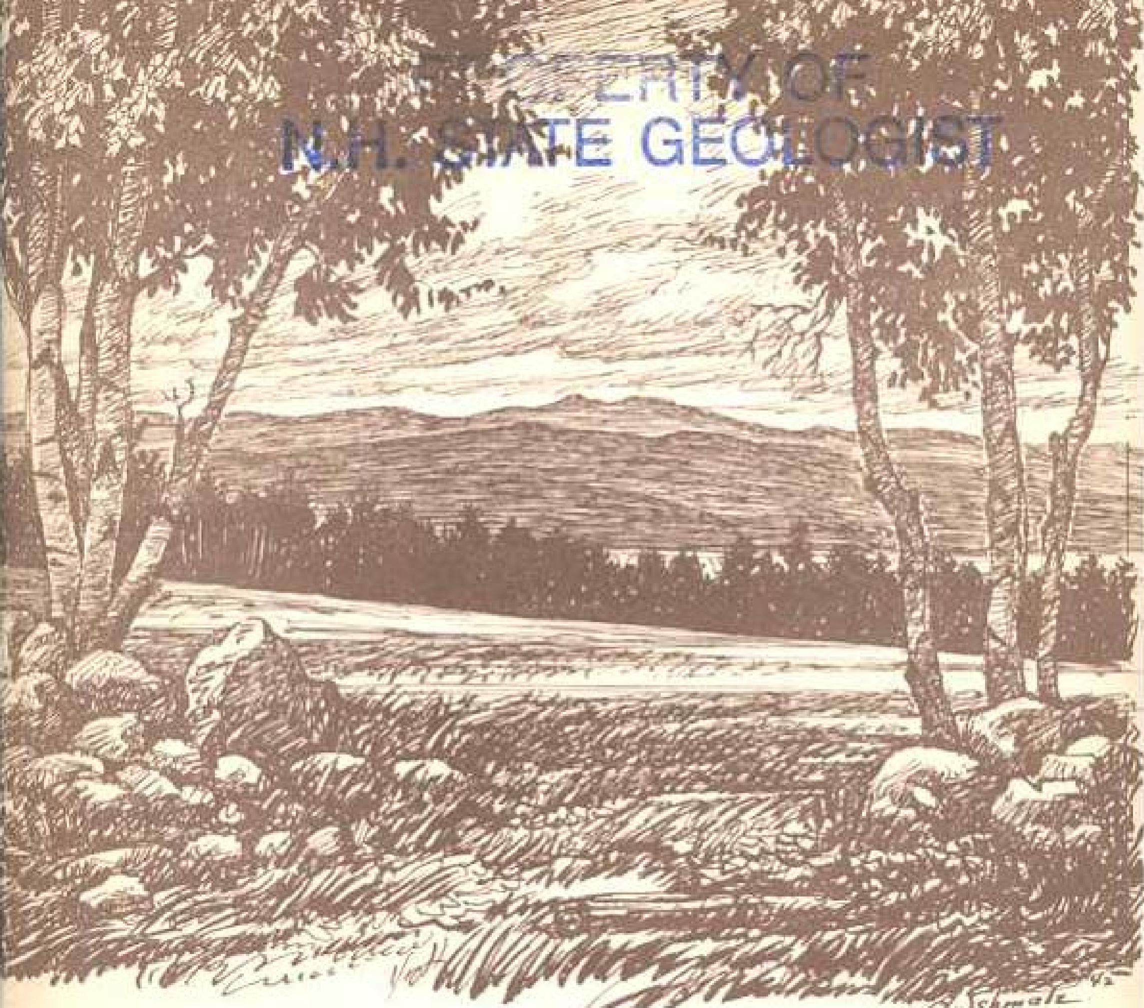

THE GEOLOGY OF THE Cardigan and Rumney Quadrangles NEW HAMPSHIRE

BY

Katharine Fowler-Billings and Lincoln R. Page

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1942

—*Moody's Picture Shop, Bristol, N. H.*

View of Mt. Cardigan Across Newfound Lake

Geology

of the

Cardigan and Rumney Quadrangles

New Hampshire

By

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and

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Foreword

This pamphlet is designed to appeal to the layman and is not intended to be an elaborate report for the professional geologist. The text is written in simple language and few scientific names are used. The maps accompanying the pamphlet show the details of the geology of the region, with a key for reading it. All that need concern the layman are the formation names. It is not essential for him to read or understand the detailed mineral and rock descriptions. The fascinating story of the rocks can be understood without these details.

The field work in the Rumney quadrangle was done by Lincoln R. Page from 1933 to 1937, under the direction of the Department of Geology, University of Minnesota; the laboratory work incidental to this study was in part sponsored by the Department of Geology of Dartmouth College. The field work in the Cardigan quadrangle was done by Katharine Fowler-Billings and Louise Kingsley in 1935 and 1936.

The geological maps were contributed by the New Hampshire Highway Department, and the publication of this pamphlet was financed by a special revolving fund set aside in 1934 from the State Highway Fund for that purpose.

Geology of the Cardigan and Rumney Quadrangles
New Hampshire

By Katharine Fowler-Billings and Lincoln R. Page

THE SCENERY

MANY a motorist touring the shores of Newfound Lake has gazed with interest at the bare rounded summit of Mt. Cardigan silhouetted in the western sky, and has wondered about the origin of the mountain. How did it get there? Why does it stand out as such a prominent landmark? Driving north, he finds himself surrounded by a maze of ridges such as Mt. Crosby, Tenney Mountain, and Stinson Mountain. He will undoubtedly be tempted to stop at the Polar Caves to see some of nature's wonders close at hand. Continuing north along the valley of the meandering Baker River with its peaceful farms, he may have begun to wonder why nature has been so lavish in shaping the hills and valleys which make this part of New Hampshire such a scenic region. This pamphlet has been prepared for these people with inquiring minds in order that they may read the geologist's fascinating story of the formation of the landscape of the Cardigan and Rumney regions.

The earliest history of the area starts some four hundred million years ago, when volcanoes erupted molten lava and fragments of rock. Later, when the region was covered by the sea, rivers brought down mud and sand to be reworked by the waves into deposits which subsequently hardened into solid rock. Heat, pressure and the intrusion of molten material from the depths of the earth helped to make the rocks which we see today. Then, for many millions of years, the land was gradually worn down by streams. The history is so complicated and varied that the appearance of the Cardigan and Rumney regions must have changed many times. Finally, more than 30,000 years ago, when the surface of the earth appeared much as it does today, a great Ice Sheet covered the whole region.

