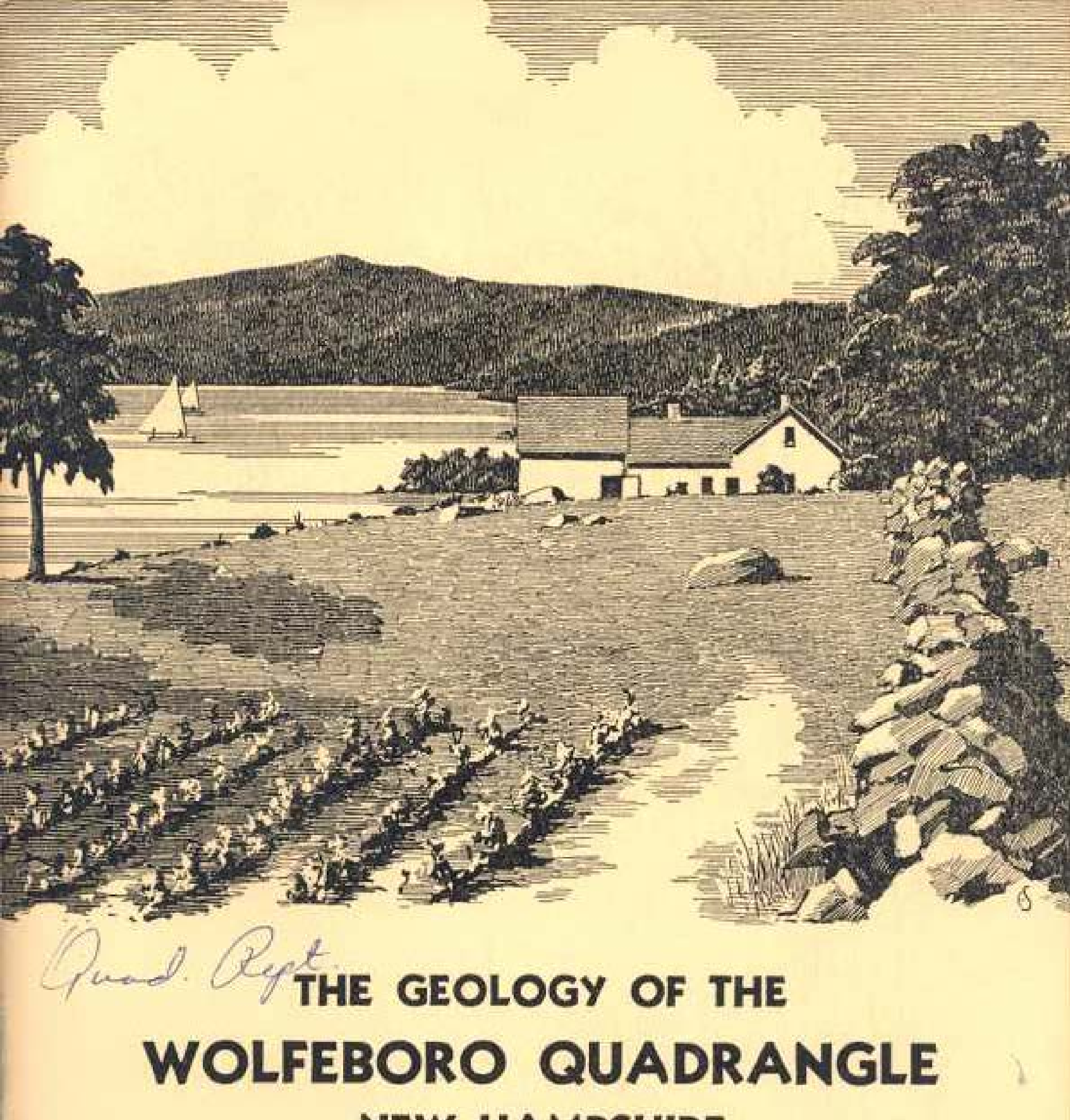

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THE GEOLOGY OF THE WOLFEBORO QUADRANGLE NEW HAMPSHIRE

by

ALONZO QUINN

Published by THE NEW HAMPSHIRE STATE PLANNING AND DEVELOPMENT COMMISSION

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Foreword

This pamphlet is designed to appeal to the layman and is not intended to be an elaborate report for the professional geologist. Technical words are avoided as far as practical. The map accompanying the pamphlet shows the details of the geology of the region, with a key for reading it. All that need concern the layman are the formation names. It is not essential for him to read or understand the detailed mineral and rock descriptions. The story of the rocks can be understood without these details.

