THE GEOLOGY OF THE PLYMOUTH QUADRANGLE NEW HAMPSHIRE

by

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The Geology of the Plymouth Quadrangle
New Hampshire

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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. The text is written in simple language and few scientific names are used. 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 fascinating story of the rocks can be understood without these details.

The study of the geology of the Plymouth quadrangle was carried on from 1935 to 1937 under the auspices of the Division of Geological Sciences, Harvard University. Financial aid was obtained from the Whitney Fund, Harvard University. Professor Marland P. Billings edited the geological map and prepared the figures accompanying this pamphlet.

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THE SCENERY

The Plymouth quadrangle lies near the center of New Hampshire on the southern edge of the White Mountains. Its roads, trails, farms, hotels, cottages, and cabins have made it possible for thousands of people to enjoy its beauty and charm both in summer and winter. It is hoped that these people and many more will find this pamphlet with its accompanying geological map an aid to the understanding and enjoyment of the natural wonders of the region.

For many years, the valley of the Pemigewasset River, the principal stream of the area, has been an important route of travel north through the mountains. Today thousands of motorists follow United States Highway No. 3 northward along the west bank of this river. These travelers observe that through most of its course the river flows quietly on a fairly flat valley floor, but occasionally, as at Livermore Falls, it plunges violently through a deep, narrow gorge. The other streams of the area, with the exception of a few small ones which flow into Squam Lake, are tributaries of the Pemigewasset River. Two of these are worthy of mention. The Baker River flows into the Pemigewasset from the west just north of Plymouth. The Mad River flows through Waterville Valley in the northeast corner of the quadrangle and thence southwest to the Pemigewasset.

Almost all of this quadrangle is hilly or mountainous. Mount Tecumseh (4004 feet), in the northeast part of the quadrangle, is the highest peak in the area. Jennings Park (3500 feet) and Sandwich Mountain (3993 feet), lying near the eastern edge of the area, are the highest mountains in the western end of the Sandwich Range. Squam Lake and the arcuate Squam Mountains are conspicuous features of the southeastern part of the area.

THE STORY OF THE ROCKS

The Sea

About 330 million years ago, in early Devonian time, a narrow, shallow sea, called the Appalachian trough, extended from Newfoundland through New England and on southwest toward what is now the Gulf of Mexico. To the west of this trough lay the main mass of the North American continent, which for millions of years was periodically flooded by shallow seas. To the east of New England lay a narrower and rugged strip of land, which extended far out into what is now the Atlantic Ocean. Rain and frost, assisted by other chemical and mechanical agents, slowly brought about the disintergration of the rocks of this easterly land mass. Rivers and streams picked up the products of rock weathering, chiefly mud and sand, and carried them into the Appalachian trough. Here, through the ages, the sediments accumulated in horizontal layers totalling thousands of feet in thickness. As the weight of the overlying sediments increased, the mud was compressed into a thinly laminated rock called shale, and the sand grains were cemented together to form sandstone. Thus ended the first chapter in the history of the rocks of the Littleton formation (Fig. 1).

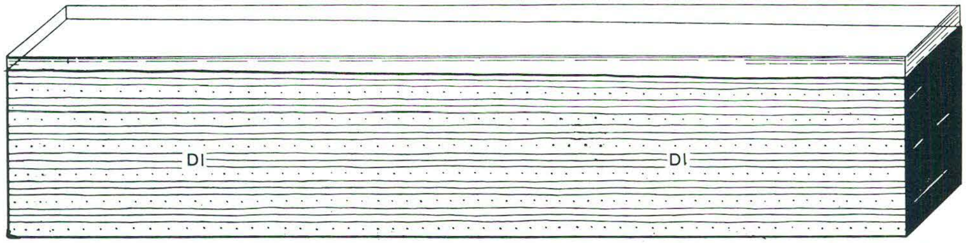
The Folding

Near the middle of the Devonian period, the crust of the earth in the New England section of the Appalachian trough began to rise. The uplift continued until near the close of the Devonian period (about 300 million years ago), at which time the whole region was subjected to a tremendous horizontal squeezing force. The results were almost unbelievable. The beds of sandstone and shale were compressed into tight folds (Fig. 2). Layers which had been horizontal were rotated into vertical positions and some were completely overturned. Breaking and slipping of the beds accompanied the folding.

