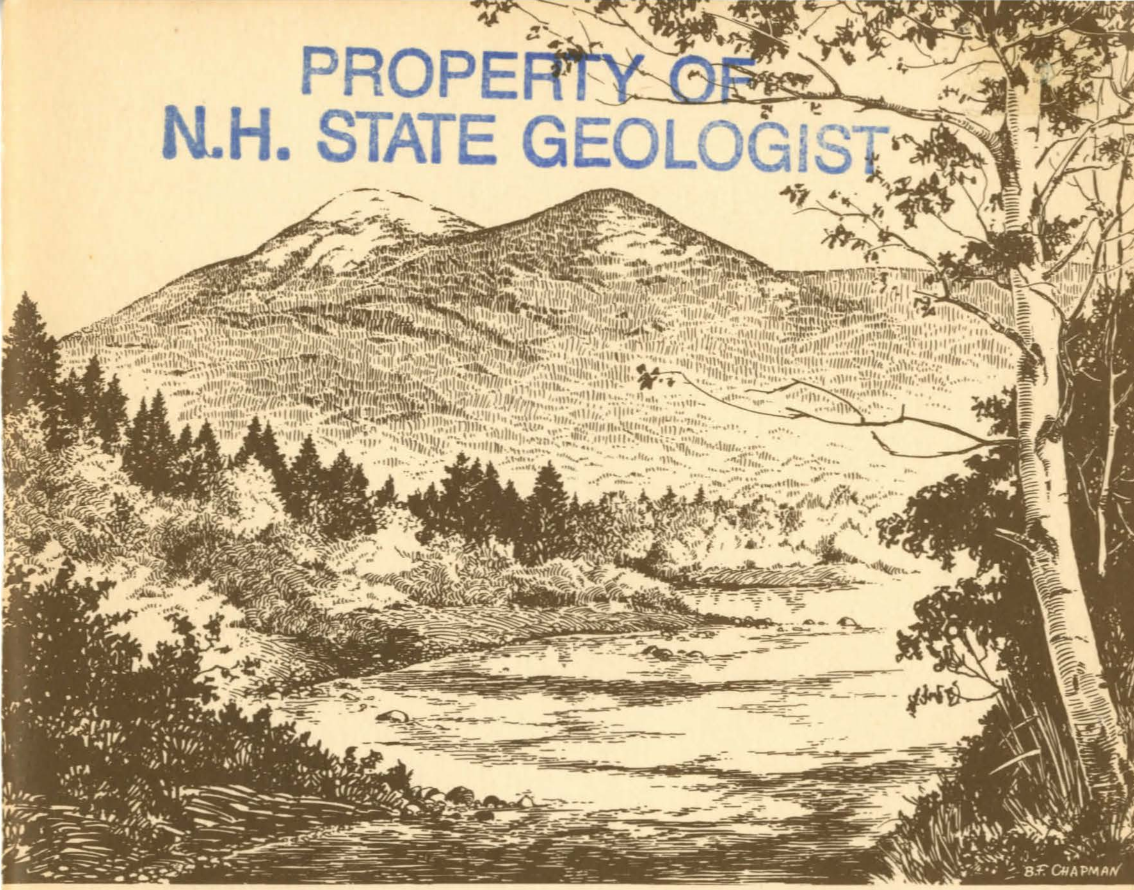

THE GEOLOGY OF THE
PERCY QUADRANGLE
New Hampshire

by

RANDOLPH W. CHAPMAN

PUBLISHED BY THE NEW HAMPSHIRE PLANNING AND DEVELOPMENT COMMISSION

1949

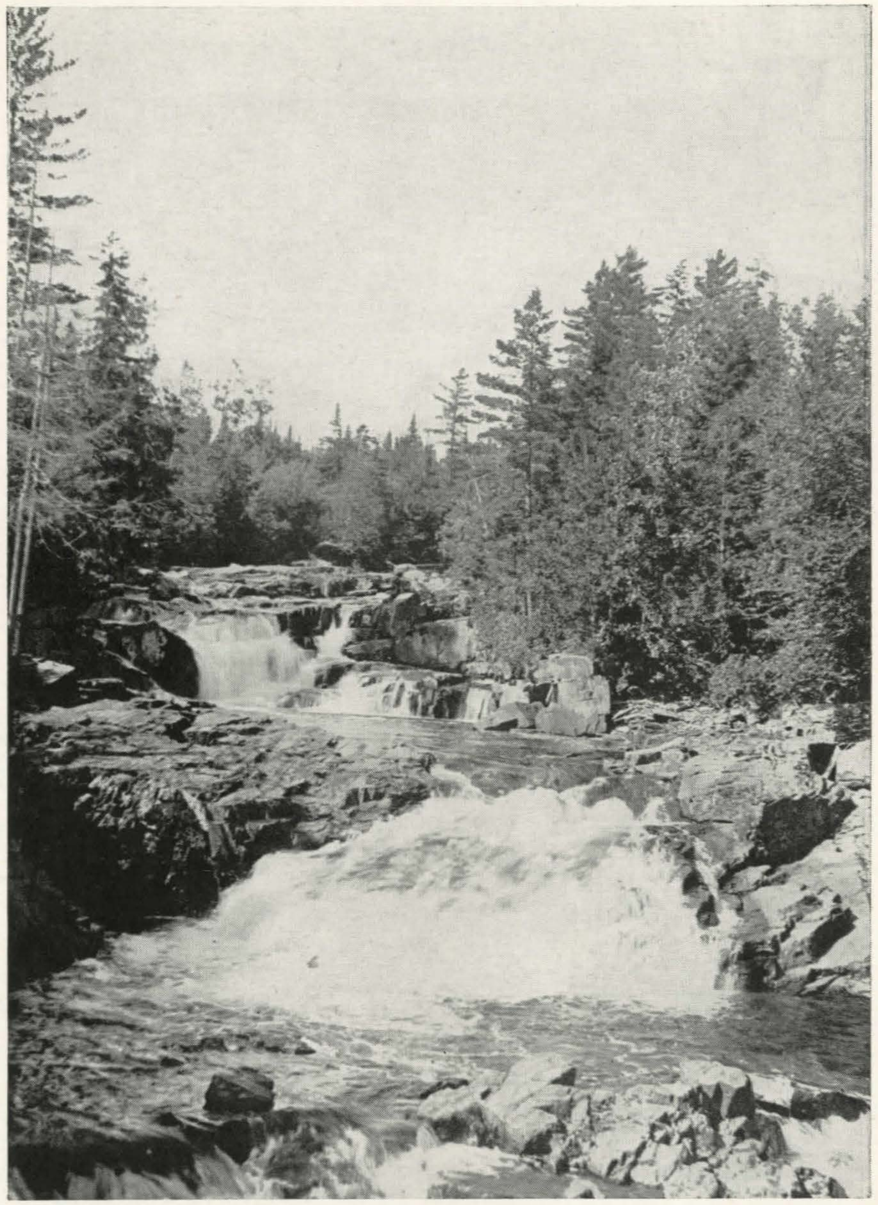

FIGURE 1. Crystal Falls in the village of Crystal. These picturesque falls are made by Phillips Brook as it flows over quartzites of the Albee formation.

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FOREWORD

This pamphlet is designed to appeal to the average reader and is not intended to be a scientific report for the professional geologist. The text is written in non-technical language and few scientific terms are used. The map accompanying the pamphlet shows the detailed geology of the region, with a key for interpreting it. All that need concern the average reader of the map, however, are the formation names. It is not essential for him to understand the mineral and rock descriptions. The fascinating story of the rocks can be appreciated without these details.

