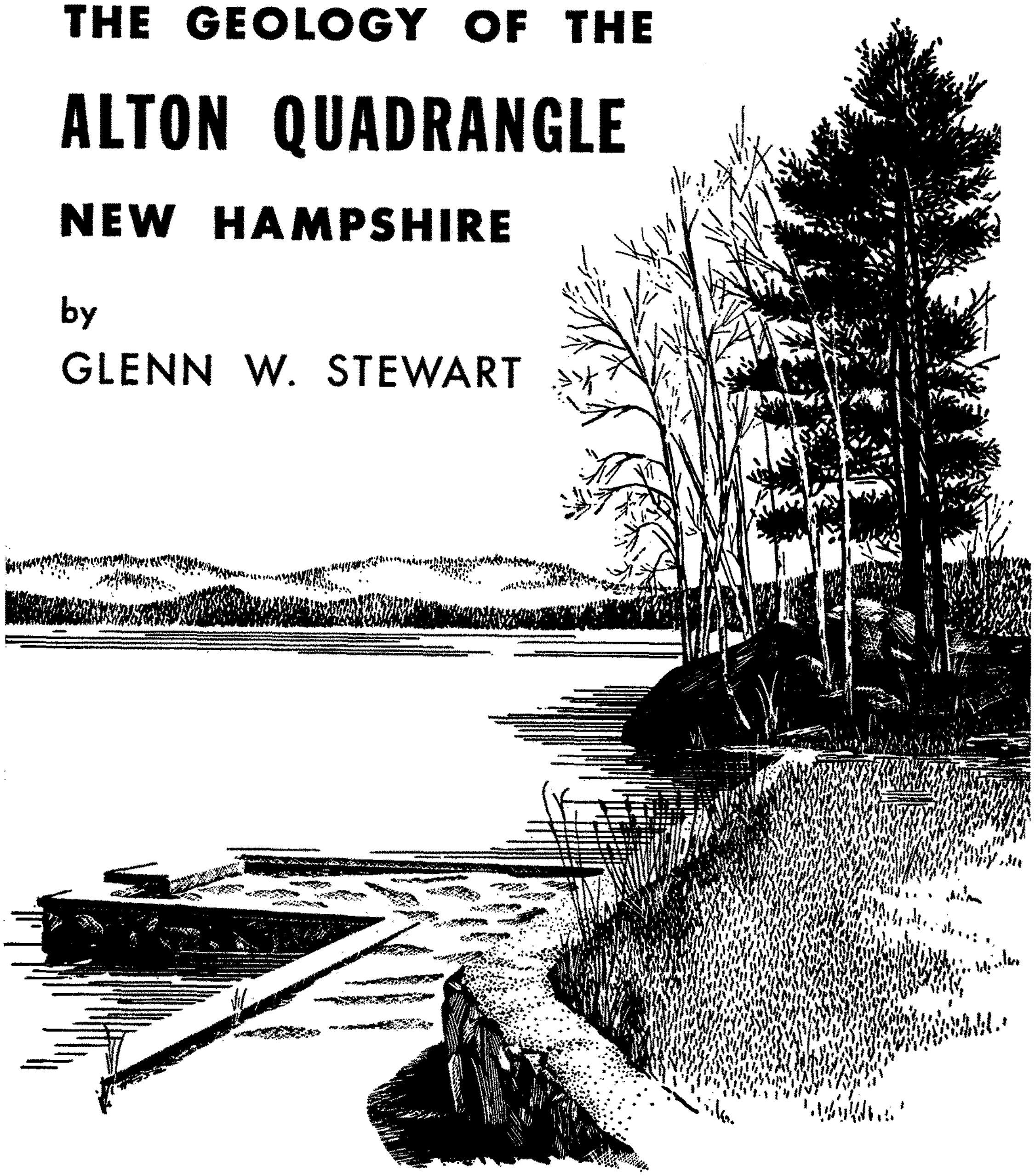
THE GEOLOGY OF THE

ALTON QUADRANGLE

NEW HAMPSHIRE

by

GLENN W. STEWART



Published by THE NEW HAMPSHIRE STATE PLANNING AND DEVELOPMENT COMMISSION

1961

Alton Bay — Lake Winnipesaukee

GEOLOGY OF THE ALTON QUADRANGLE, NEW HAMPSHIRE

By

Glenn W. Stewart

Published by the
NEW HAMPSHIRE
STATE PLANNING AND DEVELOPMENT COMMISSION
CONCORD, NEW HAMPSHIRE 1961

NEW HAMPSHIRE
STATE PLANNING AND DEVELOPMENT COMMISSION

ROLAND O. R. DIONNE, Chairman
ANDREW CHRISTIE
GEORGE CUTHBERT
WALTER D. HINKLEY
LEON H. RICE, SR.
RICHARD PRESTON, Executive Director
MARY LOUISE HANCOCK, Planning Director
WINFRED L. FOSS, Industrial Director
JOHN BRENNAN, Promotion Director

MINERAL RESOURCES COMMITTEE

JOHN B. LYONS, Chairman
MARLAND BILLINGS
LEONARD FROST
PAUL OTIS
EDWARD ELLINGWOOD
ARTHUR WHITCOMB
HAROLD M. BANNERMAN, Advisor
T. RALPH MEYERS, State Geologist

TABLE OF CONTENTS

ILLUSTRATIONS

FOREWORD

The Geology of the Alton Quadrangle, New Hampshire, is the twentieth of a series of pamphlets published by the New Hampshire Planning and Development Commission and is concerned with popular accounts of the geology of a particular area. The quadrangle covers an area of about 225 miles. It is 15 minutes of Longitude wide (71° 00′ to 71° 15′) and 15 minutes of latitude long (43° 15′ to 43° 30′). In an attempt to make the story of the geology both interesting and understandable to the layman, technical terms have been held to a minimum. In 1941 the bedrock geology of the northern part of the quadrangle was described by Dr. Alonzo Quinn of Brown University and Glenn W. Stewart, University of New Hampshire, in one of the professional geological journals (see list of references at the end of the pamphlet). A topographic map and a geological map of the quadrangle accompany this report.

Laboratory equipment and space were provided by the University of New Hampshire. Financial assistance was given by the New Hampshire State Planning and Development Commission and the New Hampshire Academy of Science.

During the field and laboratory work and in the preparation of this manuscript T. R. Meyers, State Geologist, made many valuable suggestions and criticisms. Dr. Marland P. Billings of Harvard University and Dr. John B. Lyons of Dartmouth College, have made helpful suggestions.

Geology of the
Alton Quadrangle,
New Hampshire

By Glenn W. Stewart

LOCATION AND SCENERY

Many of the wooded foothills and mountains of southeastern New Hampshire and Alton Bay, the well-known southerly extension of Lake Winnipesaukee, lie within the boundary of the Alton quadrangle. Of unusual interest to some is the fact that the quadrangle contains parts of five counties, Belknap, Carroll, Merrimack, Rockingham, and Strafford: parts of eleven townships, Alton, Barnstead, Barrington, Farmington, Middleton, Milton, New Durham, Northwood, Pittsfield, Strafford, and Wakefield; and a small section of one city, Rochester.