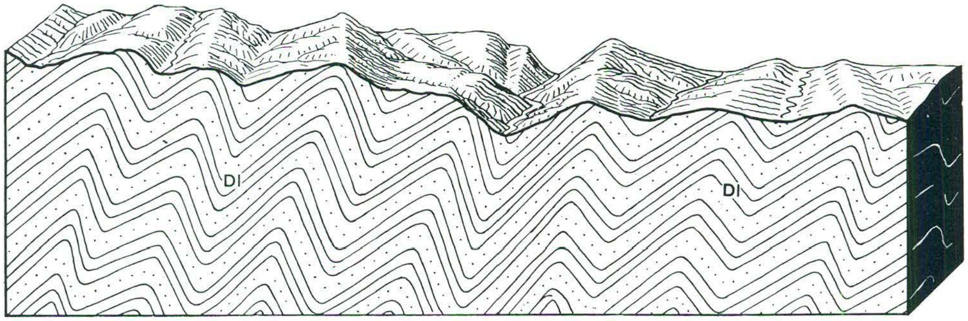
The New Hampshire Magma Series

Near the end of the Devonian time, while the folding was in progress, great masses of molten rock originating deep within the earth worked slowly upward by forcing apart or engulfing portions of the overlying rock (Fig. 3). Irresistibly the hot viscous fluids moved upward, finally invading the deformed sedimentary beds of the Little formation. Movement of the molten masses continued for a time, but stopped before they had broken through to the surface. The continuous loss of heat during the invasion lowered the temperature to such an extent that the molten rock solidified into a number of rock types which the layman might call "granite." Although there is a superficial resemblance among the types of rock found in the various igneous bodies, close examination has proved that they differ in texture, in composition, and in exact time of emplacement. The Norway quartz monzonite, a medium- to coarse-grained pink rock found in the northeast portion of the map, was the first one to solidify. The Kinsman quartz monzonite, which is found in large and small bodies throughout the area, was the second to solidify. It is rather striking in appearance because in many places it contains elongate white feldspar crystals which average one to two inches in length and are locally much longer. These crystals are embedded in a medium-grained gray groundmass composed of quartz, feldspar, and mica. The third intrusive body was the Winnipesaukee quartz diorite, a medium-grained gray to dark-gray rock, which is exposed in and around Squam Lake. The Concord granite, which was intruded next, is exposed in the southwest and the northeast corners of the area. All of these rocks are more or less foliated; that is, the platy minerals, such as mica, tend to lie with their flat faces parallel to one another so that the rocks tends to break into sheets. This indicates that they were intruded before the squeezing of the region had been completed. The process of intrusion, cooling, and solidification described above was very slow, requiring hundreds of thousands, perhaps millions, of years.

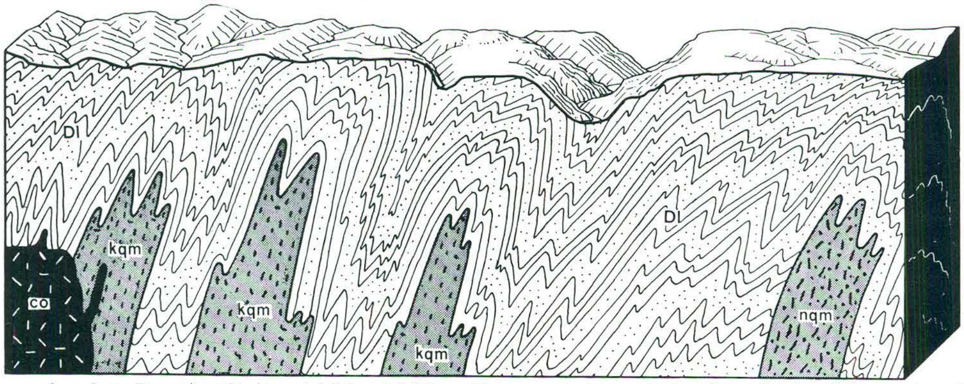
The closing phase of the New Hampshire magma series is represented by numerous pegmatite dikes, tabular bodies of igneous material cutting across the structure of the other rocks. While the chief minerals in pegmatite are essentially the same as those found in most of the igneous rocks of the region, namely quartz, feldspar, and mica, the crystals are much larger, locally a foot or more in length. The origin of pegmatite is directly connected with the crystallization of the larger igneous masses with which it is associated. The crystallization of any large molten mass starts at the margins