The geologic study of the Percy quadrangle was carried on from 1932 to 1934 under the auspices of the Division of Geological Sciences, Harvard University, and with the assistance of Marland P. Billings, Bernard F. Chapman, and Carleton A. Chapman. Financial aid was obtained from the Holden Fund and the Whitney Fund of Harvard University.

Publication of the geological map, inserted in the pocket at the end of the pamphlet, was financed by the New Hampshire State Planning and Development Commission, the New Hampshire State Highway Department, and the Geological Society of America. The drawing on the front cover of this pamphlet and Figures 3 to 8 were prepared by Bernard F. Chapman.

The Geology of the Percy Quadrangle

New Hampshire

By Randolph W. Chapman

THE SCENERY

The Percy quadrangle lies in northern New Hampshire, northwest of the city of Berlin, and takes its name from the little village of Percy which is situated near its center. Located in a rather remote and sparsely settled region, it embraces some of the finest scenery in the state. The area is largely mountainous and, except along the major streams, is covered with heavy forest.

The highest and most rugged peaks are in the Pilot Range in the southern part of the quadrangle, but none of these reaches above timber line. Mt. Cabot is the highest with an elevation of nearly 4200 feet. To the east and northeast is a group of lower and less rugged mountains, including Deer Mountain, Round Mountain, Square Mountain, and Mill Mountain. To the west, in the southeast corner of the Guildhall quadrangle, is Cape Horn, a curious crescent-shaped ridge rising approximately 1,000 feet above the surrounding lowland. In the northern part of the quadrangle are several dominating elevations including Sugarloaf, Whitcomb Mountain, Long Mountain, and Percy Peaks. Percy Peaks (Fig. 2) are particularly striking when viewed from the southwest since their profiles resemble symmetrical volcanic cones.

Some of the summits, such as The Horn and Greens Ledge in the southern part of the area, are now bare rock, due partly

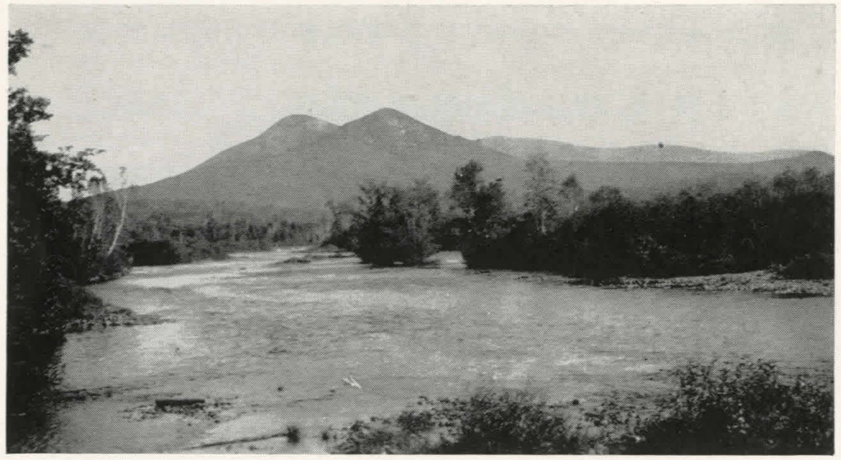

FIGURE 2. Percy Peaks as seen from the southwest in the vicinity of Groveton. These magnificent peaks are made of coarse-grained, pink Conway granite of the White Mountain magma series.

to the great ice sheet which moved over them and partly to forest fires which swept them some 50 years ago. Whether the northern of the Percy Peaks has been bare ever since the retreat of the ice sheet is not known. In addition to forest fires, extensive lumbering operations have done their share toward destroying the original dense forest cover. In spite of these facts, however, the mountainous areas are now heavily wooded, and an abundance of partly burned logs, low scraggy spruce, and blown-down or cut-down timber makes certain parts of the mountains almost inaccessible. On the steep slopes on the west side of the Pilot Range and also on Long Mountain several long landslides have exposed narrow strips of bare rock.

The area is drained principally by the Upper Ammonoosuc River which flows north as far as West Milan and then swings westward to join the Connecticut River at Groveton. Along the greater part of its course, the Upper Ammonoosuc River has a fertile floodplain which furnishes opportunity for the cultivation of hay, corn, and oats, but these are grown rather sporadically. Locally, the course of the river is constricted by steep mountain slopes. Tributary to this major river are Nash Stream and Phillips Brook, two large streams flowing directly south and draining the mountainous regions to the north. The

area to the south is drained by a complex network of streams flowing in all directions.

Because of the rough mountainous character of its greater part, the Percy quadrangle is sparsely settled. The few villages, such as Stark, Percy, Crystal, and West Milan, located along the valley of the Upper Ammonoosuc River, have altogether not more than a few hundred inhabitants. They are but mementoes of earlier days when extensive lumbering was the main industry. Most of the region is now a part of the White Mountain National Forest.

Because of its wild, unspoiled character, the Percy quadrangle is a haven for wild game and a source of delight to the hunter, fisherman, and nature lover. Bear, deer, wildcat, raccoon, beaver, and a multitude of smaller game abound in the forests, and fish of many kinds swim the lakes and streams. The hunter and fisherman are practically assured of a sucessful catch when they venture forth into this region. The lover of nature will be genuinely charmed as he hikes the wooded trail along a rushing stream fed by spring thaws, or as he scrambles up a steep mountain slope in the autumn of the year and views the distant ripening forest splashed with vivid reds and yellows. Even the hurried tourist, rushing along by automobile, may breathe deeply of the fresh forest air and marvel at the beauty of the mountainous landscape.

THE STORY OF THE ROCKS

The Geological Map

Before beginning the story of the rocks, the reader should unfold the colored geological map at the back of the pamphlet and get acquainted with the region as a whole. This map includes the Percy quadrangle and the southeastern portion of the Guildhall quadrangle. It is really a bird's eye view of an area of about 230 square miles, and a study of it will help the reader to comprehend better the rocks and their history. The technicalities of reading the map are discussed in detail in a separate section at the end of this pamphlet, so that here we need concern ourselves with these only in a general way.

Each color and pattern on the map represents a particular type of rock, and the outline of the color and pattern indicates the boundary of that rock on the ground. On the margin of the map is a legend in which all rock types are shown in little blocks and their ages indicated. Note that the oldest rocks are at the bottom of the legend and the youngest at the top. Letter symbols associated with each color insure that a particular color on the map is compared with the same color in the legend. The name of each rock and a brief description is printed beneath each block. Careful note should be made of the distribution of the rocks on the map. This will help one to understand better their story.

The geological map, of course, shows the rocks as they appear from above. The "structure sections" below the map show how the rocks would look beneath the surface if deep trenches were cut through them. Each section extends from the surface downward to sea level.

The geological time-scale on page 11 will also help one to understand the rock history. This table shows the eras and periods of earth history from the beginning of geologic time to the present, with the approximate number of years since each began. Important geological events which occurred in the Percy quadrangle are shown in the last column, the earliest event appearing at the bottom of the scale. Upon perusal of column 3 one can hardly fail to be impressed by the immensity of geologic time.

