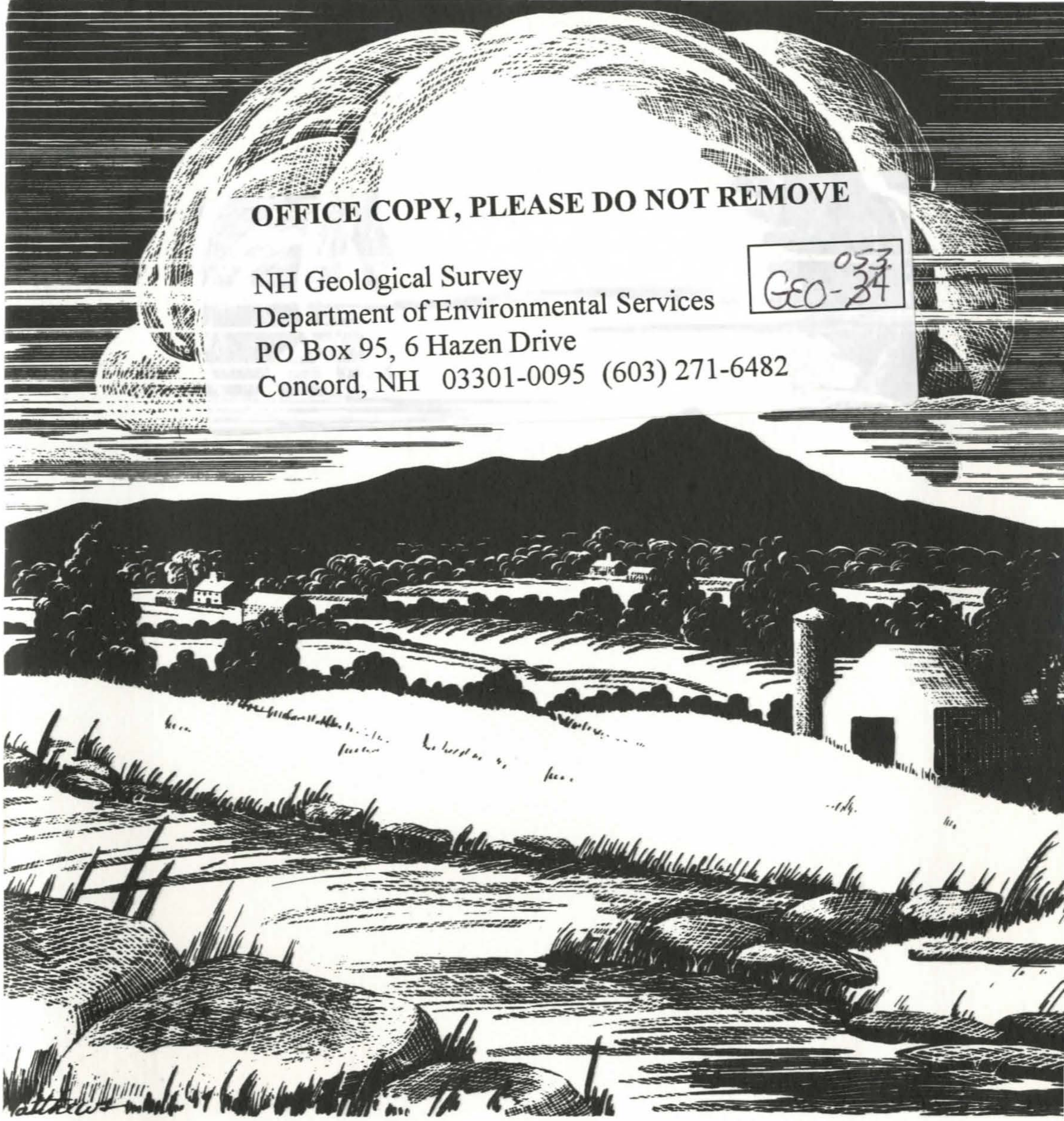

THE GEOLOGY OF THE

MONADNOCK QUADRANGLE

New Hampshire

by

KATHARINE FOWLER-BILLINGS

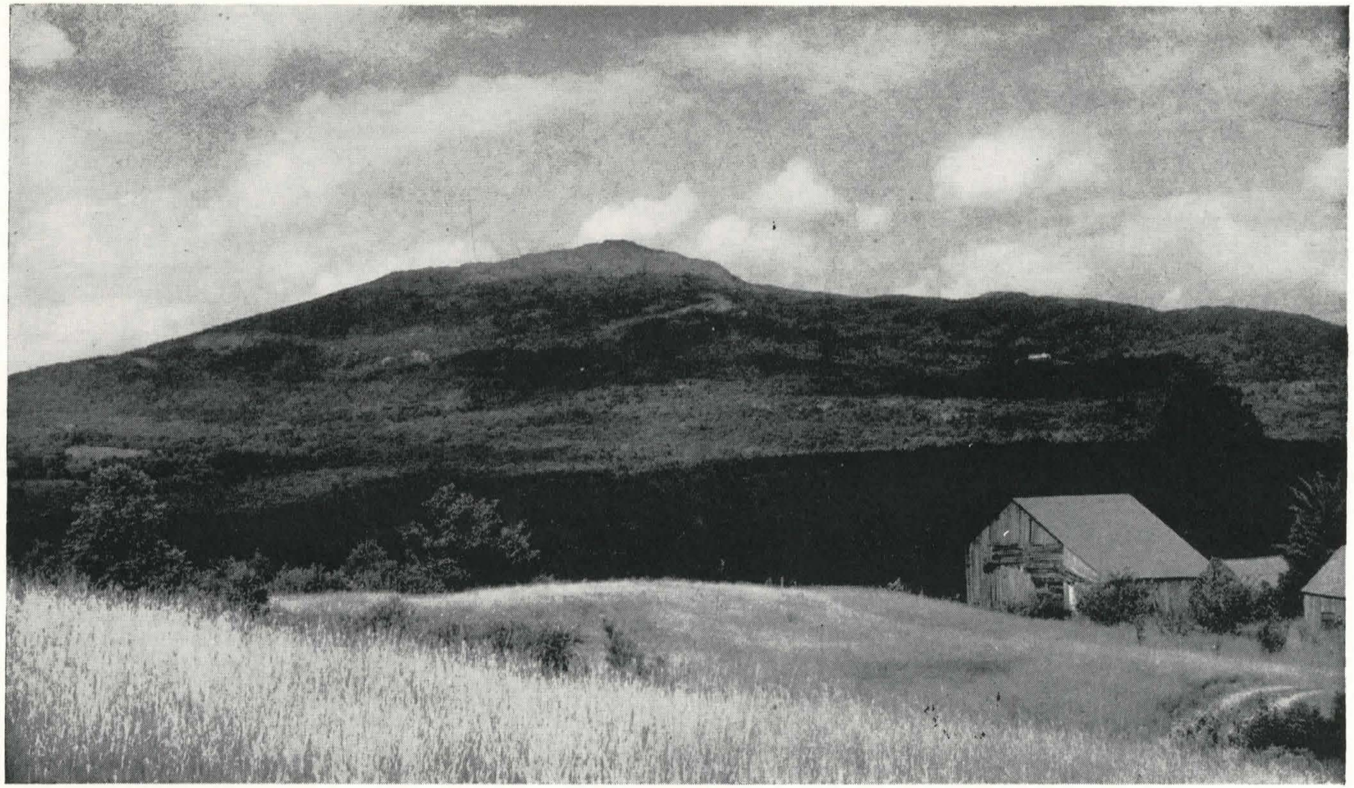

Fig. 1 — Mt. Monadnock rising above the New England Upland. View was taken from Troy, New Hampshire
Photo by Harold Orne

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DEPARTMENT OF RESOURCES AND ECONOMIC DEVELOPMENT

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Concord, New Hampshire
1979

FOREWORD

This pamphlet presents the story of the rocks of the whole of the Monadnock quadrangle, New Hampshire, as well as the adjoining northern part of the Winchendon quadrangle as far south as the Massachusetts State Line. The origin and history of the scenery, the folding and uplift of the mountains, and their shaping by the work of streams and ice is told in simple language for the layman. Few scientific names are used. The colored map accompanying the pamphlet shows the topography of the region as well as details of the geology, with a legend for interpreting the map. 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.

There are many references to Mount Monadnock in geological literature, but this is the first attempt in recent years to work out the history of the rocks of the mountain in relation to the region as a whole. A partial bibliography is found at the back of this pamphlet for those who wish to consult the previous publications.

The writer is indebted to Marland P. Billings for supervising the field work and laboratory investigations. Field assistants were Leo Nolan, Donald Mork, and Ursula Bailey Chaisson. The New England Museum of Natural History, Boston, has supplied the plates for figures 9, 10, 11, 12, and 14. These illustrations were originally published in the New England Naturalist in November, 1941. The drafting of figs. 2-8 was done by Edward Schmitz.