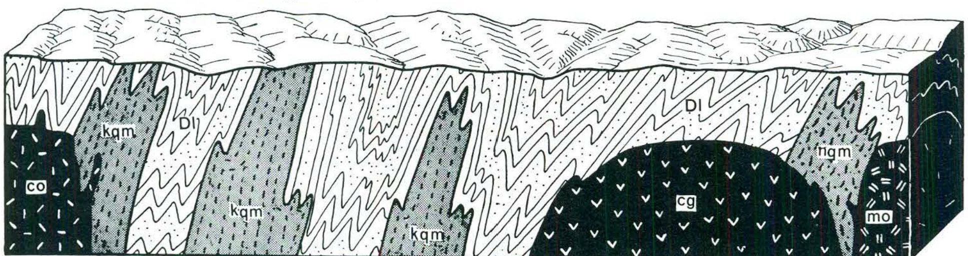
1 — End of lower Devonian time. Mud and sand of Littleton formation (*Dl*), many thousands of feet thick, has accumulated in a shallow sea, the bottom of which sank as deposition went on.



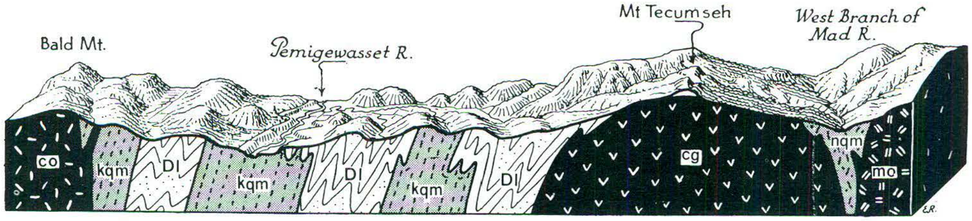
2 — Middle Devonian (?) time. Rocks are folded.



3 — Late Devonian (?) time. Additional folding. Molten rock (magma) rises from depths of the earth and freezes to form Kinsman quartz monzonite (*kqm*) and Norway quartz monzonite (*nqm*); Winnipesaukee quartz diorite, not shown in these diagrams, formed about the same time. Somewhat later, more magma came into the area and froze to form Concord granite (*co*).



4 — Mississippian (?) time. After some erosion, more magma rose from the depths and consolidated to form the Mount Osceola granite (*mo*) and Conway granite (*cg*); syenite in The Rattlesnakes, not shown in this diagram, is about the same age.



5 — Present. Region was eroded to present topography.

FIGURES 1-5 — Series of diagrams to illustrate the story of the rocks of the Plymouth quadrangle. The cross sections are imaginary trenches a mile or more deep cut across the Plymouth quadrangle from southwest on the left to northeast on the right. Each section shows a stage in the development of the region. *Dl* equals Littleton formation; *kqm* equals Kinsman quartz monzonite; *nqm* equals Norway quartz monzonite; *co* equals Concord granite; *mo* equals Mount Osceola granite; *cg* equals Conway granite.

and progresses inward. This process concentrates a residual liquid containing most of the volatile juices of the entire mass near the center. Eventually, this fluid is injected into cracks in the solid portions of the igneous body and the surrounding rocks. The volatile constituents of the liquid decrease its viscosity and aid crystallization, thereby permitting the development of large crystals. Several bodies of pegmatite have been exposed by blasting along Highway No. 3. There, one may see not only the common constituents mentioned above, but also garnet and black tourmaline and in some places crystals of beryl or other rare minerals.

The Metamorphism

Many of the rocks of the Littleton formation today bear little resemblance to the mud and sand poured into the Appalachian trough in early Devonian time, or to the shale and sandstone which were formed by compaction at a later date. These rocks have been metamorphosed (changed) by the tremendous pressures and high temperatures developed a mile or more below the surface during the folding of the region and the intrusion of the igneous rocks. The fine-grained shales and sandstones have become medium to coarse-grained schists, foliated rocks which contain many minerals not found in the original sediments. Black mica, white mica, and quartz are particularly abundant, and the parallel arrangement of the mica flakes gives the rock its foliated character. Feldspar, garnet, andalusite, sillimanite, and other minerals are locally abundant. In some places the change has been so complete that it is almost impossible to distinguish between the intrusive igneous rock and the metamorphosed sedimentary rock.

