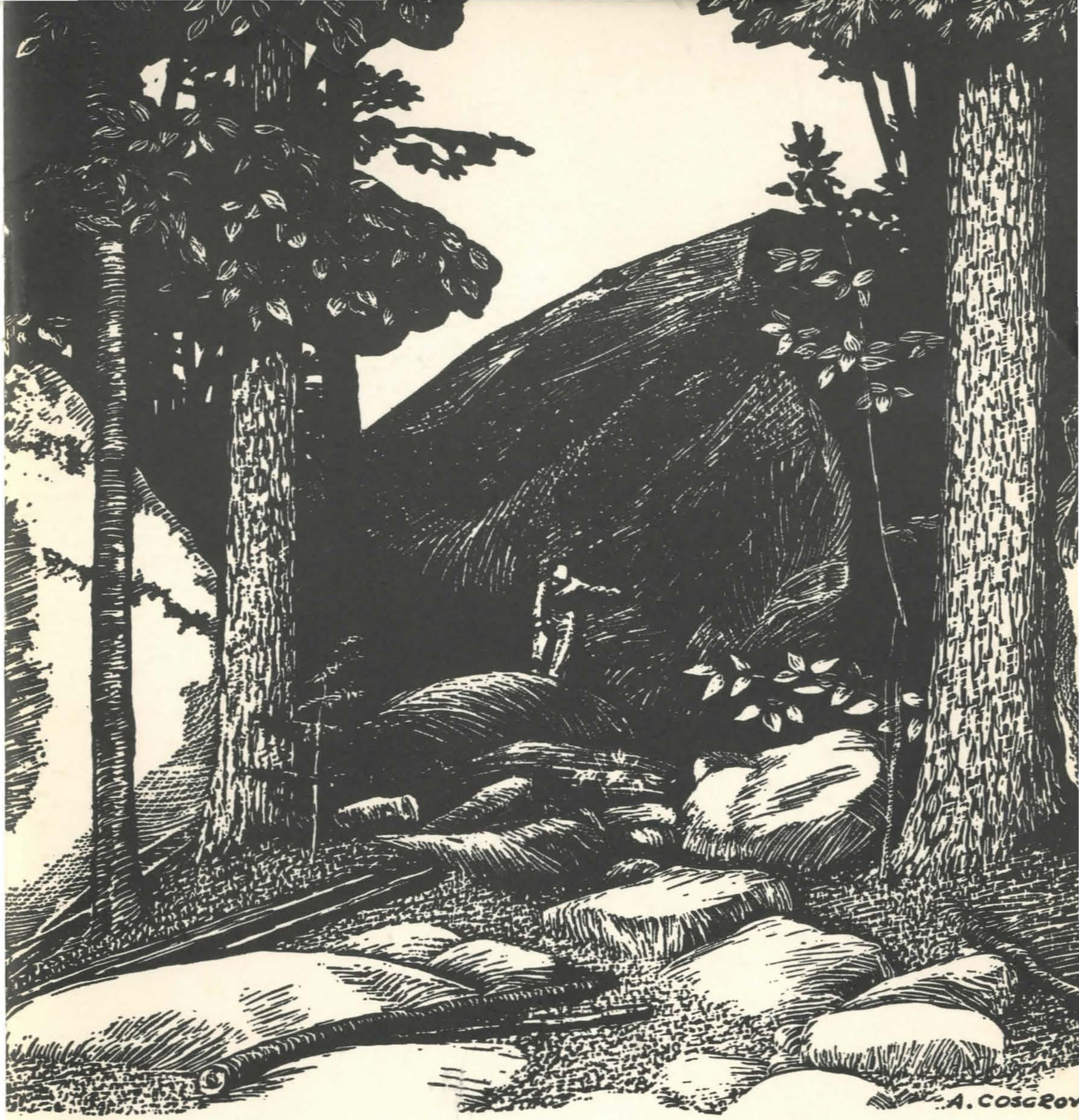

THE GEOLOGY OF THE

Mt. Pawtuckaway Quadrangle

New Hampshire

by

JACOB FREEDMAN

Published by
NEW HAMPSHIRE DEPARTMENT of RESOURCES and ECONOMIC DEVELOPMENT

Frontispiece. Aerial Photograph of Pawtuckaway Mountains. North is toward top. Scale about 1 inch equal 4200 feet. The small black area on right is Round Pound. South Mountain is at the bottom of the photograph. North Mountain is at the top. The displacement of North Mountain by a fault is shown.

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1950

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Division of Forests and Lands
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Concord, New Hampshire
1980

NEW HAMPSHIRE DEPARTMENT OF

RESOURCES & ECONOMIC DEVELOPMENT

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State Geologist

CONCORD, NEW HAMPSHIRE
1950
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FOREWORD

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

The study of the geology of the Mt. Pawtuckaway quadrangle was carried on from 1940 to 1942 and from 1946 to 1947 under the auspices of the Division of Geological Sciences, Harvard University. Financial aid was obtained from the Department of Mineralogy and Petrography, Harvard University.

The publication of the geological map in the pocket at the end of the pamphlet was financed by the New Hampshire State Planning and Development Commission, the New Hampshire State Highway Department and the Geological Society of America.

Geology of the Mt. Pawtuckaway Quadrangle New Hampshire

By Jacob Freedman

THE SCENERY

Rolling hills, long stretches of dark pine and hardwood forest interspersed with open meadowland and patches of scrub brush — this is the Mt. Pawtuckaway quadrangle in southeastern New Hampshire. Innumerable streams and tree-bordered lakes challenge the fisherman. Modern highways, country roads, lumber roads and woodland trails abound. Pastures, hayfields, and gardens break the monotony of the extensive forests. Many of the former fields have been reclaimed by wild growth. Overgrown trails lead to little private cemeteries, deserted farmhouses, or overgrown farms. Trees have grown so tall that lumbering is again in progress and in places the land is being cleared once again. Summer homes are not uncommon on the shores of beautiful lakes. Picturesque villages and towns are scattered along the highways.

