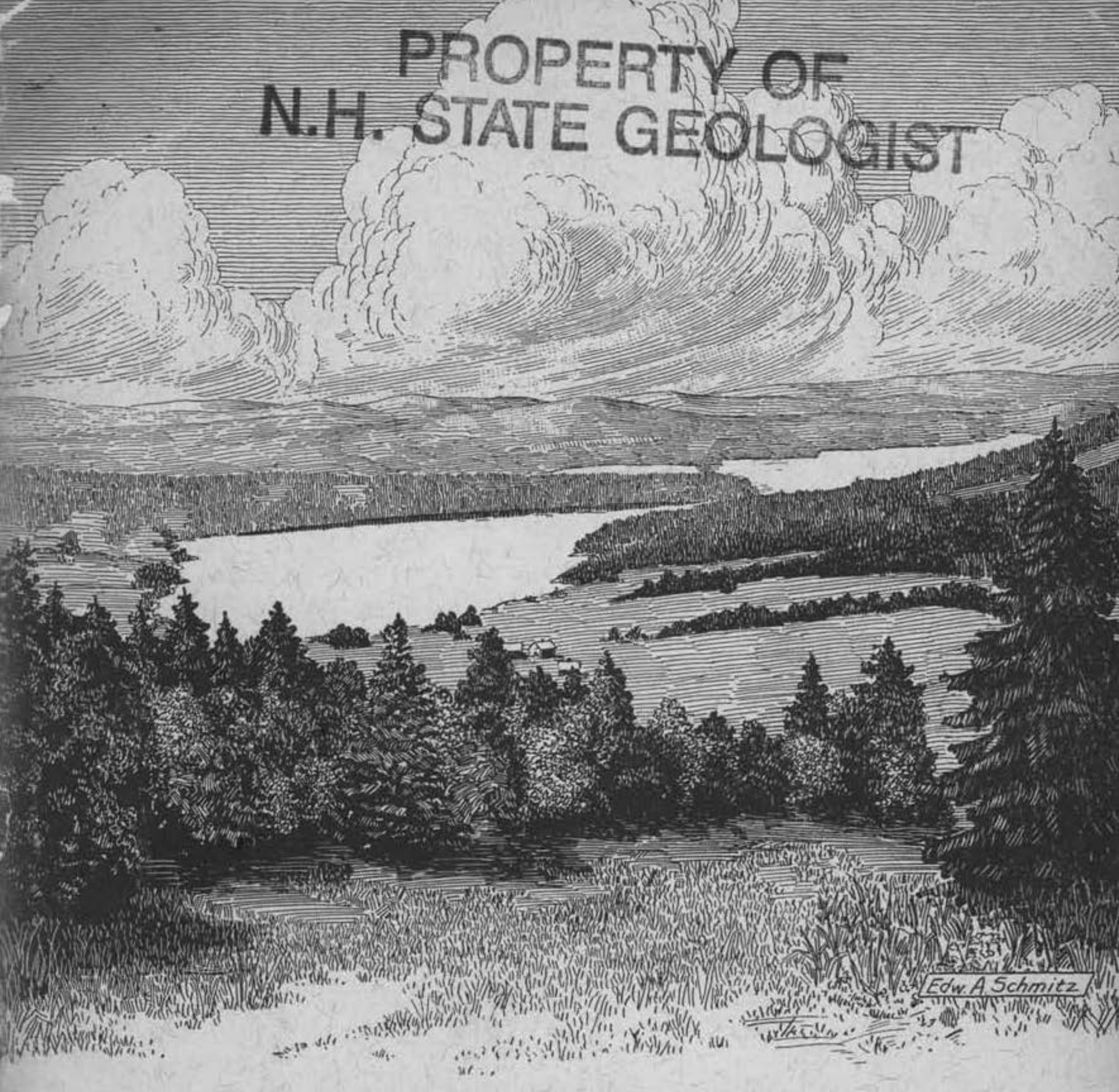

THE GEOLOGY OF
Mt. Cube and Mascoma Quadrangles
NEW HAMPSHIRE

BY
Jarvis B. Hadley and Carleton A. Chapman

PUBLISHED BY THE NEW HAMPSHIRE PLANNING AND DEVELOPMENT COMMISSION

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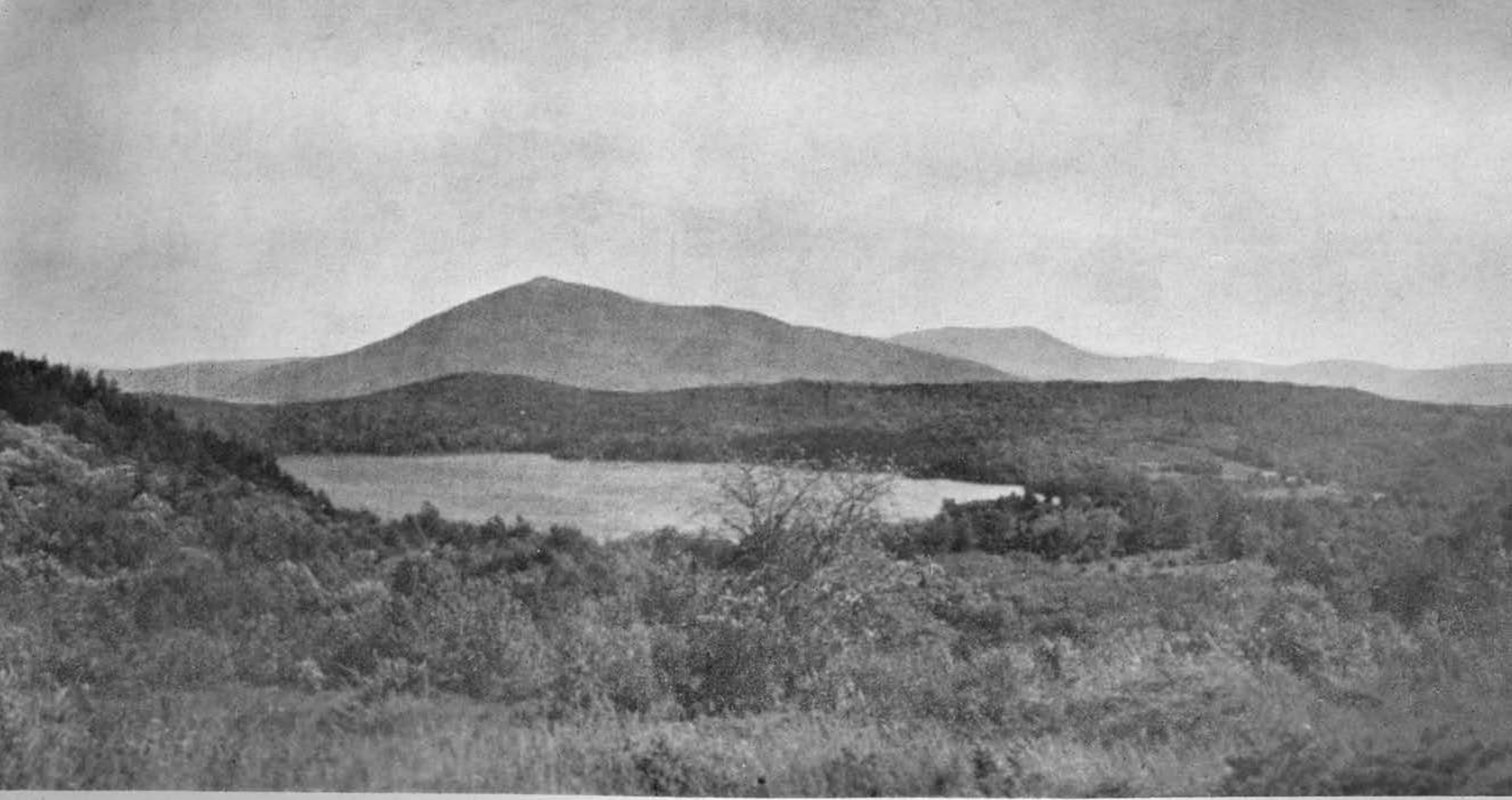

INDIAN POND WITH MT. CUBE BEHIND IT; SMARTS MOUNTAIN TO THE RIGHT OF MT. CUBE. VIEW LOOKING SOUTH-SOUTHEAST

J. B. Hadley

Geology

of the

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New Hampshire

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THE SCENERY

THE traveler in the Mt. Cube and Mascoma quadrangles, maps of which are in the pocket at the back of this pamphlet, cannot fail to be impressed with the charm of the hills and valleys about him. Green pastures and forested mountains combine with rushing brooks and azure lakes to give scenes of unsurpassed beauty. But this scenery is a heritage of a long history: of long ages when western New Hampshire was beneath the sea; of periods of unrest when the crust of the earth was buckling under terrific pressure and great masses of molten rock were rising from the depths of the earth; of millions of years of erosion, when rain and frost, wind and storm slowly wore away the solid rock; and of a Great Ice Age, when an ice sheet a mile thick overwhelmed the region. It is this fascinating story which is described in the following pages.

In the Mt. Cube quadrangle, which is the more northerly of the two quadrangles discussed in this pamphlet, the slowly flowing Connecticut River is the master stream. In the immediate vicinity of the river the land rises in most places in a series of sandy terraces a few feet to twenty feet high. In places, however, steep cliffs rise almost directly from the river's edge. The most notable of these are the Palisades opposite Orford, precipitous cliffs 400 feet high, and cliffs on Sawyer Mountain, 500 feet high.