The field work in the Wolfeboro quadrangle was done in the summers of 1939 and 1940 and was in part financed by a grant from the Bache Fund of the National Academy of Science. Professor Marland P. Billings of Harvard University spent several days in the field with the writer and aided greatly by suggesting correlations with other areas in New Hampshire. The late Professor J. W. Goldthwait of Dartmouth College, who contributed so much to New Hampshire geology, gave much help and encouragement during the course of this work.

The laboratory study of the rocks and the writing of the report were done at the Department of Geology, Brown University. An earlier paper describing some of the rocks at the southern part of the adjacent Alton quadrangle was published in collaboration with Glenn W. Stewart in 1941. The present report has been long delayed by a variety of circumstances, among which was the interruption of normal geological work by World War II.

Geology of the Wolfeboro Quadrangle New Hampshire

By Alonzo Quinn

Introduction

The Wolfeboro quadrangle is a favorite vacation place for many people. Summer cottages are numerous on the shores of not only the larger lakes, Winnipesaukee and Wentworth, but also of the smaller lakes and ponds. Many of the farmhouses on the hills away from the lakes are also occupied by vacationers. It is hoped that this pamphlet will add to the pleasure of the vacationers and of the permanent residents by helping them understand what these old hills and valleys have gone through to come to their present beauty.

The Landscape

By a long and complex history, to be recounted in the following pages, this part of the earth's crust is composed of several different kinds of rock, some with great resistance to erosion and some relatively weak. A comparable situation would be a much used pavement composed of slabs of rock having greatly different hardness. The softer slabs would wear down faster and would eventually be low places in the pavement, where puddles of water would collect after storms. The Winnipesaukee-Wentworth lowland, which extends into the Winnipesaukee quadrangle to the west, corresponds to such a soft pavement block. The resistant blocks are represented by the higher area that includes Mt. Long Stack, Copple Crown Mountain, the Moose Mountains, and Devils Den Mountain. Other similar high areas, which lie mostly in adjacent quadrangles are the Ossipee Mountains at the northwest corner, Green Mountain just north of the northern edge, and the Belknap Mountains to the west of the southwest corner. Areas of intermediate resistance to erosion include Moody Mountain, Whiteface Mountain, Tumbledown Dick Mountain, and Foggs Ridge. Within each of these areas are hills and valleys, just as each of the pavement slabs might have irregularities within it. Of course this part of New Hampshire is more complicated than any pavement and the chief complication resulted from the ice sheet that covered all of New England only a few tens of thousands of years ago. The effects of glaciation will receive more attention in later parts of this report.

THE ROCKS AND THEIR STORY

Major Units

The bedrock of this quadrangle may be divided into three main groups on the basis of origin and age. The oldest is a group of schists and granulites, belonging to the Littleton formation, which underlie several areas in different parts of the quadrangle and which have intermediate resistance to erosion. The second group includes two main types of rock, one of which underlies the Winnipesaukee-Wentworth lowland and the other of which forms such hills as Whiteface Mountain and Foggs Ridge. Both are igneous in origin (i. e., they were once molten) and belonging to what has been called the New Hampshire magma series. The third and youngest group includes a considerable variety of igneous rocks, best developed within this quadrangle in the Copple Crown Mountain area, and even better developed in adjacent quadrangles in such areas as the Belknap Mountains and the Ossipee Mountains. These rocks are related to each other in age and origin and are members of the White Mountain magma series.

Littleton Formation

The Littleton formation consists predominantly of mica schist, quartz-mica schist, and quartzite. The chief minerals are quartz, black mica, white mica, and garnet. The abundant mica flakes are usually parallel to one another, with the result that the rock has a layered or slabby structure, known as "schistosity." In many parts of the Wolfeboro quadrangle these layers are greatly contorted and folded because of the squeezing and mashing that affected this area in an earlier geologic age. Good exposures of the schists may be seen on the hills around the Beech Ponds, at Tumbledown Dick Mountain, and on Ballards Ridge.

A second important type of rock included in the Littleton formation is the lime-silicate granulite exposed especially in the southern part of the village of Sanbornville, at Nutters Point on Lovell Lake, and near Burleyville Station. This rock consists mainly of such minerals as diopside, actinolite, quartz, plagioclase, clinozoisite, and calcite. It is well banded but not very schistose. The contrasting character of the thin beds of this rock displays the contortion and folding especially well.

Most outcrops of the Littleton rocks contain dikes, seams, and irregular stringers of both coarse-grained and fine-grained granitic rocks.