The Sea Invades the Land

Our story of the rocks begins about 375 million years ago in the latter part of what is called the Ordovician period. If we could have flown over the Percy quadrangle in those early days of earth history, we would have seen a landscape quite different from the present one of high rugged mountains and green, heavily-wooded valleys. The Percy region then was covered with a great inland sea of salt water, several hundreds of feet deep. As near as can be determined, the eastern shore of this sea was a great land mass which stretched far out into what is now the Atlantic Ocean. Westward flowing streams,

Geologic Time-scale, with sequence of events in the Percy Quadrangle

OLDEST EVENT IS AT BOTTOM OF CHART; YOUNGEST IS AT TOP

Era	*Period*	*Time-scale (time elapsed since beginning of period)*	*Sequence of geological events*
	Recent	30 thousand years	Weathering and slight erosion.
Cenozoic	Pleistocene	2 million years	Continental ice sheet covered the region, scouring the bedrock and depositing gravel, sand, and till.
	Tertiary	60 million years	Uplift and renewed erosion.
	Cretaceous	120 million years	Erosion.
Mesozoic	Jurassic	150 million years	Erosion.
	Triassic	175 million years	Erosion.
	Permian	210 million years	Erosion.
	Pennsylvanian	255 million years	Erosion.
	Mississippian	290 million years	White Mountain magma series intruded as ring dikes and stocks.
	Devonian	330 million years	Erosion. New Hampshire magma series intruded as a stock as folding subsided. Folding and metamorphism of the rocks. Oliverian magma series intruded as huge dome, partly exposed in southeast corner of quadrangle.
Paleozoic	Silurian	355 million years	Erosion.
	Ordovician	415 million years	Dikes and sills intruded throughout quadrangle. Highlandcroft magma series (Lost Nation group) intruded in southwest corner of quadrangle. Ammonoosuc volcanics accumulated. Albee formation, mostly impure sands, deposited.
	Cambrian	515 million years	No record.
Pre-Cambrian		More than 1000 million years	No record.

coursing across this land, deeply eroded the rocks and swept large quantities of fine sand and mud into the inland sea. These sediments were deposited as thin layers or beds on the bottom in much the same way as muds are being deposited today in the Gulf of Mexico by the Mississippi River to build its great delta. From the human point of view, of course, this process of deposition was exceedingly slow, but it continued for so many millions of years that eventually thousands of feet of sediment piled up on the floor of the inland sea. Probably at no time was the sea very deep, but the bottom sank gradually as the sediments accumulated. These sands and muds were later to become the quartzites and schists of the Albee formation which are widely distributed throughout the quadrangle. Then, far to the east, and probably on the land mass from which the sands and muds were swept, great volcanoes built up their cones and erupted vast quantities of volcanic ash into the air. Some of this ash was carried westward by the wind and settled into the inland sea, later to accumulate on the bottom. Much, undoubtedly, was dropped directly onto the land and later picked up by streams and swept westward into the sea. Evidence from the Mt. Washington quadrangle directly to the south indicates that the volcanic debris thus deposited became almost a mile thick. It has long since been converted to dark green, solid rock and is now known as the Ammonoosuc volcanics. These volcanics crop out along the highway north of Hodgdon Hill in the southeast corner of the quadrangle.

Volcanic activity finally ceased, and northern New Hampshire rose steadily, causing the inland sea to withdraw. At once streams became active and began to wear down the land. At the same time hot molten rock, called "magma," rose from deep in the earth and forced its way into the Albee formation and Ammonoosuc volcanics. Here it cooled far below the surface to form dark-colored, medium-grained, granite-like rocks known as the Lost Nation group of the Highlandcroft magma series, which are now exposed in the southwest corner of the quadrangle. These rocks, mainly quartz diorite and diorite, are composed of feldspar, quartz, black mica, hornblende, and epidote. Somewhat later, magma worked its way upward along cracks and fissures and consolidated to form dark-colored "dikes" and "sills." Sills are thin sheet-like bodies which trend parallel to the "bedding planes" of sedimentary rocks; dikes have the same shape but cut across bedding planes. These may be seen in various parts of the quadrangle where they penetrate rocks of the Albee formation, Ammonoosuc volcanics, and Lost Nation group.

The Percy region continued to stand high above sea level for millions of years while streams carved away the surface of the rocks. There is evidence elsewhere to indicate that about 330 million years ago, in early Devonian time, the region was again covered by the sea and thousands of feet of sand, mud, and impure limestone were deposited. However, none of these deposits are now present in the Percy quadrangle because they have been removed by erosion.

Folding and Metamorphism of the Rocks

In the middle Devonian, about 310 million years ago, important things began to happen in northern New Hampshire. In the first place, hot molten rock of the Oliverian magma series was forced upward into the overlying beds where it crystallized as a huge dome of granite-like rock. Most of this dome lies in the Mt. Washington quadrangle to the south, but its northern flank crops out in the southeast corner of the Percy quadrangle. Here the rock is chiefly medium-grained, gray, foliated quartz diorite consisting of feldspar, quartz, and black and white mica. As this rock gradually crystallized and became solid in its upper part, highly volatile liquids or "magmatic juices" worked upward into it from below to form narrow sheet-like bodies called "pegmatites." These contain coarse crystals of feldspar, quartz, and mica.

Then great disturbances began to affect the crust of the earth. The sandstones, shales, and volcanic rocks were squeezed under intense pressure and heat until they became highly plastic so that instead of fracturing and crumbling, they flowed like hot tar and bent into great folds. Under these new conditions of temperature and pressure, the minerals in the rocks began to change gradually. Eventually the sandstones and shales

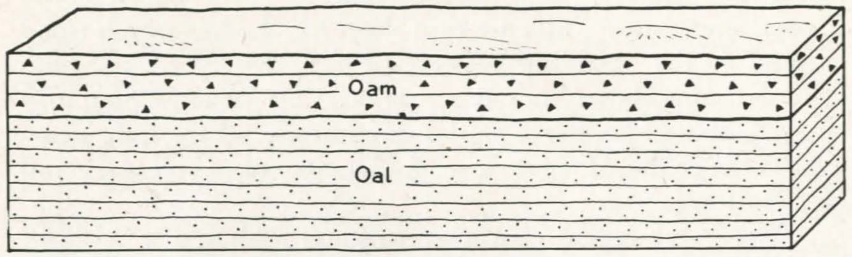

FIGURE 3 — Sands (Oal=Albee formation) and volcanic rocks (Oam=Ammonoosuc volcanics) are deposited, probably in late Ordovician time.

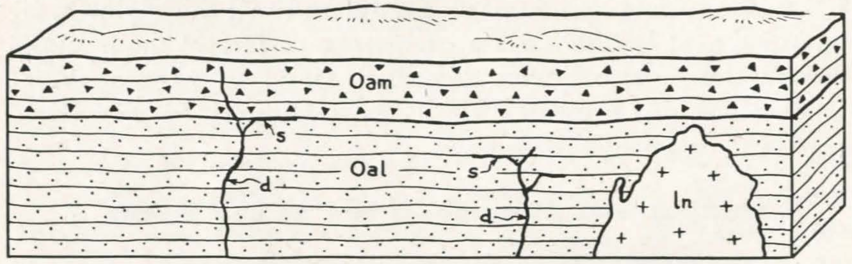

FIGURE 4 — Molten rock invades region and consolidates to form Lost Nation group (ln) and dikes (d) and sills (s), probably in latest Ordovician time. Some erosion during Silurian time.

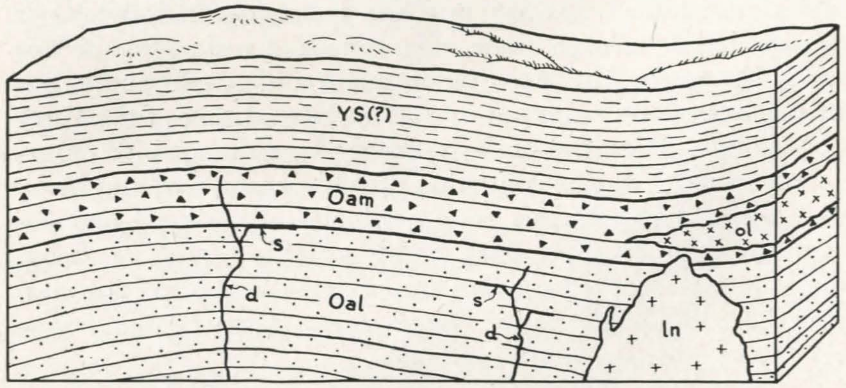

FIGURE 5 — Younger sediments (YS(?)) probably deposited in early Devonian time although now absent in Percy quadrangle. Sediments are gently bent and molten rock pushed in as great lens-like body which consolidates to form Oliverian magma series (ol), probably in middle Devonian time.