In the back pocket of the pamphlet are included two colored maps—one of the Cardigan quadrangle, and one of the Rumney quadrangle. These maps contain a wealth of information about the region. By studying them, the reader can follow the course of every stream, or find the altitude of any point in the area. The colors show the kinds of rocks found in different localities. An explanation of how to read these maps will be found in a later paragraph.

THE STORY OF THE ROCKS

Volcanoes and Invasion by the Seas

To understand the present scenery of the Cardigan and Rumney regions we must go back to the very beginnings, to the first threads of the story as the geologist unravels the history. The oldest rocks of both quadrangles are found in the northwest sections. These rocks are interlayered black and white volcanic rocks, called the Ammonoosuc volcanics, which poured out as lavas, or were hurled out as fragments from volcanoes which existed nearly four hundred million years ago, in Ordovician time. (Fig. 1).

But volcanic activity ceased and the sea began to encroach upon the land. On the shore of this sea, coarse pebbles and sand grains collected, in Silurian time, as the waves battered the lands. These deposits can be recognized in a narrow belt of the so-called Clough formation exposed in the northwest part of the Rumney quadrangle. As the seas became clear, limestones were deposited instead of sands. (Fig. 1). There are only a few traces of these limestones exposed in this area. They are called the Fitch formation, and parallel the sandy deposits of the Clough formation in the northwest part of the Rumney quadrangle.

As time went on, the seas became more and more widespead, and sand and mud began to accumulate all over the Cardigan and Rumney region, until many thousands of feet of thin alternating layers had accumulated. This happened at least three hundred million years ago in what the geologist calls Devonian time. Later, as explained in the next paragraph, the soft sand and mud was changed to hard, resistant quartzite and schist called the Littleton formation, which holds up such prominent peaks as Mt. Stinson, Mt. Carr, Mt. Moosilauke, Mt. Washington, Mt. Kearsarge, and Mt. Monadnock.

Folding and Invasion of Molten Rock

After the seas had withdrawn from the region, and while the accumulated layers of mud and sand were hardening into rock, disturbances originating in the depths of the earth were felt throughout the area. The first of these disturbances occurred when the molten Owl's Head granite, the Baker Pond gneiss and the Smarts Mountain granite pushed their way into the rocks of the area. (Fig. 2). As time went on, the unrest became more and more intense, and this part of New Hampshire became squeezed so tightly by pressures accumulating in the earth's crust that the rocks were thrown into great folds, as they were changed from muds and sands to schists and quartzites. (Fig. 3). During this time, great tongues of molten rock were thrust up into the sediments due to the enormous pressures. This molten material cooled and solidified to form granitic rocks that are called the Bethlehem gneiss and Kinsman quartz monzonite. They were themselves crushed by the intense pressure. This long history of folding and invasion by molten rock took place in the later part of Devonian time. (Fig. 4).

Following the formation of the Bethlehem gneiss and Kinsman quartz monzonite, a fine gray granite called the Concord granite invaded the rocks. Blocks of the surrounding rocks were caught up in this granite as it worked its way up into the overlying rocks in the vicinity of Rumney, Mt. Crosby, Newfound Lake and Grafton Center. (Fig. 5).

A dark colored rock, called gabbro, invaded the rocks in the vicinity of Black Hill, north of Stinson Lake, even later than the Concord granite, possibly in Carboniferous time.

Pegmatites, exceedingly coarse-grained rocks, came into the region at the close of the Devonian period. Pegmatites form when molten material, rising from the depths of the earth, solidifies in the cracks through which it is moving. Such long narrow bodies are called dikes. (Fig. 5). The pegmatites are the most interesting rocks of the area to the amateur and mineral collector because of the variety of minerals they contain. Feldspar, quartz, mica, black tourmaline, beryl, garnet and many rare minerals occur in the pegmatites. Liquids and gases made the pegmatites fluid, since they are formed from "juices" left over from the crystallizing granites. Hence, they could work their way upward into the overlying rocks along lines of weakness, making dikes of all sizes and shapes throughout the area. Although the pegmatites are scattered all over the region, they are especially abundant in the schists which lie directly east of the Bethlehem gneiss. Apparently the Bethlehem gneiss was unusually rich in the pegmatite juices. This accounts for the long line of large pegmatites, many of which have been worked for feldspar and mica, which make an intermittent belt starting near the town of Wentworth, south through Dorchester along the ridges of Kimball Hill, and Mt. Tug, to the Ruggles mine in Grafton.

Erosion

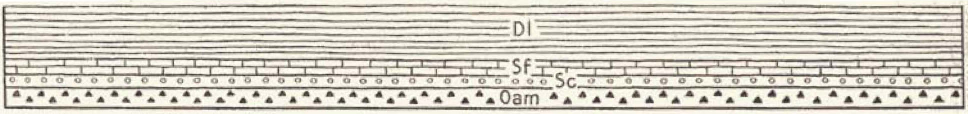
Since many of the rocks we now see at the surface in the Cardigan and Rumney region are granites which cooled more than a mile below the surface of the earth, it is obvious that a lot must have happened in order to expose them. The overlying rocks into which they were thrust have disappeared, and we are really looking into the depths of the earth. During a very, very long period of erosion the land was worn down by rivers, ice, wind and rain. (Fig. 6). Probably this region was once much higher than it is now—great mountains loftier than the present ones may have stood where Cardigan now stands. Or perhaps the whole region was gradually lifted into its present position. At any rate, the rivers have worn away thousands of feet of material, and carried it to the sea fragment by fragment until the land appeared much as it does today.

The Great Ice Age

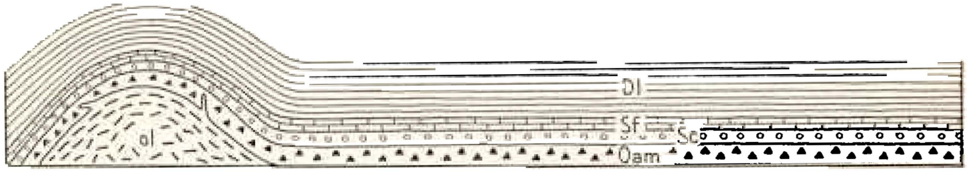
There was one interruption in the wearing down of the region. More than 30,000 years ago a great sheet of ice spread over the hills and valleys, covering everything to a depth of several thousands of feet. As the ice moved to the southeast across the area it smoothed off the irregularities, removing soil, leaving grooves and scratches on the bare rock to mark its passing. On the summit of Mt. Cardigan many of these scratches are still visible, and show that the ice came from a little west of north. Glacial erratics, brought from a distance and abandoned by the ice when it melted, are seen perched on the bare rounded summit, as well as in many other places throughout the region. Glacial drift, a clay containing sand and boulders, was plastered irregularly over the surface, often concealing the underlying rock. The glacial deposits dammed the stream valleys, causing temporary lakes, as in the Baker River Valley, which finally drained when the streams could establish new courses. The Appalachian Mountain Club Ski Lodge at the base of Mt. Cardigan is located in the middle of a small flat which was formerly a temporary lake. The lake was filled by sands from the melting ice, and was drained when the ice in the lower valley melted, uncovering an outlet for the brooks which drain the eastern slopes of Mt. Cardigan.