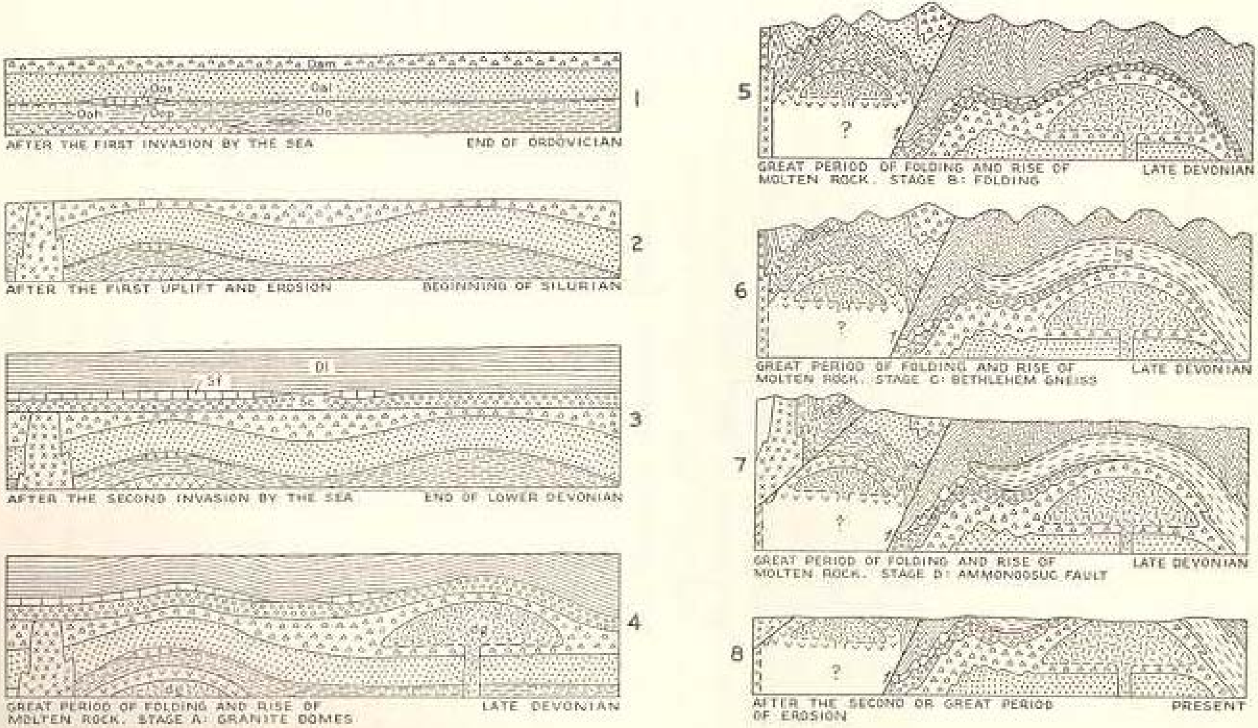

Figure 1-8. Series of diagrams illustrating the story of the rocks which is fully described in the text. Oo=Orfordville formation; Oop=Post Pond volcanics; Ooh=Hardy Hill quartzite; Oos=Sunday Mountain volcanics; Oal=Albee formation; Oam=Ammonoosuc volcanics; f=Fairlee quartz monzonite; Sc=Clough formation; Sf=Fitch formation; Dl=Littleton formation; dg=granites and related rocks of the Oliverian magma series; bg=Bethlehem gneiss.

In a belt three to five miles wide east of the river are rolling, pastured hills which in places attain elevations 1000 feet above the level of the river and 1400 feet above the sea. Local eminences rise even higher, such as the symmetrical cone of Sunday Mountain in Orford, the top of which is 1800 feet above sea level, and sharp, conspicuous Peaked Mountain in Piermont, the top of which is 1580 feet above the sea. The highest mountains, however, are six to seven miles east of the river. At the north end of this chain is Piermont Mountain, a long, narrow ridge, the highest part of which lies in the adjacent Rumney quadrangle. Farther south is Mt. Cube (2911 ft.), a massive, rocky summit whose white ledges glisten in the sun. The highest peak in the quadrangle is Smarts Mountain, a heavily forested mountain with an altitude of 3240 feet. To the south are Holts Ledge (2100 feet) with a 400 foot cliff on its east side, and Winslow Ledge (2240 feet) with a 500 foot cliff on its southwest side.

The mountains of the Mascoma quadrangle are not so high as those in the Mt. Cube quadrangle. A series of ridges, trending almost north-south, splits the quadrangle into a western third and an eastern two-thirds. At the north this series of ridges is represented by Moose Mountain, a long, narrow ridge extending for eight miles north of Enfield. Moose Mountain reaches its highest altitude in North Peak, 2300 feet above sea level. South of Mascoma Lake is a series of hills and mountains, such as Montcalm Hill (1750 feet) and Sargent Hill (1780 feet), but the culminating summit is Grantham Mountain (2661 feet).

West of these hills and mountains, trending north-south through the quadrangle, are rolling hills with many pastures. East of Moose Mountain is a low forested area with small hills and many swamps, while in the extreme southeast corner of the quadrangle we find conspicuous hills, such as Aaron Ledge (2022 feet) and Melvin Hill (2280 feet).

The lakes of the Mascoma quadrangle add to its charm and beauty. The largest is Mascoma Lake, over four miles long, with sandy beaches interspersed with rocky shores.

THE STORY OF THE ROCKS

The First Invasion by the Sea

Our story begins some four hundred million years ago in what is known to geologists as the Ordovician period. A vast but shallow sea covered most of what is now New England. To the east, on the site of the Gulf of Maine, a high mountain range was being slowly worn down by the elements. Swift torrents, flowing westward from these mountains, carried tiny particles of sand and mud to the sea. Here they dropped their load, and alternating layers of sand and mud were deposited on the sea floor. Although each layer was only an inch or a few inches thick, ultimately the total thickness of sediments grew to many thousands of feet. During the early part of this period there were prolonged eruptions from abundant volcanoes. Vast quantities of volcanic dust and ash were strewn about. Some of this fell directly into the shallow sea, but much of it fell upon the land to the east and was later washed down to be redeposited on the sea bottom. Thus the volcanic material became mixed or interbedded with the fine sedimentary material brought normally by the streams to the sea. Some of the volcanoes were submarine, and lava flows poured forth intermittently upon the sea floor.

The sedimentary and volcanic material thus deposited is found throughout a large part of the Mt. Cube-Mascoma region, and is known as the Orfordville formation. It can be seen in many outcrops in the vicinity of Orfordville, whence it receives the name. The total thickness of volcanic material deposited during the early part of the period amounts to about 2000 feet, and is called the Post Pond member of the Orfordville formation. Volcanism eventually became much less vigorous and sand, mud and silt 3000 feet thick accumulated on the sea floor.

One of the most interesting beds in the Orfordville formation is the Hardy Hill quartzite. Originally this consisted of alternating layers of sand and gravel with abundant pebbles of white quartz. The Hardy Hill quartzite is an extremely resistant rock and caps the tops of numerous hills and ridges. It can be readily traced in the field and is a great aid in deciphering the intricate folding in the Mascoma quadrangle. At the close of the deposition of the Orfordville formation there was a short period of renewed volcanic activity, and the Sunday Mountain volcanics were laid down.

Then the Albee formation was deposited. Sand and mud, carried to the sea by westerly flowing streams, accumulated on the continually sinking sea floor, and finally sediments 4000 feet thick had been deposited. Once again volcanism played a dominant role. Countless volcanoes which dotted the neighboring landscape issued such quantities of volcanic debris that the Orfordville and Albee formations were buried beneath 2,000 feet of rock fragments, dust, ashes and lava. These are the Ammonoosuc volcanics (Fig. 1).