The accumulated geological knowledge from this and other areas leads to the conclusion that the various layers of the Littleton formation were formed as accumulations of sediment in a shallow sea that covered a large part of New England in the Devonian period, approximately 355,000,000 years ago. (Fig. 1).

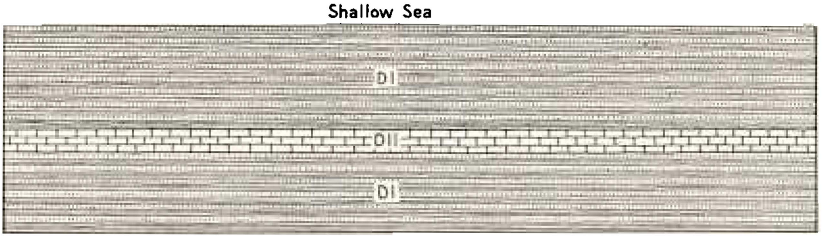
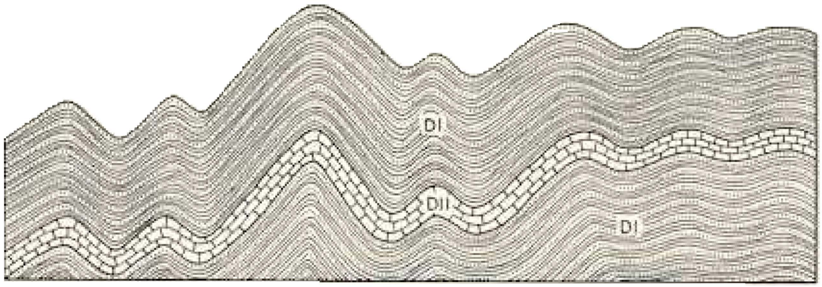


Figure 1. Deposition of thousands of feet of sand and mud *(Dl)* in sea during early Devonian time. *Dll* represents more limy beds.

The shales, sandstones, and shaly sandstones in this old sea are now represented by the schist layers, and limy shales and limestones have turned into the present lime-silicate granulite. The contortion and later breaking of the rock, together with the effects of the igneous intrusions, have been so great in this part of New Hampshire that no accurate estimate of the thickness of the Littleton formation can be made, but in other parts of the state the evidence seems to indicate a thickness of at least 10,000 feet of sediments that accumulated in the Devonian sea before the deposition was stopped.

The period of slow settling of sand, mud, and limestone in the sea was brought to an end by a drastic change; this part of the crust was squeezed into tight wrinkles (Fig. 2). The compressive force and the accompanying heat caused the chemical elements



'igure 2. Folding during early part of Late Devonian time.

of the sand, shale, and limestone to rearrange themselves into new minerals, such as the micas, diopside, garnet, clinozoisite, and actinolite. This process, which is known as "metamorphism," has affected most parts of New England at one time or another during geologic history.

New Hampshire Magma Series

The episode of folding and recrystallization of the Littleton formation was followed immediately by the formation of the New Hampshire magma series, here including the Winnipesaukee quartz diorite and the Concord granite (Fig. 3). Both rocks

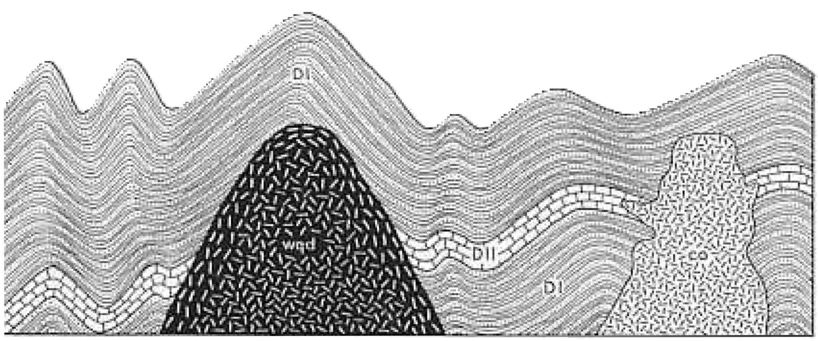


Figure 3. Intrusion of molten magma to form Winnipesaukee ıartz diorite *(wqd)* and Concord granite *(co)* in Late Devonian time.

originated from great masses of magma (molten rock) that worked upward from within the earth but did not reach the surface before solidifying. We know that this occurred after the folding and recrystallization of the Littleton beds, because engulfed pieces show that they were already folded and recrystallized when the magma came in. On the other hand, the New Hampshire magma series is weakly foliated, which suggests that it, too, was affected by the compression. The conclusion seems justified that the New Hampshire magma series came in after the climax of the folding and recrystallization, but before the compression had completely died out.