Newfound Lake owes its origin both to the overdeepening of an old river valley by the scouring action of the ice, and to the damming of its outlet by glacial debris.

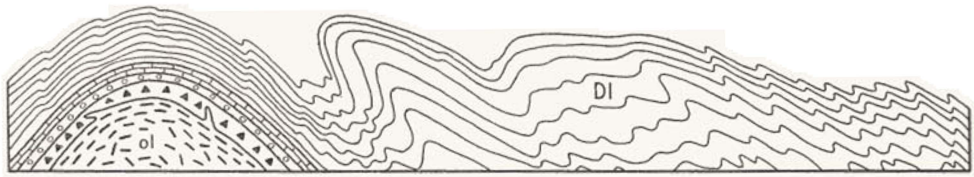
The rivers of today are continuing the process of wearing away and sculpturing the land. The natural beauties of the region are due primarily to the geological processes of stream erosion and glaciation.



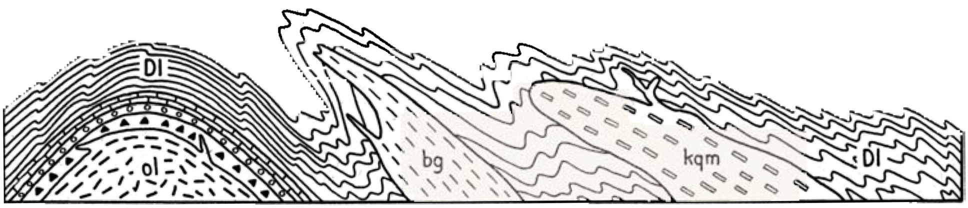
1. Volcanic rocks (solid triangles) are covered by a great thickness of sediments. (Ordovician, Silurian and early Devonian).



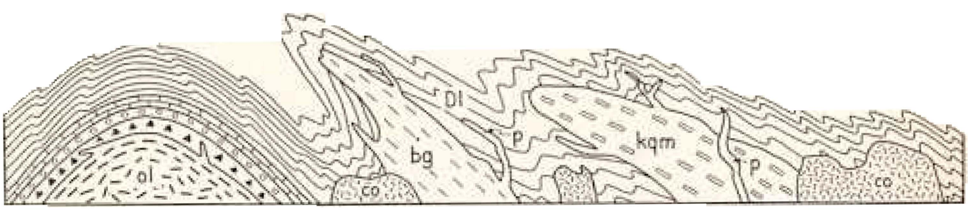
2. The invasion by bodies of granite is the first evidence of unrest in the area. (Late Devonian).



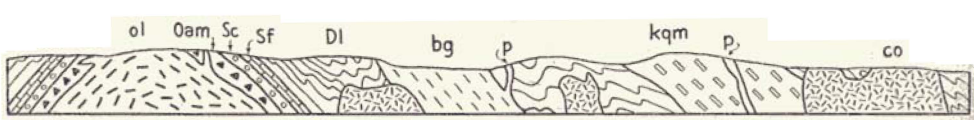
3. Folding of the sediments. (Late Devonian).



The invasion by large granite bodies at the end of the period of folding. (Late Devonian).



5. The invasion by small granite bodies and pegmatites brings the period of igneous activity to a close. (Late Devonian).



6. Continued erosion from the end of Devonian time to the present has exposed the granite cores and the highly folded sediments in a series of outcrops.

Figure 1-6. Series of diagrams to illustrate the story of the rocks described in the text. The cross sections are imaginary trenches a mile or more deep cut across the Cardigan and Rumney quadrangles from northwest on the left to southeast on the right. Each section shows a progressive development in the history of the region. *Oam*=Ammonoosuc volcanics; *Sc*=Clough conglomerate; *Sf*= Fitch formation; *Dl*=Littleton formation; *ol*=Oliverian magma series (Smarts Mountain group, Owl's Head granite, Baker Pond gneiss); *bg*=Bethlehem gneiss; *kqm*=Kinsman quartz monzonite; *co*=Concord granite; *p*=pegmatite.

Geologic Time-scale, with Sequence of Events in the Cardigan-Rumney Region

Era	*Period*	*Time-scale*	*Sequence of geologic events*
Cenozoic	Recent	Thirty thousand years ago to present time	Slight erosion.
	Pleistocene	Two million to thirty thousand years ago	The Great Ice Sheet covered the region.
	Tertiary	50 to 10 million years ago	Uplift and erosion.
Mesozoic	Cretaceous	100 million years ago	Erosion.
	Jurassic	150 million years ago	Erosion.
	Triassic	175 million years ago	Erosion.
Paleozoic		200 million years ago	Gabbro at Three Ponds intruded. End of folding and beginning of erosion.
	Devonian	300 million years ago	Concord granite intruded. Kinsman quartz monzonite intruded with pegmatites. Bethlehem gneiss intruded with pegmatites. Smarts Mountain group of intrusives; Owl's Head granite; Baker Pond gneiss. Littleton formation deposited.
	Silurian	350 million years ago	
	Ordovician		
	Cambrian		
Pre-Cambrian		More than one thousand million years ago	No record.

INTERESTING LOCALITIES

Cardigan Quadrangle

The Cardigan quadrangle is full of interesting localities and beauty spots where geological features can be studied at first hand. It is impossible to mention them all. A few of the outstanding places will be described below. The motorist or hiker can, of course, take the map from the pocket of the pamphlet, pick out some destination which appeals, and explore on his own. The Appalachian Mountain Club publishes a Trail Map with their most recent guide book on a scale of two inches to the mile, showing the trails in the vicinity of Mt. Cardigan in great detail.

Mt. Cardigan is a most rewarding climb because of the extensive view it offers in every direction. Its accessibility from the east and west over well cleared forest trails makes it a popular goal for the vacationist. The bare summit has been rounded by glacial action, and displays many grooves and scratches made by the great Ice Sheet as it swept across the mountain from a northwesterly direction. On the east side, which was in the lee of the Ice Sheet, are occasional natural caves due to the plucking action of the ice as it passed over the summit. Great blocks of the Kinsman granite were pulled out by the ice, leaving jagged edges on this side. This is in contrast to the scouring action and smoothing off of the rocks on the northwest side of the mountain. Scattered boulders which were carried along by the ice and dropped when the ice melted, are further evidence of glaciation. White ribbon-like dikes of coarse pegmatite or fine-grained granite criss-cross the granitic rocks of the summit. Black tourmaline, garnets and an occasional beryl may be found in these dikes. The bedrock all over the summit is typical of the Kinsman granite, with conspicuous rounded crystals of feldspar that are one to three inches long. The amateur frequently mistakes these white feldspar crystals or aggregates of feldspar for pebbles.