Driving on South Side State Road, Route 101, east of Candia, one is impressed by a small cluster of mountains rising sharply above the surrounding countryside. These are the Pawtuckaway Mountains in Pawtuckaway State Park. Steep rock cliffs rise out of the dense forest valleys. Hiking trails traverse the mountains and lead to striking natural phenomena. High up on South Mountain a dike of black trap rock cuts the granite-like rock of the mountain, and breaking out in rectangular blocks provides the treads and risers of the Devil's Staircase. The top of South Mountain and the firetower rising above it command a view overlooking the sea to the east and the mountains to the north. The Devil's Den Trail to North Mountain first passes among the huge Pawtuckaway Boulders. These tremendous blocks of rock ranging up to 60 feet in some dimensions and probably comprising the largest group of boulders anywhere, are strewn for about a quarter mile along the trail. Once a part of North Mountain, they were plucked by the glacier during the Great Ice Age and dumped in their present position when the ice melted. Devil's Den was hollowed out by this same plucking action.

From Route 4 near Northwood, on the Concord-Durham road, the Pawtuckaway Mountains can be seen—no less spectacular though they are farther away. Very close by, however, is Saddleback Mountain rising to 1184 feet, the highest elevation in the quadrangle. This mountain has not been opened for the benefit of the tourist, camper or hiker and it is a rough climb to the top with no trail to guide one. Once there, however, a vast area of rolling, wooded hills lies at one's feet. Here, standing on solid rock, it is difficult to visualize the turmoil and upheaval, the long sequence of events which left this part of New Hampshire as it is today. The solid rock under foot was once muddy sand at the bottom of a sea that covered most of the state. Later this muddy sand was squeezed and folded to become solid rock. Hot, molten rock welled up from the depths and penetrated the newly risen land. Long after this molten material had congealed to solid rock, more molten material rose into it. Then, during a long period of time, erosion wore down the mountains to a rolling plain almost at sea level. The whole area was then uplifted and eroded again. After that came the Great Ice Age. Glaciers swept down over the country, rounded off and eroded the land, but finally melted away, leaving the country much as it is today.

THE STORY OF THE ROCKS

The Great Inland Sea

About 355 million years ago, most of central and southeastern New Hampshire lay under a great inland sea. The eastern shore rose out of this sea far to the east where now surges the broad Atlantic Ocean. How far this eastern landmass extended nobody knows. Erosion attacked and gradually lowered and removed the highland mass during hundreds of millions of years. Streams flowing westward from the highland carried vast amounts of sand

and mud into the inland sea overlying New Hampshire. The sea received sediments until all the rocks of sedimentary origin in the Pawtuckaway quadrangle were deposited (Fig 1). By this time a great sheet of sand and mud more than 20,000 feet thick had accumulated in the sea. When the sea receded, about 290 million years ago, the whole area became dry land and remained so until approximately 30,000 years ago when the sea once again swept over the coastal area.

All the rocks deposited in the Pawtuckaway quadrangle during Silurian time, about 355 million years ago, are included in the Eliot and Berwick formations. Although the individual beds in these formations ranged from a fraction of an inch to a few feet thick, the successive layers built a great sheet of sediment thousands of feet thick. The sea was never very deep, for as the sediments were laid down, the floor of the sea sank. No fossils have been found in the Pawtuckaway quadrangle to determine the age of the formations. Age determinations were made by correlation with rocks of known age in central Maine.

The sediments of the Eliot formation were deposited as three fairly distinct units: first, limy muds and a little pure limy ooze; second, sandy mud with local layers of limy mud; and third, mud and sandy mud. Only the last two units appear in the Mt. Pawtuckaway quadrangle. Rocks derived from the limy mud and lime, now mainly phyllites and limestone, are exposed east of the Mt. Pawtuckaway quadrangle. That portion of the Eliot formation on the accompanying geologic map is made up of the second and third units. The third unit, called on the map the Calef member of the Eliot formation, is composed chiefly of phyllites, which are micaceous rocks similar to roofing slate. These are best exposed along Calef Road, south of the Strafford-Rockingham County line. Calef Road is a superb highway built on the right-of-way of the abandoned Worcester, Nashua, and Portland Division of the Boston and Maine Railroad. The second unit, which comprises most of the Eliot formation in the Mt. Pawtuckaway quadrangle, is chiefly phyllite and mica schist, rocks which were originally mud. Local limy beds are now actinolite granulite. Actinolite is an elongate green mineral.

The Berwick formation is composed of two major kinds of rock, schists and actinolite granulites. The schists, orginally muds and muddy sands, have been altered to phyllites, mica schists and quartz-mica schists. The best exposures of the schists are along Calef Road between the Strafford-Rockingham County line and Wheelwright Pond, along South Side State Road, between Raymond and Bunker Pond, and in the vicinity of Jones Hill. The actinolite granulites are similar to those in the Eliot formation. Outcrops of the actinolite granulites are scattered about Raymond and Fremont townships.

The rocks of the Littleton formation were deposited about 330 million years ago in the same sea. A glance at the geologic map shows that most of the Littleton formation occurs as isolated patches in a large area of granitic rock. Once, however, these rocks also formed a continuous sheet in the inland sea. The sediments were composed of mud, muddy sand and some layers of limy mud; these muds have been recrystallized to mica schist, garnet schist, staurolite schist, sillimanite schist, quartzite and actinolite granulite. A distinctive, narrow belt of staurolite schist and sillimanite schist betwen Nottingham Square and Raymond has been designated the Gove member of the Littleton formation. The Littleton formation is well exposed on Saddleback Mountain, on Oak Hill, at West Barrington, on South Side State Road between Raymond and Long Hill, and on Rattlesnake Hill.

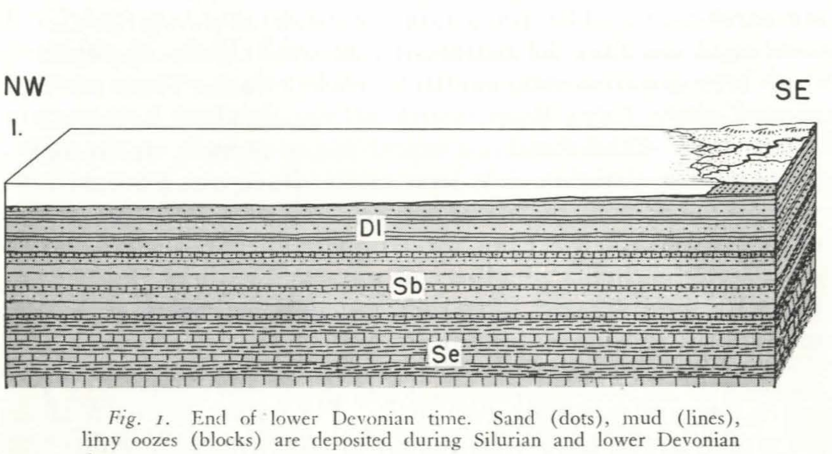


Fig. 1. End of lower Devonian time. Sand (dots), mud (lines), limy oozes (blocks) are deposited during Silurian and lower Devonian time.