Although the mountains have only low to moderate relief and represent foothills of higher mountains to the north, they offer many inspiring views. The highest mountain is Mt. Prospect (1451 feet) in Alton; other comparable elevations occur at Mt. Bet and Mt. Jesse in New Durham, and the mountains of the Blue Hills Range in Strafford and Farmington.

The natural and man-made lakes and ponds, the mountains, and the wooded areas attract summer and winter vacationists to the area for fishing, hunting, hiking, bathing, and boating. Several lakes are sites for boys' and girls' summer camps.

More than half of the quadrangle is drained by the Cocheco River and its tributaries. Tributaries of the Suncook, Salmon Falls, and Merrymeeting Rivers drain the remaining parts.

To a geologist the area has considerable significance in addition to its natural beauty because he is interested in discovering the facts about the geological history of its numerous physical features. In many ways a geologist may be compared to a detective because he observes, records, and interprets the physical events, some of which have happened millions of years ago, and tries to reconstruct their geologic history.

In the following pages the geologic history of the Alton quadrangle is reviewed.

THE STORY OF THE ROCKS

The Geologic Map

A topographic and geologic map accompany this pamphlet and detailed instructions for reading and interpreting them are given in the last section.

The geologic map shows the distribution of the different rock types and should be used as a reference during the reading of this pamphlet. Each type of rock has been given a specific pattern and letter-symbol. To show inferred relationships of the rocks at and below the surface, cross-sections have been prepared and placed at the bottom of the map. Distortion of the cross-section has been avoided by using the same scale for both the vertical and horizontal measurements.

The Inland Sea

One of the basic principles of geology is that the present is the key of the past. To understand the geologic history of the Alton quadrangle, one must attempt to visualize and place the significant events in the order in which they have occurred.

To begin such a task one must be able to distinguish the principal types of rock — igneous, sedimentary, and metamorphic, and to explain their mode of origin. Only igneous and metamorphic rocks crop out in New Hampshire. Igneous rocks are formed when molten rock material, called magma, crystallizes within the earth's crust or when it reaches the surface more or less quietly to form lava flows or to form layers of volcanic debris ejected from explosive volcanoes. Most of the igneous rocks in New Hampshire have been formed within the earth's crust and have been exposed by prolonged weathering and erosion. In places considerable quantities of igneous rocks have accumulated during periods of explosive activity of volcanoes.

Sedimentary rocks, such as sandstone or shale (mudstone), consist of individual mineral particles which have accumulated in layers or beds and are held together by a natural cement. Most of the sandstones are composed of quartz grains and the shales are composed of clay and other fine-grained minerals. Many sedimentary rocks are mixtures of clay and sand in varying proportions. The mineral grains are derived from the weathering of older igneous, metamorphic and sedimentary rocks. Limestones consist of interlocking grains of calcite (calcium carbonate) which precipitate chiefly in a marine environment. Sedimentary rocks do not crop out in New Hampshire but they are common in the Connecticut Valley of Massachusetts and Connecticut.

Igneous and sedimentary rocks may become metamorphic rocks if increases in temperature or pressure are sufficiently great. In general the igneous rocks are changed from rocks of equigranular texture to rocks with a banded structure of light and dark minerals; these are called gneisses. The clay minerals of the sedimentary shales commonly are recrystallized into micaceous minerals and form foliated or scale-like rocks, called schists.

Table 1

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

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

ERA	PERIOD	Time-scale (age of beginning of period)	Sequence of Geological Events
Cenozoic	Recent	25,000 years ago	Slight erosion chiefly of glacial deposits
	Pleistocene	One million years ago	Ice sheet covered the area depositing glacial till, sand and gravel, and clay
	Tertiary	60 million years ago	Uplift and renewed erosion
Mesozoic	Cretaceous	120 million years ago	Erosion
	Jurassic	150 million years ago	Erosion
	Triassic	175 million years ago	Erosion
Paleozoic	Permian	210 million years ago	White Mountain Plutonic Series
	Pennsylvanian	255 million years ago	Erosion
	Mississippian	290 million years ago	Erosion
	Devonian	330 million years ago	Binary granite, biotite granite and pegmatite intruded End of folding Winnipesaukee quartz diorite and quartz diorite (Ayers Pond area) intruded Folding and recrystallization of rocks began Littleton formation deposited in an inland sea Jenness Pond member: Alternating thin layers of mud and sandy mud (now schist) Pittsfield member: mud and sandy mud (now gneiss and schist)
	Silurian	335 million years ago	No record
	Ordovician	415 million years ago	No record
	Cambrian	515 million years ago	No record
	Pre-Cambrian	More than one thousand million years ago	

Table 2

Description of Rock Formations in Alton Quadrangle

LETTER SYMBOLS ARE THOSE USED ON MAP

Permian-Triassic	White Mountain Plutonic Series	Conway granite (cg): Medium to coarse-grained granite, composed of microperthite, quartz, oligoclase, biotite and hornblende.
		Granite porphyry (gp): Pink to light gray granite porphyry; phenocrysts of microperthite, quartz, and hornblende.
Early Devonian-Late Devonian	New Hampshire Plutonic Series	Pegmatite: Extremely coarse-grained rock composed chiefly of microcline-perthite, albite, and quartz with some muscovite and biotite.
		Biotite granite (bg): Medium-grained, gray granite composed of orthoclase, quartz, oliglocase, and biotite.
		Binary granite (big): Medium-grained, gray granite composed of orthoclase, microcline-perthite, quartz, muscovite and biotite.
		Winnipesaukee quartz diorite (wqd): Medium-grained, gray quartz diorite including some granodiorite; composed of oligoclase or andesine, orthoclase, quartz, biotite, and muscovite.
		Quartz diorite (qd): Medium-grained, dark-gray quartz diorite with some quartz monzonite; composed of andesine, orthoclase, quartz, and biotite.
	Early Devonian	Littleton formation: Jenness Pond member, Dlj, composed of thinly bedded andalusite and pseudo-andalusite schist, quartz-mica schist, and pyrrhotitic schist; Pittsfield member, Dlp, composed of gneiss, sillimanite gneiss, sillimanite schist, quartz-mica schist, and pyritiferous schist.

Locally the shales have been changed to slates. The sandstone is changed to quartzite and the limestone to a marble. In general these last two rock types are not foliated. In New Hampshire and in the Alton quadrangle the quartz-mica schists are the most common metamorphic rock. In places garnet, andalusite, staurolite, and sillimanite are abundant in the schists. If the metamorphic rocks are observed carefully one may find traces of the original bedding or layering. In addition, a noticeable change in the minerals from one layer to another, such as alternating layers of quartz grains and mica grains, suggests that the original material may have been alternating layers of mud and sand which accumulated at the bottom of the sea. Mud and sand are being transported and deposited in some parts of the oceans today. Laboratory investigations and field observations on the transportation and deposition of sediments clearly demonstrate the basic geological principle that the present is the key to the past.

Parts of North America, such as Hudson Bay, are flooded today by the ocean. In the past much of North America has been flooded by shallow seas. The evidence is found in the thick layers of shale, sandstone, and limestone. Some of these sedimentary rocks contain marine fossils. Geologic investigations have shown that at one time or another during the Ordovician, Silurian, and Devonian periods (see table 1) sediments accumulated in various localities in New Hampshire. In the Alton quadrangle all of the rocks derived from sediments are Devonian in age (see figure 2).