The Winnipesaukee quartz diorite is a gray, somewhat foliated rock that looks like a granite and differs from it only in ways revealed by microscopic study. It is the weak rock that has been eroded to form the Winnipesaukee-Wentworth lowland. The Concord granite is somewhat coarser and is distinguished by having white mica in addition to black mica. The fact that this rock forms such hills as Trask Hill, Whiteface Mountain, Cotton Mountain, and Foggs Ridge indicates that it is somewhat more resistant to erosion than is the Winnipesaukee quartz diorite.

Both the Winnipesaukee quartz diorite and the Concord granite contain irregular stringers and dikes of coarser grained granitic material (pegmatites) due to the final crystallization of the last juices of the magma. Larger pegmatites in other parts of New Hampshire have considerable commercial value as sources of mica and feldspar. One such deposit is present in the Wolfeboro quadrangle, 1.5 miles southeast of Leighton Corners. It was once worked in a small way for feldspar and scrap mica and contains also columbite and crystals of beryl.

Acadian Disturbance

The events just described, the folding and recrystallization of the sedimentary beds together with the large-scale intrusion of granitic rock, constitute a geologic disturbance. The long period of quiet deposition of sediments was brought to an end by a time of violent disturbance. The usual consequence of such a geologic disturbance is that mountain ranges are elevated at the surface while the beds a mile or more beneath are being recrystallized. This is apparently what happened in New Hampshire and in the Acadian area of the Maritime Provinces of Canada, and the gnarled rocks we see in these areas today are what is left of the roots of this once mighty range that has been largely eroded away.

White Mountain Magma Series

After the Acadian disturbance the sea never again invaded central New Hampshire. The area underwent a few million years of erosion (Fig. 4) and then igneous activity again began and the

Figure 4. Thousands of feet of rock have been worn away by erosion during Late Devonian and Early Mississippian time.

White Mountain magma series was formed. A characteristic of this series is that certain rather restricted areas contain a great variety of igneous rocks that reveal a rather striking sequence of events. Where fully developed, the sequence usually starts with volcanic eruptions that pour out flows of lava alternately with explosions of volcanic debris (Fig. 5). These volcanic rocks

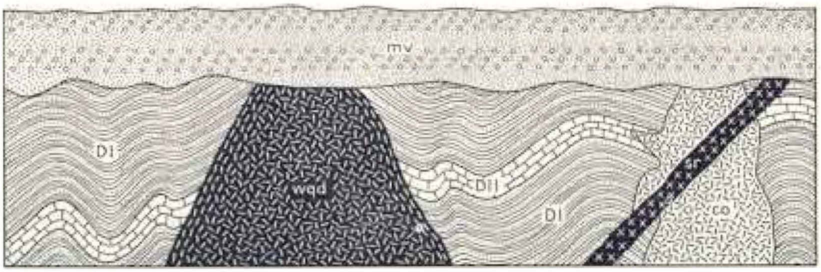


Figure 5. Eruption of Moat, volcanics, *(mv)* during Mississippian time. Moat volcanics include lavas, flows and breccias. Spherulitic rhyolite *(sr)* intruded as molten magma.

(Moat volcanics) are abundant in the Ossipee Mountains and are present in the Belknaps. The fine-grained rhyolite on the upper slopes of Copple Crown Mountain and on the top of the Moose Mountains may have formed as outpouring of lava, but the absence of flow lines suggests that this magma solidified a short distance beneath the surface rather than as lava flows on the surface. A finer-grained rock (spherulitic rhyolite) that may also have formed either as a surface lava or a shallow intrusion, is poorly exposed in the area between East Wolfeboro and Brookfield Station.

The volcanic events of the White Mountain magma series are generally followed by the intrusion of magma in the form of round, ring-like, or irregular masses. The Ossipee Mountains are bordered by a remarkable ring intrusion, or ring dike, one quadrant of which is marked by Brier Hill, Wallace Hill, Oak Hill, and Eldridge Hill (Fig. 6). A short segment of a ring dike of

