STATE GEOLOGICAL AND
NATURAL HISTORY SURVEY
OF CONNECTICUT

THE GEOLOGY OF THE NEW PRESTON QUADRANGLE

With Map

Open Map

By

DR. ROBERT M. GATES and WILLIAM C. BRADLEY

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State Geological and Natural History Survey of Connecticut

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THE GEOLOGY OF THE NEW PRESTON QUADRANGLE

With Map

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by

DR. ROBERT M. GATES

and

WILLIAM C. BRADLEY

ABSTRACT

The principal rock units of the New Preston quadrangle are 1) the Waramaug formation, 2) the Stockbridge marble, 3) the Hartland formation, 4) the Mt. Tom hornblende gneiss, and 5) the rocks of the Mt. Prospect intrusive complex. The Waramaug formation is proposed as a new name for the rocks in this quadrangle hitherto described as the Berkshire schist. The Waramaug formation is thought to be unrelated to rocks of the Berkshire schist in other parts of Connecticut. The Stockbridge marble and the Hartland formation are considered part of the quartzite-limestone-schist sequence found at many places in western Connecticut, Massachusetts, and eastern New York. The suggestion is made that the Hartland formation should be correlated with the Salisbury schists, the Canaan Mountain schist, and possibly, with the Hudson River pelites west of Harlem Valley.

The structural relations of the Waramaug formation to the Stockbridge and Hartland formations are explained as due to compressional forces operating in a northwest-southeast direction. These have thrust up the Waramaug block and have isoclinally folded and overturned the Stockbridge and Hartland formations to the southeast.

The staurolite-cordierite-magnetite facies of the Hartland formation is considered to be the result of hydrothermal metamorphism by the Mt. Tom hornblende gneiss This involved a local migration and accumulation of mafic constituents.

The Mt. Tom hornblende gneiss was intruded into the Waramaug and Hartland formations and the dioritic gneisses of the Mt. Prospect intrusive complex after or during the last stages of deformation. Its gneissic structure is thought to have developed during emplacement and to be in part inherited from the schists.

The topography of the New Preston quadrangle is in part rock-controlled, in part drift-controlled. The role of plucking in glacial erosion, set off against variations in bedrock lithology and structure, is the key to the development of the bedrock topography. Striae and drumlins indicate that the last major ice advance in this area was in a direction S2OE, with a minor fluctuation to S2E. Several drainage changes have resulted from the glaciation. Crevasse-fillings, eskers, and kame terraces indicate mass stagnation of the ice.

Part I

THE BEDROCK GEOLOGY

by

ROBERT M. GATES

INTRODUCTION

Two topics of special interest were studied in the New Preston quadrangle—1) the relationship of the Berkshire formation (Waramaug formation of the present report) to the Hartland formation, and 2) the nature of the Mt. Tom hornblende gneiss. The New Preston quadrangle was considered especially suited for this study because it is one of the few places where the Hartland and the supposed Berkshire formations are known to be in close proximity for a favorable distance. Furthermore, although rocks similar to the Mt. Tom hornblende gneiss are found at many places in the Hartland formation in other quadrangles to the northeast and southwest and in the Berkshire formation and the dioritic gneisses of the Mt. Prospect complex, study of the hornblende gneiss in this area is facilitated by its abundance and by the extensive outcrops of the contiguous formations.

The New Preston quadrangle is situated in the Western Connecticut Highlands, which are the southern end of a larger physiographic province, the Green Mountain Plateau. The Western Connecticut Highlands are bounded on the east by the Connecticut Valley and on the west by the Housatonic lowlands. The regional distribution of the two principal formations, the Berkshire and the Hartland, may best be considered in relation to the Green Mountain axis. The Green Mountains enter Massachusetts as the Hoosac Mountains, which maintain a north-south trend into the Norfolk Hills of Connecticut. From the Norfolk Hills the Green Mountain axis passes diagonally across the northwest corner of Connecticut through a series of hills, Barrack Mountain and Cream and Sharon hills, and enters New York just north of the most westerly bend of the Housatonic River. The New Preston quadrangle is located approximately ten miles east of this westerly swing of the Housatonic River and is, therefore, on the east side of the Green Mountain axis.