2.

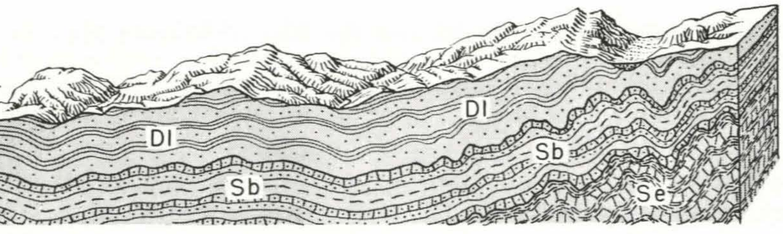


Fig. 2. Late Devonian time. Rocks are folded and contorted. Erosion going on all the time.

3.

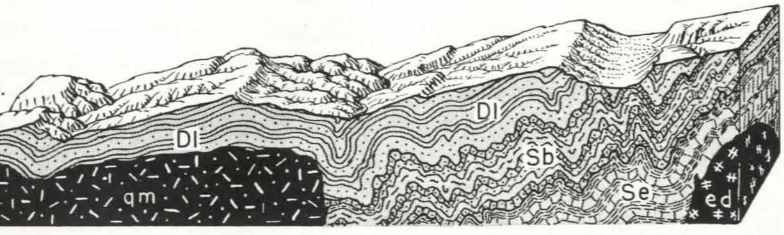


Fig. 3. Late Devonian time. Concommittant with or just after folding, intrusion of the New Hampshire magma series (*ed* and *gm*).

4.

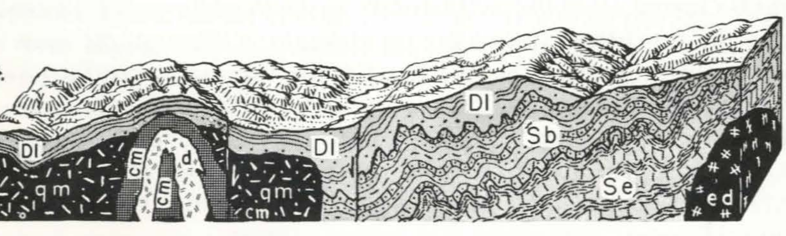


Fig. 4. Mississippian time. Intrusion of the White Mountain magma series (*d* and *cm*) in the Pawtuckaway Mountains and volcanic activity in the Little Rattlesnake Hill area. Faulting preceded and followed intrusion of White Mountain magma series.

5.

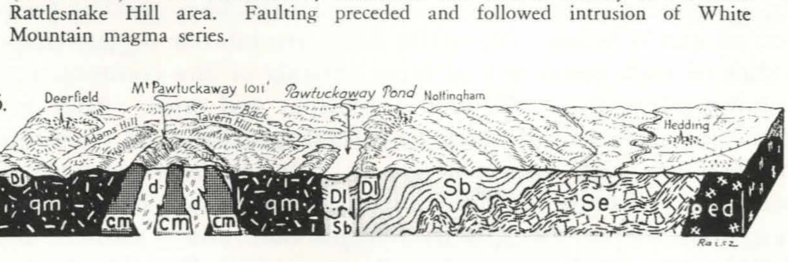


Fig. 5. Present. Region eroded to present topography.

Figures 1-5. Series of diagrams to illustrate the story of the rocks of the Mt. Pawtuckaway quadrangle. The cross sections are imaginary trenches several miles deep cut across the Mt. Pawtuckaway quadrangle at successive stages in its development. Se = Eliot formation; Sb = Berwick formation; Dl = Littleton formation; ed = Exeter diorite and qm = quartz monzonite, both belonging to the New Hampshire magma series; d = diorite and cm = coarse-grained monzonite, both belonging to White Mountain magma series.

The Folding of the Rocks and the Rise of Molten Magma

About 300 million years ago, the land began to rise and the great inland sea retreated from this part of New Hampshire, never to return until 30,000 years ago. The sediments laid down in the sea became dry land and were exposed to the forces of erosion. Before erosion could do much to the newly exposed land, great subterranean forces exerted tremendous pressure against the thick pile of layered sediments. As a hand pressing edgewise against a flat pile of papers would cause them to buckle and fold, so did the pile of horizontal sediments buckle and fold from the colossal forces exerted against our eastern shore (Fig 2). The layers of rock bent into gigantic upfolds, called anticlines, and into downfolds called synclines. Innumerable smaller folds formed on the flanks of the bigger ones.

As the sedimentary rocks folded, molten rock called magma rose from the depths of the earth and invaded them (Fig 3). The Exeter diorite and some of the quartz diorite were probably intruded at an early stage. As folding become more intense, the magma forced aside the sedimentary rocks to make room for itself, as in the northeast part of the quadrangle. Throughout most of the northwest half of the quadrangle, the magma worked up long bedding planes and fractures in the sedimentary rocks, forced off blocks and layers, and finally engulfed them. This last stage, the most extensive, removed so much of the Littleton formation that only scattered large and small patches of it remain in the vast expanse of quartz monzonite and binary granite.

The closing phase of intrusion of the New Hampshire magma series consisted of the injection of pegmatite dikes and the formation of quartz veins. Pegmatite dikes are tabular or lens-shaped bodies of rock composed of large crystals of the common rock-forming minerals, chiefly quartz, feldspar and mica. After most of the magma had solidified, a residual, gas-rich fluid containing rock-forming and ore minerals in solution was concentrated locally. Eventually the fluid forced its way into fractures in the rock, and slowly the quartz, feldspar and mica formed large crystals as the fluid cooled. Locally, rare minerals such as tourmaline, beryl and uranium minerals are present in small quantities. Pegmatite dikes are very numerous in the Mt. Pawtuckaway quadrangle. A number of them are exposed along Route 101 west of Raymond. The quartz veins were formed by water that contained silica in solution. This solution gradually deposited some of the silica to form the tabular or lens-shaped bodies of pure quartz. Quartz veins are very abundant. Almost every outcrop in the quadrangle is cut by one or more quartz veins a fraction of an inch to a foot thick.