Geology of the Mt. Monadnock Quadrangle

New Hampshire

By Katharine Fowler-Billings

THE SCENERY

Mt. Monadnock, towering 2000 feet above the surrounding lowlands, dominates the landscape of the Monadnock region (Fig. 1). Its characteristic pointed profile and broad sloping shoulders make a landmark readily recognized from great distances. It is such a striking example of a high mountain rising above a level upland that the term "monadnock" was coined by Wm. Morris Davis in 1896 for any such hill or mountain rising above a flat surface produced by deep erosion. The term "monadnock" is now used throughout the world. Its proximity to the main centers of population in New England, its accessibility by car, bus, or train, and the excellent trails which lead to the 3165 foot summit, make it one of the most popular mountains in New England. Unobstructed views in every direction can be obtained from its ledges. Because of the bare open slopes, the steep rocky cliffs, and an unpredictable climate resulting from its height and exposure to strong winds, Mt. Monadnock in many ways simulates higher mountains. The rocks which make up the mountain reveal a fascinating story, and few hikers fail to be curious about the rounded ledges, ragged cliffs, and the alternating dark and light bands or white and black streaks across which the trails pass. They may even imagine raised "turkey tracks" on the bare rocks, and wonder whether these are fossils (Fig. 9). In gazing across the flat lowland spread out below, they may wonder why there are so many lakes scattered in every direction, and why some of the streams have cut deep into this lowland. These questions, and many others, will be answered in the story that follows. For it has taken many millions of years to form the rocks, to fold them and to wear them away. What we see today is merely a clue to the past; and even today the face of the earth is ever changing.

THE STORY OF THE ROCKS

The Colored Geologic Map

To understand the story of the rocks, the reader must first unfold the colored geologic map at the back of the pamphlet, get acquainted with the region as a whole. As he looks at the map, he may be impressed by the variety of rock formations in the Monadnock region. Each pattern means a different kind of rock with an individual story of its own.

The legend at the edge of the map gives a complete list of all the types of rock in the area, starting from the oldest rocks at the bottom of the column to the youngest at the top. Detailed descriptions of each rock formation are printed in small type in the legend. This detail concerns the professional rather than the amateur. Any technical names will be explained simply in the following account of the story of the rocks. The little letters in the boxes of the legend are a second device in addition to the color patterns to aid the reader to find out what particular kind of rock occurs in any locality. The cross sections at the foot of the map are to show what would be found in trenches cut down through the earth far below sea level. They should help the reader visualize the rocks in the depths of the earth, while the geologic map simply shows the plan of the rocks. There is more complete description of how to read the map at the end of the pamphlet.

To help understand the legend of the map, a chart summarizing the sequences of events of the region is included in the text on page 10. There is also a series of diagrams, Figs. 2-8, which represent the history of the region from the laying down of the oldest rocks until the coming of the Great Ice Sheet. These cross sections are to aid in visualizing the history of the region; how the rocks were laid down under water, then folded, later injected by hot molten rock, and finally worn away, producing our present mountains with many rock types exposed at the surface.

Volcanic Activity

The oldest threads of history in the Monadnock region take us way back through time to at least 370 million years ago, near the end of the Ordovician period, when volcanoes were erupting in the vicinity. Volcanic debris in the form of airborne or water-laid ash and lava flows covered the area (Fig. 2). The volcanic deposits have been changed, during a period of folding to be described on a later page, to light-colored fine-grained gneiss and to black "amphibolite," which is composed chiefly of a mineral called hornblende. Only a narrow belt of these rocks called the "Ammonoosuc volcanics" now remains to tell the story. They occur in a narrow strip a few hundred feet wide south of South Keene, as shown by the purplish strip labelled *Oam* on the geologic map. Because this belt is so thin, the rocks are well exposed only along the railroad cut one mile west of Webb, or where brooks, such as the one three-quarters of a mile due west of Corey Pond, cut across the upturned volcanics.

The Great Inland Sea

Widespread seas then spread over the land. The shore of this inland sea was far to the east of the present coastline, probably somewhere in what is now the Gulf of Maine. Land lay east of the Gulf of Maine, and the Atlantic Ocean was even farther to the east of these vanished hills of the Gulf of Maine. Westward flowing streams attacked this land, and carried mud and sand into this inland sea (Fig. 2). At first, a thin layer of mud was laid down in the Monadnock region. This mud, which is found only in a few places on top of the Ammonoosuc volcanics, is now a mica schist, and is called the Partridge formation. The seas seem to have become shallow, and temporarily withdrew from the area, for most of the Partridge formation was removed by the work of streams in this region (Fig. 3). When the seas returned to the area a thin layer of white sand, not over 100 feet thick, was deposited on top of the mud. This sand has been changed to a white compact rock called the "Clough quartzite." It was laid down in what is known as Silurian time, which began 355 million years ago. It is easily recognized by its white color and the smooth, hard, angular blocks into which it breaks. It is well

Geologic Time-scale, with sequence of events in the Mt. Monadnock Region

OLDEST EVENT IS AT BOTTOM OF CHART; YOUNGEST AT TOP

Era	*Period*	*Time-scale (age of beginning of period)*	*Sequence of geological events*
Cenozoic	Recent	Thirty thousand years ago.	Slight erosion
	Pleistocene	Two million years ago	Wisconsin stage of the Continental Ice Sheet covered the region, depositing glacial till, sands and gravels. Earlier ice sheets probably covered the region, but left no recognized records.
	Tertiary	60 million years ago	Uplift and renewed erosion; valleys carved below New England Upland. Rocks eroded to New England Upland which was not much above sea level, but above which "monadnocks" rose.
Mesozoic	Cretaceous	120 million years ago	Erosion
	Jurassic	150 million years ago	Erosion
	Triassic	175 million years ago	Erosion and faulting (?)
Paleozoic	Permian	210 million years ago	Erosion
	Pennsylvanian	255 million years ago	Erosion
	Mississippian	290 million years ago	Erosion and faulting (?)
	Devonian	330 million years ago	Erosion Faulting (?) New Hampshire magma series intruded: amphibolite dikes and sills; Kinsman quartz monzonite; Spaulding quartz diorite; Concord granite; pegmatites and quartz veins. Folding and recrystallization of the rocks. Oliverian magma series intruded as a dome in the western part of the area, probably Middle Devonian. Littleton formation deposited in a large inland sea — 17,000 feet accumulated. Upper part: 6,000 feet of mud; now a rusty-weathering gneiss and schist. Middle part: 5,400 feet of mud and sand; now schist containing different minerals and quartzite. Rusty quartzite member: 600 feet of sand, mud, and limestone; now rusty weathering quartzite containing actinolite granulite. Lower Part: 5,000 feet of mud and sand laid down; now schist and quartzite.
	Silurian	355 million years ago	Clough quartzite at least 100 feet thick laid down in shallow sea as sand; now quartzite.
	Ordovician	415 million years ago	Withdrawal of sea and erosion. Partridge formation — at least 50 feet of mud laid down in an inland sea; now a schist. Ammonoosuc volcanics — at least 600 feet of ash and lava accumulated in some places; now gneiss and amphibolite.
	Cambrian	515 million years ago	No record
Pre-Cambrian		More than one thousand Million years ago	No record

exposed in the railroad cut one mile west of Webb, and a quarter of a mile south of South Keene.

Gradually the great inland sea deepened, and quantities of mud and sand brought by the streams from the east accumulated on the sea floor. Thousands of feet of debris poured into the sea over a period of many millions of years, making what is now known as the Littleton formation (Fig. 4). Near Littleton and Whitefield, New Hampshire, fossils of marine animals of Early Devonian age have been found in the Littleton formation. But in the Monadnock region the sands and muds have been heated and folded until they have been changed to quartzite and schist, destroying any trace of the animals which may have lived in these seas. The original bedded or layered character of the rocks can still be seen in many places, especially on Mt. Monadnock, despite the later folding of the rocks.

Almost 17,000 feet of mud and sand of the Littleton formation accumulated layer on layer in the Monadnock region (Fig. 4). The sands of the lowermost 5,000 feet have been changed into gray quartzite, and the muds are now schist with many minerals such as black and white mica, garnet, tourmaline, and a blue-gray bladed mineral called "sillimanite." Little Monadnock Mountain, or the Ashuelot River Gorge, are excellent places to see these lower beds of the Littleton formation.

A distinctive series of rocks called the "rusty quartzite member," labelled *Dlr* on the geologic map, separates the lower part of the Littleton formation from the middle part (Fig. 4). The rusty quartzite member is only about 600 feet thick, and can be recognized by its conspicuous rusty color — a stain due to the weathering of the mineral pyrite. Fine-grained black mica schist and a few beds of a light-colored rock with needles of a green mineral called actinolite are present in the formation. The rusty quartzite member zigzags back and forth across the central part of the Monadnock area in great loops or folds. A study of these folds gives the geologist the main clue to the folding of the beds of the Littleton formation. The rusty quartzite member is especially well exposed along the southern quarter of a mile of the road to the Halfway House on Mt. Monadnock; at the Poole Reservoir; on the grounds of the Ark, an inn one mile northwest of the town of Jaffrey; at the northeast corner of Dublin Pond; in the Eliza Adams Gorge below the dam at the

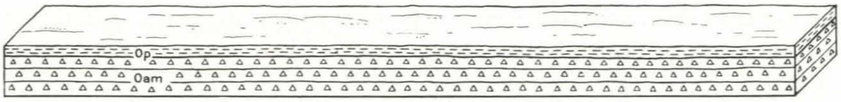

FIG. 2 — Volcanic debris (*Oam* = Ammonoosuc volcanics) and muds (*Op* = Partridge formation) are deposited, probably in Ordovician time.