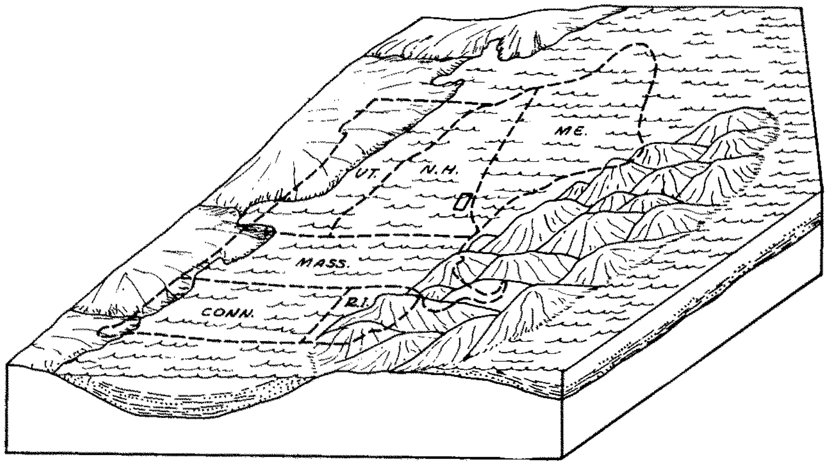


Figure 1. A geologist's interpretation of the inland sea which flooded much of New England during the Early Devonian period and received sediments from adjacent land areas. The location of the Alton quadrangle is shown by a small rectangle in southeastern New Hampshire.

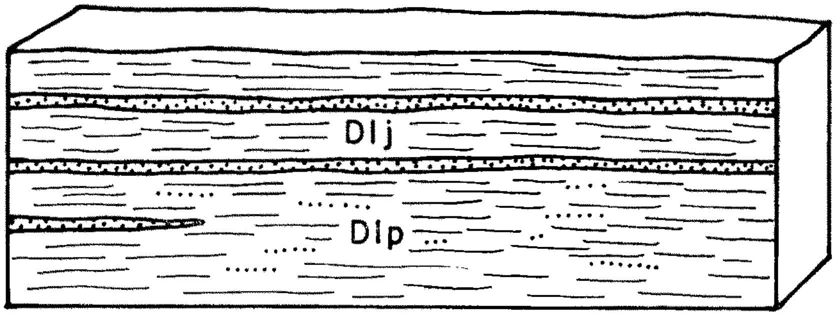


Figure 2. Muds and sands were deposited in Early Devonian time which were to become the Littleton formation; Dlp and Dlj.

According to the geologic record an arm of the sea not only covered most of New Hampshire during the Devonian period but it covered much of New England. The date for the beginning of the Devonian has been determined by radiometric methods as more than 330 million years ago. The source of the mud and sand is not definitely known but land areas probably existed in the area now occupied by the Gulf of Maine (see figure 1). During the time that these land areas were being worn down, the streams carried considerable amounts of mud and sand and deposited them in the inland sea. No fossils have been found in the Alton quadrangle, but fossil remains found near Littleton, New Hampshire, are similar to Devonian fossils found in other parts of the eastern United States. The name Littleton formation is used in New Hampshire to designate the sediments deposited during the Devonian period.

The Littleton formation in the Alton quadrangle can be subdivided into two units, the Pittsfield member and the Jenness Pond member. These units were first described in the Gilmanton quadrangle which borders the Alton quadrangle on the west. The Pittsfield member is the older unit and crops out principally in the northern two-thirds of the Gilmanton and Alton quadrangles. The younger unit, the Jenness Pond member, crops out chiefly in the southern third of the Alton quadrangle.

The Pittsfield member is believed to have been deposited as thick layers of mud and lesser amounts of sand. In some places the muds appear to have been mixed with a high content of sand and in other places the sand layers contained small amounts of mud. After these sediments were consolidated into rock they were probably sandy shales and muddy sandstones. As a result of high temperatures and pressures developed during a Middle to Late Devonian interval of intensive folding and accompanying injection of magmas into the deformed rocks, the shales and sandstones were recrystallized into coarse-grained metamorphic rocks called schists and gneisses. In places thin quartzites are common. Gneiss is the most abundant rock type and is composed chiefly of black mica (biotite) layers with light colored layers and lenses of quartz and feldspar. In some of the dark layers white mica muscovite is common. The impure quartzitic layers are fine- to- medium-grained and in places may be more accurately identified as dark-colored quartz-biotite schists. The gneisses are best exposed in the Blue Hills Range east of Parker Mountain, in the Ragged Mountain-New Durham Ridge area, and on Teneriffe Mountain. In places rust-colored pyritiferous schists crop out in the gneiss.

The Jenness Pond member, exposed chiefly in the southern third of the quadrangle, consists of quartz-mica schists, mica schists, andalusite schists, pseudo-andalusite schists and pyrrhotitic schists. Thin beds of coarse-grained quartzite and conglomerate are interbedded with the schists in the vicinity of Jenness and Wild Goose Ponds. The general characteristics of the original sediments which accumulated were very similar to those of the

Pittsfield member. Specific differences would be a higher alumina content in the muds, which contributed to the formation of andalusite, and a more extensive distribution of stagnant bays in which black muds containing high quantities of sulfur and iron accumulated.

In figures 2-6 a series of diagrams illustrates the geologic events which

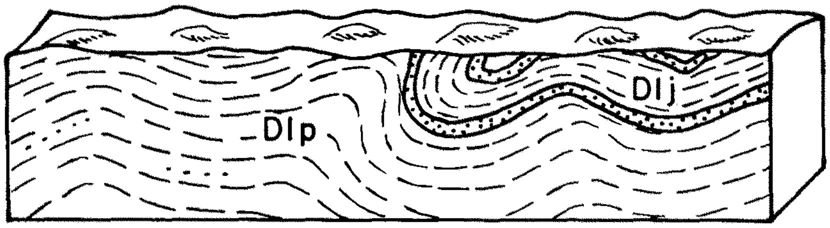


Figure 3. The sedimentary rocks were folded during Middle Devonian time and eroded.

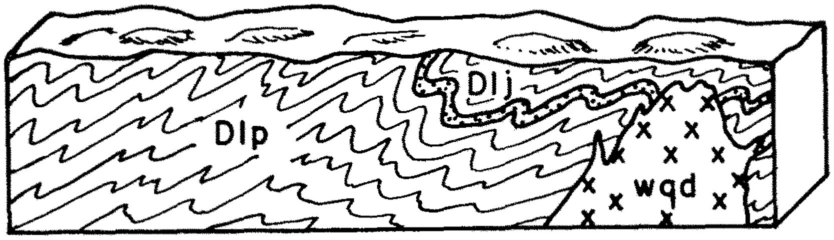


Figure 4. The sedimentary rocks became more intensely folded and were intruded by the binary granite during Late Devonian time. At this time the rocks were recrystallized and became metamorphic rocks.