The trails north from Mt. Cardigan over the Firescrew to Oregon Mountain or to the south over Gilman Peak (the summit one and one quarter miles due south of Mt. Cardigan) to Crane and Brown Mountains, are over the same Kinsman granite. Many fine views are seen along these ridge trails.

Cilleys Cave, one and one quarter miles north of the summit of Mt. Cardigan, is a natural cave in the Littleton schists. The cave is on the southeast side of the ridge, so it was not smoothed over or obliterated by the ice. It is being undermined gradually by weathering at the head of Davis Brook.

The West-Side Trail up Mt. Cardigan ascends over the Littleton schists. The contact of these schists with the Kinsman quartz monzonite is well exposed on South Peak, one half mile south of the summit, and at the base of the west side of the little knob one quarter mile due south of South Peak.

Mt. Crosby, three miles northeast of the small town of Groton, is a 1500-foot climb by a trail starting near Spectacle Pond. The Littleton schists are well exposed on the west side of the mountain near the summit. A mass of Concord granite caps the summit, overlying the schists. Bald Knob and the ridge to the south show an interesting banding of garnets and black tourmaline in the dike-like intrusion of Concord granite which cuts into and is mixed with the schists.

Bear Mountain, the prominent ridge rising above the west shore of Newfound lake, has an interesting summit composed of schist which extends north and south as a series of hogback ridges that dip 70° west. There are no trails up Bear Mountain, but the cliffs on the east face of the mountain offer some rather interesting rock climbs, starting in over large blocks of Concord granite talus, and up a steep face of granite to the schists above.

Sugarloaf Mountain is a favorite trip with many summer visitors, the climb being made from Nuttings Beach on Newfound Lake. The summit presents a rewarding view of the Lake and surrounding mountains. Many fine and coarse-grained pegmatite dikes cut the well exposed Concord granite on the top of the mountain.

Hemp Hill. A trail starting behind Bungalow Village at the extreme south end of Newfound Lake leads to a delightful picnic spot on the ledges on the north end of Hemp Hill. Views of the Cardigan Range, Newfound Lake and Mt. Crosby are well worth the short climb. Exposures of the Littleton schist show extreme folding of the rocks which are full of garnet and sillimanite crystals.

Severance Hill, two miles west of Danbury, can be reached easily from Pleasant Pond. A rewarding view of the Cardigan Range to the north and Ragged Mountain to the south is obtained from the hill top. The Kinsman quartz monzonite with large crystals of feldspar, as well as the many pegmatite dikes, is well exposed on the bare hill.

Welton Falls, three quarters of a mile northeast of the Appalachian Club Ski Lodge, and one and one half miles due south of Oregon Mountain, is a 20 foot fall in Bailey Brook. The fall itself is held up by a fine-grained vertical granite layer in a pegmatite which is made up of coarse and fine layers due to successive intrusions. The total width of this composite pegmatite is about 60 feet. The pegmatite lies across the course of Bailey Brook, so that the narrow gorge with great potholes above the falls cuts across the pegmatite. The gorge below the falls is parallel to the pegmatite, the water having scoured out a pothole 20 feet deep and 60 feet long at the base of the falls. The channel makes an abrupt turn of more than 90 degrees at this pothole so that it parallels the more easily eroded portion of the pegmatite. This strange course of Bailey Brook is due to the fact that after the Ice Sheet melted in this area, Bailey Brook took up a course on the glacial deposits. After these were eroded, the stream encountered the hard layers in the pegmatite at the site of Welton Falls. Consequently, the stream has been unable to widen its channel at this point but has had to cut its way down vertically. Large potholes, partially preserved, show the slow process of down-cutting. Below the falls, there are a series of potholes and rapids where the river has widened its course in the coarse-grained pegmatite. Upstream, above the falls, a broad valley was formed in the softer Kinsman quartz monzonite.

Sculptured Rocks is a gorge with remarkable potholes that have been cut in the Kinsman granite by the Cockermouth River. The locality is one mile west of Groton, close to a large parking place built by the Highway Department. The foliation, or banding of the mica flakes, in the Kinsman granite is prominent and easily seen in the walls of the potholes. Erosion of the gorge has uncovered numerous pegmatites. The potholes are believed to have been cut for the most part at the close of the glacial period by the churning action and undercutting of the flood waters heavily laden with silt and sand.

Fowler River, which enters the southwest side of Newfound Lake, is an interesting stretch of water, especially below the junction of Bailey and Brock Brooks where there are rapids over series of exposures of the Kinsman granite with feldspar crystals well aligned. A mile downstream from the brook junctions, the river has cut good exposures in the Littleton schists.

Orange Basin on the west side of Mt. Cardigan is a deep gorge made by Orange Brook in the Littleton schists. These schists contain many sillimanite crystals which are strikingly lined up in the planes of schistosity. By following Orange Brook downstream for half a mile, the contact of the schist and the Bethlehem gneiss may be seen in the brook bed near a series of rapids.

Tewksbury Pond on U. S. Highway No. 4, about 3 miles north of Grafton Center, has interesting exposures of Littleton schists on the east side of the Pond in the highway road-cuts. A number of folds in the Littleton schists are visible, showing how intensely the original muds and shales have been squeezed in reaching their present position.

The Smith River Valley, which is followed by U. S. Highway No. 4 from Grafton Center to Danbury, is in general a broad valley with the river meandering rather sluggishly back and forth over sands and gravels. These sands and gravels were washed in by water from the melting Ice Sheet at the close of the glacial period when a great deal of sand was poured into the valley.

Newfound Lake, one of the larger lakes in New Hampshire, is encircled by a good highway. Splendid views of Mt. Cardigan and the lower mountains are obtained from the east side of the lake. On the west side, at the Ledges, recent blasting has exposed great cliffs of Concord granite. Here, one can see many inclusions of schist as well as numerous varieties of the Concord granite from coarse to fine-grained types. The State bathing beach, Wellington Beach, is a sheltered, sandy cove just southeast of the Ledges. It is flanked on the east by a rocky peninsula of Concord granite. The very southern end of Tenney Hill, where it juts into Newfound Lake, has some interesting outcrops of Littleton schist with white pegmatite dikes which show up rather strikingly under the water. The red garnets and shiny sillimanite needles of the schist likewise show up especially well in the submerged outcrops and in the bleached zone below the high water mark. Newfound Lake was formerly a deep river valley in pre-glacial times. The Ice Sheet scoured it deeper, then filled the valley with glacial debris at its present outlet, thus damming up the water to form a very deep lake, far larger than the present one. In the vicinity of Groton, sand deposits mark the height of the lake at the close of glacial times. Since then, the outlet of the lake has been lowered to its present level.