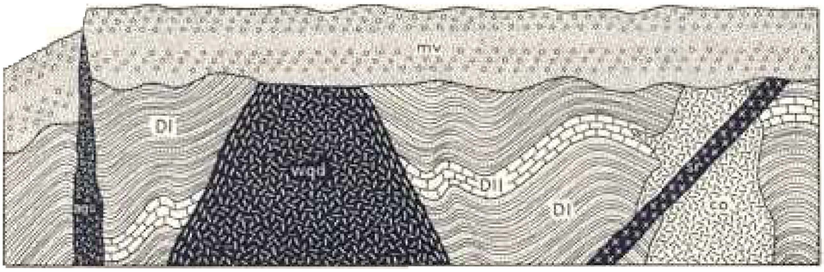


Figure 6. Sinking of Moat volcanics in Ossipee Mountains area and intrusion of Albany porphyritic quartz syenite *(aqs)* during Mississippian time. Small bodies of gabbro, diorite-gabbro, granodiorite, quartz monzonite, and granite porphyry, none of which are shown in this diagram, were intruded after eruption of Moat volcanics but before the intrusion of the Albany porphyritic quartz syenite.

the Belknaps is present at Chestnut Cove. The large mass of Conway granite in the Copple Crown Mountain area is a good example of a round intrusion (Fig. 7).

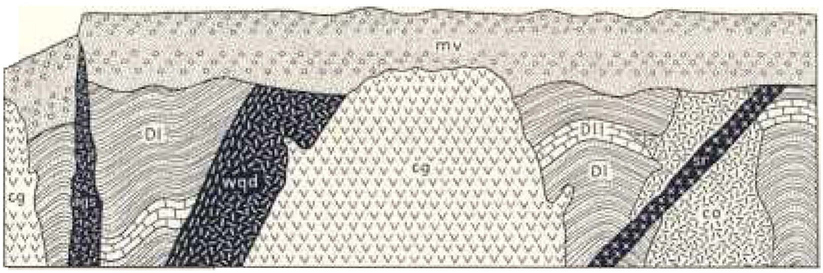


Figure 7. Intrusion of molten magma to form Conway granite *(cg)* during Mississippian time.

The intrusions of this series commonly follow a systematic order with respect to the composition of the rocks. Thus, the dark heavy gabbro of Phoebes Nable Mountain and the intermediate granodiorite near Rust Pond were intruded early and the light Conway granite came in later.

Geoloqic Time-Scale, Wolfeboro Quadrangle

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

Era	*Period*	*Time-Scale (age of beginning of period)*	*Sequence of Geological Events*
	Recent	30 thousand years ago	
ıozoic	Pleistocene	Two million years ago	Continental ice sheet invaded this area one or more times. Glacial till, sand gravel deposited.
	Tertiary	60 million years ago	Erosion.
	Cretaceous	120 million years ago	Erosion.
Mesozoic	Jurassic	150 million years ago	Erosion.
	Triassic	175 million years ago	Erosion.
	Permian	210 million years ago	Erosion.
	Pennsylvanian	255 million years ago	Erosion.
		290 million years ago	4. Intrusion of molten magma to form subporphyritic quartz syenite and Conway granite. 3. Subsidence of Moat volcanics in Ossipee Mountain area and intrusion of Albany porphyritic quartz syenite. 2. Intrusion of molten magma to form small bodies of gabbro, diorite-gabbro, granodiorite, quartz monzonite and granite porphyry. 1. Eruption of molten magma on to surface of earth to form Moat volcanics; also some of magma froze at depth to form rhyolite and spherulitic rhyolite.
Paleozoic	Devonian	330 million years ago	5. Deep erosion. 4. Injection of molten magma to form Concord granite. 3. Injection of molten magma to form Winnipesaukee quartz diorite. 2. Folding. 1. Deposition of thousands of feet of sand, mud and a few limy beds in a shallow inland sea.

Among the youngest rocks in the quadrangle are the scattered dikes of various types of rock cutting through the country rock and they range in width from a few inches to several feet. Most commonly the dike rock is black "trap" rock or basalt, but some are of light-colored rock. All of them had their origin from magma that moved into fractures and there solidified.

Green Mountain, over in the Ossipee Lake quadrangle to the north, in contrast to other areas of the White Mountain magma series, has only one type of rock, the Conway granite. It is possible that a greater variety of rocks lies unexposed at depth.

The whole sequence of events involved in forming the White Mountain magma series seems to have occurred during the Mississippian period, 200,000,000 to 250,000,000 years ago.

The Wearing Down of the Land

The mountains resulting from the Acadian disturbance were partly worn down before the first volcanic activity of the White Mountain magma series, but the renewed igneous activity soon piled up high masses of lavas and exploded materials. Weathering and erosion immediately attacked these high areas and started on the process of wearing them down to sea level. Probably the process continued long enough that the area was eroded to a low plain near sea level a few million years ago. This was followed by at least one other uplift, whereupon erosion carved the uplifted land into hills and valleys very similar to the present except for the lakes and swamps (Fig. 8).