White Mountain Magma Series

Millions of years later, new masses of molten rock probed their way upward (Fig. 4) into the contorted metamorphic rocks of the Littleton formation and the intrusive igneous rocks of the New Hampshire series. These later igneous rocks seem to form roughly circular or oval bodies having easily recognizable contacts with the invaded rocks. These facts contrast sharply with the indefinite and sometimes gradational boundaries of the irregular and elongate igneous bodies produced in the preceding period. Also, unlike the members of the older series, these new intrusive rocks show no signs of foliation, indicating that they were emplaced after the major folding. The course pink syenite and its darker fine-grained border phase outcrop on the Rattlesnakes in the southeast corner of the area. The Mount Osceola granite is a coarse to medium-grained green rock which underlies a small section in the northeast corner of the quadrangle. The large circular body in the northeastern part of the quadrangle is coarse pink Conway granite.

The last phase of igneous activity in the area was the invasion of all the rocks by some fine to medium-grained, dark-green to black trap dikes. They vary in width from a few inches to over ten feet.

Erosion

Following the emergence of the sediments of the Littleton formation from the sea, and even during the periods of folding and igneous activity, the agents of weathering and erosion were engaged in carving the surface of the land. Mechanical agents of weathering, such as frost, broke up the rocks; chemical agents, such as water, oxygen, and carbon dioxide, caused their disintegration; rain water carried the resulting particles into streams; and the streams carried them away. At the same time, the streams were scouring and deepening their own valleys. The process was incredibly slow, but there was plenty of time to develop the topography which exists today — over 200 million years. Continuous erosion cut deeper and deeper into the crust of the earth and finally uncovered those great masses of igneous rock which originally had solidified a mile or more beneath the surface.

Following the exposure of the granites, the main features of the present topography (Fig. 5) gradually developed, controlled, in part, by the unequal resistance of the rocks of the area. Some of the highest mountains are formed of Conway and Mount Osceola granite, indicating that they are among the more resistant rocks. On the other hand, there is a zone of weakness along most of the contact of the large body of Conway granite, which has favored the development of valleys by Smarts Brook, Haselton Brook, and Tecumseh Brook. One of the most easily eroded rocks, the Winnipesaukee quartz diorite, now underlies the lowland which contains Squam Lake. The harder syenite is responsible for the existence of the Rattlesnakes. Variations in hardness within the Littleton formation account for some of the topographic features. The Squam Mountains and the ridge of Bald Mountain are held up by more resistant layers.

The Ice Age

About two million years ago, stream erosion was interrupted by the advance of a great sheet of ice which covered the eastern United States as far south as Long Island. It had developed as a huge ice cap centering in Labrador and had slowly spread out in all directions. It covered everything, even Mount Washington, the highest peak in New England. As it moved, the ice scooped up soil, sand, gravel, boulders, and even great pieces of the bedrock. These fragments embedded in the ice scratched and polished the rock surfaces and in many places smoothed and rounded the hills and mountains. The scratches or "glacial striae" are visible today on many rock ledges. Finally, as the climate became warmer, the ice melted, dropping the debris which it had gathered in its long journey. This material, called glacial drift, now covers most of the bedrock in glaciated regions. Melt water from the glaciers carried quantities of the smaller particles into temporary lakes, where they accumulated as beds of clay and sand. A sand deposit of this type may be seen along Mill Brook east of Pine Grove cemetery.

About 30,000 years ago, the last of the ice melted away and there has been little change in the topography since that time.

Geologic Time-scale with Sequence of Events in the Plymouth Quadrangle

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

Era	*Period*	*Time-scale*	*Sequence of Geologic Events*
Cenozoic	Recent	30,000 years go to present	Slight erosion, chiefly of glacial deposits
	Pleistocene	2 million to 30,000 years ago	Ice sheets covered the region
	Tertiary	Began 60 million years ago	Uplift and erosion
Mesozoic	Cretaceous	Began 120 million years ago	Erosion
	Jurassic	Began 150 million years ago	Erosion
	Triassic	Began 175 million years ago	Erosion
Paleozoic	Permian	Began 210 million years ago	Erosion
	Pennsylvanian	Began 255 million years ago	Erosion
	Mississippian	Began 290 million years ago	Syenite, Mt. Osceola granite and Conway granite formed from molten rock (magma)
	Devonian	Began 330 million years ago	5. Concord granite formed from magma. 4. End of folding. 3. Norway quartz monzonite, Kinsman quartz monzonite, and Winnipesaukee quartz diorite formed from magma. 2. Folding began. 1. Littleton formation deposited as mud and sand.
	Silurian	Began 355 million years ago	No record.
	Ordovician	Began 415 million years ago	No record.
	Cambrian	Began 515 million years ago	No record.
Pre-Cambrian		Began 1600 million years ago	No record.