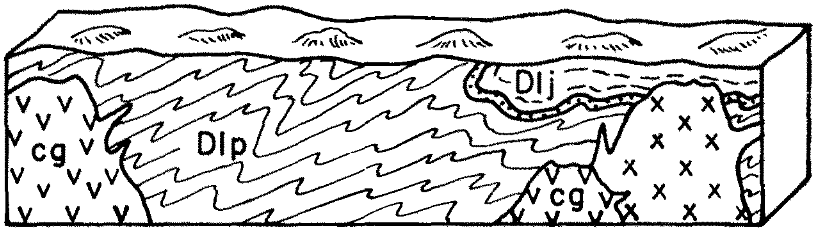


Figure 5. The White Mountain Plutonic Series was intruded during Permian-Triassic time (?).

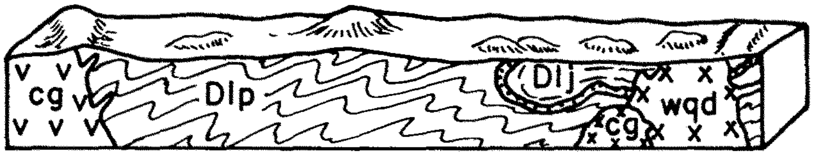


Figure 6. Erosion of the area to present topography.

have occurred in the Alton quadrangle during and following the Devonian period. Thousands of feet of mud and sand must have accumulated in the sea. These sediments accumulated over a period of many millions of years and were slowly changed to sedimentary rocks by compaction and cementation. Ripple marks and mudcracks probably existed in some of the rocks of the Alton Bay area but they have been destroyed during metamorphism. These features indicate that the sea floor subsided very slowly during deposition in shallow water. The nearby land areas which acted as the source of the sediments (see figure 1) are believed to have been elevated steadily to compensate for the gradual subsidence in the areas where sedimentation was taking place. Natural forces in the earth have tried to maintain a balance between the land and sea areas throughout geologic time.

Folding of the Rocks

Another part of our story of the rocks is the period of folding, which commonly occurs in an area where enormous thicknesses of sediments have been deposited. Toward the close of the period of accumulation of sediments pressures developing within the earth's crust tilted and ultimately squeezed these rocks into folds (see figure 3). The size of the folds range from those present in a hand specimen to folds whose crests are several thousand feet apart. The variation in size and continuity of the folds may be a result of differences in the strength of the rocks and variations in the temperature from place to place. In nearly all of the road cuts and outcrops the metamorphic rocks are strongly tilted or highly deformed. In places, the banding in the gneiss and the foliation of the schist have been intricately folded. In some of the outcrops of the Jenness Pond member between the road that crosses Parker Mountain and a point south of Blue Job Mountain the rocks have been so tightly folded and deformed that some of the beds are overturned. In most places all of the folds, regardless of size, have a similar pattern and orientation, indicating that most of the folds were developed by the same deforming forces. The strike and dip symbols on the geologic map indicate the measured attitude of the bedding or the foliation in the metamorphic rocks. A major down-fold, or syncline, occurs at the western and eastern ends of the Jenness Pond member. The cross-sections at the bottom of the geologic map may aid in visualizing some of the folding in the area.

Metamorphism

Many of the original characteristics of the sedimentary rocks were lost during metamorphism. New minerals and new textures developed as the pressure and temperature increased. The appearance of abundant white and black mica, red garnet, andalusite, and sillimanite, to mention a few, are minerals characteristic of metamorphic rocks such as the schists and gneisses. Many of the quartz grains which occurred in the original sediments have been recrystallized into larger grains. Much of the feldspar that occurs in the gneisses may be a result of "granitization" by magma which penetrated and soaked the schists, absorbed some of the minerals, and provided materials for the formation of feldspar.

The older (Pittsfield) member of the Littleton formation had a considerable range in original composition and consisted of muds, sandy muds, muddy sands, and some limy sands. During metamorphism the original sedimentary rocks were transformed into schists, gneisses, impure quartzites, and locally into layers of diopside-actinolite granulites. The most common metamorphic rock is quartz-biotite schist, which may contain varying amounts of muscovite, sillimanite, and garnet. In places muscovite is abundant, and locally at Parker Mountain sillimanite crystals are as much as one and one-half inches long and one quarter of an inch thick. The gneisses are widely distributed but appear to have close areal relations to the igneous rocks. In the central part of the quadrangle the inferred contacts between the metamorphic and igneous rocks are extremely irregular. In places along some of the valleys the igneous rocks appear as finger-like projections into the metamorphic rocks and the contact lines closely parallel the contour lines. These observations may be interpreted as evidence that locally the roof of an igneous pluton may be nearly flat and close to the surface. One might also deduce from this evidence and from their rather indefinite contacts with the plutonic rocks that the gneisses result from soaking of the schists by granitic juices (granitization).

The alternating andalusite, or pseudo-andalusite, schists, and layers of quartzite of the Jenness Pond member are easily distinguished, particularly if the surface exposures have been weathered. If fresh, the andalusite crystals stand out in relief as flesh- to pink-colored crystals. If the andalusite crystals have been altered to quartz or to quartz and muscovite they occur as rough, gray knots. In places chiastolite, a variety of andalusite, occurs with its characteristic internal cross. The schists in which the andalusite crystals are abundant have a matrix with a high content of muscovite. Biotite is common in the quartzitic layers. One of the best exposures of the andalusite crystals is at the new road cut on Route 11 about one and one-half miles north of the Spaulding Turnpike. On the road east of Adams Pond red staurolite crystals are up to one-half inch long and one-eighth inch in diameter. Minute, reddish-brown staurolite crystals have been found with garnets about 150 feet south of U. S. Route 202A and approximately 0.3 miles west of Berry's Corner.

Probably the most unusual mineralization in the Jenness Pond member is the occurrence of strongly magnetic pyrrhotitic schists. The two largest occurrences are between Jenness and Wild Goose Ponds and a narrow belt that extends northeasterly along U. S. Route 202A in the vicinity of Meaderboro Corner. The schists weather rapidly and are stained red to black by the iron oxides formed when the pyrrhotite decomposed. The pyrrhotite occurs abundantly as isolated grains and in minute stringers and lenses which parallel the foliation of the schists. Fresh samples broken from outcrops contain pyrrhotite visible to the naked eye. On a fresh surface it is bronze-colored rather than the yellow which is characteristic of pyrite (fool's gold). It is believed that the pyrrhotite formed during the metamorphism from the muds which accumulated in stagnant pools and contained concentrations of iron and sulfur.

Intrusion of the New Hampshire Plutonic Series

Another major geologic process associated with the accumulation of thick sediments and subsequent deformation and mountain building is the generation of magma at great depths in the deformed belt. During the late stage of folding, magma began to intrude upward along lines of weakness, or to invade the overlying rocks by forceful injection. Some of the magma reached the surface through fractures and flowed as lava. In some places gases were sufficiently abundant in the magma to produce explosive materials which would accumulate in beds or layers or be concentrated into volcanic cones. Evidence for this type of igneous activity occurs in other parts of New Hampshire, but none has been found in the Alton quadrangle. The coarse-grained textures of the plutons in this region indicate that the magma cooled slowly and crystallized at a depth of several thousand feet. The effects of regional compression can be recognized in places where the platy minerals in the igneous rocks closely parallel the strike and dip of the enclosing metamorphic rocks. Geologic investigations in New Hampshire indicate that igneous intrusions may be grouped into four plutonic series. Only two of the series have been recognized in the Alton quadrangle — the New Hampshire and the White Mountain Plutonic Series. The age of the New Hampshire Plutonic Series is believed to be Devonian and the White Mountain Plutonic Series is Permian-Triassic (?) in age.