The First Uplift and the First Erosion

Near the end of the Ordovician period, about three hundred and sixty million years ago, the sea floor was elevated. The Mt. Cube-Mascoma region became dry land. Uplift had not been uniform and the layers of rock already deposited were warped into gentle folds. During the millions of years that this region lay above the sea, rain and rivers slowly wore away the rocks (Fig. 2). Beds many hundreds of feet thick, perhaps thousands of feet thick, were thus stripped away. Only a land of rolling hills and gentle valleys remained.

The Second Invasion by the Sea

Then came the second invasion by the sea near the beginning of the Silurian period, some 350,000,000 years ago. Marine waters coming from the southwest slowly spread northeasterly across western New Hampshire. The shore line advanced, at the most only a few feet a year, so that storm waves by their constant pounding and rolling action had plenty of opportunity to sort the debris they encountered. The softer and finer particles were carried far out to sea. The harder and larger particles, chiefly sand and quartz pebbles, were carried out only a short distance from the shore where they formed alternating beds of sand and gravel. Hundreds of feet, and locally, as on the site of Croydon Mountain, a thousand feet of sand and gravel accumulated to form the Clough formation (Fig. 3).

As the sea spread far to the north and east less sand and mud was available in the Mt. Cube-Mascoma region. The sea was shallow, warm and clear. Corals and shell fish flourished, but during the occasional storms which swept the seas the animals were killed and their shells smashed to powder. The pulverized shells accumulated in layers to form limestone. Thus the Fitch formation, several hundred feet thick, was deposited. Later in early Devonian time, sand and mud were deposited. Thousands of feet, in alternating layers, accumulated to form the Littleton formation.

The Great Folding and the Rise of Molten Rock

Sometime near the close of the Devonian period, about 300,000,000 years ago, a period of great crustal unrest set in. Western New Hampshire, which for a hundred million years had been dominantly a region of widespread seas, began to be uplifted, never again to be covered by marine waters. This period was marked by two major phenomena; intense compression of the earth's crust and the rise of molten rock into the crust.

Great compressional forces, acting horizontally in a more or less east-west direction, squeezed the rocks and forced them to buckle (Fig. 5). Gigantic folds, both upwarps and downwarps, trending about north-south were produced. Upon these major folds were countless minor folds of various sizes. The intricacy of this folding is well shown in the structure sections accompanying the geologic maps.

In places the compression, instead of folding the layered rocks, produced great fractures. The rocks on opposite sides of a fracture slipped past one another, forming what is known as a fault. One of these great fractures is called the Northey Hill fault or thrust. Since the fault originally inclined toward the west, compressional forces caused that part of the earth's crust on the west side of the fault to ride up over the block on the east side. Subsequent to this faulting, erosion has cut and smoothed a new surface across the two blocks, but the break is still apparent and is known to extend from Piermont in the Mt. Cube quadrangle to Cornish in the Mascoma quadrangle. The Ammonoosuc thrust is a similar fault, causing the western block to ride over the eastern block a distance of nearly three miles (Fig. 7). Another fault in Grantham and Enfield (structure section C-C′, Mascoma quadrangle) allowed the block east of it to slip downward about 4000 feet relative to the block on the west.

The intensity of folding increased to such a point that the rocks were mashed as if in a gigantic vise. The tremendous heat and pressure accompanying this deformation caused all the rocks to recrystallize and become metamorphosed, that is, changed in form. Many old minerals were destroyed and new ones formed in their place. As thin, flaky crystals of mica grew, they arranged themselves in parallel planes, nearly at right angles to the direction of greatest compression. The direct result of this reorganization of material and the parallel arrangement of flaky and elongated crystals was to impart a cleavage to the rocks themselves. This property of a rock to split into more or less thin slabs, characteristic of slate, is spoken of as rock cleavage or schistosity. Thus the original muds were converted into slate and fine-grained schist. Sand and gravel became hardened to form quartzite and conglomerate. Limestone was changed to marble. From the original lavas and volcanic ash, gneiss and amphibolite were formed.

While the layered rocks were being folded and metamorphosed, large masses of molten rock began to rise from the depths of the earth. Slowly and forcefully they worked their way upward. Some of them did not penetrate farther than the upper part of the Ammonoosuc formation. Here they spread out and congealed, forming huge domes (Fig. 4), such as that shown in green in structure section E-E′, Mt. Cube quadrangle. Later, after the folding had become much more intense, two more masses of molten rock wedged their way upward into the crust. These, too, finally solidified and formed the Bethlehem gneiss (Fig. 6). The present shape of one of these bodies is shown in structure section C-C′, Mascoma quadrangle. The Bethlehem gneiss in the central part actually came from the eastern part of the section.

In the final stages of the solidification of the Bethlehem gneiss a residual liquid formed. This was squeezed out into openings in the surrounding rocks and ultimately crystallized to form extremely coarse-grained granitic dikes called pegmatites. These pegmatite dikes or veins are the source of most of New England's commercial feldspar and mica. They also contain quartz, tourmaline, garnet, apatite and many rarer minerals. They are located, as the map shows, largely along the east side of the body of Bethlehem gneiss in the Mascoma quadrangle.

After a relatively quiet period of several millions of years, molten rock once again welled up from the depths of the earth. The resulting congealed rocks are common in the White Mountains, but are relatively unimportant in the Mt. Cube-Mascoma region. One of the bodies, labelled "vb" on the map and found in the north part of Canaan (Mascoma quadrangle) one mile north of Lary Pond, is of interest because it is the throat of an ancient volcano of which the superstructure has long since been worn away.