The Rumney Quadrangle

Baker River Valley is the largest and perhaps the most beautiful valley in the Rumney quadrangle. State Highway No. 25 follows this valley from West Plymouth past Mt. Stinson, Rattlesnake Mountain and Carr Mountain as far as Warren. For the motorist this is one of the most scenic drives in the Rumney area, especially if he follows the new road built by the Civilian Conservation Corps from East Warren along the old North Woodstock Trail to Jackman Camp and the Lost River-Woodstock area. The trout fisherman will find that this route will lead him to many streams where he will want to try his luck.

The Baker River valley is essentially the same as it was before it was covered by the Great Ice Sheet. However, the valley was probably much deeper in pre-glacial times, because eighty feet of sand, gravel and clays were encountered when foundations for the bridge were being constructed at Rumney. These, as well as other sand and gravel deposits, now used for road materials, were all formed while the Ice Sheet was melting. At this time, when a lake filled the valley, tributary streams formed delta deposits along the shores. Some of these may be seen in the gravel banks on the west side of the road at the mouth of Groton Hollow Brook in Rumney, near the West Rumney Post office, and at the mouths of many tributary brooks entering the Baker River south of Buffalo School in the town of Wentworth. This old lake was eventually either completely filled with sand and gravel from the melting ice or drained when the main lake in the Pemigewasset valley to the south ceased to exist. Since that time the Baker River has meandered over these lake sediments and has formed the crescentic ox-bow lakes and terraces which characterize the valley near Rumney and Polar Caves. The north end of this ancient lake was at Wentworth. Farther north, sand and gravel accumulated in small lakes between the melting ice in the valley and the valley sides. Overflow from these lakes and from the melting ice filled the valley farther downstream with large amounts of gravel and sand, and the present flat valleys of the Baker River, Berry, Oak Hill and Black Brooks were formed. The gravel bank near the Warren cemetery gives a good exposure of these gravels.

Northeast of Warren, the Baker River valley is narrow and, in places, choked with gravels and coarse boulders brought in by recent floods. Near the mouth of Batchelder Brook, and also where the road to Breezy Point crosses the river, small channels have been carved in the soft Bethlehem gneiss. Many potholes and smoothly polished waterworn surfaces have been formed by the grinding action of sand particles carried by the stream. These are particularly good places to study the Bethlehem gneiss because the exposures are fresh. Inclusions of schist in the gneiss are abundant here. Other potholes, made when the Baker River flowed at a much higher level, may be seen on the west and south side of Prospect Hill just east of the road at the turn to Foster School, at West Rumney. Others may be seen a few hundred feet south of the point where the road from West Rumney to Buffalo School crosses Stevens Brook.

The Baker River has made many interesting exposures of the bedrock, especially of the Bethlehem gneiss over which it flows for much of its length. One half mile east of Breezy Point in the town of Warren it flows through a deep narrow valley carved in mica schists of the Littleton formation that are in contact with the Bethlehem gneiss. South of the village of Wentworth, it has cut through schists and fine-grained gneisses formed from material erupted by ancient volcanoes. One half mile northwest of Prospect Hill, in the valley of the South Branch Baker River, very interesting outcrops of garnet-hornblende and mica schists are exposed. These have been altered by heat from the Bethlehem granite, and are criss-crossed by thin quartz veins.

Perhaps the best exposures of volcanic rocks belonging to the Littleton formation are found near the old mill site on the South Branch Baker River just west of bench mark 662. They are now white fine-grained gneisses, black to green hornblende schists, mica schists and schistose volcanic breccia. At the falls, sills of fine-grained light colored biotite gneiss may be seen cutting the dark hornblende schists.

Stinson Mountain, with its fire tower, is one of the outstanding landmarks in the southeastern portion of the Rumney quadrangle. This mountain offers a superb view of the Rumney quadrangle and many of the mountains of central New Hampshire. It may be reached by road and an easy trail from Stinson Lake. The top of the mountain offers a superb view of the Rumney quadrangle and many of the mountains of central New Hampshire. It may be reached by road and an easy trail from Stinson Lake. The top of the mountain is made of banded quartzite and sillimanite-mica schists of the Littleton formation which were crumpled and folded during the last period of mountain building. On the eastern and southern slopes numerous small dikes and sills of white Concord granite and pegmatite cut these schists. The Concord granite is well exposed in streams flowing down the east slopes of the mountain. On the north side of the mountain glacial till conceals the bedrock to within a few hundred feet of the mountain top.

Three Ponds are the small lakes which lie on the Warren-Ellsworth town line between the northern end of Carr Mountain and Black Hill. These lakes are well known to trout fishermen for the excellent fly fishing, and may be reached from the north end of Stinson Lake by a trail which follows Sucker Brook, or from the Warren-Woodstock road by a trail that follows Batchelder Brook past Foxglove Pond. The trail from Warren crosses the Bethlehem gneiss. The Sucker Brook trail starts near the contact of the Kinsman quartz monzonite, which outcrops around Stinson Lake, crosses a band of Littleton schists and also a band of Bethlehem gneiss. The ponds are on the border of an area of gabbro, a dark grey to black rock which is well exposed in Sucker and Brown Brooks, and on Black Hill. At its contact with the gabbro in Sucker Brook, the Bethlehem gneiss contains many garnets up to three fourths of an inch in size. At the Middle Pond exposures, the gabbro is cut by trap dikes.

The streams entering Three Ponds from Carr Mountain have many cascades which, during a wet season, would be worth a side trip to see. If one has sufficient time, it is suggested that a trip to the top of Carr Mountain or Mt. Kineo by trail would be well worth while. On top of Mt. Kineo, which lies northeast of Three Ponds, some of the higher points northwest of the trail give by far the best views of the country. From here the trail continues into the Hubbard Brook valley and eastward to North Woodstock. Until 1937, this area could not be reached by road, and consequently the wild wooded scenery of this area surpasses that in the rest of the quadrangle.

Polar Caves. Many tourists have enjoyed a visit to Polar Caves, about one mile and a quarter northwest of West Plymouth. The caves are in a pile of huge boulders of Littleton schists, cut by dikes of pegmatite and Concord granite, that have collected at the base of a cliff on the southeast side of a small precipitous hill. These boulders have accumulated over a long period of time, perhaps starting before the Ice Sheet covered the top of the hill, and continuing to the present day. Ice remains deep down among the boulders throughout the year. Similar caves, although not as accessible, are present at the base of cliffs on Rattlesnake Mountain, as well as at the foot of the cliffs one half mile south of the Rumney Depot railroad station.