FIGURES 3-8 — Series of diagrams to illustrate the story of the rocks. The cross sections are imaginary trenches, a mile or so deep, across the Percy quadrangle from northwest to southeast. The sections are diagrammatic with some foreshortening. Each section shows one or more new developments in the geologic history of the region. Consult the geologic time-scale in this pamphlet for the sequence of events in the region. Oal=Albee formation; Oam=Ammonoosuc volcanics; ln=Lost Nation group of the Highlandcroft magma series; d=dike; s=sill; YS(?)=younger sediments; ol=Oliverian magma series; lg=Long Mountain granite of the New Hampshire magma series; wm=White Mountain magma series.

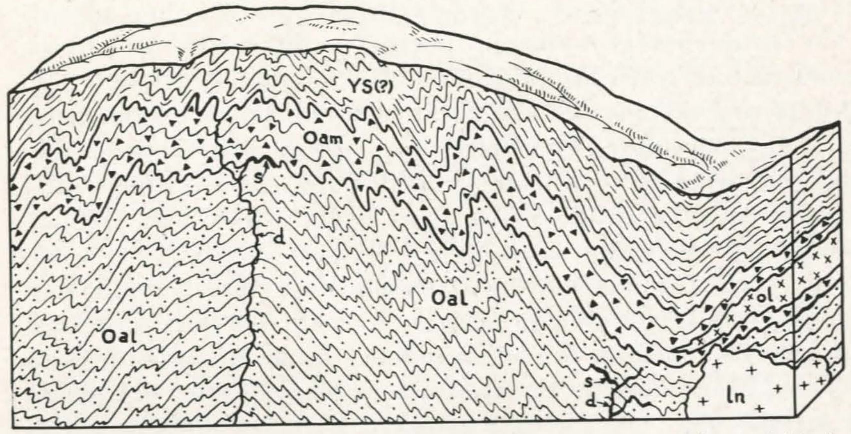

FIGURE 6 — Intense folding, metamorphism, and rise of high mountains, probably in late Devonian time.

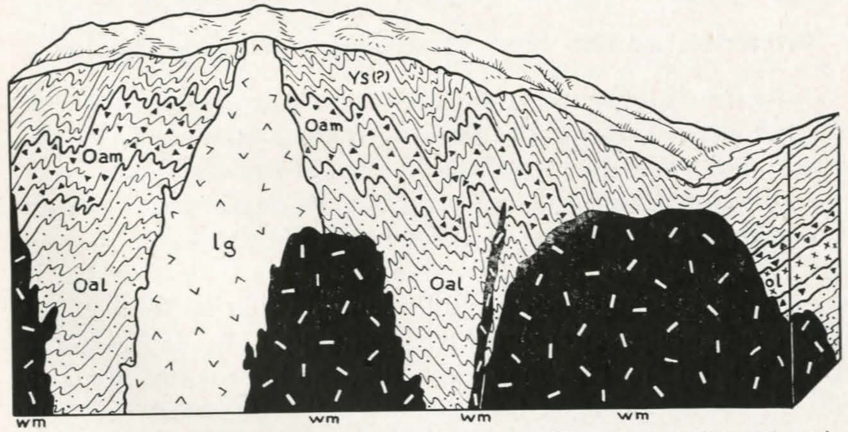

FIGURE 7 — Molten rock invades region and consolidates to form Long Mountain granite (lg). Erosion of high mountains during late Devonian time. Final invasion of molten rock to form White Mountain magma series (wm), probably in Mississippian time.

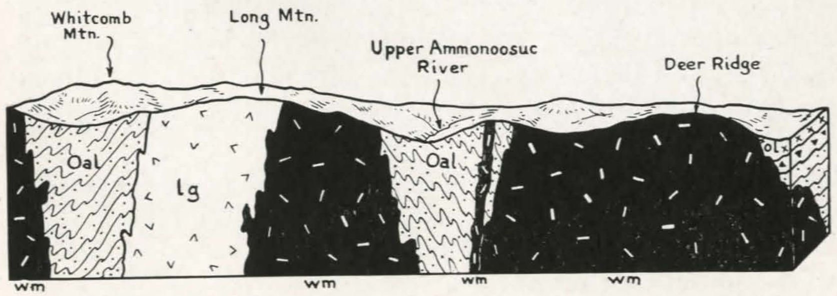

FIGURE 8 — Rocks are eroded to present surface.

were "metamorphosed" or converted to quartzites and schists. The Ammonoosuc volcanics became amphibolites which are dark-colored rocks composed of feldspar and hornblende. These folded and metamorphosed rocks may be seen in various parts of the quadrangle. The beds, originally horizontal when deposited, were tilted into inclined positions, and on the geological map the attitude of the tilted layers is shown by "strike" and "dip" symbols.

As the folding continued, the land rose steadily and eventually great mountain ranges were formed. There is no reason to believe that these ranges were much higher than the present White Mountains, however, since as soon as they started to rise they were immediately attacked by eager streams which proceeded to wear them down.

Intrusion of the New Hampshire Magma Series

As the disturbances in the earth's crust gradually subsided, another great mass of hot granitic magma rose up from the depths and worked its way into the Albee formation. This great plug-like intrusion or "stock" of Long Mountain granite crops out in the northern part of the quadrangle and extends from Long Mountain to the upper edge of the map. Note that it is somewhat egg-shaped in ground-plan and that its longer axis trends roughly parallel to the strike and dip of the layers in the Albee formation. This may mean that the hot magma actually forced its way between layers of the Albee formation shortly before folding ceased and the granite stock was squeezed into this shape. This is uncertain, however, and the magma actually may have risen upward by prying off large blocks of the Albee formation from above and engulfing them, thereby making room for itself higher up. The Long Mountain granite is medium-grained and light-gray and contains feldspar, quartz, and black and white mica.

Intrusion of the New Hampshire magma series marks the third great episode of igneous activity in northern New Hampshire. This was followed by a relatively brief period of erosion which came at the close of the Devonian.

Intrusion of the White Mountain Magma Series

As far as the Percy quadrangle is concerned, the Mississippian period of earth history was the most interesting of all, since it was then that the intrusions of the White Mountain magma series were formed. Some of these consist of granite, a granular rock containing feldspar, either mica or hornblende, and over 15 per cent quartz. Others are made of syenite, a rock with feldspar, either hornblende or mica, and less than 5 per cent quartz. A few rocks are quartz syenites which resemble syenites but contain from 5 to 15 per cent quartz. Most of the rocks of the White Mountain magma series are "even-grained" — i.e., all the minerals in a single specimen are approximately the same size. A few, however, are "porphyritic" — i.e., some mineral grains, known as phenocrysts, are distinctly larger than other grains.

