sandy mud deposited on a relatively shallow sea floor. After burial these sediments hardened into thin layers and lenses of sandstone, shale, and sandy shale. Metamorphism has since converted many of the shale minerals into mica flakes and some of the sandy shales produced crystals of the mineral garnet. The pale-green color of the Pinney Hollow schist is caused by the presence of the green mica-like mineral, chlorite, which developed during the process of metamorphism.

No fossils have been found in the Pinney Hollow formation of this region; however, evidence from other parts of Vermont indicate that these rocks are of Cambrian or perhaps *Ordovician*[1] age. This dates these rocks as approximately 500 million years old.

The *Ottauquechee formation*, next above the Pinney Hollow formation and therefore younger in age, was named for the Ottauquechee River along which this formation is well exposed and was first studied in detail. The Ottauquechee River is located just north of Calvin Coolidge State Forest Park where it flows through the towns of Bridgewater and Bridgewater Corners. You can see this formation along State Highway 100A approximately nine-tenths of a mile north of the Park entrance road. Here, the formation crops out on the west side of the road, or on your left if traveling toward Bridgewater Corners (See photograph, Fig. 4). A hike along the recently diamond-blazed Coolidge Forest trail, which leads from behind the Ranger's cabin to the Picnic area, affords an almost continuous view of this formation. The highly resistant quartzite layers within the Ottauquechee formation are very conspicuous features along this trail as they form several ridges trending across the footpath.

The Ottauquechee formation, estimated to be 3,000 feet thick, contains rocks which contrast sharply with the underlying pale-green schists. The formation consists of alternating black phyllite and layers, up to several feet thick, of dark- to light-colored quartzite. The black carbonaceous color of the phyllites and dark quartzites indicate the presence of life, either animal of plant, during the original deposition of the sediments forming these rocks. The phyllite was, before metamorphism, a black shale which formed from black muds rich in organic matter. From studies done in areas where black muds are accumulating today it seems quite probable that the ocean waters of Ottauquechee time were of a restricted nature, that is to say, the waters were stagnant due to the lack of oxygen. Pinney Hollow shallow marine water conditions remained, but for some reason, such as a barrier of islands or shallow water sand bars, the circulation of ocean waters was hindered, leading to the accumulation of stagnant organic matter on the ocean bottom. This organic matter gives the Ottauquechee phyllite and some quartzites a dark to black color.

No fossils have been found in the Ottauquechee formation of the

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[1] The geologist divides geologic time into four major sections, designated Eras. These Eras are in turn subdivided into Geologic Periods which are of shorter time duration. The Cambrian Period is the oldest of the Paleozoic Era and began some 550 million years ago. The Ordovician Period is the next oldest of the Paleozoic Era and started about 440 million years ago and ended close to 360 million years ago.

Figure 4. The Ottauquechee formation as exposed approximately nine-tenths of a mile north of the Park entrance road and on the west side of State Highway 100A. Note the massive quartzite layers above, the black phyllite below.

Coolidge Forest Park, but, as with the Pinney Hollow formation, evidence from other areas indicates a Cambrian or perhaps Ordovician age for this formation.

Above the Ottauquechee rocks lie those of the *Bethel formation*. Approximately 2,000 feet thick, this formation is composed mainly of pale-green schist with interlaminated thin layers of white to greenish quartzite. The rock presents a distinct banded appearance and contains conspicuous crystals of garnet and the black mica, biotite. The best view of this schist is found along State Highway 100A and slightly over