Lakes Tarleton, Armington and Katherine, in the northwest corner of the Rumney quadrangle, have been for many years well known to fishermen, tourists and hikers. The many summer camps on the shores of the lakes attest to the beauty of the locality. The lakes are in a basin surrounded by low hills on the north, south and east and by the steep slopes of Piermont Mountain on the west. Hiking and horseback trails lead to the neighboring mountains. The lakes are reached by paved and graded roads from Warren on the south and from Pike on the north. Few rocks are exposed on the shores of the lakes, but on the hills surrounding the lakes biotite schists and gneisses of the Ammonoosuc volcanics are well exposed.

Piermont Mountain. A short but steep climb by trail from Lake Armington to the top of Piermont Mountain in the northwest corner of the Rumney quadrangle, is rewarded by views across Lakes Tarleton, Armington and Katherine to Mt. Moosilauke, and west to the Connecticut River valley. On the lower slopes, the trail passes over biotite gneisses and schists, with a few interbedded layers of hornblende schist, of the Ammonoosuc volcanics. The top of the mountain is made up of quartzite and quartz conglomerate of the Clough formation. The lower contact of this formation with the underlying Ammonoosuc volcanics is irregular, indicating that there was a period of erosion by streams before the sands and gravels of the Clough formation were deposited in the shallow seas of Silurian time.

Webster Slide Mountain. One of the most outstanding views in the Rumney area is obtained from the top of Webster Slide Mountain, northeast of Lake Tarleton. From the summit, one may obtain an uninterrupted view down the Baker River valley to the south, to Mt. Cube and Piermont Mountain on the southeast, to Mt. Moosilauke on the northeast, and to Owl's Head Cliff on the north.

The top of the mountain may be reached by a trail which leaves U. S. Highway No. 25, one and one half miles northwest of Glencliff. The trail is about one and one half miles long, gradually rising up a gentle slope to Wachipauka Pond, and then around the base of the mountain to the saddle between Webster Slide Mountain and Mt. Mist. From this point, a Dartmouth Outing Club trail winds up the south side of the mountain to a shelter at the top of the cliff of Owl's Head granite that rises above Wachipauka Pond. These cliffs offer rock climbs of varying degrees of difficulty, while the pond below offers fine fishing.

Upper Baker Pond and Lower Baker Pond are on State Highway No. 111 which leads from Wentworth past Mt. Cube, to Orford, in the Connecticut River valley. In traveling from Wentworth to Lower Baker Pond one sees the lower part of the Bethlehem gneiss, the Fitch and Clough formations, and also part of the Ammonoosuc volcanics where they are exposed in road cuts. The Fitch and Clough formations are very poorly exposed, but fine-grained, almost schistose, Bethlehem gneiss is well worth study near the contact where it lies above the Fitch formation. Mica schists and fine grained biotite gneisses of the Ammonoosuc volcanics crop out in Pond Brook and in the cliffs north of Lower Baker Pond.

Upper Baker Pond is in a basin formed in the grey porphyritic portion of the Baker Pond gneiss. This is part of a complex igneous intrusive mass which is probably connected, beneath the Ammonoosuc volcanics, with the Owl's Head granite exposed north of Lake Tarleton.

ECONOMIC RESOURCES AND MINERAL LOCALITIES

The Cardigan Quadrangle

The economic resources of the Cardigan region include feldspar, mica, beryl and garnet. Other economic products are building stone from the local rocks of the region, especially from the fine-grained gray Concord granite. There are also abundant sand and gravel deposits which are used for road-building.

There are many abandoned mines and prospects throughout the area. With the stimulus to develop natural resources due to the increased demand in the defense industries, some prospects have been reopened, while new ones are being developed.

Because almost all of the rocks of the region are cut by pegmatites of varying size, the mineral collector has unlimited scope for exploration. Possible mineral collecting localities are so numerous that it is impossible to enumerate them. Some of the largest pegmatites are shown on the map in a long line of exposures extending northeast of the town of Orange. There are many old mines and prospect holes in this belt of exposures, the large waste dumps of The Pinnacle and Mt. Tug being favorite haunts of the mineral collector. Alexandria, with the old Alexandria mica mine two miles west of the village, and Groton and Danbury, all have their share of pegmatites. The local inhabitant is always glad to direct anyone interested in minerals to nearby mica or feldspar mines, where one has a chance of finding at least a dozen or so minerals.

The most profitable mine in recent years has been the Ruggles mine, one and one half miles northwest of Grafton Center. The large dumps can be seen for many miles. Mining operations have made excellent exposures so that one can study the complicated relationship of the invading pegmatites to the Littleton schists. Although mica and beryl have been produced in the past in limited quantities, feldspar (microcline, orthoclase and albite) is the mineral mined today for use in the abrasive industry. Some of the feldspar crystals are of very large size, one crystal over fifteen feet long having been reported. The mica (biotite and muscovite) occurs in sheets or leaf-like aggregate varying from an inch to several feet across. The beryl varies from a light green to a dark pea-green color. Quartz, black tourmaline and garnet are common. There are many other minerals of less economic importance but of great interest to the mineral collector including beautiful specimens of platy albite (cleavelandite), apatite, montmorillonite and the rare lithium-manganese phosphates and metallic sulphides.

Garnets are abundant throughout the Littleton schists, occurring as large aggregates in many places. They are especially abundant in the Littleton schist along the contact of the Kinsman granite, as well as in the fragments of schist caught up by the Kinsman granite intrusives. Two of the best localities for collecting are due south of Taylor Hill one and one half miles northeast of Danbury where aggregates of garnet measuring up to three inches are prominent, and in the Fowler River in the road cut one mile southwest of Sugarloaf Mountain. Here, garnet aggregates several inches across are present in the "intrusive breccia," a rock made up of angular fragments of granite and schist.

Locally garnets occur in sufficient abundance to warrant mining. The North Wilmot garnet mine, four miles southwest of Danbury, was the latest one to be in operation. The garnets occur in a belt of schist which is surrounded by Kinsman quartz monzonite. Garnets one half inch in diameter are peppered through the schist, having developed to this size due to the action of the Kinsman granite which supplied the materials necessary for their development.

The Rumney Quadrangle

The economic resources of the Rumney quadrangle include mica, feldspar and beryl from the pegmatites in the North Groton-Cheever-Rumney area; copper, lead, zinc and mica from the Ore Hill Mine west of Warren; building stone, notably from the Concord granite at Quincy in the town of Rumney; chicken grit from the Bethlehem gneiss; and sand and gravel from the Baker River and tributary valleys.