Some intrusions of the White Mountain magma series are ring-like in ground-plan and others are circular. As one meditates on these strange bodies which are chiefly clustered about the Pilot Range in the southern part of the map, he cannot fail to be impressed by their peculiar shapes and their smooth, symmetrical boundaries. On the west, in the southeast corner of

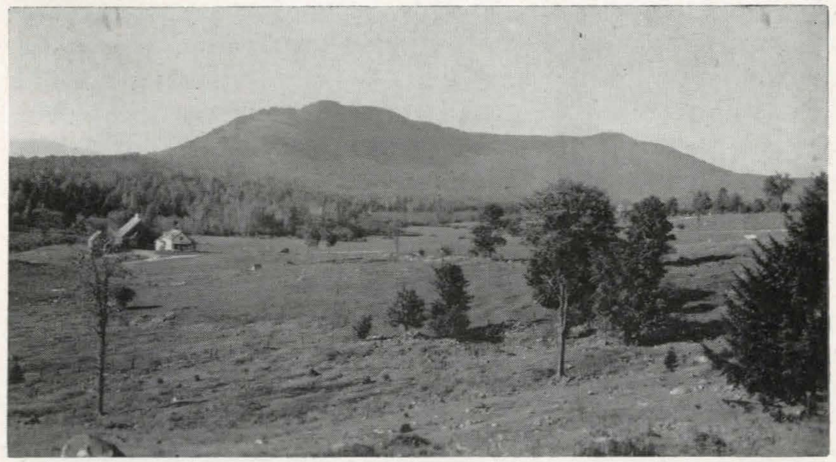

FIGURE 9. Cape Horn viewed from the southeast. This crescentic ring dike, composed of syenite porphyry of the White Mountain magma series, rises 1000 feet above the lowland and is probably the best expressed topographically of any similar geologic feature in North America.

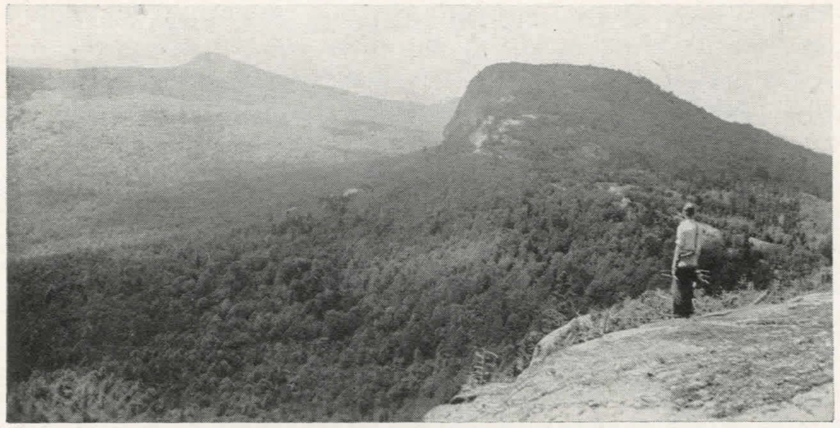

FIGURE 10. View looking west from Greens Ledge. Square Mountain in the foreground and Nigger Nose in the left background are made of coarse-grained, pink Conway granite of the White Mountain magma series. In the center background, on the skyline, is Hutchins Mountain.

the Guildhall quadrangle, is the Cape Horn ring dike (Fig. 9), the shape of which in ground-plan resembles that of a crescent moon. This intrusion is made of syenite porphyry. Farther east, near the western foot of the Pilot Range, are other ring-like intrusions, the largest of which, composed of syenite, begins at The Horn near the southern edge of the map and sweeps gracefully westward and thence northward for about 10 miles, nearly to McCordick Brook. This slender, arcuate body is separated from the much wider syenite intrusion of the Pilot Range to the east by thin sheets of rock which form a "screen." The northern part of this screen consists of rocks of the Albee formation and the southern part of rocks of the Lost Nation group. Several small ring dikes of granite and syenite form the Devils Slide (Fig. 13) east of the village of Stark near the center of the quadrangle.

Some of the ring dikes appear to have been cut off and obliterated by the large, crudely elliptical body or stock of coarse-grained, pink Conway granite lying between the Pilot Range and South Ponds (Fig. 10). Just north of the center of the quadrangle is another roughly circular stock of pink Conway granite called the Percy Peaks stock, and in the northwest corner is a part of a round body composed of blue-green syenite. Along the southern edge of the map is a portion of

another intrusive body which is made of granite containing two special kinds of hornblende known as "hastingsite" and "riebeckite." These roughly circular bodies for the most part formed after the ring dikes.

"How do ring dikes form?" is a question which has puzzled geologists for years. We know that these are unusual features since they have been found in abundance chiefly in two localities — Scotland and New Hampshire. The ring dikes of the Percy quadrangle, when grouped with those of the Mt. Washington quadrangle immediately to the south, form one of the finest clusters in the world. It is fairly obvious that to form ring dikes, magma must have come up along circular cracks in the earth's crust, but just how the cracks formed is somewhat of a mystery. Possibly there was settling of the crust in this region, which resulted in a series of concentric fractures. It is equally possible that forces pushing upward from below could have produced them. In any event, the fractures must have intercepted a great reservoir of molten magma somewhere at depths and this rose along the fractures and congealed to form the ring dikes. Some of the stocks of granite associated with the ring dikes may owe their smooth circular boundaries to similar fractures.

The Wearing Down of the Land

The intrusion of the White Mountain magma series was the last event in the formation of the bedrock, and a long period of erosion now ensued. Since the land surface stood high above sea level, streams became active and cut deeply into the bedrock. All through the Pennsylvanian, Permian, Triassic, Jurassic, and Cretaceous periods they worked, tearing down the hard rocks and carrying the detritus away to the sea. In the Tertiary period there was a further slight uplift of the land and the streams attacked again with renewed vigor. Large ones and small ones worked together in unison, the smaller ones scouring away at the rocks in their particular localities and washing the sediment into the main stream, the Upper Ammonoosuc River. The latter then swept it westward into the Connecticut River.

A process such as this is exceedingly slow. When we recall that streams work energetically only during times of flood, we are amazed by the immensity of time it must have taken to wear down the Percy region. But we must remember that this erosion continued for perhaps 250 million years, and during this long interval, the streams were able to remove thousands of feet of rock. Thus the region was gradually worn down almost to its present level.

Rocks differ greatly in hardness and in their resistance to erosion. Streams tend to seek out the softer rocks and to flow on them since they can cut downward more rapidly. In the Percy quadrangle the rocks of the White Mountain magma series are unusually resistant, but those of the Albee formation, Ammonoosuc volcanics, Lost Nation group, and Oliverian magma series are considerably softer. Note on the map that most of the larger streams like the Upper Ammonoosuc River, Nash Stream, and Phillips Brook are now flowing across the softer rocks. Instead of flowing directly westward into the Connecticut River, the Upper Ammonoosuc River winds northward and thence westward in a gigantic arc about the harder rocks of the White Mountain magma series.

FIGURE 11. The Pilot Range as seen from the vicinity of Lost Nation village. This rugged range, culminating in Hutchins Mountain in the center background, is composed of hard, resistant syenite of the White Moutain magma series. The lowland in the foreground is underlain by quartz diorite and diorite of the Lost Nation group.

In a general way, the height and shape of the mountains in the Percy quadrangle reflect remarkably well the kind of rocks that underlie them. For example, notice how closely the contour lines of Cape Horn in the Guildhall quadrangle conform to the outline of the ring dike. This hill stands up as a high crescentic ridge because the rock of which it is composed is unusually tough and shaped like a crescent. The rocks surrounding Cape Horn are the softer Albee formation and Lost Nation group. The rugged Pilot Range (Fig. 11) towers above the lower, flatter land to the west because it is made of the more resistant rocks of the White Mountain magma series. We could almost guess that these rocks are ring dikes by merely observing the arcuate bend of the range.