The New Hampshire Plutonic Series is represented in the Alton quadrangle by six individual plutons. It is possible that one or more may be connected at depth but at the surface they appear to be individual units. A small pluton of quartz diorite occurs in the southeast corner of the quadrangle and has finger-like projections which extend northeasterly and closely parallel the strike of the enclosing metamorphic rocks. The quartz diorite is dark gray, medium-grained, and the principal minerals are feldspar, quartz, biotite, and hornblende. In places this pluton is faintly foliated and spindle-shaped inclusions which range from one-half inch to eight inches in length and from one-quarter to one and one-quarter inches in width closely parallel the foliation. The Winnipesaukee quartz diorite occurs in the northwestern corner in the vicinity of Alton Bay. It is medium-grained, gray, and is composed chiefly of feldspar, quartz, biotite, and muscovite. Plutons of binary granite are present in the Parker Mountain-Bow Lake area in the southwestern part of the quadrangle, in the Mad River section in the central part, and in the Coffin Brook area of Alton. These rocks are light-colored, medium- to coarse-grained, faintly foliated, and are composed chiefly of feldspar, quartz, biotite, and muscovite. Garnets are common in the eastern third of the pluton that surrounds Bow Lake. A medium-grained, light-colored biotite granite has been mapped in the southeastern corner of the quadrangle.

Very coarse-grained, more or less tabular and lens-shaped plutons, called pegmatites, are widely distributed in the quadrangle. They range from hand-specimen size up to bodies many tens of feet long and a few tens of feet wide. Their texture is coarse and some crystals may be measured in feet rather than inches. Only the pegmatite at Parker Mountain mine has been operated for mica, later for feldspar, and recently for mica and beryl.

Intrusion of the White Mountain Plutonic Series

The northern and western boundary of the Alton quadrangle cuts across the outer edges of two large centers of igneous intrusions that have been dated as Permian-Triassic (?) in age and are assigned to the White Mountain Plutonic Series. The Conway granite and granite porphyry in the northwest corner of the quadrangle represent very small segments of larger intrusions that belong to the Pine Mountain-Rocky Mountain center of intrusion in the Gilmanton quadrangle. The Conway granite is commonly a medium-grained, pink granite and is composed of feldspar, quartz, biotite, and hornblende. The granite porphyry is pink to light gray and has large grains of feldspar, quartz, and biotite embedded in a fine-grained groundmass of the same minerals.

Along the northern boundary of the Alton Quadrangle the Conway granite crops out on several of the mountains north of Merrymeeting Lake and along Birch Ridge south of Merrymeeting Lake. Although this pluton of Conway granite does not appear to be connected with the other pluton of Conway granite in the northwest corner of the quadrangle, it has a similar appearance and composition. The contact line of this pluton shows that it is nearly circular in plan and the absence of abrupt changes in direction across the mountains and valleys suggest that the walls may be nearly vertical.

The Wearing Down of the Land

The land area which was once covered by the sea and received thousands of feet of sediments during the earlier part of the Devonian period began to rise again during the period of folding. The sea gradually withdrew and the rocks of this mountainous region became subjected to weathering, and the rocks were broken down by mechanical and chemical processes. Streams became active and removed some of the weathered materials to lower elevations and eventually to the sea. For more than 200 million years the area has been subjected to the processes of weathering and erosion. The accordance of many mountian tops indicates that the New England area was once eroded to a nearly flat plain which has been subsequently elevated as much as several thousand feet in the White Mountain area. The present mountains and valleys are probably not in the same locations as the ones which occurred in the Devonian and Mississippian periods.

In some parts of New Hampshire the mountains and valleys are closely related to the type of bedrock because some mountains are underlain by rocks that are more resistant to weathering and erosion than the rocks in the valleys. Lake Winnipesaukee is underlain by weaker igneous rocks than those cropping out of many of the adjacent groups of mountains. The resistance of the rocks to weathering may be related to the mineral composition, the number and size of the joints (fractures) or both. In the Alton quadrangle correlations between topography and rock type are not easily explained. Two of the higher mountains, Mt. Bet and Mt. Jesse, and part of Birch Ridge are underlain by the Conway granite, but a major depression occupied by Merrymeeting Lake is also underlain by the same rock. A similar relation occurs in the Mad River pluton in the town of Farmington. Lowlands occur throughout most of the areas underlain by granitic plutons. In contrast, however, Whitehouse Mountain and Nubble Mountain are underlain by granite. The Blue Hills Range is underlain by coarse-grained schists and gneisses, with pegmatites more abundant at the highest elevations. Similar schists occur northwest of the Blue Hills Range but the pegmatites are absent or much less conspicuous.

The Great Ice Age

Approximately one million years ago unusual amounts of snow accumulated in northern Canada. Gradually the snow changed to ice, principally by compaction. This change may be observed today during the winter months along the edges of our highways. The snow is plowed into high ridges during the winter and a low ridge of ice remains long after the snow has melted. The thickness of the glacial ice varied from place to place but was several thousand feet thick in New Hampshire and in most of New England. In those places where the ice became sufficiently thick, a slow movement of the ice began. Scratches and grooves on the ice-polished bedrock surfaces indicate that the principal direction of glacial movement was from northwest to the southeast, but in mountain areas some local deflections occurred.

During the accumulation of the snow the soil and mantle material was saturated with water which later became frozen ground. When the ice began to move some parts, or all, of the frozen ground became an integral part of the glacier. Grinding and crushing of the debris occurred as the glacier moved along the bedrock surfaces, and the bedrock surfaces were locally scratched and polished by the rasping action. Along its outer margin, parts of the glacier overrode the heavily loaded bottom ice and here unusual thicknesses of debris-loaded basal ice were formed. When the climate changed and melting of the basal ice began, a mantle of glacial till, called ground moraine, covered the bedrock surface. The till consists of unsorted and subangular boulders, cobbles, and pebbles, mixed with sand and clay. In those places where the basal ice was thickest or where overriding had occurred, elongate and oval hills of till, called drumlins, were formed. Hayes Hill, southeast of Meaderboro Corner in Rochester, the unnamed hills at Strafford Corner, and the hills in the vicinity of Halfmoon Lake are typical drumlins. Unusually large glacial boulders are called erratics.