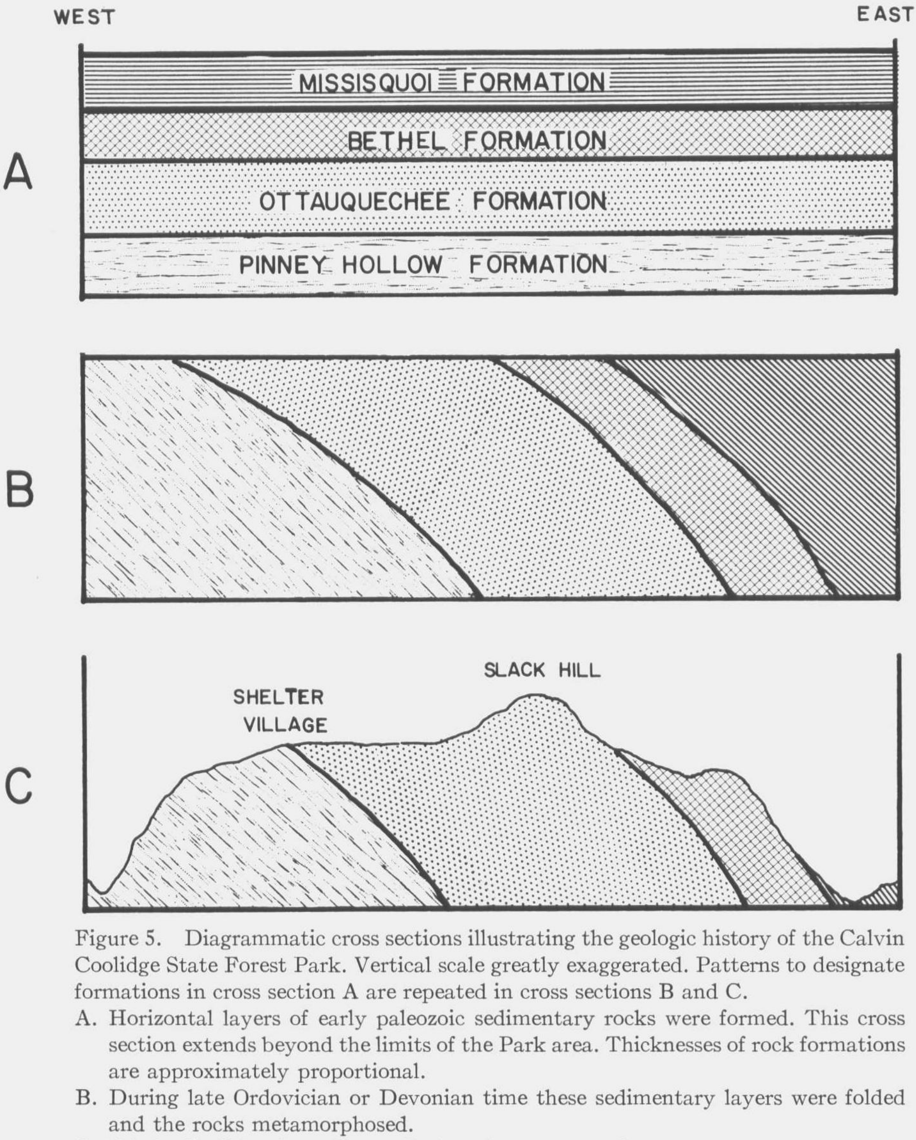

Figure 5. Diagrammatic cross sections illustrating the geologic history of the Calvin Coolidge State Forest Park. Vertical scale greatly exaggerated. Patterns to designate formations in cross section A are repeated in cross sections B and C.

A. Horizontal layers of early paleozoic sedimentary rocks were formed. This cross section extends beyond the limits of the Park area. Thicknesses of rock formations are approximately proportional.

B. During late Ordovician or Devonian time these sedimentary layers were folded and the rocks metamorphosed.

C. Calvin Coolidge State Forest Park as it appears today.

two miles north of the Park entrance road. The relatively steep rock cliffs which line the west side of this road are composed of the resistant Bethel formation. In the northeast portion of Coolidge Forest Park several excellent exposures of this formation in contact with the underlying Ottauquechee formation can be seen, but, to reach these areas you would have to leave the beaten trail. If you are interested in visiting these contact locations it would be best to consult the geologic map for approximate directions.

The conditions under which the Bethel formation was originally deposited are similar to those which existed during Pinney Hollow time. Shale, sandy shale and thin-bedded sandstones formed under shallow water marine conditions; however, restriction with accompanied organic accumulation did not occur. This formation is thought to be of either Cambrian or Ordovician age.

The easternmost, and therefore youngest formation to be found in the Park area is known as the *Missisquoi formation*. This formation, which is only partially represented here, is made up of dark phyllite, light blue-gray schist with conspicuous crystals of garnet and biotite, and gray quartzite. The rocks of this formation can be seen along Broad Brook which flows north along the eastern border of Coolidge State Forest Park.

This formation is considered Ordovician in age with the conditions of deposition being quite similar to those which existed during Ottauquechee time. Once again the ocean waters were restricted and organic-rich black muds accumulated in quantity on the ocean floor.

THE GEOLOGIC HISTORY

The early geologic history of Calvin Coolidge State Forest Park is known from the rock formations discussed in the previous section of this pamphlet. The Pinney Hollow, Ottauquechee, Bethel and Missisquoi formations of Cambrian and Ordovician age were deposited, essentially horizontally, from the shallow seas which covered this area 550 to 450 million years ago (See cross section A, Fig. 5). During some of this time these seas were at least partially restricted as evidenced by the Ottauquechee and Missisquoi black phyllites. Other Ordovician formations were deposited on top of these four formations, but have been completely stripped away by erosion during the millions of years since their deposition. Some of these later Ordovician sediments contain great thicknesses of volcanic rocks which probably covered the Coolidge Park area.

Sometime after these later Ordovician rocks formed, great stresses within the earth's crust folded and in some places faulted these older rocks. The pressure and resultant heat created during these earth movements converted the rocks into metamorphic schists, phyllites and quartzites which are seen today (See cross section B, Fig. 5). Exactly when these diastropic events took place is still open to question, but they probably occurred near the end of Ordovician time or perhaps millions of years later during the last phases of the Devonian Period.