The Second or Great Period of Erosion

Near the end of Paleozoic time, about 175,000,000 years ago, western New Hampshire had become relatively quiescent. The forces which had caused the great folding and the rise of molten rock had died away. Erosion attacked the rocks, seeking to destroy the mountain ranges erected by the compressional forces. Under the constant assault of the rain, wind and frost the hills and mountains were worn down. In general, slow regional uplift kept pace with erosion, so that the actual altitude above sea level has not greatly changed. Finally, after nearly 175,000,000 years of erosion, but just before the Great Ice Age, the mountains and valleys resembled those now found in the Mascoma-Mt. Cube area (Fig 8).

The Great Ice Age

Then one of the most fascinating events in the history of the Mascoma-Mt. Cube region took place with the beginning of the Great Ice Age, a million years ago. As the earth became cooler, great ice caps began to form in northern Canada. Each winter more snow fell than could melt during the ensuing summer. As successive layers of snow piled one on top of the other, the snow recrystallized to ice. Then the ice began to spread out in all directions, creeping east, west, north and south. This great ice cap finally pushed into the Mascoma-Mt. Cube region, at first burying only the lower hills but ultimately overwhelming even the highest mountains. Sand and boulders embedded in the ice polished and scratched the bed rock. Many of the scratches have since been destroyed by erosion, but in a few places they may still be seen trending somewhat east of south. As the ice advanced, there accumulated beneath it large masses of boulder-filled clay, known as glacial till. As the ice melted, heaps of sand and gravel accumulated in small temporary pools beneath the ice and between the ice and the steep slopes of the hills.

While the ice was melting away, a temporary lake formed in the Connecticut River valley, a lake in places at least 300 feet deep. Much of the sand and clay now found in the valley accumulated in this lake. Then the lake was drained. The Connecticut River cut down into the old lake beds, and, as it swung from side to side in its downward cutting, left a series of terraces on both sides of the valley. The small tributaries, since their depth of downcutting is controlled by the level of the Connecticut River, were, in turn, able to cut sharp V-shaped valleys into the sand terraces.

HOW TO READ THE MAPS

The geological maps of the Mascoma and Mt. Cube quadrangles will be found in the pocket inside the back cover. Each map represents an area called a quadrangle. An inch on the map represents slightly less than one mile; hence the territory covered by each map is about twelve by eighteen miles. The colored patterns, indicating different types of bedrock, are printed over a topographic map showing the shape of the land surface, as well as roads, houses, towns, rivers and lakes.

A good place to study a part of the topographic map without the geological overprint is the northwest part of the Mt. Cube quadrangle. Roads are shown as parallel black lines, solid if good motor road, dashed if poor motor road or private road. Trails are shown by single dashed lines, which should not be confused with the dashed lines used to show geological boundaries. Houses are indicated by small black squares to which a flag is added to indicate a schoolhouse, and a cross to indicate a church. An area enclosed by a dashed line and marked by a cross or "CEM" indicates a cemetery. Boundaries of towns, counties and states are shown by heavier dashed lines. Streams, rivers, lakes and ponds are shown in blue. Swamps are designated by a blue symbol representing tufts of grass.

The most unusual feature of the topographic map is the maze of fine brown lines which covers it. These are lines of equal elevation, or contour lines, which represent the third, or vertical, dimension of the earth's surface. Each contour line follows the ground surface in such a way that it traces a level line at a given altitude above sea level. Thus a contour line may wander across the map, going around hills or along the sides of valleys. Every fifth contour line is somewhat heavier than the others and indicates hundreds of feet of altitude. Many of them are labeled with their respective altitudes in feet above the sea. The thinner lines are spaced every twenty feet of altitude, and the "contour interval" is twenty feet (see the legend at the bottom of the maps). Crossing from one contour to the next is equivalent to climbing, or descending, 20 feet; thus, where the contours are closely spaced, the slope is steep, and, where they are spaced far apart, the slope is gentle.

Around a hill more than 20 feet above its surroundings the contours obviously make complete circuits showing the shape of the hill. The altitude of the hill can then be read to the highest 20-foot interval by finding the altitude of the highest (innermost) closed contour. Altitudes of some of the more important hills and other points, such as crossroads, bridges and lakes, are given more exactly by figures in black.

For example, on Spaulding hill, 2½ miles northwest of Lake Morey, the highest labeled contour is 1500 feet above the sea. This contour, if traced around the hill, makes a complete circuit, within which is another heavy contour. This must be the 1600-foot contour. Within this four more light contours may be counted, the innermost of these having an altitude of 1680 feet. The actual altitude of the summit of the hill within the 1680-foot contour is 1690 feet, as shown by the figure in black. The tiny oval contour just above the "S" indicates a minor knob, near the summit, but lower,—barely 1660 feet.

The topographic maps are used as a base on which to plot the character of the rocks appearing at the earth's surface, in other words, to show the geology of the region. The distribution of the different types of rock is shown by a number of colored patterns, bounded by thin, solid, or dashed or dotted lines. A key to the patterns and to the meaning of the different types of geological boundary lines can be found in the legend at the right of the maps. The patterns are based on the careful study of several thousand outcrops, or exposures above the soil, of the bedrock in each quadrangle. These outcrops, when plotted on the map, show the location, size and shape in ground plan of the various bodies of rock. In other words, the map represents the appearance at the earth's surface of the architectural units of which the earth's crust in this region is built.

One of these units, for example, is the layer of white, hard rock known as the Clough formation which is shown on the map by a band of solid purple. Wherever it occurs at the surface, it appears in glistening white ledges. These can be traced from Croydon Mountain in the southern part of the Mascoma quadrangle, northward across Mascoma Lake to the north end of Moose Mountain. There the belt enters the Mt. Cube quadrangle, continuing along Holt's Ledge, across Winslow Ledge and Lambert Ridge, thence around Smarts Mountain, on across Mt. Cube and out at the northeast side of the quadrangle on Piermont Mountain, a total distance of 34 miles.