We mapped the entire quadrangle with the exception of the northeast corner for the Connecticut Geological and Natural History Survey during the summer of 1950 using preliminary United States Geological Survey topographic maps on a scale of 1:20,000 as base maps. Mr. William C. Bradley mapped the glacial features while assisting the senior author with the bedrock geology (see Part II of report). Dr. E. N. Cameron (1951) mapped and described the Mt. Prospect complex and has graciously permitted us to use his maps in the preparation of the accompanying geologic map of the New Preston quadrangle.

The writers gratefully acknowledge the financial support of the Connecticut Geological and Natural History Survey in the field and in the preparation of the report and appreciate the continued interest of its Director, Dr. Edward L. Troxell, in the detailed remapping of western Connecticut. Special thanks are due to Drs. R. C. Emmons, E. N. Cameron and S. A. Tyler for much helpful discussion during the preparation of the report and for useful criticism of the manuscript.

PREVIOUS WORK IN THE AREA

There has been little work done in this quadrangle since Rice and Gregory's Manual of the Geology of Connecticut was published in 1906. Agar (1927) studied the northeastern section in some detail in conjunction with the construction of the Shepaug Aqueduct Tunnel. He also collaborated with Balk (1936) in the preparation of a map which includes the western part of the quadrangle. Cameron's report (1951) on the Mt. Prospect complex has already been mentioned. Agar's published papers (1929, 31, 32 and 34) on the geology of western Connecticut have been of considerable help in relating the various formations on a regional scale. Moore (1935) mapped the narrow marble tongue lying between the Hartland and Waramaug formations as part of his study of the limestones and marbles of Connecticut.

GENERAL GEOLOGY

The principal rock units in the New Preston quadrangle from oldest to youngest are 1) the Waramaug formation, 2) the Stockbridge marble, 3) the Hartland formation, 4) the Mt. Tom hornblende gneiss, and 5) the Mt. Prospect intrusive complex. Granites and granitic gneisses range in age from pre-Cambrian to the youngest intrusives. The Waramaug formation occupies most of the northern half of the quadrangle; the narrow marble belt bounds it on the south; and the Hartland formation extends across the southern half of the quadrangle. The Mt. Tom hornblende gneiss is found mainly in the Hartland formation, but also occurs in the Waramaug formation and other rocks. The older granites are restricted to the Waramaug formation, but the younger granites are found in all formations. The Mt. Prospect complex occupies the northeast corner of the area.

The west flank of the Green Mountains in Massachusetts is composed of a series of formations—the Dalton gneiss, Cheshire quartzite, Stockbridge limestone, and the Berkshire formation. These formations maintain their position on the east side of the Green Mountain anticlinorium down into Connecticut, where the Berkshire is thought (Agar, 1927) to lap over the axis and come into contact with the Hartland formation in the vicinity of Litchfield and also west of Mt. Tom.

The name Waramaug has been substituted for those rocks in this quadrangle previously called Berkshire, for the following reasons. The name "Berkshire formation" has been used extensively in the past for a wide variety of rock types that have since been shown to be separate units. These rocks include the Hudson River pelites (Balk, 1936), the Hudson River slates metamorphosed north and east of the Hudson River Highlands, and the rocks of the Taconic Mountains. Agar (1932) gave the name Salisbury schists to the rocks of the Berkshire formation occurring at the southern end of the Taconic range (Indian Mountain, Mount Riga, Bear Mountain, and Mount Everett) and in the schist ridges which rise above the Stockbridge marble in the Housatonic Valley. Also, whereas Agar (1927, p. 26) had at first considered the Berkshire in the Shepaug Reservoir area as "... almost certainly a continuation of the Canaan Mountain rock...", he later (1934, p. 363) questioned the correlation and preferred to reserve judgement on it. The name Waramaug is assigned temporarily to the rocks called the Berkshire formation in the New Preston quadrangle which do not correspond to most of the rocks previously or presently called Berkshire. The name Waramaug was chosen because of the occurrence of typical rock types around Lake Waramaug. This name can be abandoned as soon as these rocks are definitely correlated with other established units. The Waramaug formation discussed below is known to correlate with the gneisses around Mohawk Mountain and along the west side of the Torrington quadrangle.