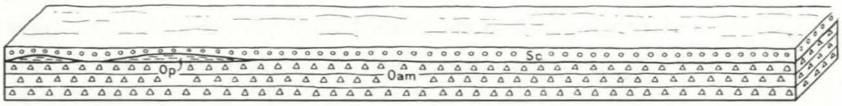

FIG. 3 — After most of the mud (*Op*) had been removed by erosion, a thin layer of white sandstone (*Sc* = Clough quartzite) was laid down across the area when the seas returned to the area, probably in Silurian time.

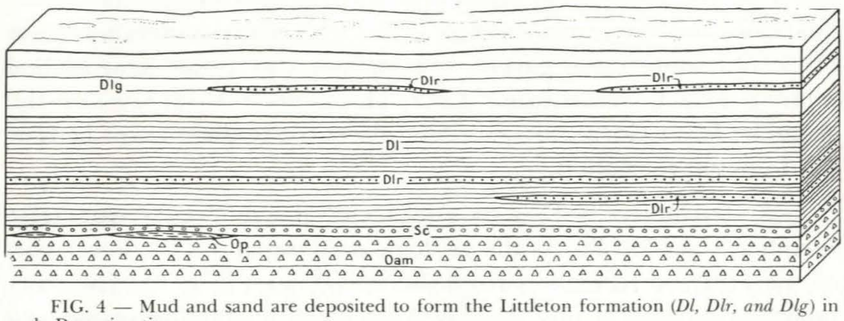

FIG. 4 — Mud and sand are deposited to form the Littleton formation (*Dl, Dlr, and Dlg*) in early Devonian time.

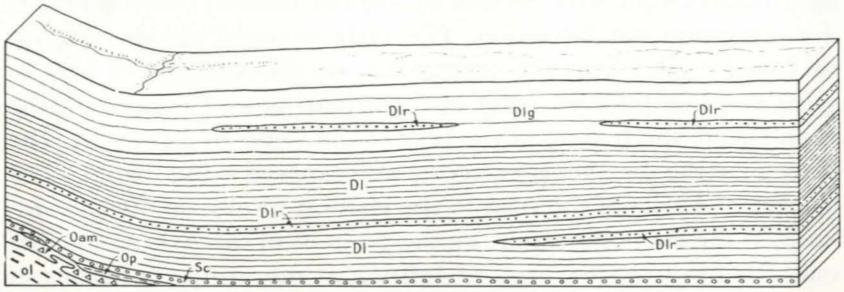

FIG. 5 — Molten rock is pushed into the western part of the Monadnock area in the form of a great dome in middle Devonian time. It hardened to form the Oliverian magma series (*ol*).

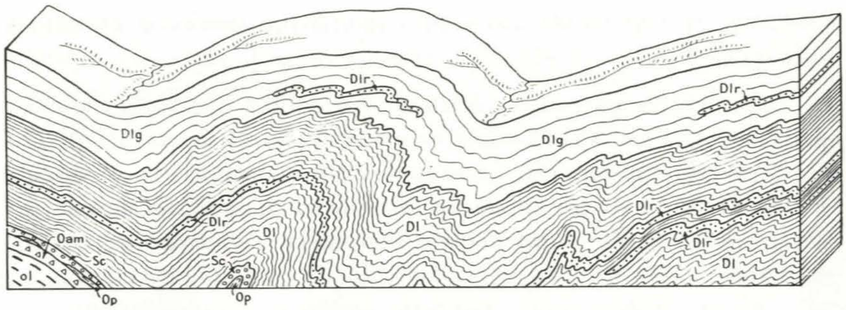

FIG. 6 — Great folding, probably in late Devonian time.

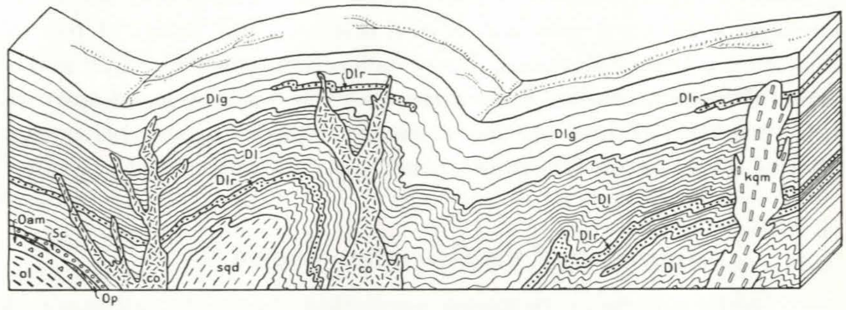

FIG. 7 — Invasion of molten rock in late Devonian time. The molten rock hardened into the granitic rocks of New Hampshire magma series. The first of these granites to be intruded is called the Kinsman quartz monzonite (*kqm*). This was followed by the Spaulding quartz diorite (*sqd*), and finally the Concord granite (*co*).

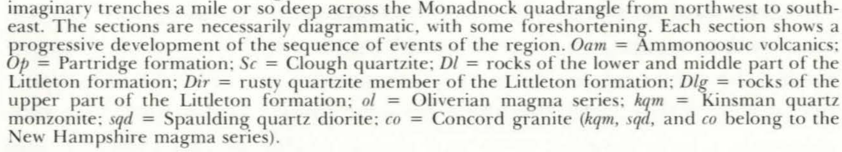

FIG. 8 — Rocks are worn down to present topography.

FIG. 2-8 — Series of diagrams to illustrate the story of the rocks. The cross sections are imaginary trenches a mile or so deep across the Monadnock quadrangle from northwest to southeast. The sections are necessarily diagrammatic, with some foreshortening. Each section shows a progressive development of the sequence of events of the region. *Oam* = Ammonoosuc volcanics; *Op* = Partridge formation; *Sc* = Clough quartzite; *Dl* = rocks of the lower and middle part of the Littleton formation; *Dlr* = rusty quartzite member of the Littleton formation; *Dlg* = rocks of the upper part of the Littleton formation; *ol* = Oliverian magma series; *kqm* = Kinsman quartz monzonite; *sqd* = Spaulding quartz diorite; *co* = Concord granite (*kqm*, *sqd*, and *co* belong to the New Hampshire magma series).

northwest end of Howe Reservoir; and at the southeast corner of Thorndike Pond.

The middle part of the Littleton formation, overlying the rusty quartzite member, was first laid down as mud and sand (Fig. 4). The beds, about 5,400 feet thick, are now schist and quartzite. The rocks on Mt. Monadnock are made up entirely of this middle part of the Littleton formation, and are exceptionally well exposed on the mountain.

The uppermost 6000 feet of the Littleton formation are found in the northern part of the area, and are labelled *Dlg* on the geologic map. It is difficult to see the original layers in this part of the Littleton formation, as it was originally almost wholly mud, and now has become a highly contorted rusty-weathering gneiss and schist. It contains a few hard spherical or oval masses, a few inches or feet in diameter, called concretions. These concretions contain garnet and a mineral called actinolite. Some rusty quartzite was also layed down at this time (*Dlr*). There are many excellent places to see this upper part of the Littleton formation, notably in the village of Harrisville.

Intrusion of the Oliverian Magma Series

In the middle of Devonian time, after the muds and sands of the Littleton formation had accumulated, great disturbances began to occur within the earth. Molten rock was pushed into the already hardened rocks and formed a great dome in the western part of the Monadnock region (Fig. 5). The molten rock froze or consolidated to form granitic rocks, called quartz diorite and granodiorite, belonging to the so-called Oliverian magma series. These rocks are now found along the west side of the quadrangle south of South Keene.

Folding of the Rocks

Then came a period of intense folding, when the rocks were squeezed and warped (Fig. 6). They became plastic under intense heat and pressure, and the original minerals of the rocks changed under the new temperature-pressure conditions until the sandstone became quartzite, and the shale became gneiss and schist. The new minerals which formed were not always stable as the pressure and temperatures increased. Thus the bladed mineral sillimanite which developed in many of the schists changed in many instances to mica as the pressure and temperature changed and solutions moved through the rocks. The marks in the schists on Mt. Monadnock which look like giant bird tracks or fossils are some fo these sillimanite crystals, three inches long, which have been changed to mica. They stand up on the surface of the rock because they are etched out by weathering (Fig. 9); or they are cigar-shaped crystals in some of the rocks. A green mineral called chlorite developed from black mica, and in a few places a blue-green mineral called chloritoid developed as the temperature decreased.