INTERESTING LOCALITIES

Mount Tecumseh. Numerous trails lead to the top of this mountain, 4004 feet above sea level. Several of them start from the road which now connects[1] Tripoli Road and Waterville Valley by way of West Branch and Thornton Gap. The one from the east starts near the mouth of Tecumseh Brook. About one-quarter mile from the foot of the trail there are excellent exposures of Conway granite in the brook. Other exposures may be seen by following upstream from the point at which the trail crosses the brook. The top of the mountain is composed of inclined beds of greenish schist belonging to the Littleton formation. From the summit one may follow the trail down Johnson Brook, or he may take another one down Haselton Brook to the road near Mill Brook Cascade. At the Cascade are large outcrops of schists of the Littleton formation full of igneous material including pegmatite.

Mount Osceola. Although this 4326 foot peak lies just north of the Plymouth area in the Franconia quadrangle, the best trails to its summit start from Thornton Gap and the West Branch. The trail up Osceola Brook provides an interesting trip. Near the north edge of the area, it becomes very steep as it climbs up a continuous smooth exposure of Mount Osceola granite. At the top of the mountain is a fire tower which affords spectacular views of the higher mountains to the north as well as views of Mt. Tecumseh and the highlands to south, east, and west.

A trail from Waterville Valley up Mad River also gives access to the wilderness which lies to the north in the Franconia quadrangle.

Jennings Peak, Sandwich Mountain, and Smarts Brook. The Sandwich Mountain trail starts from the Mad River road south of Waterville Valley. From Noon Peak to Jennings Peak the trail crosses almost continuous outcrops of pink Conway granite. Most of it is coarse-grained but some is a fine-grained phase. Large areas of schists of the Littleton formation outcrop on Sandwich Mountain. Because of the lack of outcrops between the two mountains, the con-

[1]The topographic base map upon which the geology has been overprinted was surveyed in 1928. Consequently, some changes made since the original survey, such as the road connecting Waterville Valley with Tripoli Road, are not shown on the map in the pocket at the end of this pamphlet. The White Mountain Guide issued by the Appalachian Mountain Club gives accurate information on the trails as they change from year to year.

tact cannot be seen. The Smarts Brook trail, which starts its descent from the saddle between Jennings Peak and Sandwich Mountain may be used for the trip down. Outcrops are lacking in the upper part of the trail, but the contact between the Conway granite and the Littleton formation is well exposed in the brook near the point at which the trail splits about seven-eighths of a mile east of the road. About one-third mile from its mouth, Smarts Brook flows through a deep narrow flume cut in Conway granite. Apparently the stream follows a zone of weakness controlled by a trap dike and a system of joints which are parallel to the flume. The bridge at the mouth of Smarts Brook is over the contact of the Conway granite and the schists of the Littleton formation.

Welch Mountain. A trip up the Welch Mountain trail is well worth while. From an elevation of 1400 feet to the top, one will be walking over almost continuous outcrops of pink Conway granite. Glacial striae are numerous on the smooth rock surface. Combined with some other evidence, they indicate that the ice moved toward the east. This is a local variation from the usual southerly direction.

Squam Mountains. The trail starts at the Sandwich Notch road near the east edge of the map. It climbs very steeply at first and then more gently to the top of the hill about one-half mile northeast of Doublehead Mountain. At this point may be seen large areas of Kinsman quartz monzonite containing many large feldspar crystals. Except for this patch of Kinsman, almost all of the outcrops along the crest of the ridge are the harder quartzose beds of the Littleton formation. Branch trails lead down toward Squam Lake from Mount Morgan and Mount Percival, while the main trail continues to the south end of the range. The view to the south from the Squam Range is one of the most beautiful in the region, for one can see Squam Lake and Red Hill in the foreground and the Ossipee Mou tains and Lake Winnipesaukee in the distance.