Metamorphism

At the time of the folding and intrusion of the New Hampshire magma series, changes (metamorphism) took place in the sedimentary rocks. The enormous amount of heat given off and the pressure induced by the magma pervaded the sedimentary rock. The original sands were recrystallized to quartzites, a tough rock that breaks across rather than around the original sand grains. The muds and sandy muds became medium-to coarse-grained schists, foliated rocks made up mostly of mica, a newly formed mineral. Chlorite, black mica, garnet, staurolite and sillimanite are some of the new minerals formed as the result of the metamorphism. The limy muds were metamorphosed to granulites, dense, granular rocks, also composed of newly formed minerals. Locally, the metamorphism of the sedimentary rock has been so great that the rock is difficult to distinguish from an igneous rock.

Intrusion of the White Mountain Magma Series

Long after the magmas of the New Hampshire magma series had cooled to hard rock, and the folded sedimentary rocks had been metamorphosed, more magma worked up into the crust of the earth in the Pawtuckaway Mountains area and around Little Rattlesnake Hill near the south border of the quadrangle (Fig. 4). During Mississipian time, about 275 million years ago, a body of magma, deep in the earth, lay under the Pawtuckaway Mountain area. Over a long period of time, the composition of the magma changed as successive intrusions found fractures or openings along which the magma could rise. The first magma to rise probably moved upward by forcing aside the heated, plastic rock of the New Hampshire magma series surrounding it. At this stage the consolidation of the magma produced black, very coarse-grained granite-like rock that makes up the interior valleys of the Pawtuckaway Mountains, the rocks called gabbro, diorite, and diabase on the map. Forces in the earth developed a circular fracture around the solid rock, and into this fracture more magma of a different composition rose. It consolidated to form a gray coarse-grained granite-like rock called monzonite, which now makes up the outer circle of the Pawtuckaway Mountains in what is called a ring-dike. Magma intruded an inner, arcuate fracture at the same time to form another body of coarse-grained monzonite. Very soon thereafter, magma of similar composition rose along smaller fractures and chilled to form fine-grained monzonite. Still later, magma filled narrow, straight fractures at successive intervals with magma of three different compositions. These are now dikes, which are long, narrow, tabular bodies a few feet wide and hundreds of feet long.

At this same time three volcanoes erupted lava, angular blocks and ash, in the vicinity of Little Rattlesnake Hill. The volcanic peaks composed of lava flows and ash have long since been eroded. All that remains are the vents, or throats of the volcanoes. Coarse-grained rocks in the centers of two of the vents, and fine-grained rocks surrounding them, are very similar to rocks in the Pawtuckaway Mountains. Large, angular blocks embedded in fine-grained rock, and the small, circular shapes of the vents are the best clues to their volcanic origin.

Faulting

The heavy black lines on the geologic map are faults, which are fractures along which the rocks on opposite sides have slipped past each other. Movement along active faults causes earthquakes, but the faults in the Mt. Pawtuckaway quadrangle have been inactive for hundreds of millions of years. One of these faults extends from Rattlesnake Hill, southeast of the village of Raymond, through Flint Hill to Huckleberry Hill in Barrington; a second is in Nottingham township; a third is at the east edge of the quadrangle in Barrington township; a fourth is at the Gulf in Northwood township; a fifth is at Saddleback Mountain; and several across the Pawtuckaway Mountains. These faults, except those in the Pawtuckaway Mountains, occurred some time after the intrusion of the New Hampshire magma series at the end of Devonian time, about 300 million years ago. Water containing silica in solution worked up along these faults and gradually some of the adjacent rock was removed and replaced by quartz. Large patches of such quartz are separately shown on the map as silicified zones.

Three breaks disrupted the earth's crust at the Pawtuckaway Mountains after the rocks of the White Mountain magma series had been intruded. The north ends of the two northeasterly faults are marked by steep cliffs about 200 feet high at the northeast end of North Mountain. The southwesterly fault is not so well marked, but had a more far-reaching effect on the present distribution of the rock masses. The southwestern part of the ring-dike of coarse-grained monzonite was dropped down out of sight, leaving only two-thirds of the original 360° circle.

Injection of the Dikes

Only twenty dikes were observed in the Mt. Pawtuckaway quadrangle outside of the Pawtuckaway Mountains. Dikes are long, narrow tabular bodies of rock that formed when magma injected a fracture and froze. Eighteen of the dikes are dark-green to black trap rock, and two are gray to dark-green. All but three are from one to five feet thick. The three exceptionally thick dikes are: one, 20 feet thick on the road southeast of West Epping; one, 60 feet thick on the Central State Road, south of Mendums Pond; and one, 100 feet thick in a railroad cut 0.6 mile east of Onway in Raymond township.

The thinner dikes were probably derived from the White Mountain magma series. The thick dikes were probably injected during Triassic time, about 175 million years ago.

Erosion

When the great inland sea receded and exposed the horizontal sediments of the Littleton formation, the agents of weathering and erosion started to sculpture the land. Agents of mechanical weathering, such as frost-action and root-prying, broke up the rock. Agents of weathering such as dew and rain-water, oxygen and carbon dioxide from the air, rotted the rocks and caused them to disintegrate. Rain-water carried the particles down hill to streams which carried them away; or used them as tools of abrasion to scour their valleys deeper and wider. All during the folding of the rocks and during the successive igneous intrusions, erosion continued to carve the rocks. Erosion works slowly, but time — about 300 million years — enabled the herculean task of carving the present topography to take place (Fig 5). Miles of overlying sediments were removed to expose the igneous rocks, but probably at no time was the elevation of the surface much higher than it is today. For as erosion cut down the surface, the land slowly rose to maintain a balance deep within the earth.