Mount Monadnock is one of the best places to see the folds in the rocks (Figs. 10-11.) The lighter layers are quartzite, whereas the darker layers are schist. White veins of quartz or black tourmaline cut across the folds. They came into cracks in the rocks much later than the folding. Mt. Monadnock is part of a great saucer-shaped fold or syncline; the lowest part of the bowl lies about underneath the so-called "Sarcophagus," a great block of rock on the Pumpelly Trail a little over half a mile east of the summit. The sloping of the rock layers to make this basin is shown in the diagram (Fig. 12) which represents an imaginary trench 2000 feet deep extending from the summit northeastward along the Pumpelly Trail. The folds are also shown in the cross section BB′ accompanying the geologic map.

The great zigzags of the rusty quartzite member (*Dlr*) of the Littleton formation, which shows so clearly on the geologic map in light-purple color, were formed during the folding. They represent a series of great synclines, or downward warps, and anticlines, or upward warps. Of course we now see only the stumps of these folds, because the rocks have been worn far below the original surface, as you will see by studying the series of diagrams (Figs. 6-8). The cross section BB′ at the foot of the geologic map shows the way these folded layers would appear below the surface.

Intrusion of the New Hampshire Magma Series

When the folding of the rocks was almost completed, molten rock or "magma" rose from the interior of the earth, and was forced

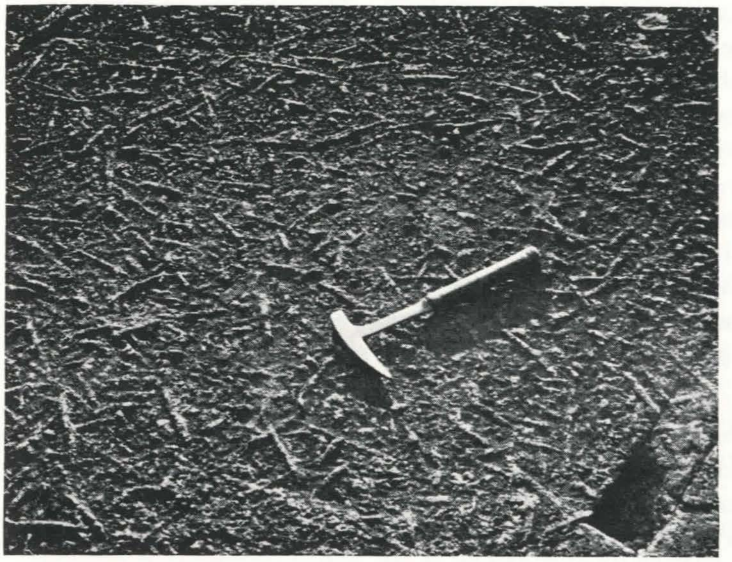

Fig. 9 — Crystals of sillimanite stand out on the weathered surface of the schists on Mt. Monadnock. Many of the sillimanite crystals have been altered to mica. Photo by K.F. Billings.

into the altered and recrystallized sediments. The magma never reached the surface, but froze at some depth below the surface as granite or granite-like rocks. These granites belong to the so-called New Hampshire magma series, and came in successively over a period of hundreds of thousands or millions of years (Fig. 7). A few dark-colored dikes and sills, called "amphibolite," because they contain a mineral called amphibole or hornblende, were forced into the older rocks just before the granites were intruded. An area in which these are abundant, one mile west of Corey Pond, is marked by a special symbol.

The first of the granite-like rocks of the New Hampshire magma series to be intruded is called the Kinsman quartz monzonite. It is a coarse-grained gray rock with crystals of white feldspar as much as five inches long; these feldspars are set in a matrix of quartz, feldspar and biotite (black mica). There are many localities to see the Kinsman quartz monzonite. The exposures around Nubanusit Lake and on Skatutakee Mtn. are excellent.

A rock similar to the Kinsman quartz monzonite, but lacking in the large crystals, was the next to be intruded. It is called the Spaulding quartz diorite, and is dark-gray and splotchy appearing. It can

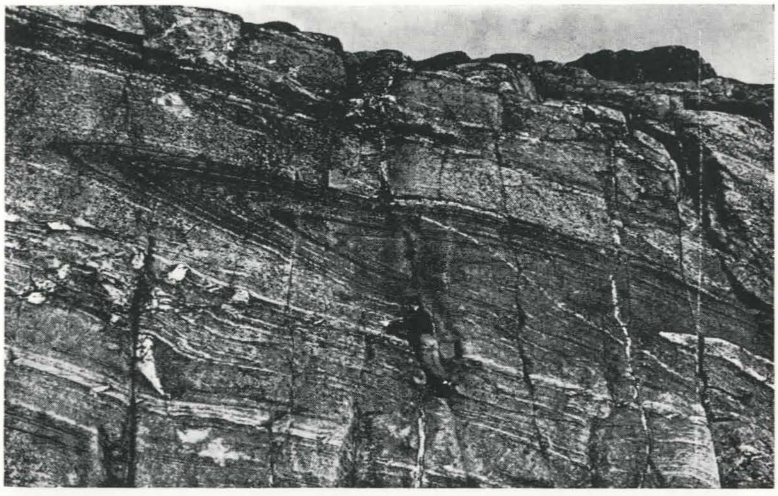

Fig. 10 — Large fold in the rocks of the Littleton formation near the summit of Mt. Monadnock. Light-gray layers are quartzite; dark-gray layers are mica schist; white streaks are quartz and pegmatite. Photo by K.F. Billings.

be seen on the northern slopes of Gap Mtn. or on the highway west of Howe Reservoir.

The last of the New Hampshire magma series to invade the rocks is the Concord granite, a light-gray, fine-grained granite which has been quarried extensively. One of the most interesting and accessible of these quarries is one mile south of the village of Marlboro east of the highway. The granite shows excellent jointing or cracks, some of which display a remarkable sheeting parallel to the surface (Fig. 13). This sheeting is developed in the granite when it is exposed at the surface. It is an expression of the relief in pressure the rock experiences when the overlying thousands of feet are removed by erosion. The rock expands and cracks along planes of weakness. Another large quarry in the Concord granite is on the north side of Webb Hill, one-half mile south of Fitzwilliam Depot.

In many places vein-like masses of coarse granite of varying width came in as dike-like bodies and cut across the rocks. These are called "pegmatites," and were formed when hot fluids were forced out of the larger bodies of granite as they cooled. They contain feldspar, quartz, mica, garnet and black tourmaline, and are conspicuous because of the way in which they cut across the other rocks. Sometimes veins of pure white quartz were deposited from solutions

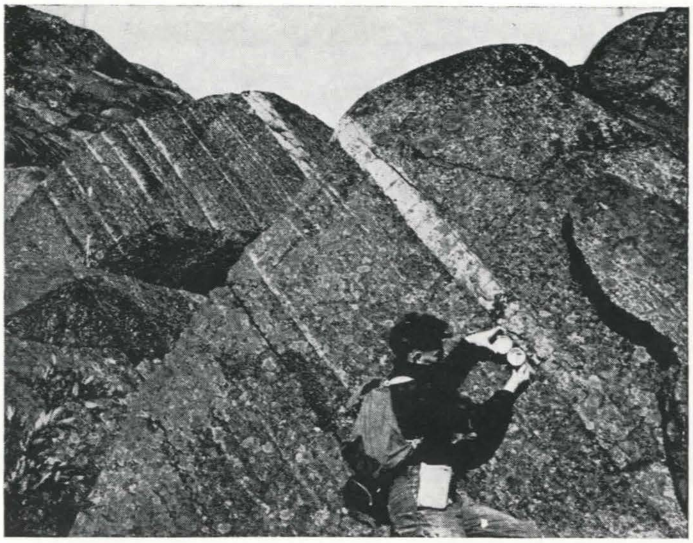

Fig. 11 — East-dipping beds of the Littleton formation near the summit of Mt. Monadnock. Light layers are quartzite; gray layers are mica schist. Photo by K.F. Billings.

which worked their way up into the cracks in the rocks; or thin inch-wide black veins made up of needles of tourmaline were deposited in cracks in the rocks. The pegmatites, quartz veins, and tourmaline veins can be found in many places on the ledges of Mt. Monadnock.

Faulting

Long after all the rocks of the Monadnock region had been laid down, folded, recrystallized, and intruded by the great granite bodies, the southern part of the area was dislocated along fractures called faults. Solutions deposited silica in these fractures in several places to the west and north of Sip Pond. They are now called "silicified zones" and are shown by an orange-striped pattern on the geologic map. These "silicified" zones are several hundred feet wide, and are the clue to the disruptions of the earth at some time following the formation of the rocks, possibly at the end of Devonian times, or even in a later period (Mississippian or Triassic).

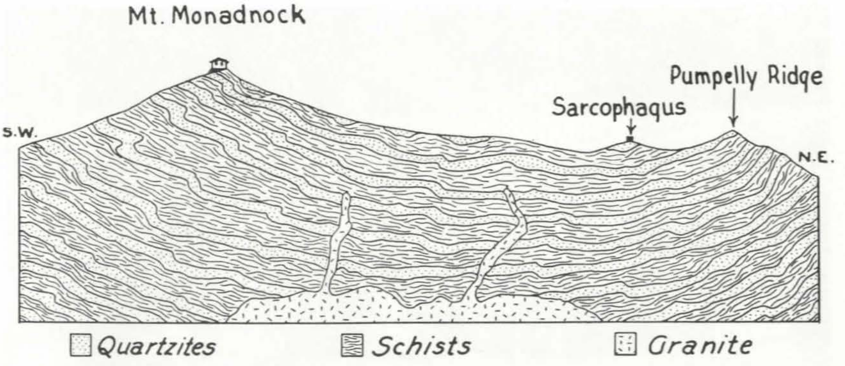

Fig. 12 — Diagrammatic sketch across Mt. Monadnock to show the basin-like structure of the rocks.