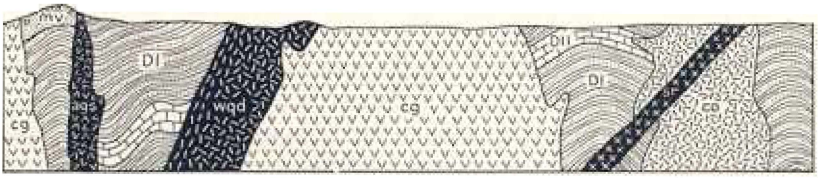


Figure 8. Deep erosion since Mississippian time has removed Moat volcanics from most of the area. The Great Ice Age interrupted the normal processes of erosion near the end of this period of eruption.

The processes of weathering and erosion are going on today, much as they have throughout the geologic ages. Frost breaks the rock, water seeps in between the grains and loosens them, roots pry the rocks apart, and water slowly dissolves some of the minerals. Brooks and rivers carry this material to the sea where it is deposited. The extreme slowness of these processes is evident today and gives an indication of the immensity of geologic time necessary to accomplish these large results.

The Great Ice Age

Under present climatic conditions the winter snows all melt away during the summer. At least four times during the last million years the climate changed so that one winter's snow did not all melt during the next summer. As a result, the snows built up deeper and deeper until they compacted into ice and the ice eventually began to move outward under its own weight. Thus was started the great glaciation that affected much of North America north of Long Island. In New Hampshire the ice became so deep that it rode over the top of Mount Washington.

The moving ice plowed up the soils, plucked away blocks of rock from the solid ledges, and ground the bedrock to smooth surfaces. The hills and valleys were thus streamlined and the ledges were scratched. The streamlining of the topography in a southeast direction, in agreement with the direction of ice motion in this part of New Hampshire, is illustrated by Mount Long Stack, Mount Delight, and Foggs Ridge, as well as by some of the valleys. There is also a tendency for the hills to have gentle slopes on the northwest where the ice was pushing against them and steeper bluffs to the southeast where the ice was plucking away blocks of the ledge. Glacial scratches are to be seen on recently uncovered ledges, although they have been obliterated by weathering at many places.

When the climate warmed up again, the ice began to lose its vigor and finally it melted away. The boulders, sand, and soil that had been carried in and on the ice were dumped. Part of this load of sediment was dropped directly by the ice as hardpan, or till. The rest was strewed out by meltwater and deposited as outwash. Outwash is especially abundant along Pine River in the northern part of the quadrangle. A striking ridge following Pine River is what is left of the sand and gravel filling of a tunnel in the former ice. This is an esker. Outwash is the source of most of the sand and gravel used in this area.

The boulders plucked away from the ledges were carried "downstream" and dropped wherever they happened to be when the ice melted. Most of them traveled only a mile or two, but some were taken miles away. A peculiar kind of syenite from Red Hill in Moultonboro can be found in this quadrangle and it indicates that the ice moved in a southeast direction, as is indicated also by the streamlined hills and the scratches. In the vicinity of Mount Long Stack and Rines Hill the Conway granite ledges have so few seams and joints that the boulders are remarkably large.

This dumping of the glacial debris was highly irregular, so that the drainage, which had formerly been good and systematic, was greatly disarranged. Many of the valleys were dammed to form lakes and ponds. The islands in the present lakes are the small hills that were too high to be flooded.

These various glacial features are much as they were formed because there has not been enough time to modify them greatly; the most recent evidence indicates that the ice disappeared from this area only 10,000 to 12,000 years ago.

HOW TO READ THE MAP

A colored geologic map is found in the envelope in the back of the pamphlet. This map contains a wealth of information about the country itself, as well as showing the kind of rock found in each locality. The legend at the side of the map, as well as the structure sections at the base of the map, help the reader understand and interpret the geology.

The geology has been added in color to the regular topographic map of the Wolfeboro quadrangle. One inch on the map represents approximately one mile on the ground. Automobile roads are indicated with double black lines; poor roads or logging roads as double dashed lines; trails as single dashed lines; railroads as solid black lines with cross-bars; township boundaries with long dashed lines. Houses are represented as little black squares, to which a flag is added to indicate a school house, and a cross a church. Lakes and streams are blue; swamps are blue tufts.