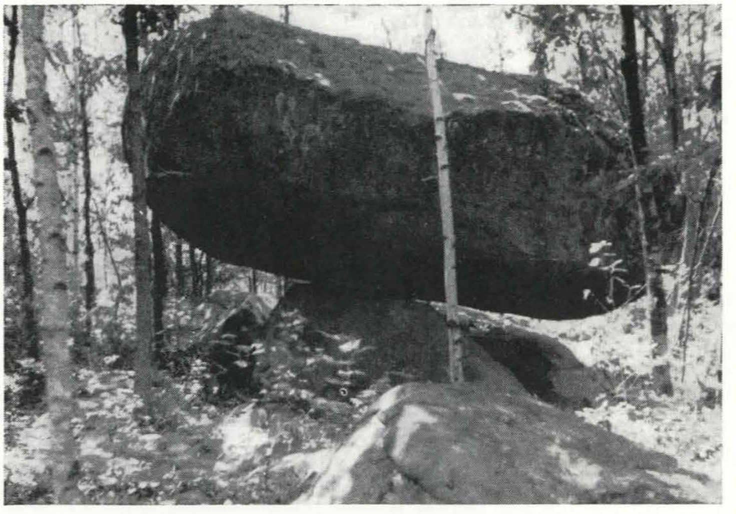


Fig. 6. A balancing boulder (65 tons).

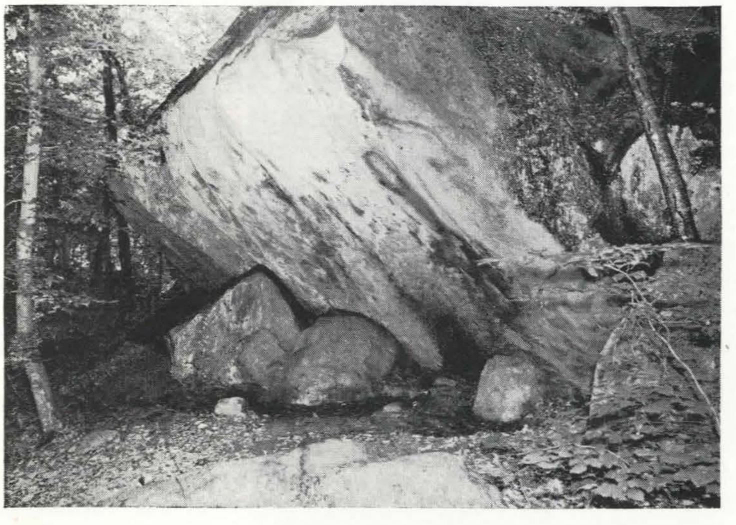
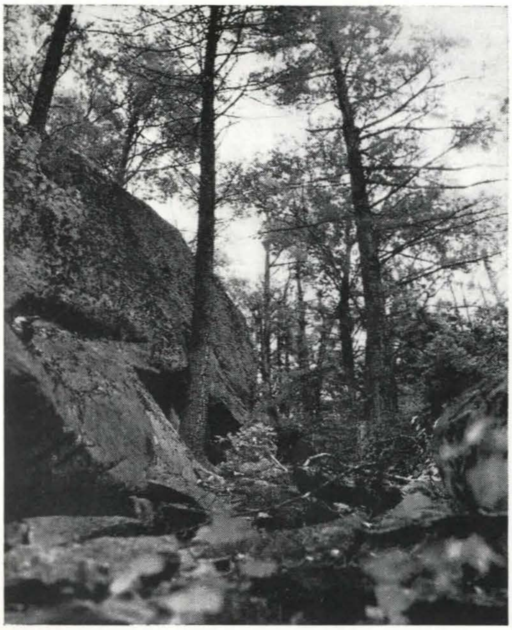
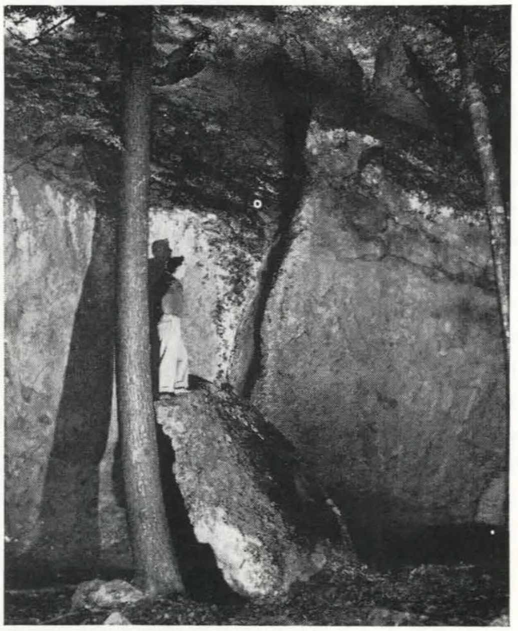


Fig. 7. Along Boulder Trail.



Figs. 8 - 9. Boulders on Mt. Pawtuckaway.



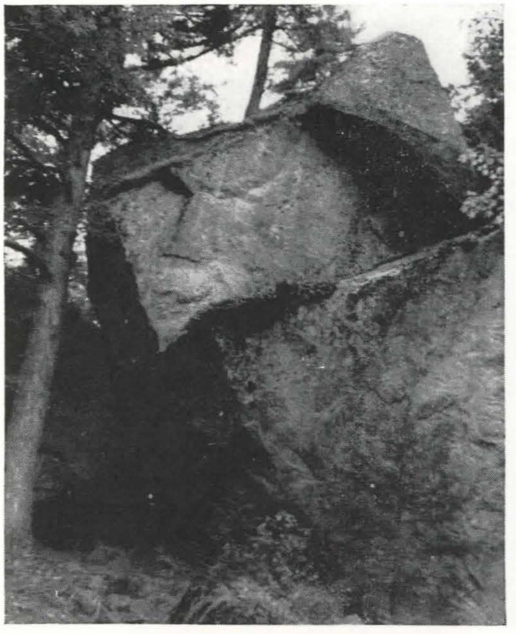


Fig. 10. Ballad Rock.

Fig. 11. Boulder — Mt. Pawtuckaway.