Increased demands have recently stimulated domestic production of mica, and some of the old mines are being reopened. It appears possible that the entire area will be reprospected, and that old mines will be reopened, or new ones started. The demand for beryl is increasing, and this, plus feldspar as a by-product, should make mica mining on a small scale profitable.

Groton-Rumney Pegmatites. Many pegmatite dikes in the towns of Rumney and Groton have been mined for mica and feldspar and are excellent places to collect rare mineral specimens. Most of these dikes are in the Littleton schists and lie on the east side of the Bethlehem gneiss in a zone that extends from West Rumney on the north, to Groton Hollow on the east, and southward into the Cardigan quadrangle. Nearly all of the old prospects and mines may be reached by old roads, shown by double dashed lines, which leave the main road that goes from Cheever, through North Groton, to Rumney Depot. The mica mine of the General Electric Company at West Rumney closed in 1916.

The most famous locality for mineral collecting is the old *Valencia Mine* which is N. 75° E. of the village of North Groton, at the end of the old road that goes from Halls Brook toward the north end of Fletcher Mountain. It was originally operated in the 1890's for feldspar, and was reopened in 1925-1926. Aquamarine (beryl) may be found here together with other pegmatite minerals such as mica, feldspar, garnet, tourmaline and apatite. In 1885, over one hundred gems weighing one to four carats were cut from aquamarine from this mine.

Lazulite, a blue lithium phosphate, among other minerals, may be collected from a small quarry, visible from the North Groton-Cheever road, about one third of a mile west of the village of

North Groton. For a complete guide to pegmatite deposits, the reader is referred to Sterrett's report on *Mica Deposits of the United States,* listed in the bibliography.

Ore Hill Mine. The Ore Hill Mine, 0.7 mile south of Ore Hill, on the western edge of the town of Warren, was a copper mine in the early 1800's and during World War I was worked for lead and zinc. Recent mining operations have produced some mica. The mineral collector will find this spot well worth a visit, for it is possible to collect as many as thirty-five different minerals within a few hours. Especially good specimens of zoisite, anthophyllite, galena, black sphalerite, rutile and brown tourmaline may be found. The purple fluorite present was brought in for smelting operations. Native copper can be collected where waters draining the dump have come in contact with iron pipes and culverts. Good specimens of vesuvianite, epidote and garnet are found to the north of the mine. In this same area the chlorite schist contains fine octrahedrons of magnetite. Biotite, pyrrohotite, apatite, muscovite, phlogopite, pyrite, malachite, chalcopyrite, quartz, feldspar, limonite, hematite, hornblende and black tourmaline are among other minerals present. Most of these minerals were formed by the alteration of a magnesium-rich rock by heat and ore-bearing solutions rising from the adjacent Baker Pond gneiss. A number of barren quartz veins may be seen in the schists around the old workings.

Beech Hill. One and a half miles southwest of Warren village on the southwest side of Beech Hill, where a stream crosses the contact of the Fitch formation and the Bethlehem granite, a pegmatite dike contains small but perfectly crystallized yellowish-green beryl. One mile southwest along the Bethlehem gneiss contact there are numerous localities containing garnet, vesuvianite, epidote and diopside. These minerals were formed under the influence of heat and solutions escaping from the Bethlehem gneiss as it invaded the limestone layers in the Fitch formation. Garnets up to two inches in diameter with perfect crystal faces have formed a shell one fourth of an inch thick around calcite and other minerals.

Downing Mountain. East of Stinson Lake, on Downing Mountain and Eagle Cliff, the Littleton schists have been cut by many sills and dikes of Kinsman granite. The granite typically contains large crystals of microcline, and in some places visible grains of brownish titanite. The schists consist of alternate bands of biotite quartzite and sillimanite-biotite-garnet schist. Sillimanite in unusually large specimens, one to three inches long, is very abundant in these schists. Good sillimanite specimens can also be found on the little hill south of the road about one half mile east of Polar Caves, in Rumney.

Mica Crystal Company Quarry. The Bethlehem gneiss is quarried by the Mica Crystal Company one half mile northwest of Warren. The rock is crushed and sized at the quarry and then sold as chicken grit. This industry has employed about ten men continuously for the past ten years.

In Retrospect

The Cardigan and Rumney region, with its lakes, mountains, swift-flowing streams, pastureland and forest, offers the visitor as varied scenery as can be found in any part of New England. The fisherman, the mountaineer and the nature lover, all find ample opportunity for their favorite sport or interest in this unspoiled part of New Hampshire. Except for an occasional farmhouse, the population is centered along the main roads. Once off the highway, the hiker has the hills to himself, and can explore to his heart's content. By studying the map, he can choose a trail or logging road leading to a remote hill where a view of the surrounding country can be obtained.

If the hiker has an inquiring mind about the cause of the hills and valleys, or wonders about the origin of the shiny rocks, the map and pamphlet will help him to understand the fascinating geologic history of the region. He will learn that many of the rocks were laid down as mud in a great sea; that the mud became rock which was squeezed and folded into high mountains; that great molten bodies of granite from the depths of the earth were pushed into the region and can now be seen as hard rock ridges making up the crest of Mt. Cardigan.

The mineral collector, interested in the more scientific aspects of the country, will find that the region is rich in mica, feldspar, beryl, and tourmaline. The old mine dumps, as well as the new prospects which are being opened up for mica, which is urgently needed in defense industries, are good mineral collecting localities. The great asset of the Cardigan and Rumney region is that there is a wealth of interest for the scientist as well as the layman.

HOW TO READ THE MAP

Two colored geological maps, one of the Cardigan quadrangle and the other of the Rumney quadrangle, will be found in the envelope in the back of this pamphlet. These maps contain a wealth of information about the country itself, as well as showing the kinds of rock found in any particular place. The legend at the right of the map, as well as the structure sections at the base of the map, are to help the reader understand and interpret the geology.