The Rattlesnakes. Large outcrops of typical coarse pink syenite are visible along the trail which crosses the west summit of the Rattlesnakes. The hiker may also see patches and dikes pf pegmatite containing large feldspar crystals, and several trap dikes. Deeply rotted syenite is exposed in a pit near the northern border of the syenite body.

Livermore Falls. Under the bridge at Livermore Falls are some well-bedded, hard, white quartz-rich rocks and schists which dip about 60° toward the southeast. Cutting these rocks are a number of dark-green to black trap dikes ranging in thickness from two to ten feet. Near the dam, the beds are greatly folded and intruded by pegmatite.

Campton Hollow. Between the village and the bridge which lies one-quarter mile to the southwest, Beebe River has cut a shallow gorge in schists and quartzites of the Littleton formation. Igneous material has been injected into these metamorphic rocks. Just below the bridge is a good swimming hole.

Woodstock. An interesting outcrop may be examined under the bridge which spans the Pemigewasset River at Woodstock. On the smooth, water-worn surface one can see schists and quartzites of the Littleton formation invaded by a mass of granite at the south end, and cut by stringers and dikes of pegmatite and trap rock. More of the schist outcrops along the road just north of bridge on the west side of the river.

USEFUL MINERALS

During the Second World War three mica mines were opened in this region. The White Mountain Mica Company operated a mine 1.6 miles north of Campton Upper Village, on the crest of the hill marked on the map as having an altitude of 1516 feet. The Crystal Mica Company opened two mines, one of them one mile N.15°W. of altitude 890 on the Logging R.R. along Beebe River, the second 0.7 mile N.23°W. of the same point on the railroad. Minor amounts of beryl have been reported from the pegmatites near Plymouth and Campton.

Just west of Highway No. 3, almost due west of the village of Beebe River, and just south of bench mark 619, is a small quarry. Several types of medium-grained granite, which had been intruded into mica schist, have been quarried at this point. A quarry containing similar rocks has been worked on the southwest side of Sunset Hill.

The Conway granite or the Concord granite, where not too badly weathered, are potential sources of cut stone.

On Beaver Brook, about one-tenth mile from Highway No. 3, near the north edge of the quadrangle, is an old silver mine which shipped a small amount of ore in the last century. A tunnel with two short branches was run 125 feet due west into the side of the hill along a shear zone. The two commonest metallic minerals are galena (lead sulphide) and sphalerite (zinc sulphide). Chalcopyrite (copper-iron sulphide) is also present. Because of the small percentage of these minerals in the deposit, it is unlikely that there will be any future production. Mineral collectors can obtain specimens showing small amounts of the sulphides from the dump or from the tunnel.

Tripoli Mill lies along the north edge of the quadrangle, 5.5 mile east-northeast of Woodstock. The diatomaceous earth is obtained from East Pond, which lies one mile northeast of the mill and is in the Franconia quadrangle. The deposit varies from six to more than eleven feet in thickness.

The sand and gravel deposited by the glacier are probably the most valuable mineral products of the area.

HOW TO READ THE MAP

In the envelope at the back of this pamphlet is a map on which are shown both the topography and geology of the region. To the right of the map is the legend explaining the colors and patterns used for the various geological formations. At the bottom are four structure sections.

The geology of the area has been added in color to the regular United States Geological Survey topographic map surveyed in 1928. A study of the scale at the bottom indicates that one inch on the map equals approximately one mile on the ground. Surfaced or improved roads are shown as double black lines; poor or private roads as double dashed lines; trails as dashed single lines; railroads as solid black lines with short crossbars; township boundaries has heavy dashed lines; and county boundaries as heavier dashed lines alternating short and long dashes. Houses are shown as small solid black squares to which a flag is added to represent a schoolhouse and a cross to represent a church. A cemetery is represented by a cross or the letters CEM surrounded by a fine dashed line. Lakes appear as concentric blue lines which are always parallel to the nearest shore. This pattern makes it easy to locate small islands. Streams are blue lines; swamps are blue tufts.