Geologic Time-Scale with Sequence of Events in the Mt. Pawtuckaway Quadrangle

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

Era	*Period*	*Time Scale (Age of beginning of periods)*	*Sequence of geologic events*
Cenozoic	Recent	Thirty thousand years ago	Deposition of marine clay; slight erosion.
	Pleistocene	Two million years ago	Continental ice sheet covered the region, eroding rocks and depositing till, sand and gravel.
	Tertiary	60 million years ago	2. Uplift and renewed erosion. 1. Rocks eroded to a surface near sea level above which low hills rose.
Mesozoic	Cretaceous	120 million years ago	Erosion.
	Jurassic	150 million years ago	Erosion.
	Triassic	175 million years ago	Erosion. Some of trap dikes injected.
Paleozoic	Permian	210 million years ago	Erosion.
	Pennsylvanian	255 million years ago	Erosion.
	Mississippian	290 million years ago	White Mountain magma series intruded in Pawtuckaway Mtns. and Little Rattlesnake Hill area.
	Devonian	330 million years ago	5. Erosion. 4. Faulting and silicification. 3. New Hampshire magma series intruded, probably late Devonian. 2. Folding and recrystallization of the rocks. 1. Littleton formation deposited in large inland sea in early Devonian.
	Silurian	355 million years ago	2. Berwick formation deposited. 1. Eliot formation deposited.
	Ordovician	415 million years ago	No record.
	Cambrian	515 million years ago	No record.
Pre-Cambrian		More than one thousand million years ago	No record.

Erosion exposed the metamorphic rocks of the Eliot, Berwick and Littleton formations. Differences in composition and structure determined the ease with which each formation was eroded. The Eliot formation contains easily soluble limestone. This formation was eroded deepest and underlies the lowest parts of the quadrangle. The Berwick formation is generally composed of thin alternating layers of hard and soft rocks. It stood up better than the Eliot formation, but not as well as the Littleton formation. The granitic rocks of the New Hampshire magma series are only moderately resistant and consequently form rolling hills. The coarse-grained monzonite of the Pawtuckaway Mountains, on the other hand, is exceptionally resistant to erosion and held up the striking arcuate mountains of that area.

The Great Ice Age

Two million years ago the Great Ice Age began. In the higher latitudes the snow stayed all year on mountains and hills, and became deeper and deeper. Eventually the mass of snow reached a critical thickness, ice formed, and slowly moved outward. Starting in Labrador and Canada, the ice spread out in all directions and slowly a continuous mass of ice, called a continental glacier, moved down over the northern United States. In north-central United States there is definite evidence that continental glaciers advanced four times and then melted away. Between the glacial stages, the ice melted away and the climate became warmer than at present. In New Hampshire, probably all four glacial advances occurred. However, there is actual evidence for only the last glacial advance, called the Wisconsin glaciation, which started about 50,000 years ago. A solid mass of ice over a mile thick swept down over New Hampshire. In the Pawtuckaway quadrangle it came from the northwest, as can be determined by scratches and grooves on rock surfaces made by the glacier as it slid over them, and by the shape of hills carved or deposited by the glacier.

The great weight of the ice caused it to act like a gigantic bulldozer. It pushed the soil off the bedrock. Ice and meltwater worked into cracks in the rock, and the forward motion of the glacier then plucked out blocks of rock surrounded by ice. These rocks at the bottom of the glacier were dragged under great pressure over rock surfaces. The hard rock was grooved, scratched, smoothed and polished. Soil, rock, and rock debris were picked up and carried along by the glacier. In places the glacier dropped some of its load of debris to form oval-shaped hills called drumlins and composed of till, which is a heterogeneous assortment of boulders and clay. Deer Hill in Brentwood township and Bald Hill in Newmarket township are drumlins. In many places the till formed a thin, irregular discontinuous layer on the solid rock.

When the glacier started to melt and the ice front to retreat, about 30,000 years ago, the remaining debris was dropped. Melt-water from the glacier deposited patches of clean sand and gravel, generally called glacial outwash. Most of the quadrangle is covered with a variable thickness of till and glacial outwash. Consequently most of the material directly at the surface is not bed-rock, but is till and outwash. Bedrock may be many feet below the surface. The geologic map, therefore, shows the rocks that would be exposed if all the glacial deposits were removed. The irregularly distributed till and outwash dammed many of the pre-glacial streams and formed the numerous lakes and swamps that are so characteristic of the whole quadrangle.

As the glacier melted, the tremendous amount of water that had been locked up on land as ice, found its way to the sea. The sea rose higher and higher on the continent and drowned the valleys of the Lamprey and Piscassic Rivers, making them tidal estuaries. Mud was deposited on the floors of the estuaries, which had much wider banks than the present day streams.

The great weight of the glacier, when it lay over the land, depressed the land. When the glacier melted, there was a slow but gradual recovery and the land rose. Sea level dropped, the estuaries were drained, exposing the widespread mud flats around Epping, and the streams resumed their task of erroding the newly exposed land.

INTERESTING LOCALITIES

Pawtuckaway Mountains

The Pawtuckaway Mountains area, within Pawtuckaway State Park, is probably the most interesting part of the whole quadrangle. Roads traverse the area and make most places easily accessible by a short climb or hike. Wild flowers, in great variety, grow profusely. Numerous species of hard-wood and soft-wood abound, and locally, virgin timber towers more than 200 feet above the ground. The state maintains the roads and a few primitive parking places for those who enter the mountain area from Route 107. Trails over the mountains are easy climbs; a jaunt over the trails on all three mountains would take less than a full day.

As one enters from the west, the road rises to a crest which provides a scenic view of most of the mountains. At the crest, the rock is dark-gray hornblende diorite of the White Mountain magma series, but only 100 feet west, down the road, are exposures of the white to light-gray, coarse-grained quartz monzonite of the older New Hampshire magma series. Continuing eastward, the road is over rock that gradually gets darker as one approaches the south contact of the two magma series. The color is due to the increasing abundance of a black mineral, augite. At the contact, the rock, called a porphyritic gabbro, is composed largely of augite and other dark minerals. Beside the road between Middle and South Mountains, light-gray, coarse-grained monzonite is exposed. A trail leads up South Mountain to a fire tower which rises high above the light-gray, coarse-grained monzonite of the ring-dike. The view from the tower commands the whole mountain area, looks eastward to the sea, and north and west to the rolling uplands of the interior. Just north of the fire tower is the Devil's Staircase, a dike composed of trap rock, about one foot thick, from which blocks have been eroded along joint planes to make a series of steps. A trail, west of the fire warden's cabin, leads over Middle Mountain fine-grained and coarse-grained monzonite.