The same principle holds for such summits as Mt. Cabot near the southern edge of the map, Percy Peaks in the center of the map, and Sugarloaf in the northwest corner. All these are made of tough rocks of the White Mountain magma series. On the other hand, most of the low hills and the flat land in the quadrangle are underlain by much softer rocks.

The Coming of the Great Ice Sheet

By Pleistocene time thousands of feet of bedrock had been eroded from northern New Hampshire. The lowlands had been carved out, the mountains etched into relief, and the streams flowed generally on the softer formations. The topography of the Percy quadrangle resembled closely that of today.

Then, gradually, a great change overcame the region. The winters became longer and colder, and the precipitation, chiefly in the form of snow, increased. The crest of the Pilot Range and the summits of the other high mountains remained white throughout the year. In the Presidential Range to the south, great thicknesses of ice accumulated at the heads of large valleys, and little mountain glaciers wormed their way slowly downward. As they moved along they dug and scraped away the rocks and formed broad U-shaped valleys. The mountains of the Percy quadrangle are lower than the Presidential Range, and it is not certain that mountain glaciers accumulated on them. However, the broad rounded valleys near The Horn, The

Bulge, and Mt. Cabot, along the southern edge of the quadrangle, resemble somewhat valleys that have been carved by mountain glaciers.

The great change in climate affected not only New Hampshire, but the whole northern part of North America, and about 50,000 years ago a great ice cap began collecting in Canada. As layer upon layer of ice and snow accumulated, the weight upon the lower layers became unbearable and the whole mass flowed outward like thick molasses. Part of this great ice sheet, or continental glacier, spread southeastward over New England, slowly and inexorably covering everything in its way. Even Mt. Washington to the south was completely covered by ice, so we know that the great sheet must have been at least a mile thick. As a result of this tremendous load on the rocks, the earth's crust throughout New England was depressed, in much the same way that a roof sags downward slightly when covered with heavy snow.

As the ice moved slowly southeastward it scooped up the soil and weathered rock lying on the surface and carried them along. Even large chunks of rock, some weighing many tons, were pried from cliffs and ledges, and these were frozen into

FIGURE 12. View, looking west from York Pond road, showing glaciated mountain topography. The high cliffs, such as on Round Mountain (left middleground), are composed of Conway granite of the White Mountain magma series. These were steepened when the great ice sheet plucked away blocks from their bases.

the ice and carried away bodily. The scraping and rubbing action of these blocks as they moved over the area rounded off the hills and grooved and polished the bedrock ledges. In many parts of the Percy quadrangle, particularly on hill slopes and mountain tops, smooth, polished rock surfaces show deep grooves or "striations" which point southeastward in the direction of ice movement.

If one stands on the York Pond road in the southeast part of the quadrangle, just south of its junction with the main highway, and looks west, an impressive view of the effects of the ice may be obtained (Fig. 12). Several summits with relatively gentle northern slopes present sheer cliffs several hundred feet high facing south and southeast. These cliffs existed long before the continental glacier came, but they were probably made much steeper by the ice which plucked away the large loose blocks from their bases.

The soil and rocks scooped up in the Percy region were carried away far to the southeast. When the continental glacier finally melted away, the vast quantity of debris which it had brought in from the north was dumped in a haphazard manner over the Percy quadrangle. Some of this is in the form of large, more or less rounded boulders or "erratics," many measuring 10 or 15 feet on a side and weighing several tons. These erratics are frequently found in peculiar places, such as on high mountains where they may be perched precariously on a sharp ridge or on the brink of a precipice. Since most erratics have been moved some distance, they are often made of rock which differs from that of the bedrock on which they now rest.

The most abundant type of debris dropped by the Pleistocene ice sheet was "till" and loose gravel and sand. Till consists of a mixture of boulders and bluish or grayish clay, the clay representing solid rock which was thoroughly pulverized by the glacier. Most of the stream valleys and the low ground and rolling hills in the Percy quadrangle are covered by a veneer of gravel, sand, and till. These deposits may be seen in road and railroad excavations, along streams, and on cultivated fields. In one place, along the Upper Ammonoosuc River, about 2 miles south of West Milan, the till is nearly 100 feet thick.

On the geological map the glacial deposits are not shown systematically; they are indicated only where they are especially thick or extensive or where they hide the bedrock completly.

Horn Hill and the two low hills northeast of Dummer Hill, near the eastern edge of the map, are glacial forms called "drumlins." These elongate mounds, shaped like the bowl of an inverted teaspoon, are composed entirely of glacial till and always point in the direction of ice movement. Cummings Mountain, Bickford Hill, and Hodgdon Hill are "drumloids" which consist of cores of solid rock covered with till.

The drainage pattern of the Percy quadrangle was considerably modified by continental glaciation. The vast quantities of till, sand, and gravel which were brought in and spread over the surface filled in the stream valleys, covered the flat ground and low hills, and greatly modified the old topography. As the ice melted away, small new streams originated in depressions in the irregular surface and these cut downward, making new valleys. Although the larger rivers, like Nash Stream and the Upper Ammonoosuc River, followed their previous course in a general way, even the Upper Ammonoosuc River appears to have been deflected by the glacial deposits. Field studies near the central part of the quadrangle suggest that prior to the Pleistocene this river flowed westward between Dickey Hill and Christine Lake rather than through Stark as it does today.

The new ground surface was rough and irregular so that surface drainage was poor. Rather than run off, some water collected in depressions, and numerous swamps and lakes were formed. Two of the most picturesque of these lakes are Christine Lake and South Ponds.

Recent Events

Geologically speaking, a short time has elapsed since the retreat of the great ice sheet about 30,000 years ago. During the brief interval since then, no startling geological changes have occurred in the Percy region. Instead those slow, interminable, non-spectacular processes of weathering and erosion dominate the scene. Water, oxygen, and carbon dioxide from the atmosphere attack the rocks chemically, causing them to crumble and decay. Water seeps into the cracks in ledges where it freezes and pries off irregular blocks. Streams and rivers collect sediment along their courses and sweep it eventually to the sea. All these processes, although imperceptible and unbelievably slow, are working together toward a common end. Given sufficient opportunity, they will eventually accomplish the seemingly endless task of leveling the land surface to a low flat plain. What a strange landscape we might see if we returned to the Percy region 50 million years from now!

MINERAL AND ROCK RESOURCES

The Percy quadrangle probably has few if any mineral resources of great value. In the early part of the present century, copper, gold, and silver were obtained in small quantity from the Milan mine northeast of Hodgdon Hill in the southeast part of the quadrangle. The ores soon ran out, however, and the operation was abandoned. This mine is described briefly in the section on *"Interesting Trips and Localities."*

The pegmatites associated with the Oliverian magma series in the southeast portion of the quadrangle contain feldspar and white mica, but these intrusives are too small to be worked profitably at present.

Sand and gravel deposits are numerous especially along the valley of the Upper Ammonoosuc River. Some of these were accumulated by the river itself and others were deposited by the great ice sheet in Pleistocene time. Sand and gravel are useful for road construction and for concrete aggregate.

The Percy quadrangle has a practically inexhaustible supply of good building stone known as the Conway granite, the same rock which has been quarried for years in the famous Redstone quarries near Conway, New Hampshire. This rock is medium-to-coarse-grained, is pink in color, and can be worked into a good dimension stone. Many years ago a small quarry was opened on the knoll (elevation 1620 feet) 1¼ miles southwest of Blake School (west-central ninth of quadrangle) and this supplied considerable building stone for nearby localities.

The tough, resistant syenite of the Pilot Range cannot be worked easily into dimension stone, but it would make excellent riprap, ballast, and road metal. The syenite porphyry of Cape Horn would be especially good for road metal since it is fine-grained and unusually tough.