The reader will notice scattered along this belt on the map a series of symbols shaped like a T with an arrowhead at the bottom. The Clough formation was deposited in layers or beds, one on top of the other. The layers were originally nearly horizontal but are now tilted like the roof of a house. The direction of the top of the T indicates the *strike* of the layers, comparable to the direction of the ridgepole of the roof; and the arrow shows the *dip,* or direction in which the layers slope downward. The figures indicate the steepness of the slope, or the *dip,* measured in degrees from the horizontal. A dip of five degrees means that the beds are almost horizontal, a dip of eighty-five degrees, that the beds are nearly vertical.

Other rocks, like the Bethlehem gneiss, although they were not deposited in layers, have planes of weakness due to the parallel arrangement of flaky minerals due to pressure. These planes are called *schistosity* or *foliation;* their strike is shown by a straight line, with a solid triangle to indicate the direction of the dip and a figure to give the value of the dip. Commonly both types of structure are found in the same rock body.

More about the arrangement of the rock units of the crust may be learned from the structure sections below the maps. These are lettered to correspond with lettered lines on the maps. They represent what would be seen in the sides of a trench half a mile to a mile deep, dug along the designated lines. Of course, no one has ever actually seen such a section in the Mascoma-Mt. Cube region, but from a study of the dips and strikes as shown in exposures on hillsides and in cliffs, such as that on Holts Ledge, the geologist can make a good approximation to what such a trench would show.

A few more words in explanation of the legend. Underneath the colored rectangles are the names of the rock units represented and a brief scientific description of the types of rock included in them. The rock units are arranged in order of their relative age, the oldest at the bottom and the youngest at the top; their ages in terms of the standard divisions of geologic time are shown at the left. How long the divisions were and what happened during them in this region is told briefly in the section on *The Story of the Rocks.*

INTERESTING LOCALITIES AND ITINERARIES

Mt. Cube Quadrangle

The following itineraries are suggested for short walking trips which will afford an opportunity to see good exposures of some of the rocks described on the map. Several of the trips follow trails of the Dartmouth Outing Club (D. O. C.), and those over Mt. Cube, Smarts Mountain and Holts Ledge are worth while for the sake of the fine views obtained from those summits.

Mt. Cube. This peak, rising 1500 feet above the surrounding country, owes its existence to a great mass of the Clough formation which has resisted erosion more than the adjacent rocks. The best trail starts from a farmhouse on the west side of the mountain which may be reached by car from state highway No. 25-A (labeled 111 on the map) by following a dirt road one mile south from the Mt. Cube School. Good outcrops of the Bethlehem gneiss may be seen in a pasture opposite the farmhouse. Near the D. O. C. cabin a greenish lime-silicate rock of the Fitch formation is poorly exposed in the trail. About one-half mile above the cabin outcrops of quartzite and quartz-mica schist of the Clough formation appear, and these continue intermittently to the top of the mountain. The upper part of Mt. Cube is covered with white outcrops of quartzite, typical of the Clough formation. A short distance northwest of the trail, between the north and the south outlooks, good bedding may be seen, highly folded. Some of the grayer beds contain small, white, quartz pebbles. The structure of the beds on Mt. Cube is very complicated, and the inclination of individual strata will be found to vary greatly from place to place.

The resistance of the quartzite to decay by weathering has helped to preserve a wealth of glacial markings, rubbed into the quartzite by the slow creep of the ice sheet, many thousand years ago. Polished rock surfaces, striae or scratches, crescentic fractures and lunoid furrows may be observed, especially on the knob southeast of the trail, a third of a mile southwest of the southern or highest summit.

Exposures are poorer on the north side of Mt. Cube. South of highway No. 25-A opposite the Mt. Cube House, 7½ miles from Orford, the first outcrops seen near the trail are a dark, coarse-grained border phase of the Baker Pond gneiss. Above the sharp bend, small outcrops of dark, biotite-amphibole schist of the Ammonoosuc volcanics occur in the trail. Above the 2200-foot contour outcrops of Clough quartzite are common.

Smarts Mountain. The most rewarding trail is that from the Lyme-Dorchester road, 5 miles east of Lyme. Quartzite of the Clough formation may be seen on the north side of the road near where the trail leaves and in the bed of Grant Brook just south of the road. The trail follows a lumber road for the first mile until the site of a lumber camp is reached. Outcrops of the Ammonoosuc volcanics occur in the stream just east of the camp.

Three-fourths of a mile from the camp the trail crosses from the Ammonoosuc formation into the Smarts Mountain granodiorite. This is a gray, granular rock, outcrops of which may be seen in and near the trail from the 2200-foot contour nearly to the top of the mountain. At the summit of Smarts Mountain is a green amphibolite, containing much epidote. This is a part of the Ammonoosuc volcanics, exposed in a cap on the top of a large dome of the Smarts Mountain granodiorite (see the map and structure section D-D′).

Holts Ledge. This mountain may be reached by trail from the Lyme-Dorchester road, 2.5 miles east of Lyme. For the first half mile the trail follows a road in which outcrops of the Bethlehem gneiss may be seen. At Holts Ledge Camp the trail turns eastward up the hill, and, shortly, ledges of quartzite in the Clough formation appear. These beds dip about 25 degrees northwest and lie on the northwest side of a great dome, the core of which is composed of the rocks of the Mascoma group. A section passing through Holts Ledge is shown in structure section E-E′. At .4 of a mile from the camp the Clough formation has been removed by erosion, and dark amphibolite of the underlying Ammonoosuc volcanics appears. Outcrops of the amphibolite continue intermittently to the top of the ridge. This point is directly above the Holts Ledge cliffs, 400 feet high. The Ammonoosuc volcanics lie along the top of the cliffs, but the lower two-thirds are composed of the quartz-diorite of the Mascoma group. From the top of the cliffs one looks eastward toward Winslow Ledge where rocks similar to those on Holts Ledge occur and out over the lowland eroded from the softer granitic rocks of the Mascoma dome.