Where the glacial meltwater became concentrated in depressions on the ice surface or the land, stream drainage systems were developed. These stream systems transported, rounded, and sorted, and finally deposited their glacial rock debris as outwash. These outwash deposits include materials that range in size from clay particles to very coarse gravels, and occasionally boulders. The outwash deposits are grouped according to their form. The outwash that is deposited beyond the ice front as sheets of gravel, sand, and silt are called outwash plains; if ice blocks were buried in the deposit and subsequently melted, pitted outwash plains were formed. Stratified sand and gravel were deposited in places along the irregular ice front as hillocks and knobs and are called kames. Sand and gravel deposits that were formed in ice tunnels or crevasses may, after the ice had disappeared, have formed sinuous ridges called eskers and crevasse fillings respectively. Wherever elongate masses of ice were present in valleys and meltwater streams flowed in depressions between the valley wall and the ice, deposits of sand and gravel may have been deposited to form kame terraces. Examples of these outwash deposits are most conspicuous in the Cocheco Valley southeast of the village of Farmington. The widespread sand deposits in the Big River area of Barnstead are suggestive of deposition in a small lake held temporarily between an ice block and the Blue Hills Range.

Removal of some rock material by glacial erosion, particularly by the quarrying and plucking action of the ice, has accentuated the relief in places. Glacial deposition, on the other hand, has developed additional hills, terraces, and plains in the major valleys, thereby helping to reduce the relief.

AEROMAGNETIC SURVEY

Prior to World War II a physical device known as the airborne magnetometer was developed for geophysical exploration, but during the war it was turned over to the government and used in tracking submerged submarines. Further refinements have been made since the war, and at present the airborne magnetometer is used extensively as one of the principal methods of geophysical prospecting in locating magnetic mineral deposits. The magnetometer, whether used on land or in the air, is designed to measure the vertical magnetic intensity at a particular point, or at many points along a continuous traverse if being carried by plane. The aeromagnetic surveys in New Hampshire have been cooperative projects between the New Hampshire State Planning and Development Commission and the U. S. Geological Survey.

The aeromagnetic map was a useful guide in the geologic mapping of parts of the Alton quadrangle. Anyone interested in this map may obtain a copy from the U. S. Geological Survey, Washington 25, D. C. (see list of references for title). For the interested reader some of the basic principles involved in preparing and interpreting this map are described briefly.

The earth may be compared to a giant magnet with the lines of force directed from one pole to the other. Because the magnetic and geographic poles do not coincide, a compass needle supported on a vertical axis points to magnetic north rather than true north. The angle between magnetic and true north is called magnetic declination. When a compass needle is supported on a horizontal axis it is called a dip needle and it will point downward. This angle between the horizontal and the needle is called the magnetic inclination. By knowing the Pole strength of a particular needle the intensity of the earth's field at any one place can be calculated by formula. This property of total intensity is used in plotting aeromagnetic survey data relative to an arbitrary magnetic datum level.

The theoretical total magnetic intensity for the terrestrial magnetic field can be calculated for every point on the earth's surface. When the data obtained from an aeromagnetic survey are plotted on a map and compared with the theoretical intensity for the terrestrial magnetic field the results are seldom equal because of the magnetic effects of local geological materials. These effects, known as magnetic highs, may be produced by local accumulations of pyrrhotite, a magnetic mineral found in the Jenness Pond member of the Littleton formation in the Alton quadrangle. It is interesting to note that the pyrrhotitic areas had been mapped geologically prior to the aeromagnetic survey, but that the mineral had been incorrectly identified as pyrite. The highs which occur on the aeromagnetic map covering the area of the Alton quadrangle are very closely related to the areas of the pyrrhotite-bearing schist. Several highs which appear on the aeromagnetic map could not be examined because the bedrock is covered by glacial debris. However, these highs do not appear to be as "strong" as those in which direct relationships may be established. Minor variations in magnetic intensity are generally explicable on the basis of differences in depth, size, and concentration of magnetic minerals.

The largest high on the aeromagnetic map is closely associated with the pluton of Conway granite in the northern part of the Alton quadrangle. Joyner (1958, p. 90-98) has also found a pronounced gravity high over this body of Conway granite. He concludes that a denser rock with one or two percent magnetite lies a few thousand feet beneath the Conway granite. This is probably a gabbro similar to that exposed three miles north of Middleton Corners in the Wolfeboro quadrangle.

Highs which are located by aeromagnetic methods should be checked in detail on the ground for possible exposures which may contain concentrations of magnetic minerals of potential economic value. In some places non-magnetic minerals of economic value may be associated with the magnetic minerals.

INTERESTING LOCALITIES

General

Many moments of scenic splendor may be enjoyed by riding along the "back roads" looking at a group of white birches, a stand of neatly pruned pines, a loon or wild duck resting in a secluded pond, a herd of cows grazing on a hillside, a pumpkin patch in full bloom, or even a white ledge of pegmatite speckled with shiny black and white flakes of mica, black tourmaline, and a few red garnets.

With good visibility many excellent panoramic views are possible from most of the mountain summits. Perhaps the most accessible summit is Blue Job in Farmington. It is near the center of the Blue Hills Range and the summit may be reached by walking along a comfortable trail. From the fire tower many distant peaks are visible on a clear day.

Approximately one mile southeast of Strafford and about 2.5 miles west-southwest of Blue Job, a small, but scenic gorge has been cut in the schists and gneisses by the Big River.

Of unusual botanical interest is the virgin stand of rhododendrons on the west side of Adams Pond along the town line between Barnstead and Pittsfield in the southwest corner of the quadrangle.

Geologic

One of the most interesting geologic localities is the Parker Mountain mine located approximately 2.3 miles northwest of the village of Center Strafford and 0.2 miles east of the Parker Mountain road. During World War I the mine was worked for mica, and between 1936 and 1938 feldspar was mined. Recently mica and beryl have been recovered. In addition to the industrial minerals, many collectors have visited this mine to search for rare minerals such as triphylite, graftonite, amblygonite, fairfieldite, columbite, lollingite, cassiterite, autunite, and uraninite, to mention a few.

A pegmatite was prospected on the John Felker property which is located on the road to Blue Job about 2.0 miles northwest of Strafford Corner. No unusual minerals were noted in the small prospect. The Ashton Rollins prospect is about one-half mile north-northwest of the Parker Mountain mine. It is believed that this pegmatite was opened for mica but no records have been found.

A small deposit of idocrase and fluorapatite may be seen about one mile southeast of the Village of Center Strafford on U. S. Route 202A on the northeast side of the road in an abandoned gravel pit.

Andalusite crystals may be collected at several localities on the road east of Wild Goose Pond in the southwestern part of the quadrangle. They may be collected also along the Ten Rod road in Rochester and Farmington, and in a new road cut on State Route 11 about one mile north of the Spaulding turnpike.

Old gold prospects occur about 1.7 miles northwest of Camp Foss on the Willey Ponds in the town of Strafford and about one mile southwest of the village of Farmington and north of the Pokamoonshine Brook.

The pyrrhotitic schist which crops out along U. S. Route 202A east and west of Meaderboro Corner is of considerable interest because the pyrrhotite can be seen only in very fresh specimens. Most of the outcrops have pitted surfaces as a result of rapid weathering of this iron sulfide. Similar outcrops may be seen along the roads in the vicinity of Jenness Pond in the southwestern part of the quadrangle.

Uraninite crystals about one-sixteenth to one-eighth inch in diameter have been collected from a pegmatite that crops out on an unnamed hill about one mile east of Chesley Mountain in Farmington.