INTERESTING TRIPS AND LOCALITIES

State Highway No. 110. Along this highway, southeast of West Milan, many fine outcrops are exposed. In the village of West Milan, at the junction of State Highway No. 110-A which goes to Errol, a large road cut exposes folded quartzite of the Albee formation. The foliation and bedding here strike 70 degrees east of north and dip steeply toward the northwest. Other good outcrops of this formation may be seen along the highway at various points for about 2 miles to the northwest and for about 1½ miles to the southeast.

The Ammonoosuc volcanics crop out at various points along the highway northwest of Hodgdon Hill. Most of these are dark green or black and show layering which is probably foliation rather than bedding. These volcanic rocks have been strongly metamorphosed and now consist of tiny grains of white feldspar and needle-like crystals of black or dark green hornblende.

Many fine outcrops of the Oliverian magma series lie in the fields on either side of the road near the east edge of the quadrangle. These rocks are gray and composed of white feldspar, grayish glassy quartz, and flakes of black and white mica. The mica flakes are all arranged in a plane. Locally the rock is cut by pegmatites a few inches wide which consist of coarse crystals of feldspar, quartz, and white mica.

Milan Mine. This old copper mine lies in the Ammonoosuc volcanics northeast of Hodgdon Hill. It may be reached by taking the dirt road south of Nay Pond and proceeding about half a mile southeast of the railroad track. This mine was opened in the early part of the present century and it produced small amounts of copper and associated gold and silver. However, the ores quickly ran out and the operation was abandoned. On the old dumps are specimens of amphibolite

and white quartzite, the latter containing grains of quartz and flakes of white mica. Some specimens of the quartzite contain tiny cubes of brassy pyrite or "fool's gold," a mineral containing iron and sulphur.

Crystal Falls. The visitor will enjoy a stop at this picturesque spot in the village of Crystal, where Phillips Brook flows over hard quartzites of the Albee formation (Fig. 1). During the Pleistocene period, the continental glacier forced the stream into this new channel and as yet the stream has not been able to cut a deep gorge. The rocks here are best exposed during low-water stage.

The Albee formation is well exposed for over 1,000 feet along the stream. Bedding planes are clearly evident, individual beds or layers being a few inches thick. Although the strike of the bedding is northeast, the careful observer will note that it is not the same at every point. Near the bridge, for example, the beds strike 25 degrees east of north and dip 85 degrees to the northwest; 350 feet upstream they strike 10 degrees east of north and have the same dip; and about 950 feet upstream they strike north-south and dip 55 degrees toward the east. These discrepancies are due to the folding of the rocks.

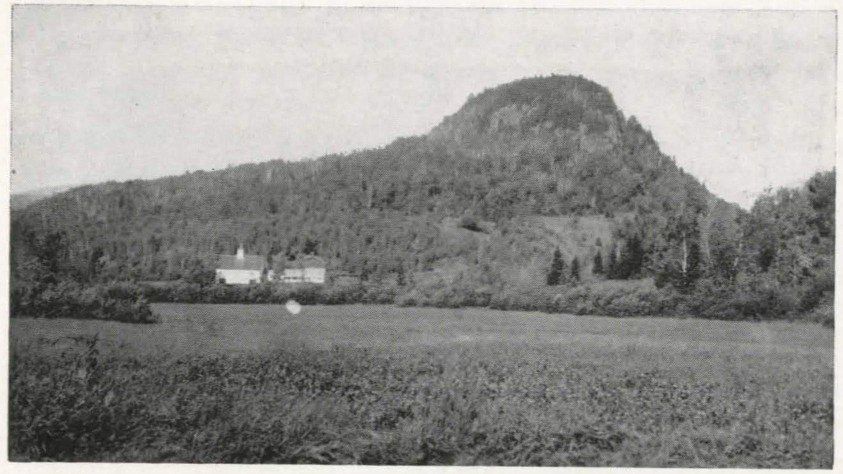

FIGURE 13. The Devils Slide as it appears from the southwest. This ring dike, composed of coarse-grained syenite, forms a high ridge which trends northeasterly, away from the observer.

This is a good place to observe some of the dikes and sills which intruded the Albee formation during Ordovician time. Several of these bodies, 6 to 8 feet wide, cut the Albee formation, the sills striking parallel to the bedding, the dikes striking across it. One particularly wide dike crops out at the top of the upper falls. These intrusions have all been metamorphosed to amphibolites which consist principally of white feldspar and greenish black hornblende.

Devils Slide. The reader who is interested in ring dikes cannot afford to by-pass the Devils Slide (Fig. 13). This spectacular ridge, with its southeasterly-facing vertical cliff, lies near the center of the quadrangle, northwest of the village of Stark. The visitor approaching on State Highway No. 110 can reach the base of the Slide by crossing the Upper Ammonoosuc River on the old covered bridge at Stark and then turning westward along the dirt road until he crosses the railroad track. From here the southwest end of the ridge can be approached easily. A little scrambling and bushwhacking will enable one to work along the base of the cliff and to study the rock. The latter is mostly coarse-grained and granite-like and represents the crystallized magma which rose from depth along a circular fracture. Locally the granite contains abundant irregular pieces of dark-colored, fine-grained schist of the Albee formation that were torn from its walls at it rose.

Cape Horn. Cape Horn (Fig. 9) is a slender arcuate ridge rising about 1,000 feet above the surrounding lowland. Its abruptness is due to the hard resistant ring dike of which it is composed. A climb to the summit of Cape Horn is well worth the effort, and the best approach is along the ridge from the general vicinity of Groveton. Good outcrops of rock occur all along the crest and a precipitous slope faces the east. In general the rock is finer-grained and darker than that in the other ring dikes and is called technically "syenite porphyry." The summit affords a fine view of the Pilot Range, and toward the northwest and southwest the Connecticut River can be seen twisting its tortuous way southward to the sea.

The less active visitor, who does not desire to climb, may

FIGURE 14. View of north Percy Peak taken from the south peak. The dome-like shape results from the scaling off of large sheets of weathered granite.

view the broad panorama of Cape Horn from a point on the road to the east in the general vicinity of Parks Brook.

Percy Peaks. Every able-bodied visitor to the Percy quadrangle should climb Percy Peaks (Fig. 2). The easiest and most rewarding approach is from the village of Percy near the center of the quadrangle. Here the visitor should leave his car and begin to hike along the unimproved road which follows the north side of Christine Lake. This beautiful lake, 200 feet above the Upper Ammonoosuc River, lies in a depression in the debris dropped by the continental glacier. The white sandy beach at its eastern end is ideal for bathing.

West of Christine Lake is Potters Ledge, a low hill with a well-marked trail leading up to its summit. A side trip to this point is well worthwhile, if time permits. The boundary of the Percy Peaks stock extends northwest-southeast right through the summit, and it may be studied critically at this point. To the southwest are dark fine-grained quartzites of the Albee formation, and to the northeast is medium-grained pink Conway granite. The boundary is very irregular with finger-like projections of granite sticking into the quartzite and small irregular chunks of quartzite entirely surrounded by granite.

The pink granite covering most of the top of Potters Ledge has been broken into huge angular blocks by "joints" or fractures. Many of these joints have been so widened by weathering and frost-heaving that a lanky hiker can squirm himself into them without difficulty.

Most of the way, the climb to the north Percy Peak is gradual and steady along a good, well-marked trail. The last few hundred feet, however, are steep and the trail leads over bare, smooth ledges of pink Conway granite. In the process of weathering, the granite is shelling off in hugh sheets which cover the whole mountain top (Fig. 14). From a distance, these overlapping sheets resemble shingles on a roof. The bare, rounded summit of the north Percy Peak affords a magnificent panorama of the surrounding wild and rugged region known throughout New Hampshire as the "North Country." The hot, tired climber, viewing this splendid scene, will readily agree that his efforts have been well rewarded.