The Wearing Down of the Land

The formation of the rocks, the folding, and the faulting are only part of the story. All rocks are subject to "erosion" or wearing away under the attack of the forces of nature. Masses of rock thousands of feet thick had to be worn away by streams before the region began to have its present aspect. As the rocks of the Littleton formation were folded and crumpled, overlying rocks which have long since disappeared were being broken down by ever active streams, and carried piece by piece to the distant seas. Figures 2-8 are over-simplified insofar as they neglect this contemporaneous erosion. As erosion progressed there was a gradual rise of the land, and the ancient mountains may never have been much higher than the present ones. As the land rose, the streams cut deeper, until even the granites which had been intruded so far below the surface of the earth were finally exposed (Fig. 8).

After many millions of years of this attack by the streams, the area sloped to the sea in a low, almost flat plain. This level surface is now called the "New England Upland;" it was surmounted by a few scattered hills or "monadnocks" which had not been worn away. Then came a period of uplift of this flat plain. It took more than a million years to finally bring the New England Upland to its present altitude of 1000 to 1400 feet. The uplift caused the streams to cut down or become "entrenched" several hundred feet below the Upland. Viewed from a distance, the New England Upland can still be seen as a flat surface with Mt. Monadnock and a few other hills or

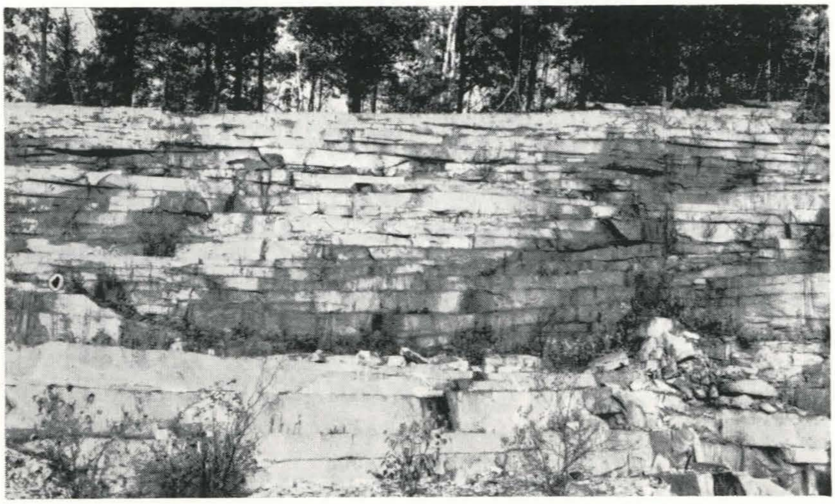

Fig. 13 — Quarry in Concord granite 1¼ miles south of the village of Marlboro, east of the highway. The well developed cracks and sheeting in the granite are called "joints." Photo by E. Wm. Heinrich.

"monadnocks" towering above (Fig. 1). The entrenched stream valleys which have made the dissected New England Upland a hilly region are not visible in Fig. 1. These streams are still attacking the land in an attempt to wear it down to a new surface of low relief.

The Great Ice Age

The wearing down of the land was not the last stage in the history of the Monadnock region. The great Ice Age was still to come and give the final molding to the surface of the land. A great ice cap slowly spread out in all directions from northern Canada. The valleys and lowlands were filled with ice, and finally even the summit of Mt. Monadnock was covered by a sheet of ice many thousands of feet thick which covered all of New England. In other parts of the United States there are records of four glacial stages involving the formation, advance, and retreat of tremendous ice fields. New England was also undoubtedly invaded by ice in all four of these stages. But in the Monadnock region there is no known evidence of more than the last or "Wisconsin stage." This stage lasted about 50,000 years. During this time, the ice scraped away soil, scoured the rock ledges thus exposed, rounded the hills, and deepened the valleys. Boulders weighing many tons were moved by this great Ice Sheet. Boulder-filled clay called "till" was laid down on the surface as thin layers, or in whale-back shaped hills called "drumlins" 100 feet or more high.

There is proof in New England that the Ice Sheet started to melt away about 30,000 years ago. As the ice front gradually retreated by slow melting, lakes formed in many river valleys. The Connecticut River Valley contained some of the best examples of these temporary lakes. The deposits laid down on the bottom of these lakes give a year by year measurement of the retreat of the Ice Sheet. Other proofs of the recency of the glaciation in New England are found in the fact that the deposits laid down by the Ice Sheet have undergone little oxidation, stain, or rotting, and only slight erosion.

The waters of the melting Ice Sheet laid down deposits of sand and gravel in the lower places. Some of the river channels were widened by the great streams which drained away the melting ice. New channels developed where the courses of the former streams were clogged by sand, gravel, and till. An occasional esker — a narrow serpentine ridge of sand and gravel — marks the position of former stream channels in the ice. Swamps and lakes remain scattered over the area where stream courses were clogged, or where glacial deposits created depressions which had no outlets. More rarely, a ridge-like deposit called a "moraine," made up of till and large angular boulders, marks the temporary front of the Ice Sheet. Melting kept pace with the advance of the ice, so that the ice front remained stationary.

The Ice Sheet thus left its mark on the Monadnock region in the form of scoured ledges, boulders, till, sand and gravel; the sand and gravel are useful to man for road material. Water power has been made possible for the mills of the region by the construction of small dams at the outlets of the lakes to insure a steady all-year supply of water. The many lakes, all of which owe their origin to glaciation, make the area an ideal summer vacation land. Since the disappearance of the Ice Sheet, there has been little change in the surface despite the slow, ceaseless attack by the streams and other forces of erosion in an attempt to wear away the land.

ECONOMIC RESOURCES

The Mount Monadnock region has been able to maintain several small mills to support the population of the small villages. *Water power* is cheap and plentiful. *Farming* and *dairying* present another form of livelihood and employment. The *summer and winter tourist trade* has been a boon to the region in recent years, for it is an ideal vacationland. But one hundred years ago, it was the *quarrying of granite* which brought employment and money into the area.

Fitzwilliam, Marlboro, and Roxbury have innumerable *quarries* in the Concord granite, the oldest of which was opened as early as 1812. Most of these were at their height of operation between 1850 and 1900, when they supplied southern New England with paving blocks and building stones worth millions of dollars. Most of these quarries have been abandoned, although some still are used to supply curbstones, tombstones, or building stone. The fineness of grain of the Concord granite, its pleasing gray color, its freshness near the surface, and its ability to split along sheeting planes and joints, make it an ideal building stone. The largest quarries are shown on the map by a special symbol. A trip to any of the quarries is interesting. But perhaps the most delightful ones to visit are those on the north slope of Webb Hill one half mile south of Fitzwilliam Depot, and the quarry one mile south of the village of Marlboro, east of the highway (Fig. 13). The deep pools of clear water in these quarries are now used as swimming holes. Other quarries deserving mention are: the quarries one quarter mile northeast of Fitzwilliam Depot; the quarries one mile west of Fitzwilliam Depot; a quarry northeast of the highway three quarters of a mile southeast of Fitzwilliam; the quarries one half mile east of the village of Troy; the quarry on the west side of Babbidge Reservoir; and the quarry three quarters of a mile north of South Keene.

Four abandoned prospects in *graphite,* or "plumbago," locally called "lead mines" are marked on the map; the first is one and one quarter miles southwest of the village of Nelson; the second, one quarter mile due south of Nelson; a third prospect, one and three quarters miles east and slightly north of the village of Marlboro; and the fourth is one quarter mile northeast of the Halfway House on Mt. Monadnock at an elevation of 2560 feet. The mineral collector will be able to find only a few small flakes of graphite sparsely disseminated in the gneiss, or scattered in small quartz veins containing pyrite. The graphite at the Mount Monadnock locality is massive; it is found in shear zones in a quartz vein which cross-cuts the chlorite/garnet schist. Graphite in tiny flakes is a common mineral in the mica schists of the Littleton formation, but is generally difficult to identify.

The shaft and dumps of an abandoned *gold mine* is located three quarters of a mile due east from School No. 3 in Dublin township. Barren looking quartz containing an occasional crystal of pyrite and mica schist can be found in the dumps. It is questionable whether the mine ever amounted to much.

Sizable *pegmatites* are most abundant in the northwestern part of the Monadnock region in the townships of Sullivan and Roxbury. They occur in many other places throughout the area associated with the granites, or cutting the schists, but are generally small and insignificant. The largest of the pegmatites are shown on the geologic map by small red crosses. In the Nimms Hill region there are several belts of pegmatite which run parallel to the structure. They contain potash feldspar, quartz, muscovite up to two inches across, and black tourmaline. One half mile northeast of Nimms Hill is the old "Price Mine," a prospect in a pegmatite fifty feet wide. Crystals of potash feldspar, six inches long, some fair-sized sheets of muscovite, quartz, and black tourmaline are present here.