Mineral Industries

The only active mineral industries in the Alton quadrangle are sand and gravel operations that are located in the glacial deposits. Most of the sand and gravel that is produced commercially is taken from an esker that occurs about 2.0 miles southeast of the village of Farmington along State Route 11.

Ground water is a valuable commodity and Farmington is supplied by water from the glacial gravels southeast of the village.

In the past and as recently as the summer of 1959 mica was being mined at the Parker Mountain mine, and, for the first time beryl as well. Several hundred tons of feldspar were mined from 1936 to 1938.

Small amounts of "flagstone" (slabs of schists) with large andalusite crystals have been quarried in Farmington and sold for walks and rock gardens.

Peat has been excavated intermittently from a bog northwest of Chesley Mountain in Farmington.

No doubt some of the granite ledges have been prospected and a few blocks quarried but no active quarry has ever been developed.

HOW TO READ THE MAPS

Two maps are folded in the pocket at the end of this pamphlet. One, in green, black, blue, and brown is a 1917 edition of a topographic map of the quadrangle issued by the U. S. Geological Survey and revised in 1957. The second map, in black and white, is the geologic map.

Topographic Map

The use of the topographic map will be discussed first. The scale at the bottom of the map shows that 1 inch is equal to approximately 1 mile on the ground. The culture — i.e., roads, houses, railroads, etc. — is shown as it existed in 1957. Roads are shown by double solid black lines. Poor roads are shown as double, dashed lines. Railroads are shown by solid lines with crossbars. Houses are shown by black squares, schools by black squares with flags, and churches by black squares with crosses. Town lines are shown by dashes 0.2 inches long; county lines are shown by alternating dashes 0.1 and 0.3 inches long. Villages, lakes, and streams are labelled in black.

In order to determine the direction of true north with a compass a correction must be made for declination. In the Alton quadrangle a compass needle will point about 16 degrees west of true north. The direction of true north and magnetic north are shown by a symbol at the bottom of the map. The direction of the long edges of the map is true north-south. It is possible to orient the map properly without a compass by lining up known features shown on the map with the actual features as seen in the field.

Features related to drainage are shown in blue. Small streams are shown by blue lines; larger streams and lakes by two or more blue lines; and marshes by blue tufts.

By studying the brown lines on the map one can determine the varying heights of the land surface. The brown lines are lines of equal elevation called contours. Thus if you were to follow one contour line you would neither go uphill nor down but would remain at the same altitude. The vertical distance between contours is 20 feet. This is known as the "contour interval." The hundred-foot contours are shown in heavy brown and their altitudes are generally marked by small brown numbers. The spacing of the contours indicates the steepness of the slopes. On slopes which are steep the contours are close together, whereas on gentle slopes the contours are far apart. For instance, the steep eastern slope of Parker Mountain in Strafford is indicated on the map by very close spacing of contours. In the flat area along Coffin Brook in Alton, on the other hand, contours are widely spaced. In closed depressions, such as the ones south of the village of Farmington the contours are hatchured.

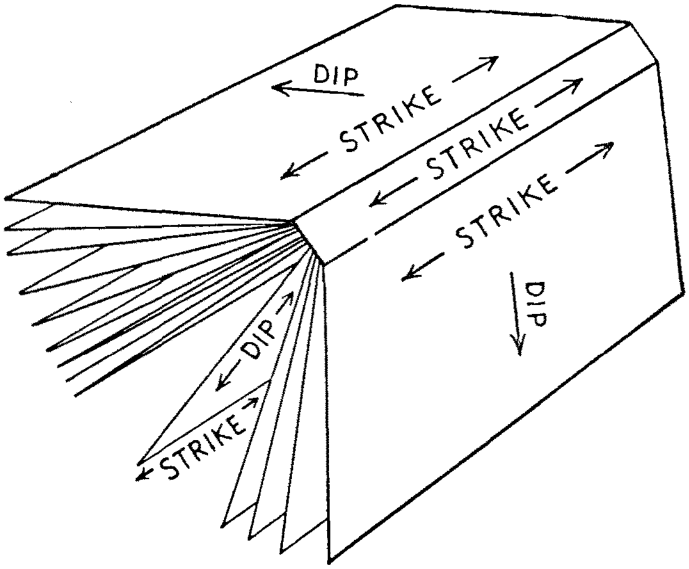


Figure 7. Diagram to illustrate strike and dip.

The altitudes of lakes and some of the hills and road intersections are given in brown numbers. The figure 639 shown on Merrymeeting Lake means that the surface of this lake is 639 feet above sea level. The figure on Prospect Mountain indicates that the elevation of this hill is 1451 feet. Points where elevations have been accurately determined are called bench marks. These are shown by crosses accompanied by the letters "B. M." with the elevations given in black figures.

Geological Map

On the black-and-white geological map the rocks underlying the entire quadrangle are shown. Actual exposures of rock may be seen only under a small percentage of the area. Elsewhere, solid rock is covered by a veneer of loose glacial deposits or stream deposits which may range in thickness from a few feet to perhaps 100 feet or more. The geological map shows, therefore, not only what the geologist sees but also what he infers about the rocks beneath the loose overlying material.

Each formation is shown by a separate symbol. To facilitate the comparison with the legend (on the right side of the map) letter symbols are also used. The legend is not only a key to the various formations but also shows the relative age of the rocks, with the youngest at the top. For a more detailed description of the rocks, the reader should refer to Table 2. For example, the Conway granite which crops out along the northern edge of the quadrangle is marked by a regular pattern of v's and is labelled cg. Reference to Table 2 indicates that the Conway granite is a medium-grained, pink granite composed of microperthite (a feldspar), quartz, oligoclase (another feldspar), biotite and hornblende.

Two structure sections are given at the bottom of the map. These sections show how the rocks would probably look along the walls of deep trenches across the area. The locations of the sections on the map are shown by lines labelled A-A' and B-B'. From these sections the probable relationship between the folded metamorphic rocks of the Littleton formation and some of the intrusions of the New Hampshire and the White Mountain Plutonic Series may be seen. The folds shown in these sections are not intended to be accurate in detail but to portray the general nature of the folding. Sections A-A' shows that near the contact between the Pittsfield and Jenness Pond members of the Littleton formation the southern limb of the anticline, or up-fold, has been overturned. Surface observations indicate that the igneous intrusions were not folded and this fact is depicted in both sections. The age relationships of the igneous intrusions of the plutonic series do not show in the sections but they may be observed in the northwest corner of the map where the younger Conway granite has intruded the older Winnipesaukee quartz diorite. The fact that these igneous rocks are not folded indicates that they were intruded after the period of deformation.

The strike and dip symbols on the map show the attitude of the layering in the rocks. The meaning of strike and dip may be explained by showing how the terms would be used to indicate the attitude of the roof of a house. The strike of the roof would be the direction of the ridge pole. Or, in general, the strike of a plane surface is the direction of the line formed by the intersection of the surface and a horizontal plane. The dip of the roof would be its inclination or pitch. The strikes and dips of the beds which have different attitudes can be visualized by placing a partially open book on a table so that it resembles the roof of a house (figure 7). In this case the strike of all pages would be the same — the direction of the binding. The dips of the pages in the book would be analogous to successive layers of rock having different dips. The longer straight line of the symbols on the map represent the strike and the arrow, or shorter line at right angles is the direction of the dip. An arrow pointing to the east, for instance, indicates that the bed is inclined downward toward the east. The numbers at the ends of the arrows show the amount of dip in degrees. A small number would indicate a gentle inclination and a large number would mean the beds were nearly vertical. If beds are overturned so that the original top surfaces downward, the special symbol given in the legend is used.