Mill Brook Trail. This trip is recommended especially for those who are fond of good hiking along mountain trails. The Mill Brook trail extends from York Pond, at the south edge of the map, across wild, heavily-forested, mountainous country to the village of Stark near the center of the quadrangle. The hiker should arrange to be transported to York Pond to begin his hike and to be picked up at Stark at the end of the day.

York Pond is cozily nestled among the rugged peaks of the Pilot and Pliny Ranges which surround it on the north, west, and south. It is an ideal spot for the United States Fish Hatchery which helps to stock New Hampshire streams with young trout. From York Pond the Mill Brook trail leads northwestward along Cold Brook almost to the top of Deer Ridge, and from there it follows East Branch to its junction with Mill Brook. Thence it follows Mill Brook north to Stark.

Few outcrops of rock will be seen, but the route leads through beautifully forested country. At each turn in the trail a new, fresh vista, such as a cool rushing stream or a distant mountain peak, delights the observer. In the autumn of the year the dry fallen leaves crackle crisply as the hiker tramps along.

HOW TO READ THE MAP

A colored geological map of the Percy quadrangle and the southeastern portion of the Guildhall quadrangle is folded into the pocket at the back of this pamphlet. At the side of the map is a legend and below it are geological structure sections. All of these are designed to show as accurately as possible the kind of rocks to be found in the area.

The colors representing the rocks have been overprinted onto the regular topographic map of the Percy quadrangle surveyed by the United States Geological Survey in 1930. The scales at the bottom show that the Percy quadrangle is about 17 miles from north to south and about 12 miles from east to west, making its area about 215 square miles.

Black is used on the map for lettering and to show the "culture" or works of man. Solid double lines indicate surfaced or improved roads, double dashed lines indicate poor or unimproved roads, single dashed lines indicate trails, and single solid lines with short cross-bars represent railroads. Heavy dashed lines are township boundaries. Houses are represented by tiny solid black squares.

On a topographic map, water is shown in blue. Streams are represented by blue lines, and lakes, such as Christine Lake near the center of the quadrangle, appear as concentric blue lines which are always parallel to the nearest shore. Swamps are marked by blue tufts.

The big advantage of a topographic map is that it shows the "relief" or varying heights of the land surface. This is done by means of imaginary lines, called "contour lines," which are drawn in solid brown. All points on a particular contour line have the same elevation above sea level, so if you walk along a contour line you will neither go uphill nor down. The "contour interval" is the distance measured vertically between two adjacent contour lines. The contour interval of the Percy quadrangle is 20 feet and this is indicated on the lower margin of the map. For convenience in reading, every fifth contour line is drawn heavier and its elevation indicated by a brown number. Where slopes are steep the contours are closely spaced, and on gentle slopes they are far apart. Contour lines always bend or "V" upstream.

The best way to learn to read contours is to study a topographic map. Trace out some of the contours on the Percy quadrangle and observe how they bend around ridges and "V" up valleys. Compare the steep, rugged topography of the Pilot Range in the southwest corner of the quadrangle with the more rolling topography in the northeast portion.

Now, let us turn to the colors on the map. Each color pattern shows the kind of rock occurring at a particular locality. In the legend along the side of the map the rock corresponding to each color is briefly described. To aid further in identification, each rock type is indicated by black letters which are scattered over the colors on the map and also printed over the color in the little block in the legend. For example, the symbol *Oam,* printed on the purple color in the southeastern part of the quadrangle, represents the Ammonoosuc volcanics of Ordovician age.

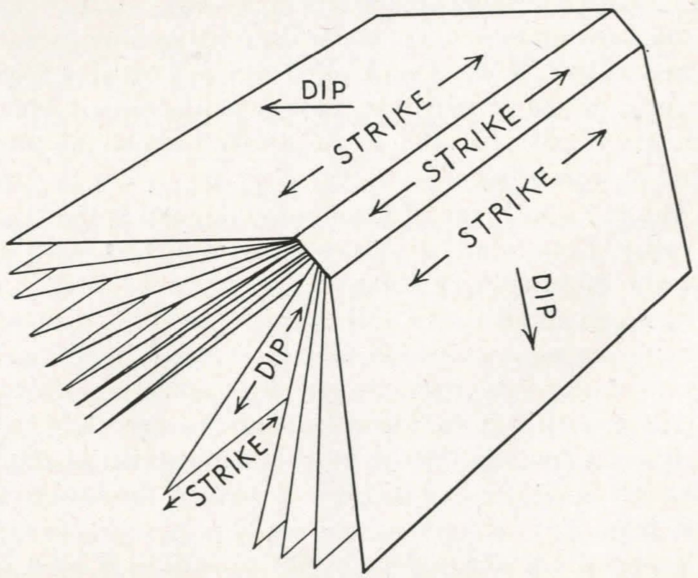

FIGURE 15 — Diagram to illustrate strike and dip.

Color patterns on the map are separated by different kinds of lines which represent rock boundaries. A solid black line means either that the boundary was actually observed in the field or that it was traced with a reasonable degree of accuracy. Dashed lines indicate that the boundary is poorly exposed so that it could not be readily traced. Dotted lines indicate that the boundary is not sharp and that one rock grades into another.

In the legend on the edge of the map all rocks in the region are listed according to age, oldest at the bottom. Each rock is described very briefly. These descriptions are somewhat technical, so that the reader need not be too concerned with them.

The special symbols represent the attitude of the layers of rock as they lie in the field. Some of these layers, known as "beds," consist of minerals of different compositions which accumulated as sediments on the bottom of the sea. Each bed is separated from its neighbors by smooth surfaces called "bedding planes." Other layers, called "foliation planes," are caused by the parallel arrangement of mineral flakes in the rock. The straight line of the special symbol shows the "strike" or trend of the bedding plane or foliation plane as it would appear on a horizontal surface. The number and little pointer on the symbol indicate the amount and direction of "dip" or slope of the layer measured from a horizontal plane. Note on the geological map that most of the bedding and foliation planes in the Percy quadrangle strike generally northeast-southwest. Figure 15 explains diagrammatically the meaning of strike and dip.

At the bottom of the map are three "structure sections" which show what the rocks would probably look like below the surface if deep trenches were dug across the area. The positions of these sections are shown on the map by solid black lines labelled A-A′, B-B′, C-C′. For example, section A-A′ cuts through the ring dikes and stocks of the Pilot Range in the southern part of the quadrangle and shows how these would probably appear below the surface of the ground.

"How is a geological map made?" is a question often asked by the curious reader. Although the answer to this question is simple, the job of making a geological map is not. The map is prepared by the geologist, a man with strong legs, a stout heart, and an avid desire to solve some of the many intricate puzzles woven into the rocks. Carrying a copy of the topographic map of the quadrangle, the geologist walks over the area looking for "outcrops" or ledges of rock. Some of the most promising places are stream valleys, mountain ridges, and road cuts. When an outcrop is discovered, the geologist breaks off a fresh chip with his geological hammer and examines it carefully with his hand lens to determine what minerals it contains. With his compass he measures the strike and dip of the bedding and foliation. All of this information he jots down in his notebook. After plotting the outcrop in its proper position on the topographic map, he moves on to the next outcrop.

The geologist must be especially careful to differentiate between true outcrops and boulders. As we have already seen, thick glacial deposits cover much of the bedrock in the Percy quadrangle and these contain many large partly buried boulders which have been transported from points many miles away. To interpret one of these boulders as ledge or bedrock might lead to serious geological error.

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