Houghton Ledge in Sullivan is an interesting pegmatite 20 to 40 feet wide on top of a ridge. It contains pockets of muscovite with crystals two inches across, black tourmaline one inch long, and potash feldspar four inches long. Quartz occurs as streaks, with the largest mica crystals near the quartz. This belt of pegmatite can be followed south for almost half a mile. One mile southwest of Houghton Ledge there is a large exposure of pegmatite 100 feet long and 30 feet wide containing muscovite two inches in diameter in small pockets. There are several large pegmatites west and northwest of Roxbury Center on the top of The Pinnacle and Bald Hill.

Pegmatites containing some large muscovite crystals crop out one mile north of the village of Marlboro; three quarters of a mile due east of Marlboro; and one and one quarter miles southeast of Marlboro.

The mineral *sillimanite* is abundant in the schists of the Monadnock region. The richest deposits have been described in an earlier paper (see bibliography). This mineral is one of the three aluminum silicates which is used in the manufacture of porcelain to give it strength and ability to withstand high temperatures. It is in demand for use in spark plugs, furnace linings and chemical wares. The belt containing the richest sillimanite extends for ten miles from Gap Mountain, three miles southwest of Mt. Monadnock, northward along the eastern ridge of Mt. Monadnock, northeast to Beech Hill and Cobb Hill. The deposit at Gap Mountain is in schist between the 1640 and 1690 foot contour on the north side of the mountain. The ridge one quarter mile east of the Halfway House on Mt. Monadnock contains a high percentage of pure sillimanite. The Beech Hill locality is one quarter mile northeast of the eastern end of Dublin Lake. The Cobb Hill deposit is on the east slope of the knob marked by the 1900 foot contour one and one half miles northeast of Harrisville. The mineral sillimanite can be recognized by its blue-gray color. It is in tiny needles, or in rectangular crystals up to several inches long which stand out conspicuously on the weathered surfaces. Many of the sillimanite crystals are no longer pure, but were altered to mica by heat and solutions during the folding of the rocks when they were far below the present surface. These crystals are called "pseudo-sillimanite" because they retain the shape of the original sillimanite crystals. These pseudo-sillimanites stand up on the weathered schist surfaces on Mt. Monadnock, and puzzle the visitor with their criss-cross pattern resembling bird tracks (Fig. 9).

Garnets are abundant in the schists of the Monadnock area. A few localities such as Beech Hill could be considered of commercial importance if the demand for abrasives ever warranted the developments of mines. The Kinsman quartz monzonite in the northeast corner of the Monadnock quadrangle contains up to twenty percent garnet in many localities.

Silica could be obtained from the silicified zone which is shown by an orange stripe on the geologic map. The silicified zone extends discontinuously along a six mile long belt north and west of Sip Pond. A slight brown discoloration of the blocks of quartz may preclude the possibility of using these deposits commercially.

It may be of interest to note that Hitchcock (vol. 3, part 5, p. 92

and 93) mentions that the bogs of Fitzwilliam contain deposits of *infusorial silica,* a white, light earth produced by the decay of tiny organisms. Several thousand dollars worth of this infusorial silica has been sold as polishing powder. Also, he mentions that Jaffrey contains bog iron ores of the nature of *ochre.*

The abundant *sands and gravels* are one of the most valuable economic resources in the Monadnock region.

INTERESTING LOCALITIES

There are many interesting localities in the Monadnock region which are not only scenic, but which should challenge the curiosity of the observant nature lover. It is hoped that the story of the rocks as told in the preceding pages will awaken the powers of observation of the reader, and, with the help of the map, make him somewhat of a detective in unraveling the fascinating history of the past. Some localities have already been mentioned where certain rock formations are well exposed. Also, the chapter on economic resources has given the location of deposits of economic interest. A few additional localities which are of special interest will be listed below. Some will be repetition, in part, but emphasis will be placed on features of outstanding interest.

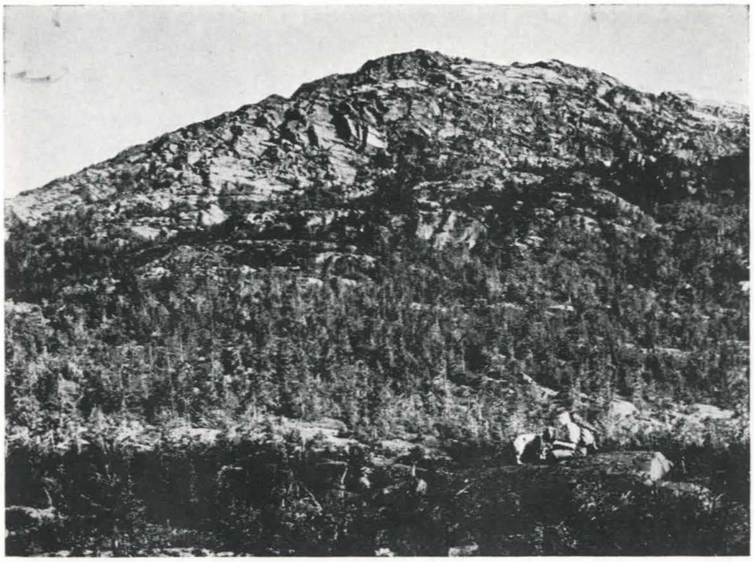

Fig. 14 — Summit of Mt. Monadnock as viewed from the south. Jagged character of the rocks is due to glacial plucking along cracks or joints on the lee side of the mountain. Photo by K.F. Billings.

Localities for Glacial Features

Mt. Monadnock carries many marks of the passing of the great Ice Sheet across its surface. The soil was removed by the ice, and the bedrock on the summit and northern slopes was smoothed and polished into sheep-back forms called "*roches moutonnées.*" The southern slopes suffered plucking by the ice, since they were on the lee, so that jagged cliffs controlled by the joints or cracks in the rocks are the rule here (Fig. 14). The average direction of the ice movement across the region was twenty degrees southeast. This is ascertained by studying the *scratches or grooves* made on the rocks by boulders dragged along in the bottom of the ice. The mountain mass itself deflected the ice flow, so that the scratches made on the ledges in the road a few hundred yards below the Halfway House swing around to the east, and one set of scratches can be seen to lie on top of the earlier ones. These different sets of scratches probably were formed many years apart. The present bareness of the summit and ridges of Mt. Monadnock is attributed to forest fires which have burned off much of the humus or soil which accumulated since the ice sheet melted. The large rectangular boulder or "glacial erratic" locally known as the "Sarcophagus" on the Pumpelly Ridge Trail at the altitude of 2800 feet was dropped by the melting ice. There are many erratics scattered over the area, but none so dramatic as this one.

Bigelow Hill one mile northwest of Perkins Pond is a typical roche moutonnée surface, the bare rock having been scoured by the Ice Sheet. From a distance, animals appear to be grazing over the area. The "animals" are glacial erratics of Concord granite, six to eight feet high, dropped by the Ice Sheet when it passed over the hill.

The whole area east, southeast, and south of Mt. Monadnock down to the Massachusetts State Line is an area of "*drumlins*" or whale-back shaped hills of clay and boulders called till. This till is debris dumped by the ice when it could not push it along any further. Possibly the excessive debris in this region is due to the fact that the Ice Sheet became saturated with soil when passing over Mt. Monadnock, dumping the clogging material on the lee side of the mountain mass in the form of drumlins. The stagnating ice, during the melting of the Ice Sheet, was full of soil and till which was converted into sands and gravels by the melt-waters. These sands and gravels were laid down in the lower places throughout the area. The region has many lakes, swamps, and sluggish streams draining the area as a result of this debris left by the Ice Sheet. In a few places, only, have the streams been able to resume their former stream courses. The three and one-half mile section of Otter Brook north of Keene is in a broad pre-glacial valley which has been filled by sand and gravel, so that Otter Brook meanders back and forth in a wide valley, rarely reaching bedrock. Large *potholes* were scoured in the bedrock almost 100 feet above the present channel of Otter Brook by glacial streams on the north side of the east-west road just north of Roxbury school. These potholes probably developed when ice still lay in the present valley. The stretch of river one mile east of South Keene is also in a sand-filled valley in which the river has not cut through to bedrock. A few swift-flowing streams have developed steep-sided, V-shaped valleys since glacial times. Otter Brook southwest of East Sullivan; Minnewawa Brook east of Marlboro; and the South Branch of the Ashuelot River north of Troy, have all cut gorges in the bedrock. They took up new courses after the Ice Sheet melted, and consequently have not had time to develop broad valleys.

Two "*eskers*" or serpentine ridges made up of sand and gravel were found in the area. These eskers mark the position of former stream channels underneath the ice. The first one is one quarter mile south of B.M. 1350, one mile west of Dublin Pond. It stands up in the midst of an area of sand, gravel, and swamps. Another one showing excellent cross-bedding in the sand is found one half mile north of Eastview at the south end of a small drumlin.