The geology has been added in color to the regular topographic map of each quadrangle. One inch on the map represents approximately one mile on the ground. Surfaced or improved roads are shown as double black lines; poor roads as double dashed lines; trails as single dashed lines; railroads as solid black lines with cross-bars; and township boundaries with heavy dashed lines. Houses are represented as little black spots, to which a flag is added to indicate a schoolhouse and a cross to indicate 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 hill, a cross road or some other place which has been carefully determined. For instance, the top of Bear Mountain, one mile west of Newfound Lake, is marked by 1812. This means that Bear Mountain is 1812 feet above sea level. Newfound Lake is shown as being 586 feet above sea level. Wherever you see "B. M." 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 above sea level of any point shown on the map. If you follow any single contour line, you will always keep at the same altitude, for a contour line is a line drawn through points of equal altitude. Since the contour interval of these maps is 20 feet, it means that wherever there is a rise of 20 feet in altitude a new contour line must be shown which is 20 feet above the last. To facilitate use of the maps every 100 foot contour line is shown in dark brown, and somewhere along each of these lines you will often find a small brown number telling the exact altitude of that particular contour. These maps will be found especially helpful in planning hiking, fishing, or other trips. For example, if you wished to climb Mt. Cardigan by the Holt Trail, starting at the Appalachian Mountain Ski Lodge, you could study the map, and see that the trip would be a little over 2 miles long, and that for the first mile, along the north side of Bailey Brook, you would have to climb about three hundred feet. After crossing Bailey Brook, the map shows that the trail steepens and that in the last mile you would climb almost fifteen hundred feet. Examination of the contours on the map shows that they are more closely spaced along the steeper portions of the trail.

At the bottom of the maps is a symbol labeled "approximate mean declination." A line shows the direction of true north, and an arrow points to magnetic north. The angle between, indicated by a figure, means that a compass needle will point this number of degrees west of true north. This deviation between true north and magnetic north in the Cardigan quadrangle is 15 degrees, and in the Rumney quadrangle is 15½ degrees, consequently all magnetic compass bearings must be corrected by this amount. You will notice that the long edges of the maps are true north-south, and the top and bottom edges of the map are east and west lines. This is useful in helping you to orient yourself as to position, for you can use the map as a compass, and by lining up certain known points on the map you can find out the names of unknown hills by sighting to them. The Fire Wardens use their maps in this way.

The various color patterns on the map show the kinds of rock in the different areas. The legend at the right is the key for finding out what each color means. In addition to the colors, each rock is also indicated by black letters which appear scattered over the map and also in the proper color pattern in the legend. For example, the rocks of Sugarloaf Mountain, west of Newfound Lake, in the Cardigan quadrangle, are represented by a triangular pattern of white and reddish purple as well as by letters "co." In the legend, this color pattern and the letters "co" are found to represent Concord granite. The legend is arranged with the oldest rocks at the bottom. 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, so only the geologist's interpretation of the underlying bed-rock, 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.

The structure sections at the bottom of the maps show what the rocks probably would look like if you dug a trench half a mile or so deep across the area. Three such sections are shown at the base of the Cardigan map, and four on the Rumney map. Their positions are indicated on the map by lines labelled A-A′, B-B′, etc. For example, in the Cardigan map the line B-B′ goes through the top of Mt. Cardigan, which is shown as Kinsman quartz monzonite. The structure section shows that the Kinsman quartz monzonite does not extend indefinitely downward below the top of the mountain, but that if you were to dig straight down about 1000 feet you would find the highly folded Littleton schists.

There are a few "special symbols" shown on the maps and in the legends. These symbols are to help interpret the structure of the rocks themselves. They represent measurements of the position, or 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 and schistosity" refer to a banding or layering of minerals in the rocks. The straight line of the symbol shows you the direction of "strike" or general trend of this banding or layering of minerals, and the number and arrow 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. 7). 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, 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 or bands corresponding to the leaves of a book. It is by measuring the changes in these directions at every available outcrop that the geologist estimates the position of the folds in any area, thus "unraveling" the story of the region from his study of the measurements taken.

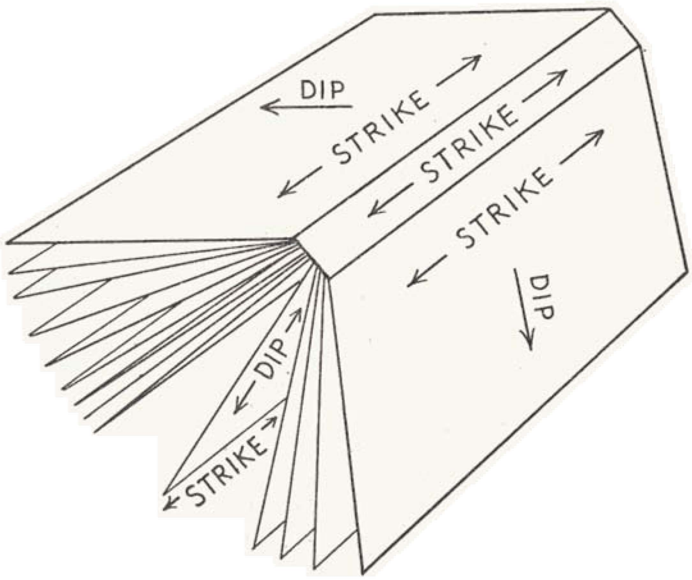


Figure 7. Diagram of a book standing on its fore edge to illustrate strike and dip. The strike parallels the binding, and does not vary from leaf to leaf or bed to bed. The dip is the slope of each individual leaf or bed in relation to a horizontal plane, and varies from leaf to leaf or bed to bed.

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*Out of print.

Further Information on the Geology of the State

The following publications on the geology of the various sections of the state may also be secured at the office of the Planning and Development Commission:

Geology of the Franconia Quadrangle. M. P. Billings and C. R. Williams. Printed, 35 pp., illus., colored map $0.50

Geology of the Littleton and Moosilauke Quadrangles. M. P. Billings. 1935. Printed, 53 pp., illus., two colored maps .... .60

Geology of the Mt. Chocorua Quadrangle. Althea P. Smith, Louise Kingsley, and Alonzo Quinn. 1939. Printed, 24 pp., illus., colored map .... .50

Geology of the Mt. Cube and Mascoma Quadrangles. J. B. Hadley and C. A. Chapman. 1939. Printed, 28 pp., illus., two colored maps .60

Geology of the Presidential Range. R. P. Goldthwait. 1940. Printed. 43 pp., illus. (Published by the N. H. Academy of Science) .... .40

Geology of the Winnipesaukee Quadrangle. Alonzo Quinn. 1941. Printed, 22 pp., illus., colored map .... .50

Mines and Minerals

New Hampshire Minerals and Mines. A directory, listing known minerals and places of occurrence. T. R. Meyers. 1941. Printed, 49 pp., map .... .50

New Hampshire Mineral Resource Survey. The results of a reconnaissance survey of the mineral resources of the state, made in 1940. Published in preliminary form in six parts: Part I—General Summary; Part II—Diatomaceous Earth; Part III— Peat Deposits in New Hampshire; Part IV—Sillimanite, Andalusite, Kyanite; and Mica Schist Deposits; Part V—Fluorite; Part VI—Quartz. Multigraphed. Entire Series .... .50

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