Mascoma Quadrangle

The Mascoma quadrangle offers several mountain climbing trips which can be taken in a period of a very few hours. There are, in addition, numerous excellent trips which may be taken on foot or by auto on which one may see considerable geological phenomena. Some of the best will be described.

Moose Mountain. The mountain offers a few short but very interesting trips which may be taken along the Dartmouth Outing Club trails. One good trail leaves the dirt road about a mile east of Hanover Center. By leaving the trail and walking a short distance north to the brook one-quarter mile east of the Dartmouth Outing Club camps, one may see good exposures of the mica schist of the Clough formation. Several other outcrops of the schist and some beds of quartzite may be observed in the brook just off the trail a little farther on. About three-eighths of a mile beyond the camp is seen the first outcrop of the Mascoma group. From here to the top of South Peak good exposures of this coarse pink granite are seen.

Having reached the summit one should climb the large evergreen to "The Crow's Nest" where an excellent view of the higher mountains in western New Hampshire may be obtained.

Heading back on the trail again for a few hundred yards one may take the north branch which cuts across the saddle and leads to North Peak. For a short distance on the north side of the saddle may be seen the amphibolite of the Ammonoosuc volcanics and beyond this are good exposures of the Clough quartzite. The amphibolites are again observed near the triangulation station at the top of the mountain.

Etna to Etna Highlands School. In Mink Brook in Etna village are numerous outcrops of the border gneiss of the Lebanon dome. About half a mile south along the dirt road which leaves the macadam road, just west of the Etna village, are exposures of a biotite gneiss of the Post Pond volcanics. Still farther south, particularly in the fields west of the road, are numerous outcrops of schist and gneiss also belonging to the Post Pond member. At the Hanover-Lebanon township line one should leave the road and climb the small hill to the northeast. From the top of this knoll to Hayes Hill there are excellent outcrops showing considerably folded beds. Two hundred yards down the east slope of Hayes Hill are exposures of the black schist of the Orfordville formation. Other outcrops of the schists may be seen in the pastures as one proceeds from here to the hill half a mile southwest of Etna Highlands School. This little hill is held up by the resistant Hardy Hill quartzite, and there is an excellent opportunity to observe the quartzite at this point. The quartzite may be followed for a short distance to the northeast where it finally thins out and disappears.

Lebanon to Grantham. A beautiful section of the Post Pond volcanics and the black schists of the Orfordville formation may be seen in new road cuts along state highway No. 14 which runs east from Lebanon village. If one turns south and proceeds along state highway No. 10 for three-quarters of a mile, one may observe the Hardy Hill quartzite which outcrops along the road. For two and a half miles farther along the road several outcrops of the Orfordville black schists can be seen. The road next crosses the Northey Hill thrust and a short distance beyond are rocks of the Littleton formation. About 200 yards south of Montcalm School is an exposure of the Littleton staurolite schist. A better place to observe this schist is at the fork in the road which runs west from Montcalm School. Here the large crystals of staurolite stand out very plainly against the silvery gray mica schist.

This staurolite schist continues for about one and a quarter miles along the main highway, and beyond is the Clough formation. This formation, chiefly quartzite and schist, extends for half a mile along the road. Beyond this point is the Bethlehem gneiss, but no exposures of the gneiss are seen along the road for over a mile south of the Lebanon-Grantham township line.

From here the road approaches the great fault, extending from Mascoma Lake to Grantham, until just west of Anderson Pond; both the road and fault turn and run parallel for over a mile. In the fields just northwest of the "N" in "North Grantham" on the map are outcrops of the Clough formation and Ammonoosuc volcanics which form part of the north side of the Croydon dome. About three-quarters of a mile farther south an outcrop of the Croydon group may be seen. At about the same point the road crosses the fault and follows along the Bethlehem gneiss to Grantham.

USEFUL MINERALS AND ROCKS

Many rock and mineral deposits in the Mascoma and Mt. Cube quadrangles were used locally and put into commerce in the earlier days. Many of these deposits were worked between 1800 and 1870, when the population in this region was at its height, and were abandoned when minerals and metals began to be supplied from farther west. Very few of them have been used in recent years, and these largely for road material. For the historical interest, however, and because the deposits may be of interest to mineral collectors or might be revived as local commercial enterprises, the more important quarries and prospects are described.

Granite. The largest quarry in the region and the only one operated in modern times is the Lebanon granite quarry, one mile north of the town of Lebanon, N. H. This quarry is actually in the Hanover quadrangle, but a considerable amount of the same rock occurs on Rix Ledges at the western boundary of the Mascoma quadrangle. The granite is pinkish and rather coarse-grained; blocks of it have been used relatively recently in buildings in Hanover and Lebanon.

The granite of the Mascoma group has been quarried locally three miles north of Enfield and 2 miles north of Enfield Center. Granite from the latter quarry was used years ago in the Shaker villages on Mascoma Lake. There is a large supply in this neighborhood, suitable for curb and foundation stones.

In the Mt. Cube quadrangle the Bethlehem gneiss, the Haverhill granodiorite and the Fairlee quartz monzonite have all been used locally for foundations, fence-posts, hitching-posts, door-steps and watering troughs. Parts of the body of Bethlehem gneiss extending through Orford and Lyme are suitable for buildings and slab-like or sheeted ledges have been quarried at several places. Stonehouse Mountain in Orford takes its name from a large stone house on its western slope, partially completed of large blocks of the gneiss. The best granite in this body is near its north end, just east of Clay Hollow. The eastern body of Bethlehem gneiss in Dorchester, Wentworth and Canaan is probably too soft and too easily split to be of use.