In fine print at the bottom of the map are the words, "Datum plane is mean sea level." This means that all altitudes given on the map represent the vertical distance in feet above mean sea level. Altitude is indicated on the map by black numbers. For example, Mount Livermore, one and one-half miles west of Squam Lake, is marked 1497. This means that the summit of Mount Livermore is 1497 feet above sea level. The surface of Squam Lake is shown to be 562 feet above sea level. The letters "B.M." accompanied by a cross and a number indicate a bench mark, a point of known elevation established by surveyors of the Coast and Geodetic Survey or the topographers of the U.S. Geological Survey. A bench mark is usually a small circular brass disc set in solid rock, in a concrete pier, in a highway, or in some other permanent or semi-permanent location.

The brown lines on the map are contour lines, lines connecting points of equal altitude. They show the shapes of the hills and valleys and the approximate altitude of any place on the map. If you walk parallel to a contour line, you will not change altitude. If you walk at right angles to the contour lines, you will be moving directly up or down a slope. At the bottom of the map is the statement, "Contour interval 20 feet." This means that the vertical distance between successive contour lines is 20 feet. In other words, any such line is either 20 feet above or 20 feet below an adjacent line. To simplify the readying of the map, every fifth contour line is heavier, and only these hundred foot lines are labeled. Somewhere on each heavy line will be found brown numbers representing the exact altitude of that line. The spacing of the lines shows the steepness of the slope. If the lines are closely spaced, the slope is steep; if far apart, the slope is gentle. As examples, note that part of the east side of Mount Prospect, three and one-half miles west of Squam Lake, is very steep, over 3000 feet to the mile, while The Plains, on the east side of the Pemigewasset River about three miles north of Plymouth exhibit a very gentle slope, about 150 feet to the mile.

One more examination of the bottom of the map reveals a symbol labeled "approximate mean declination, 1928." This symbol is necessary because of the fact that the compass does not point due north but to a magnetic pole which lies northwest of Hudson Bay about 1000 miles from the geographical north pole. In the diagram, one line points true north, and the other toward the magnetic pole. The angle between them is 16 degrees. This means that the compass needle in this area will point 16 degrees west of true north. If you intend to wander from the beaten path, take with you a map and a compass, and when using the latter, do not forget to make the proper corrections.

The top and bottom boundaries of the map and the two intermediate black lines labeled 50′ and 55′ are parallels and run due east and west. The side boundaries and the two intermediate lines labeled 35′ and 40′ are meridians which run due north and south. These lines may be used to orient yourself. Using your compass, with the proper correction, line up the map with its top toward the north; locate yourself on the map; and then it is comparatively easy to identify all topographic features in the vicinity.

The color patterns on the map show the kinds of rock in the different areas. The legend at the right explains what each color means. In addition, the rock name is indicated by black letters which appear both on the map and in the legend. For example, the rock on the shores of Squam Lake is represented by a green and white diamond pattern and the black letters "*wqd.*" In the legend, these symbols are found to represent the Winnipesaukee quartz diorite. Since the oldest rocks are at the bottom of the legend, the Winnipesaukee quartz diorite is younger than the littleton, Norway, and Kinsman, and older than all those above. the lack of any symbol for soil, glacial drift, or other unconsolidated material might give the impression that the rock is exposed everywhere. This is not true. Most of the bedrock is concealed. For this reason, more than one symbol must be used to indicate contacts between different kinds of rock. The solid line means that the contact was seen and plotted accurately. The dashed line is used when outcrops of the two rock types indicate the presence of the contact but it was not seen because it was covered by glacial deposits. The dotted line is used when there is a change from one type of rock to another but a sharp contact is lacking. In many parts of the areas mapped as Littleton, the metamorphic rock is shot full of stringers and patches of igneous material too small to map. Where such material is particularly abundant, its presence is indicated by scattered colored dashes printed over the Littleton pattern, as *Dlk* and *Dli.*

The structure sections at the bottom of the map are the geologist's pictures of what lies below the surface, of what he believes you would see if you could dig trenches to a depth of one-quarter mile below sea level along the Lines A-A′, B-B′, C-C′, and D-D′. If you were to climb Mount Tecumseh, you would find that the summit is composed of schists of the Littleton formation. However, an examination of sections A-A′ and B-B′, which pass through the top of Mount Tecumseh, shows that the Littleton is but a thin cap. If a vertical hole were drilled at the summit, it should strike the Conway granite at a depth of a few hundred feet.