Probably since late Paleozoic time the Coolidge Park area has been subjected to breaking-down rather than building-up processes. Eventually this whole region was reduced to a flat plane with only a few hills, called monadnocks, rising above the general flatness of the landscape. Still later in the history of Coolidge State Forest Park this flat plane was lifted high above its former position and streams began to shape the land into its present form. The more resistant rocks were lowered by the forces of erosion at a much slower rate than the less resistant types. The hills and valleys which you see today are primarily the result of this general uplift followed by the wearing away of the softer rocks at a more rapid rate than the harder rock types. Since the formations trend in a north north-west direction, the hills and valleys are also oriented in this general direction, as the different resistive qualities of the rocks are presented in this pattern.

The story is not complete without mention of the last modifying influence to affect this region. Approximately one million years ago the first of perhaps three glacial advances began. These large glacial masses, termed continental glaciers, slowly advanced southward over the northern sections of the United States and covered a vast region with a thick sheet of ice. As these ice masses rode over the Coolidge Park region they tended to round-off irregular features of the landscape and to fill in certain low regions with their transported rock debris. The rather smooth outlines of the hills in Coolidge Forest Park and the sand and gravel deposits so apparent adjacent to nearby streams tell the story of these glacial advances and subsequent withdrawals. Other evidence of the overriding ice is seen in the presence of scratch marks, termed glacial striae, which were produced by fragments of rock as they were dragged by the moving ice across the underlying rocks. Along the east bank of Broad Brook and approximately two hundred yards south of the bridge at Five Corners, abundant glacial striae are clearly displayed. The orientation of these striae indicates that the glacier producing them moved from north north-west to the south south-east.

Since the recession of the last ice sheet, which took place several thousand years ago, the general appearance of the Coolidge Park region has changed very little. The streams have cut their valleys somewhat deeper and some of the glacial sands and gravels have been redistributed. A few thousand years ago Coolidge State Forest Park looked quite the same as it does today (See cross section C, Fig. 5).

SIDE TRIPS OF GEOLOGICAL INTEREST

Gold Panning

There are several locations immediately adjacent to the Calvin Coolidge State Forest Park where some gold can still be obtained from stream sands and gravels. The abandoned town of Five Corners offers the park visitor ample chance to "try his luck." In fact, several local people still obtain small gold nuggets and a good deal of gold dust from the streams in the vicinity of Five Corners (See geologic map for geographic location). Other possible "panning" locations would include Reading Pond Brook, Buffalo Brook and Kingdom Brook. The gold which is found is probably derived from nearby gold-bearing quartz veins.

The equipment needed for an afternoon of panning is relatively simple to obtain. A wide, rather shallow pan with gently sloping sides is really all that is needed. Gravel and sand, which you find concentrated on the upstream side of natural rock riffles in the stream bed should be placed together with water in your pan. Then the pan should be rotated and the lighter rock materials decanted. The heavy gold will be concentrated in the bottom of the pan.

Asbestos and Talc

For you who might be interested in mineral collecting it is suggested that a trip to an old pit near Five Corners might prove rewarding. Walk down Broad Brook from the bridge at Five Corners until you locate the first small tributary entering on your left. Turn left up this tributary and continue to walk for approximately one hundred yards. On your left you will see the remains of a pit dug into the side of the stream bank which, at this location, is lined with rocks of the Ottauquechee formation.

You will quickly note the fibrous asbestos in the walls of this pit; however, if you wish to collect specimens of this mineral be extremely careful and avoid standing beneath any overhanging rock material. Talc, which feels "soapy" to the touch, is also abundant in this immediate area. This asbestos and talc occur in a lenticular-shaped body which is perhaps eight hundred feet wide and of an undetermined length. It is not certain when these minerals formed; however, it was probably in the early history of the region.

Garnet

Good specimens of garnet can be found in the rocks of the Bethel formation. These garnets are not of gem quality but still offer good collecting for the amateur mineralogist. Good collecting localities exist along State Highway 100A and at several different spots within the Park itself. A hike along the northern boundary of the Park would intersect several excellent collecting spots.

Vermont Marble Company Exhibit, Proctor, Vermont

If time permits, or a rainy day arrives, a visit to the Vermont Marble Company Exhibit in Proctor, Vermont, is highly recommended. Marble is a metamorphic rock which was originally sedimentary in nature. Lime muds hardened into limestones and then, converted by metamorphism, became marble. The marble exhibit at Proctor, termed "The largest Marble Exhibit in the World," displays over 100 varieties of marble and igneous rock, granite. Fossils can be seen in some of the varieties of marble, which demonstrates that under certain conditions recognizable fossils do occur in metamorphic rocks. Most of the marble seen in this exhibit is quarried nearby; however, for safety reasons visitors are not allowed to enter the quarries. It is interesting to note that these marbles are about the same age as the rocks seen in Coolidge State Forest Park.