An interesting "*recessional moraine*" or pile of debris deposited at the ice front where the ice stood stagnating for many years, lies along the road at the southeastern base of Skatutakee Mountain. The road follows the morainic ridge for more than a mile. Great blocks of jumbled rock and till make up this moraine which can be traced southwesterly for two miles to the abandoned railroad. Morainic deposits northeast of Skatutakee Lake at the foot of Cobb Hill are probably a part of this same moraine.

Dublin Pond is separated from Dark Pond by sand and gravel deposited by the melting waters of the Ice Sheet, as well as by morainic debris which blocked the former pre-glacial northwest outlet of Dublin Pond, forcing it to drain southwesterly.

Localities Where Rock Formations Are Well Exposed

Mt. Monadnock is a geologist's paradise. The glacial features to be found on the mountain have already been summarized under "localities for glacial features." Mention has been made that it is the locality from which the name "monadnock" was taken, for it is one of the most striking examples of an erosional remnant rising above a plain (Fig. 1). The view from the summit is most rewarding. An uninterrupted panorama extends from the Atlantic Ocean and includes Maine, the White Mountains, the Green Mountains, and southern New England. Lakes dot the lowlands. Countless streams are cutting downward in their ever-present task of wearing away the land.

The outcrops of the middle member of the Littleton formations on Mt. Monadnock are the best exposures of this formation in New England. Any one of the trails passes over the upturned rocks of the saucer-shaped basin which makes up the mountain (Fig. 12). The darker bands of schist and lighter layers of quartzite can be seen tilted on edge (Fig. 11) or folded (Fig. 10). The upper part of the Marlboro Trail passes across excellent examples of the upturned beds which tilt or dip steeply towards the east. Three quarters of a mile due west of the summit along the Marlboro Trail, the rocks are flat, as the beds roll over in a small fold, changing from easterly to westerly dips. The rocks at the summit of Mt. Monadnock are very steep, for there are complications in the folding at this point. The upper part of the White Dot Trail and the upper part of the Pumpelly Ridge Trail follow approximately the same bed of quartzite which dips towards the east, controlling the angle of the slope. The "Sarcophagus," a large glacial erratic on the Pumpelly Ridge Trail at 2800 feet, lies at the point where the beds swing from easterly dipping beds to the westerly dipping beds. In other words, this point is the bottom of the bowl of the saucer-shaped basin where the beds are flat (Fig. 12). The Pumpelly Ridge Trail continues northeast along the westerly dipping beds of the basin. A beautiful drag fold eighteen feet high and thirty feet long can be seen due west of the summit of Mt. Monadnock on a south-facing cliff west of the White Arrow Trail about 100 feet vertically below the summit (Fig. 10). This fold can be seen from a distance while ascending the White Arrow Trail.

The schists on Mt. Monadnock contain interesting minerals including garnet and blue-bladed sillimanite; in many places the sillimanite has been changed to mica or "pseudo-sillimanite" and stands up on the weathered surfaces in a criss-cross pattern (Fig. 9). The best locality for fresh sillimanite is along the ridge one quarter mile east of the Halfway House where unaltered sillimanite makes up ten to twenty percent of the rock in some places. Small pegmatites containing quartz, potash feldspar, mica, garnet, and tourmaline intrude the schists in many places. White veins of quartz are also conspicuous. There are also narrow black veins made up entirely of needles of tourmaline. These veins were deposited along fractures in the rocks when they were far below the present surface.

The *Ashuelot River Gorge* north of Troy cuts across excellent sections of mica schist and impure quartzite of the lower part of the Littleton formation. Fresh exposures have been opened along the scenic re-routed highway.

Eliza Adams Gorge or "Hemlock Gorge" is a beautiful picnic spot one mile east of Chesham. It can be reached by the trails shown on the map. The gorge is in a V-shaped valley at the head of Howe Reservoir. The stream follows the trend or strike of the bedding. A dam has been built at a natural falls to form the reservoir. The rocks of the rusty quartzite member of the Littleton formation are beautifully exposed on both sides of the gorge, and at the falls. The stream has cut down into the soft, fine-grained biotite schists of this member, the hard rusty quartzite having been undercut. The rusty quartzite can be seen on the north side of the dam dipping northward. It can be followed along the north side of the reservoir. The south side of the reservoir is in the soft biotite schists.

Minnewawa Gorge can be recommended to those who like to follow interesting and scenic stream sections. The lower part of the gorge starts at the power-house dam one mile due east of the village of Marlboro. The gorge ends at the dam of the small reservoir three tenths miles due south of Clapp Pond. Although there is no trail along the gorge, the footing is not difficult during low water. The schists above and below the upper dam are full of large red garnets. The lower dam is held up by a vertical, 50 foot wide pegmatite dike which cuts across the mica schist. The walls of the gorge give splendid sections across the mica schist of the middle member of the Littleton formation. The stream cuts across a 50 foot wide gray quartzite at the 945 foot contour. A short distance upstream from this quartzite graphite occurs in a three-inch wide quartz vein where there has been shearing. Pyrite is found on the surface of one of the fault planes in the same vicinity.

*Marienfield Camp**, one half mile due west of Silver Lake is located on some typical exposures of the gneiss of the upper member of the Littleton formation. The gneiss is rusty weathering and contains up to fifteen percent red garnet. A few pegmatites cut the gneiss. The girls' camp on Derby Hill to the southeast is located on a knob made up of highly contorted, folded, rusty quartzite which is interbedded in the gneiss. The working out of the individual folds,

*The incorrect spelling "Marienfield" is used in this report to avoid confusion, following the U.S. Geological Survey maps. "Marienfeld" is correct.

and the tracing of this member northeast towards Silver Lake where it disappears makes an interesting problem.

Parker Hill, one mile southwest of Marienfield Camp, has interesting exposures of a garnet-chlorite-sillimanite gneiss in the highly folded gneiss of the upper member of the Littleton formation. The red garnets, one quarter inch in diameter, are so numerous in places that they look like plums scattered in the gneiss.

Willard Hill, one and one quarter miles south of Marienfield Camp, has good exposures of the interbedded mica schists and quartzites of the middle member of the Littleton formation. The rocks are folded, and contain red garnets up to half inch in size, as well as small sillimanite crystals.

Kidder Hill, one mile northeast of Spectacle Pond, is another locality where there are good exposures of the interbedded schists and quartzites of the middle member of the Littleton formation.

Horse Hill, one half mile north of Spectacle Pond, is a good place to see nodular concretions and thin beds of impure quartzite folded in the gneiss and schist of the middle member of the Littleton formation. The unobstructed views of Mt. Monadnock, Little Monadnock, and the hills in the Keene quadrangle are rewarding.

Hurd Hill, one half mile north of Tolman Pond, has typical exposures of the folded, rusty weathering gneiss of the upper member of the Littleton formation. Concretions rich in garnet are present in this locality.

Gap Mountain, three miles southwest of Mt. Monadnock, has an interesting variety of rocks as well as rewarding views due to the open pastures. The lower slopes are in the dark colored Spaulding quartz diorite. The higher knobs have inclusions of schist and quartzite of the Littleton formation. Concord granite cuts across the rocks in some places. Pegmatites are present, and crystals of beryl were found in some. Large blue-gray crystals of sillimanite an inch long occur in the schist between the 1640 and 1690 foot contour on the north side of the mountain. (See bibliography for a more complete description of this deposit.)

Beech Hill has an interesting occurrence of muscovite garnet-sillimanite-chlorite-chloritoid schist one quarter of a mile northeast of the eastern end of Dublin Lake. The rocks on the south slope of the hill are bluish green due to the minerals chlorite and chloritoid. Red garnet makes up to ten percent of the schist in places. Blue-gray sillimanite crystals one inch long form a criss-cross pattern, and make up to ten percent of the rock. This view south across Dublin Lake to Mt. Monadnock makes this locality a beautiful spot to visit.

Bigelow Hill, one mile northwest of Perkins Pond, presents a variety of mixed rocks well exposed on the glaciated surfaces. The dark-colored Spaulding quartz diorite intrudes schists of the Littleton formation. Concord granite and pegmatites are also present cutting across the quartz diorite and schist. The glacial erratics of Concord granite have already been mentioned.

Little Monadnock Mountain has good exposures of schists and quartzites of the lower part of the Littleton formation, injected by small pegmatites and granites of the Kinsman quartz monzonite.

Skatutakee Mountain is in the coarse-grained Kinsman quartz monzonite. The view from the summit makes it a rewarding club.

Sip Pond has excellent exposures of the Kinsman quartz monzonite on the southeast side near the bathing beach. Large crystals of potash feldspar well aligned are conspicuous in the rocks.

One of the most complete sections of the older formations of the area is exposed along the *railroad cut one mile west of Webb.* The contact of the Oliverian magma series and the Ammonoosuc volcanics can be seen here. A fracture has developed at the contact and the Ammonoosuc volcanics have been thrust westward over the Oliverian magma series. The Ammonoosuc volcanics are about 175 feet thick, and are overlain by 100 feet of schist belonging to the Partridge formation. This in turn is overlain by fifty feet of the massive white Clough quartzite. The schists of the lower part of the Littleton formation overlie the Clough quartzite. Since the rocks are dirty and stained, and the railroad cut is narrow, a visit to this locality is worthwhile only if one wishes to study the entire section.