The shape of the hills and valleys are shown by brown lines called contour lines. Accurate altitudes are shown by black letters, which refer either to the top of a mountain, a cross road, or some other place which has been carefully determined. For instance, the top of Mt. Long Stack is 1296 feet above sea level. The figure 534 on Lake Wentworth indicates that the surface of the lake is 534 feet above sea level. A small cross, with or without the letters *B. M.*, indicates a place where the altitude is known precisely; for example, in Wolfeboro Center a cross marked 543 means this point is 543 feet above sea level. By studying the brown lines, or contours, you can tell the height above sea level of any point shown on the map. If you follow any single contour line, you will always keep at the same altitude. Since the contour interval of this map is 20 feet, it means that wherever there is a rise of 20 feet in altitude, a new contour line must be shown 20 feet above the last. To facilitate the reading of the maps, every 100-foot contour line is shown in heavy brown, and somewhere along each of these lines you will generally find a small brown number telling the exact altitude of that particular contour.

At the bottom of the map is a symbol labeled "approximate mean declination 1936." A line shows the direction of true north, and an arrow points to magnetic north. The angle between, indicated by 15°, means that a compass needle will point 15° west of true north. This means that all magnetic compass bearings have an error of 15° in this region. This is most important if you go away from a trail and try to locate yourself by a compass. You will notice that the long edges of the map are true north-south, and the top and bottom edges of the map are true east-west lines. This fact is useful in helping you to orient yourself as to position, or to check yourself and your compass reading if you are in doubt as to the direction to take. For you can use the map as a compass, and by lining up or "sighting" certain known points on the map, you can find out the names of unknown hills by sighting to them—remembering to keep your map stationary after putting it in the correct position. The Fire Wardens use their maps in this way to locate forest fires.

The various color patterns on the map show the kinds of rock in the different localities. The legend at the side of the map is the key for finding out what each color means. In addition to the colors, each rock type is also indicated by black letters which appear scattered over the map as well as in the proper color pattern in the legend. For example, the area southeast of the village of Tuftonboro is shown in pale gray as well as the letters "Dl." In the legend this color pattern and the letters "Dl" are found to represent the Littleton formation of Devonian age.

The legend is arranged with youngest rocks at the top of the left-hand column. Although the colors on the map might make you believe that rocks are exposed everywhere, this is not the case. In many places sand, glacial till and soil conceal the underlying rocks. The geological boundaries are solid black lines where it has been possible to trace them fairly accurately. Where boundaries are poorly exposed they are shown as dashed or dotted lines. The colors show only the predominant type of rock in a region, as it is impossible to show all the small pegmatites, dikes, or fragments of schist in the granitic rocks.

The three structure sections at the bottom of the map show what the rocks probably would look like if you dug a trench a mile or so deep across the area. Their positions are indicated on the map by lines labeled A-A′, B-B″ and C-C′. For example, lines B-B′ extends from west to east across the center of the map. Near the west end of the section it is obvious that the folds of the Littleton formation are truncated by the present erosion surface. Much of the eastern half of the section is occupied by Concord granite that extends to great depth.

There are a few "special symbols" shown on the map and in the legend. These symbols are to help interpret the structure of the rocks themselves. They represent measurements of the attitude of the rocks made by the geologist in the field. The symbols representing the "strike and dip of foliation and schistosity" show the attitude of a planar structure in the rocks because of a parallelism of platy minerals, such as mica; even the quartz grains in the rocks may be similarly flattened. In general in this area this planar feature is parallel to the original bedding given by alternating layers of sand and mud. The straight line of the symbol shows you the direction of "strike" or general trend of this foliation or bedding, and the number and pointer tells in what direction, and also how steeply this banding dips or is inclined. For example, if you take a book and place it on the table in front of you so that it looks like the roof of a house, you may easily visualize what strike and dip means (see Fig. 9). The binding is a line corresponding to the strike, or trend of a band in the rocks, while the angle of inclination of the cover would correspond to the dip of the band. You will notice that the pages of the book

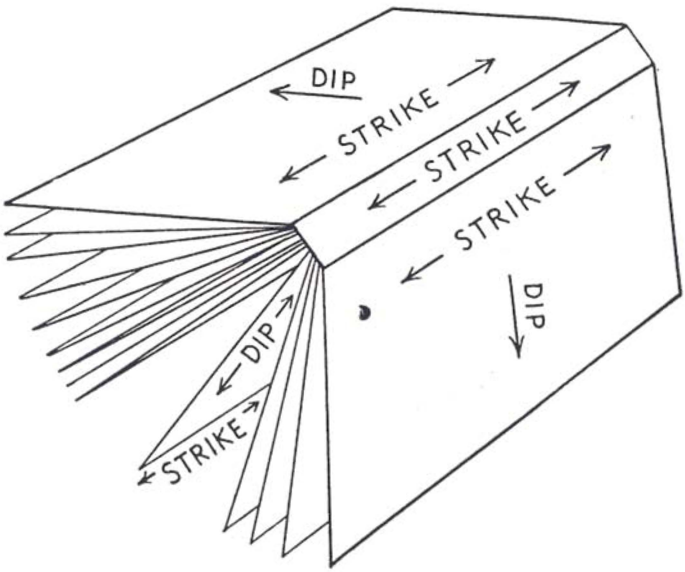


Figure 9. Diagram to illustrate dip and strike.