Limestone. At several places where relatively pure marble occurs in the Fitch formation there are long-abandoned pits from which limestone was taken and burned. Most of these are located in the vicinity of Quinttown, in the southeastern part of Orford, and are shown on the map by a crossed hammer and pick. The remains of one of the kilns are hidden deep in young forest growth, five-eighths of a mile southeast of Quinttown. There is a considerable supply of marble still available at these places but none of it is suitable for building or ornamental stone.

Slate. A rather poor grade of slate has been quarried in the Littleton and Orfordville formations at various localities in the Mascoma and Mt. Cube quadrangles. Most of the material is not a true slate but a fine-grained schist which splits evenly.

The largest quarry is in the Littleton formation in the Mascoma quadrangle, one-half mile west of the village of Mascoma. Although the slate here does not split sufficiently thin to be suitable for roofing, it can be used for chimney-pieces, table-tops, sinks, cisterns, flooring and flagstone. This quarry was once very productive; in 1868, 150 tons of the waste were ground, bolted, and sold as slate flour.

Several quarries in the Orfordville formation have yielded slate of a similar character. One of these is a few yards northeast of the Etna Highlands School in the Mascoma quadrangle; another is on the Hanover-Lyme town boundary, one-half mile southwest of King School.

Whetstone. Easily cleaved, micaceous sandstone in the Littleton formation occurs in the town of Piermont, in the extreme northeastern corner of the Mt. Cube quadrangle. This is the southward extension of a belt of similar rock which has been extensively quarried near Pike, N. H., to make scythe-stones. Several small pits and one fairly large quarry are shown on the map.

Soapstone. At two localities in Orford soapstone or talc occurs. One of these is in the village of Orfordville behind the schoolhouse; the other is near the base of the cliffs on the west end of Cottonstone Mountain, one-third of a mile from the highway. Both of the deposits lie in metamorphosed volcanic rocks in the Orfordville formation.

The Cottonstone Mountain locality is the larger and has soapstone of better quality, a rock so soft that it can be sawed into slabs and used for sinks, stoves and fireplaces. A hundred years ago the stone was taken out in considerable quantity and shipped by boat down the Connecticut

River. The pit is now about 50 feet wide and 75 feet long, but part of it has been filled by talus blocks fallen from the adjacent cliffs. Considerable soapstone of fair quality can still be found there, and scattered blocks from the original quarrying are used locally for the manufacture of paper weights and small carvings.

Amphibolite. Fine-grained, dark green rock, called amphibolite because it is composed largely of the mineral amphibole (hornblende), occurs in the Post Pond member of the Orfordville formation. This rock is similar to the trap which is commonly used for macadam roads. Such rock has been quarried for road metal in the vicinity of Post Pond in the town of Lyme. If crushed rock ever replaces the present use of gravel on imperviously surfaced roads, these amphibolites can furnish a large supply.

Sand and Gravel. Sand and gravel banks may be found nearly everywhere. They are largely of glacial origin, deposited by the melt water flowing from the retreating ice sheet at the end of the glacial period. Hence, the sand and gravel is generally washed clean of silt and is commonly free from boulders. The sand, however, is much too impure to be used in the manufacture of glass. It is used now largely in road building.

Clay. Although, to the writers' knowledge, no clay industry was ever started in this region, there is an abundant supply of clay in the vicinity of the Connecticut River. It represents deposits in ancient glacial lakes which have been drained and the sediments on the bottom exposed by modern streams. Such deposits occur at many places near the river and its tributaries, usually below the 600-foot contour. The clay is somewhat silty but some of it can be used for modeling.

Feldspar and Mica. Both of these minerals occur in many large pegmatites which cut the Littleton formation in the southeastern part of the Mascoma quadrangle. Some of these have been prospected, and there is a considerable supply of feldspar and mica here which might some day be profitably mined. In the Cardigan quadrangle to the east, uraninite, a source of radium, has been found in pegmatites, but as far as known is of insufficient quantity to be of commercial value.

MINERALS OF INTEREST TO COLLECTORS

In addition to the above rocks and minerals of present or past economic importance there are occurrences of minerals which might be of interest to collectors or to students of geology.

In the Mt. Cube quadrangle fine crystals of blue kyanite occur in white quartz veins in the Orfordville formation, on the west slope of an unnamed hill one and one-eighth miles south-southwest of North Thetford, Vermont. Abundant staurolite may be found in outcrops of the Orfordville formation, on the top and southeast slopes of Blackberry Hill, a mile and a quarter east of Orford village. Another good locality is near the road on the west side of Strawberry Hill, half a mile south of state highway 25-A (111 on the map). In both of these places dark brown crystals several inches long occur imbedded in dark gray schists.

The Mascoma quadrangle offers the mineral enthusiast many opportunities to collect a wide variety of minerals and crystals. Small but perfect octahedral crystals of magnetite may be obtained in the Post Pond member. One of the best places to obtain these crystals is at an elevation of about 900 feet on the southern slope of Signal Hill in Lebanon.

Large garnet crystals up to an inch across have been obtained from the quartz schists one-half mile southwest of Etna Highlands School in Hanover. Many of these are formed in perfect dodecahedrons. Staurolite crystals are extremely abundant in the Littleton formation from Shaker Mountain to Cornish. Some of the better collecting localities are on Hyde Hill and Stowell Hill in Plainfield and Shaker Mountain in Enfield. Pegmatite minerals of many kinds are found in Grafton and Springfield. Here in the old mines and prospects are excellent opportunities to obtain specimens. Many of these mines and prospects are shown on the map. The most common minerals obtainable here include quartz, microcline, albite, biotite, muscovite, black tourmaline, beryl, garnet and apatite.

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