Localities where the rusty quartzite members of the Littleton formation is well exposed are as follows:

Along the southern quarter of a mile of the Halfway House Road on Mt. Monadnock.

At the Pool Reservoir one and one half miles southeast of the summit of Mt. Monadnock.

On the grounds of the Ark, an inn one mile northwest of the village of Jaffrey.

At the northeast corner of Dublin Pond.

In the Eliza Adams Gorge one mile east of Chesham.

At the southeast corner of Thorndike Pond.

Along the brook one and one quarter miles southwest of Dublin Pond on the estate owned by Mr. Weld. The section starts at 1340 feet elevation and continues upstream to 1370 feet elevation. The brook cuts across the fine-grained biotite schist; the rusty quartzite is exposed west of the brook at the barn.

On the estate now owned by Mr. Foote 0.3 miles west of Dublin Pond. Here, the fine-grained biotite schist and highly contorted, light-colored beds containing a greenish mineral called actinolite are well exposed south of the house.

HOW TO READ THE MAP

A colored geologic map is 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 Monadnock quadrangle and the adjoining northern part of the Winchendon quadrangle as far south as the Massachusetts State Line. 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. Monadnock is marked 3165. This means that Mt. Monadnock is 3165 feet above sea level. Gilmore Pond is 1052 feet above sea level. Wherever "B.M." is written with a small cross and a number, it means that in making the survey, the topographers had an accurately calculated station at this point, or "bench mark." By studying the brown lines, or contours, you can tell the height about sea level of any point shown on the map. If you follow any single contour line, you will always keep at the same altitude, for a contour line is drawn through points of equal 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 map, 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.

These maps will be found especially helpful in planning a hiking or fishing trip. For example, if you wished to climb Mt. Monadnock from the Pool Reservoir, you would be able to know in advance that you would have to climb from an altitude of 1380 feet at the Pool Reservoir to 3165 feet, the summit of Mt. Monadnock. The trip would be about one and one half miles long, and the spacing of the contours indicates that the trail climbs steadily the whole way, with the steepest ascent after the first half mile where the contours are more closely spaced. You can locate yourself by noting the places the trail crosses streams, as well as by the steepness of ascent.

At the bottom of the map is a symbol labeled "approximate mean declination 1932." A line shows the direction of true north, and an arrow points to magnetic north. The angle between, indicated by 14½°, means that a compass needle will point 14½ degrees west of true north. This means that all magnetic compass bearings have an error of 14½° 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 top of Mt. Monadnock is shown in pale gray as well as by the letters *Dl.* In the legend, this color-pattern and the letters *Dl* are found to represent the Littleton formation of Devonian age, consisting of interbedded quartzites and mica schist.

The legend is arranged with youngest rocks at the top. 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. It has been impossible to show these surface deposits on a map of this scale. The geologist's interpretation of the underlying bedrock, based on information gathered from actual exposures, is shown. 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.

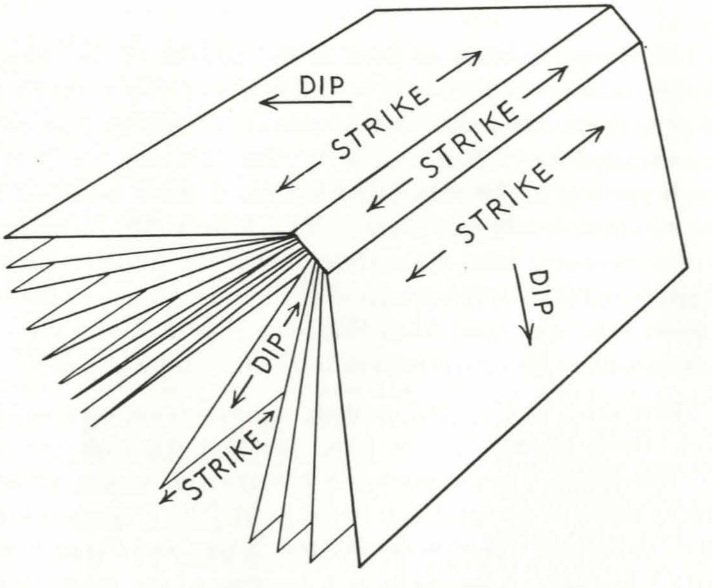

Fig. 15 — Diagram to illustrate strike and dip.

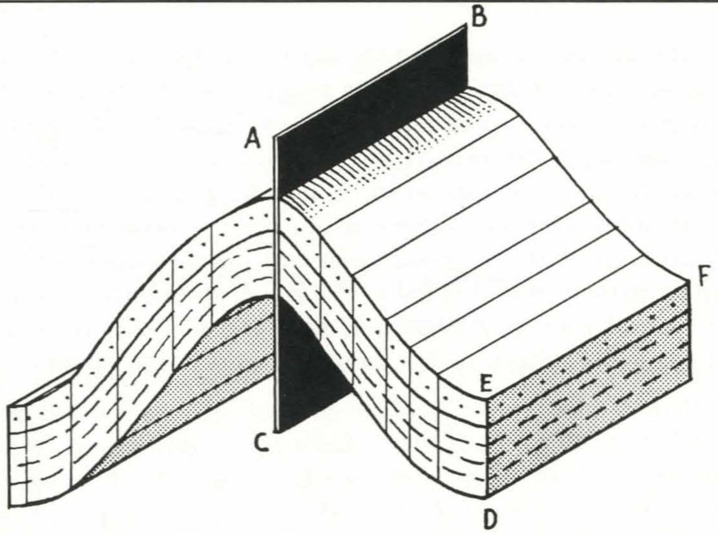

Fig. 16 — Diagram to illustrate relationship of *bedding, foliation,* and *joints.* A single fold is shown in a bed of quartzite (dotted) and bed of schist (dashed lines). The bedding is the layering. The plane ABC through the crest of the fold dividing it as symmetrically as possible is called the "axial plane." *Foliation planes* are parallel to the axial plane and cut right across the bedding (DEF is a foliation plane). There are also foliation planes in the schist (dashed lines) parallel to the bedding. *Joints* are any smooth fractures in the rocks, either parallel to the foliation, or at an angle to the bedding.

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, line B-B′ goes through the top of Mt. Monadnock from a point south of South Keene to about 1 mile northeast of East Jaffrey. Mt. Monadnock is part of a truncated fold, the middle part of the Littleton formation (quartzites and schists) being exposed continuously across the mountain mass. The upturned formations near South Keene are clearly shown, as well as an interpretation of the intruding granites.

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 bedding" and "strike and dip of foliation" refer to a layering in the rocks or a layering of the minerals in the rocks (Figs. 15 and 16). The straight line of the symbol shows you the direction of "strike" or general trend of this banding or layering, 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. 15). 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 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 the beds lie flat, or horizontal, another symbol is used. The foliation symbols are used in the same way as those of the bedding (Fig. 16).

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 "unravelling" the story of the rocks from a study of the measurements taken.

If silica has welled up along a break or fault, a special symbol with an *s* shows this silicified zone. The largest of the pegmatites in the area are shown by a red cross. Quarries are shown by special symbols.

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The Geology of the Monadnock Quadrangle, New Hampshire

Corrections to Accompany 1979 Reprint

General Statement

This brochure was originally published in 1949 and the text has been reproduced by photo-offset without change. The accompanying geological map has been obtained from surplus stock published at that time. The distribution of the rocks, their description (as given in the legend on the map), The topography, and the drainage have not changed. But the roads and the trails are not necessarily the same. Some have been abandoned, others have been modified, and still others have been made. For changes in the trails one should consult the most recent edition of the White Mountain Guide published by the Appalachian Mountain Club.

Age of Rocks

The sequence of the geologic eras and periods (p. 10) is based on relative ages, and for many decades geologists had no satisfactory method to convert this time-scale into years. But with the discovery of radioactivity and the realization that radioactive elements disintegrate at a constant known rate, it became possible to relate geological events to a time-scale expressed in years. But there are still many problems in utilizing the method.

The length of the geologic periods in years, as shown on page 10, has been revised considerably; the interested reader is referred to some of the references listed below. Radiometric dating elsewhere in New Hampshire necessitates some changes in the ages assigned to some of the rocks in the Monadnock quadrangle. The most important change is that the Oliverian Magma Series is Middle Ordovician rather than Middle Devonian (?). The amphibolite, Kinsman, and Spaulding are Middle Devonian rather than Late Devonian (?).

Some recent papers have concluded that some of the rocks assigned to the Littleton Formation are Silurian and Ordovician, and that the geologic structure may be much more complicated. There is no evidence in the Monadnock area to agree with these conclusions.

References

The references given on pages 40-41 should be brought up to date. New editiors of some of the books listed on page 40 have been published:

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Some of the reports on the bedrock geology of adjacent quadrangles are listed on page 40: Bellows Falls (Kruger); Keene-Brattleboro (Moore).

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November, 1979