Directly north of Middle Mountain, coarse-grained monzonite can be observed in a cut made by a side road leading to one of the primitive parking areas. Another road (not shown on the geologic map) winds northward down the hill, crosses a stone bridge, a makes a sharp turn southeast. Right at the bend, a trail runs north through open, tall timber to the Pawtuckaway Boulders. These constitute one of the largest aggregations of large boulders in the world. Individual boulders of greater size than any in the Pawtuckaway Boulders have been reported elsewhere in New Hampshire and in foreign countries, but nowhere have so many large boulders been reported together. Numerous boulders here range up to 50 feet in their greatest dimensions. Full grown trees rise from the tops of some and in at least one case the roots have split the giant boulder from top to bottom. These boulders are light-gray, coarse-grained monzonite. As one follows the Devil's Den Trail among the boulders toward North Mountain, the boulders become more numerous and suddenly above the trees and boulders a sheer cliff, 200 feet high, rises above the valley floor. From this cliff along one of the faults, the huge Pawtuckaway Boulders were quarried by the plucking action of the glacier and dropped as the ice melted.

The trail leaves the valley and climbs the steep side of the mountain to Devil's Den, a cave formed by the removal of a large block of rock. The trail then continues to the top of a ridge. Here there is a view of Dead Pond below and the cliff made by erosion along the fault. Glaciers further sculptured the scarp after plucking out the boulders. The trail runs west to another steep scarp rising 200 feet above it. This scarp is formed by another of the faults that cuts across the area. The trail climbs the sheer face of the scarp and continues southwest along the top of North Mountain, called Mount Pawtuckaway on the map.

East of the road running northeast through the central part of the Pawtuckaway Mountains is a quarry. Rotten rock that crumbles easily has been removed to surface the State Park roads, for which it is ideally suited. Removal of the rotten, brown porphyritic diorite has exposed four dikes: Two lamprophyre dikes, one monzonite dike, and one pegmatite dike. On the northwest side of the road is a smaller quarry from which black hornblende crystals up to six inches long have been taken.

Saddleback Mountain

The highest elevation in the whole quadrangle, Saddleback Mountain, is relatively inaccessible. One road runs northeast-southwest along its base; another crosses the mountain at its northeast end. From the west part of the latter, a trail climbs to the top of the mountain. Two things are of interest to the layman: One, the view from the treeless, bare top of Saddleback Mountain, which looks south to the Pawtuckaway Mountains and east to the ocean; the other, the minerals that can be collected on Saddleback Mountain. Most of the slope in the central part of the mountain northwest of the northeast-southwest road has numerous small, pink and red crystals of garnet embedded in the mica-garnet schist.

On the rest of the mountain, tourmaline crystals and single crystals and twin crystals of staurolite are abundant.

The Gulf

The Gulf at the south end of Suncook Pond is a canyon along a fault that has been sculptured by glacial action. The steep scarp on the west is composed of alternating, thin beds of brownish, iron-stained phyllite and quartzite. The gentler side of the Gulf on the east is composed of light-gray, binary granite of the New Hampshire magma series.

Little Rattlesnake Hill Area

Another interesting bit of geology is the Little Rattlesnake Hill area. Here on three hills about a half-mile apart are volcanic vents, remnants of volcanoes from which once issued lava flows and volcanic debris. The circular vents are all that remain. The coarse-grained rocks, gabbro and hypersthene monzonite are similar to those in the Pawtuckaway Mountains. The fine-grained rocks and the large amount of breccia, angular blocks of rock embedded in finer-grained rock, are distinctive.

Calef Road

Parts of this road, which has been built on the abandoned railroad shown on the east side of the quadrangle, have unusually good exposures. Between Epping and Lee Stations, black phyllite of the Calef member of the Eliot formation is exposed. From Lee Station to Wheelwright Pond, gray quartz-mica schist, light-green actinolite granulite, and green to gray phyllite with scattered biotite flakes outcrop. North of Wheelwright Pond the area is covered by glacial sand in what is called an outwash plain.

South Side State Road

At the Candia-Raymond township line on South Side State Road, Route 101, there is a long outcrop of pink to gray microcline granite. Black hornblende crystals are scattered thickly through some portions of it; numerous wavy layers make up other parts; and still other parts are gray, massive biotite granite.

Lakes and Streams

Many of the lakes in the Mt. Pawtuckaway quadrangle have summer homes on their shores. The number of homes and the number of lakes being utilized is increasing. Most of the lakes are suitable for swimming and all are fine for boating and fishing. Fisherman frequent the streams in the quadrangle for perch and trout. The larger lakes are dammed and their waters utilized for production of electricity for public utilities and industrial plants.

USEFUL MINERALS

Pegmatite dikes are scattered in large numbers throughout the quadrangle and are shown on the map by red crosses. Feldspar for use in manufacturing china and abrasive soaps, mica for electrical insulation, and beryl, a source of the rare element beryllium, occur in pegmatite dikes. Many are exploited in New Hampshire, but only one is quarried in the Mt. Pawtuckaway quadrangle. The Smith quarry in the southwest corner of the quadrangle is producing feldspar and a small quantity of beryl.

The number of pegmatite dikes in the quadrangle, and recent investigations by the U. S. Geological Survey in the area, indicate the possibility of more quarries being opened.

The quartz in the silicified zones at Flint Hill has been investigated by the state geologist, and is a possible source of that mineral for use in the glass industry.

Gold is reported to have been mined from quartz veins north of the road crossing Saddleback Mountain, and south of Blakes Hill, but the operations were not successful.

Granite has been quarried locally, for curbstones, foundations and monuments, south of Whittier School in the north central part of the quadrangle, and at Dumplingtown Hill in the southwest part of the quadrangle. There is probably insufficient demand for granite to warrant production for other than local use.

Peat deposits were investigated by a state geologist, and large reserves were established, but there has been no production to date.

Sand and gravel deposits are scattered over the quadrangle and are used locally. In the northeast part of the quadrangle, the sand and gravel of the outwash plain is being utilized commercially.

HOW TO READ THE MAP

A map in the envelope at the back of this pamphlet shows both the topography and geology of the region. To the right of the map is the legend explaining the colors and patterns used for the various geological formations. At the bottom are three structure sections.