hang down, or "dip" at different angles from the horizontal. Thus, the leaves in the center are almost perpendicular to a horizontal line (vertical beds), while those to the left or right of the center vary considerably in their angles of "dip." This simile of the book and rocks should help you visualize a succession of folded rocks with lots of sheets and bands corresponding to the leaves of the book. If they lie flat, or horizontal, another symbol is used.

It is by measuring the changes in direction of the bedding and foliation at every available outcrop that the geologist estimates the position of the folds in any area, thus "unraveling" the story of the rocks from a study of the measurements taken.

REFERENCES

General Geological Books

1. Billings, M. P. **Structural Geology.** Prentice-Hall, New York, 1942.
2. Branson, E. B. and W. A. Tarr. **Introduction to Geology.** McGraw-Hill, New York, 1935.
3. Fenton, C. L. and M. A. Fenton. **The Rock Book.** Doubleday-Doran, New York, 1940.
4. Fenton, C. L. **Our Amazing Earth.** Doubleday-Doran, New York, 1938.
5. Hurlbut, C. S. **Dana's Manual of Mineralogy.** John Wiley and Sons, New York, 1941.
6. Lobeck, A. K. **Geomorphology.** McGraw-Hill, New York, 1939.

Wolfeboro Quadrangle and Adjacent Areas

7. Goldthwait, J. W. **The Geology of New Hampshire.** New Hampshire Academy of Science, Handbook No. 1, 1925.
8. Kingsley, Louise. **Cauldron-subsidence of the Ossipee Mountains.** American Journal of Science, 5th ser., vol. 22, pp. 139-168, 1931.
9. Modell, David. **Ring-dike Complex of the Belknap Mountains, New Hampshire.** Geological Society of America, Bulletin, vol. 47, pp. 1885-1932, 1936.
10. Quinn, Alonzo. **Geology of the Winnipesaukee Quadrangle.** N. H. State Planning and Development Commission, Concord, 1941.
11. Quinn, Alonzo, and Glenn W. Stewart. **Igneous Rocks of the Merrymeeting Lake Area of New Hampshire.** American Mineralogist, vol. 26, pp. 633-645, 1941.
12. Smith, Althea Page, Louise Kingsley and Alonzo Quinn. **Geology of the Mt. Chocorua Quadrangle.** N. H. State Planning and Development Commission, Concord, 1939.

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GENERAL REPORTS

The Geology of New Hampshire. Part I. Surficial Geology. James W. Goldthwait, Lawrence Goldthwait, Richard P. Goldthwait. 1951. 83 p. Surficial Geology map (Scale 1"-4 miles) in pocket. $1.50.

Ore Hill Zinc Mine, Warren, New Hampshire. H. M. Bannerman. 1943. 2 p. Map.

Mineral Resources in the Lakes Region. Report of the Mineral Resources Committee, Lakes Region Survey. May, 1945. 10 p. Map.

Geologic Story of Franconia Notch and the Flume. Andrew H. McNair. 1949. 14 p. illus. 20 cents.

Geology Story of Kinsman Notch and Lost River. Andrew H. McNair. 1949. 14 p. illus. 20 cents.

QUADRANGLE REPORTS

Geology of the Franconia Quadrangle. Marland P. Billings and Charles R. Williams. 1935. 35 p. illus. Map. 50 cents.

Geology of the Littleton and Moosilauke Quadrangles. Marland P. Billings. 1935. 51 p. illus. Maps. 60 cents.

Geology of the Mt. Cube and Mascoma Quadrangles. Jarvis B. Hadley and Carleton A. Chapman. 1939. 28 p. illus. Maps. 60 cents.

Geology of Mt. Chocorua Quadrangle. Althea Page Smith, Louise Kingsley, Alonzo Quinn. 1939. 24 p. illus. Map. 50 cents.

Geology of Winnipesaukee Quadrangle. Alonzo Quinn. 1941. 22 p. illus. Map. 50 cents.

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