The special strike and dip symbols in the legend and on the map indicate the attitude of the beds in the Littleton formation and of the foliation in both the Littleton and some of the rocks of the New Hampshire magma series. For the purpose of explanation, let us consider the roof of a house. The direction of the ridge pole, a horizontal line, would represent the strike of the roof. Any horizontal line drawn on the roof would be parallel to the ridge pole and would therefore be the strike. Strike can thus be defined as the direction of a horizontal line in a plane. On the map, the straight line of the symbol is the strike of bedding or foliation. Returning to our illustration, we find that the steepness of the roof is the dip and that the two halves of the roof dip away from the ridgepole in opposite directions. The steeper the roof, the higher the dip. A vertical surface has a dip of 90 degrees; a flat surface, one of 0 degrees. All other dips must be between these two figures. In the symbols, the arrows show the directions of dip and the numbers indicate the amount. On top of Sunset Hill, the strike of the foliation is about north-south, and the dip is 87 degrees toward the east.

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9. Quinn, Alonzo, *Geology of the Winnipesaukee Quadrangle, New Hampshire,* New Hampshire State Planning and Development Commission, Concord, 1941.

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Geology of the Plymouth Quadrangle, New Hampshire

Corrections to Accompany 1979 Reprint

General Statement

This brochure was originally published in 1946, and the text has been reproduced without change. The accompanying geological map has been obtained from surplus stock printed at that time. Obviously the distribution of the rock formations, their description (as given in the legend on the map), the topography, and the drainage have not changed. But the roads and trails are not necessarily the same. Some have been abandoned and others have been built. Most notably, Interstate Highway 93 follows the Pemigewasset Valley. There are new housing developments and ski resorts, such as those at Campton and Waterville Valley. For changes in the trails one should consult the most recent edition of the White Mountain Guide published by the Appalachian Mountain Club. The cost of preparing a new map would be prohibitive.

Age of Formations

The sequence and nomenclature of geological eras and periods (p.12) have always been based on relative ages and for many decades geologists had no satisfactory method to relate this time-scale to years. But now radiometric methods are available, and it becomes possible to give approximate dates in years. The results have become progressively more reliable. Since the rate of disintegration of radioactive elements is known, it is possible to relate geological events to a time-scale expressed in years.

Radiometric methods show that the White Mountain Magma Series is considerably younger than shown on page 12 and on the legend of the map. In the Plymouth Quadrangle only one radiometric date is available; the

Conway Granite traversed by the Mad River was crystallized from magma approximately 182 million years ago. The Mount Osceola and Conway Granites in the extreme northeast corner of the quadrangle are part of the White Mountain batholith, different members of which have been dated as 168 to 180 million years old. Thus the White Mountain Magma Series in this quadrangle is Late Triassic or Early Jurassic. Radiometric dates obtained elsewhere in New Hampshire show that the Norway, Kinsman, and Winnipesaukee are Middle Devonian. It should also be noted that the ages of the geological periods shown on page 12 have been considerably revised.

Additional References

General Geological Books:

A.M.C. White Mountain Guide, 21st ed., 1976, 491 p., Appalachian Mountain Club, Boston.

Bloom, A.L., 1978, Geomorphology, 560 p., Prentice-Hall, Englewood Cliffs, N.J.

Leet, L.D., S. Judson, and M.E. Kaufman, 1979, Physical Geology, 490 p., Prentice-Hall, Englewood Cliffs, N.J

Hamilton, E.I. and R.M. Farquhar, eds., 1968, Radiometric Dating for Geologists, 506 p., Interscience

Stokes, W.E., 1973, Essentials of Earth History, 532 p., Prentice-Hall, Englwood Cliffs, N.J.

Adjacent Quadrangles:

The geology of all the surrounding quadrangles has been mapped. Reports published prior to 1946 are listed on page 21. Brochures published since then are:

Englund, E.J., 1976, The bedrock geology of the Holderness quadrangle, New Hampshire: N.H. Dept. Resources and Economic Development, Bull. No. 7, 90 p.

Henderson, D.M., M.P. Billings, J. Creasy, and S.A. Wood, 1977, Geology of the Crawford Notch quadrangle, New Hampshire: N.H. Dept. Resources and Economic Development, 29 p.

Quinn, A., 1965, reprint of Geology of the Winnipesaukee quadrangle, New Hampshire: N.H. Dept. Resources and Economic Development, 21 p.

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