The geology of the area has been added in color to the regular United States Geological Survey topographic map surveyed in 1917. The roads, railroads, and homes are therefore shown as they were 35 years ago. Since numerous changes have been made since then, the map does not everywhere indicate existing conditions. The cost of correcting the map would have been prohibitive. A study of the scale at the bottom indicates that one inch on the map equals approximately one mile on the ground. Surfaced or improved roads are shown as double black lines; poor or private roads as double dashed lines; trails as dashed single lines; railroads as solid black lines with short crossbars; township boundaries as heavy dashed lines; and county boundaries as heavier lines composed of alternating short and long dashes. Houses are shown as small solid black squares to which a flag is added to represent a schoolhouse and a cross to represent a church. A cemetery is represented by a cross or the letters CEM surrounded by a fine dashed line. Lakes appear as concentric blue lines which are always parallel to the nearest shore. This pattern makes it easy to locate small islands. Streams are blue lines; swamps are blue tufts.

In fine print at the bottom of the map are the words, "Datum is mean sea level." This means that all altitudes given on the map represent the vertical distance in feet above mean sea level. Altitude is indicated on the map by black or brown numbers. For example, the top of Saddleback Mountain is marked 1184. This means that the summit of Saddleback Mountain is 1184 feet above sea level. The surface of Swains Pond is shown to be 281 feet above sea level. The letters "B. M." accompanied by a cross and a number indicate a bench mark, a point of known elevation established by surveyors of the Coast and Geodetic Survey or the topographers of the U. S. Geological Survey. A bench mark is usually a small circular brass disc set in solid rock, in a concrete pier, in a highway, or in some other permanent or semi-permanent location.

The brown lines on the map are contour lines, lines connecting points of equal altitude. They show the shapes of the hills and valleys and the approximate altitude of any place on the map. If you walk parallel to a contour line, you will not change altitude. If you walk at right angles to the contour lines, you will be moving directly up or down a slope. At the bottom of the map is the statement, "Contour interval 20 feet." This means that the vertical distance between successive contour lines is 20 feet. In other words, any such line is either 20 feet above or 20 feet below an adjacent line. To simplify the reading of the map, every fifth contour line is heavier, and only these hundred foot lines are labeled. Somewhere on each heavy line will be found brown numbers representing the exact altitude of that line. The spacing of the lines shows the steepness of the slope. If the lines are closely spaced, the slope is steep, if far apart, the slope is gentle. As examples, note that the east side of Oak Hill, one and a quarter miles south of Bow Lake, is very steep, whereas the west side is very gentle.

One more examination of the bottom of the map reveals a symbol labeled "approximate mean declination, 1917." This symbol is necessary because the compass does not point due north but to a magnetic pole that lies northwest of Hudson Bay about 1000 miles from the geographical north pole. In the diagram, one line points true north, and the other toward the magnetic pole. The angle between them is 14½ degrees. This means that the compass needle in this area will point 14½ degrees west of true north. If you intend to wander from the beaten path, take with you a map and a compass, and when using the latter, do not forget to make the proper correction for magnetic declination.

The top and bottom boundaries of the map and the two intermediate black lines labeled 5′ and 10′ are parallels and run due east and west. The side boundaries and the two intermediate lines labeled 5′ and 10′ are meridians which run due north and south. These lines may be used to orient yourself. Using your compass, with the proper correction, line up the map with its top toward the north; locate yourself on the map; and then it is comparatively easy to identify all topographic features in the vicinity.

The color patterns on the map show the kinds of rock in the different areas. The legend at the right explains what each color means. In addition, the rock name is indicated by black letters which appear both on the map and in the legend. For example.

the rock around Bow Lake at the north edge of the map is represented by a pink diamond pattern and the black letters "bg." In the legend these symbols are found to represent the binary granite. Since the oldest rocks are at the bottom of the legend, the binary granite is younger than the quartz monzonite, quartz diorite, and Exter diorite, and older than all those above. The lack of any symbol for soil, glacial drift, or other unconsolidated material might give the impression that the rock is exposed everywhere. This is not true. Most of the bedrock is concealed. For this reason, more than one symbol must be used to indicate contacts between different kinds of rock. The solid line means that the contact was seen and plotted accurately. The dashed line is used when outcrops of the two rocks indicate the presence of the contact but it was not seen because it was covered by glacial deposits. The dotted line is used when there is a gradual change from one type of rock to another and a sharp contact is lacking.

The structure sections at the bottom of the map are the geologist's pictures of what lies below the surface, of what he believes you would see if you could dig trenches to a depth of one-half mile below sea level along the Lines A-A′, B-B′, and C-C′.

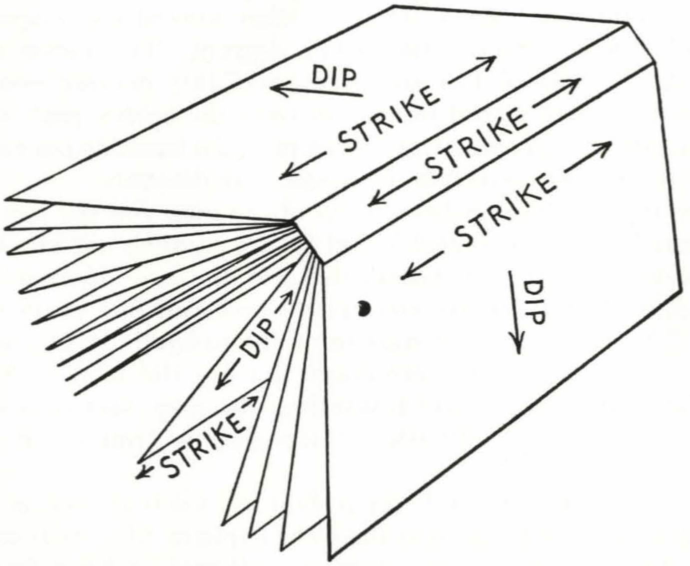


Fig. 12. Diagram to illustrate strike and dip.

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. The straight line of the symbol shows you the direction of "strike" or general trend of this bading 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 visiualize what strike and dips means (see Fig. 12). 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. Or, if they lie flat, or horizontal, another symbol is used. The foliation symbols are used in the same way as those of the bedding.

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.

A special symbol is used to show breaks or "faults" in the earth's crust; a solid line, with a "U" shows which side came up in relation to the "D" or dropped-down side. If quartz has been deposited along the break or fault, a special symbol with an *s* shows this silicified zone.

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