REFERENCES

General Geological Books

1. Billings, M. P., 1954, *Structural Geology,* 2nd. Ed. Prentice-Hall, New York.
2. Fenton, C. L. and M. A. Fenton, 1940, *The Rock Book.* Doubleday-Doran, New York.
3. Gilluly, J., Waters, A. C., and Woodford, A. O., 1959, *Principles of Geology,* 2nd. Ed. W. H. Freeman and Company, San Francisco, California.
4. Grout, F. F., 1942, *Kemp's Handbook of Rocks,* 6th. Ed. D. Van Nostrand Company, New York.
5. Leet, L. D. and S. Judson, 1958, *Physical Geology,* 2nd. Ed. Prentice-Hall, New York.
6. Moore, Ruth E., 1956, *The Earth We Live On.* Alfred A. Knopf, New York.
7. Pough, F. H., 1955, *A Field Guide to Rocks and Minerals,* 2nd. Ed. Houghton-Mifflin Company, Boston.

Alton Quadrangle and Adjacent Areas

8. Bromery, R. W., Zandle, G., and others, 1956, *Aeromagnetic Map of the Alton Quadrangle, New Hampshire:* U. S. Geol. Survey Map GP 136.
9. Bromery, R. W., Zandle, G., and others, 1956, *Aeromagnetic Map of the Berwick Quadrangle, Maine and New Hampshire:* U. S. Geol. Survey Map GP 137.
10. Billings, M. P., 1956, *The Geology of New Hampshire; Part II, Bedrock Geology:* New Hampshire Planning and Development Commission, 203 p. Map.
11. Freedman, J., 1950, *Stratigraphy and Structure of the Mt. Pawtuckaway Quadrangle, Southeastern New Hampshire:* Bull. Geol. Soc. America, v. 61, p. 449-492.
12. Goldthwait, J. W., Goldthwait, L., and Goldthwait, R. P., 1951, *Geology of New Hampshire, Part I, Surficial Geology:* New Hampshire Planning and Development Commission, 83 p. Map.
13. Goldthwaite, J. W., 1925, *The Geology of New Hampshire:* New Hampshire Academy of Sci. Handbook No. 1.
14. Heald, Milton T., 1955, *The Geology of the Gilmanton Quadrangle, New Hampshire:* New Hampshire Planning and Development Commission.
15. Hitchcock, C. H., 1874, 1877, 1878, *Geology of New Hampshire:* 3 volumes and Atlas, Concord, New Hampshire.

16. Joyner, W. B., 1958, *Gravity in New Hampshire and Adjoining Areas,* 126 pages, doctoral thesis, Harvard University.
17. Katz, F. J., 1917, *Stratigraphy of Southwestern Maine and Southeastern New Hampshire:* U. S. Geol. Survey Prof. Paper 108, p. 165-177.
18. Meyers, T. R., and Stewart, Glenn W., 1956, *The Geology of New Hampshire, Part III, Minerals and Mines:* New Hampshire Planning and Development Commission.
19. Meyers, T. R., and Bradley, Edward, 1960, *Suburban and Rural Water Supplies in Southeastern New Hampshire, Part XVIII, Mineral Resources Survey:* New Hampshire Planning and Development Commission.
20. Modell, David, 1936, *Ring-dike Complex of the Belknap Mountains, New Hampshire:* Bull. Geol. Soc. America, v. 47, p. 1885-1932.
21. Quinn, A., 1944, *Magmatic Contrasts in the Winnipesaukee Quadrangle, New Hampshire:* Bull. Geol. Soc. America, v. 55, p. 473-496.
22. Quinn, A., 1941, *The Geology of the Winnipesaukee Quadrangle, New Hampshire:* New Hampshire Planning and Development Commission.
23. Quinn, A., 1953, *The Geology of the Wolfeboro Quadrangle, New Hampshire:* New Hampshire Planning and Development Commission.
24. Quinn, A., and Stewart, Glenn W., 1941, *Igneous Rocks of the Merrymeeting Lake area of New Hampshire:* Am. Mineralogist, v. 26, p. 633-645.
25. Stewart, Glenn W., 1939, *Vesuvianite and Fluorescent Apatite from Center Strafford, New Hampshire:* Am. Mineralogist, v. 24, p. 274-275.

PUBLICATIONS
of the
N. H. STATE PLANNING AND DEVELOPMENT COMMISSION

All Geological publications are allowed a discount of 20% if purchased in quantities of 10 or more of the same publication.

GEOLOGY

The Geology of New Hampshire. Part I. Surficial Geology. James W. Goldthwait, Lawrence Goldthwait, Richard P. Goldthwait. 1951. 83 p. Surficial Geology map (Scale 1″ = 4 miles) in pocket. $1.50.

The Geology of New Hampshire. Part II. Bedrock Geology. Marland P. Billings. 1956. 203 p. Bedrock geology map (Scale 1″ = 4 miles) in pocket. $3.50.

The Geology of New Hampshire. Part III. Minerals and Mines. T. R. Meyers and Glenn W. Stewart. 1956. 107 p. Map. $1.50.

Geology of the Franconia Quadrangle. Marland P. Billings and Charles R. Williams. 1935. 35 p. illus. Map. 50 cents.

Geology of the Littleton and Moosilauke Quadrangle. Marland P. Billings. 1935. 51 p. illus. Maps. 60 cents.

Geology of the Mt. Cube and Mascoma Quadrangles. Jarvis B. Handley and Carleton A. Chapman. 1939. 28 p. illus. Maps. 60 cents.

Geology of Mt. Chocorua Quadrangle. Althea Page Smith, Louise Kingsley, Alonzo Quinn. 1939. 24 p. illus. Map. 50 cents.

Geology of Winnipesaukee Quadrangle. Alonzo Quinn. 1941. 23 p. illus. Map. 50 cents.

Geology of the Cardigan and Rumney Quadrangles. Katharine Fowler-Billings and Lincoln R. Page. 1942. 31 p. illus. Maps. $1.00.

Geology of the Mt. Washington Quadrangle. Marland P. Billings, Katharine Fowler-Billings, Carleton A. Chapman, Randolph W. Chapman, Richard P. Goldthwait. 1946. 56 p. illus. Maps. $1.00. Out of print.

Geology of the Plymouth Quadrangle. Charles B. Moke. 1946. 21 p. illus. Map. $1.00.

Geology of the Bellows Falls Quadrangle. Frederick C. Kruger. 1946. 19 p. illus. Map. $1.00.

Geology of the Keene-Brattleboro Quadrangle. George E. Moore, Jr. 1949. 31 p. illus. Map. $1.00.

Geology of the Monadnock Quadrangle. Katharine Fowler-Billings. 1949. 43 p. illus. Map. $1.00.

Geology of the Percy Quadrangle. Randolph W. Chapman. 1949. 38 p. illus. Map. $1.00.