The marble occurring in the narrow tongue from New Milford to Woodville cannot be dated definitely or correlated with the Stockbridge limestone in Massachusetts, but it seems to be the same formation (Moore, 1935). Lithologically it is quite similar to marbles in the Housatonic Valley in Massachusetts and northern Connecticut as well as that in the Harlem Valley in New York.

The Hartland formation extends in a nearly continuous belt of irregular width along the eastern side of the Green Mountains from Vermont through Massachusetts, where it is known as the Hoosac and/or Rowe schist, into Connecticut near Hartland and from there southward and westward to Long Island Sound.

Broadly viewed, the Hartland formation lies on the east flank of the Green Mountain axis, and the Poughquag quartzite, Stockbridge limestone, and Hudson River pelites (Berkshire) lie on the west flank in a regional north-northeast trend. The Hartland formation in the Litchfield and New Preston quadrangles is interpreted here as overturned to the southeast, and the formations on the west side of the axis in northwestern Connecticut are generally considered to be overturned or overthrust to the northwest. Numerous small pre-Cambrian blocks are found as inliers in the Paleozoic rocks between the major pre-Cambrian highlands (Balk, 1936).

The Mt. Tom hornblende gneiss is a mafic dioritic intrusive which cannot be correlated definitely with other gneisses, but is probably related to the many hornblendic bodies throughout western Connecticut. It occurs mainly as dikes, sills, and lenses in both the Waramaug and Hartland formations.

General Statement

The general interpretation of the sequence of geologic events presented here is based largely on the writer's detailed mapping in the Torrington, Litchfield, Woodbury, and New Preston quadrangles. The Waramaug mica quartz gneisses and mica quartzites, the granitic gneisses, and pegmatites are considered the pre-Cambrian basement upon which the Cambro-Ordovician Stockbridge limestone and Hartland formation were deposited. The dates of deformation and intrusion are not revealed in this area and consequently, only the post-Hartland orogeny is known. After the deposition of the Hartland formation and probably before major deformation, the dioritic rocks of the Mt. Prospect complex were intruded between the Waramaug and Hartland formations as indicated by the comparable metamorphism of the dioritic rocks and the Hartland (Cameron, 1951). The Stockbridge marble and the Hartland formation were isoclinally folded and overturned toward the southeast before further intrusions. A border foliation of the Waramaug probably developed at the same time. The Mt. Tom hornblende gneiss was injected mainly along the pre-existing foliation planes in the Hartland formation, but locally into fractures which cross cut the foliation. The intrusions took place during and after the last stages of the isoclinal folding.

Still later (Devonian ?) granites, granitic gneisses, and pegmatites, probably related to the Woodbury granite, intruded all these rocks in relatively minor amounts. These granites and pegmatites show a little evidence of minor deformation. The norites and younger basic intrusives making up the Mt. Prospect complex are the youngest rocks in the area and are probably to be correlated with the Cortland series intrusives. These rocks and their relations to one another will be discussed below.

Discussion of Rock Types

THE WARAMAUG FORMATION

General Statement. The mica-quartz gneisses and mica quartzites comprising the Waramaug formation as herein designated are known to extend from the region around Goshen and Mohawk Mountain in the Cornwall and West Torrington quadrangles (north and northeast of the New Preston quadrangle) southward into the New Preston quadrangle. It probably extends northward from the Goshen area to the Connecticut-Massachusetts state line and southwestward from the New Preston area in a narrow tongue almost to New Milford. In the New Preston quadrangle it borders the Mt. Prospect complex on the north and west and from there swings westward across the northern half of the quadrangle. On the western border it joins a highland range called "pre-Cambrian undifferentiated" by Balk and Agar (1936). It must be emphasized that the rock here called Waramaug (formerly Berkshire) is not considered to be the same as the schists and gneisses in the northwest corner of Connecticut (Salisbury and Canaan Mountain schists, Agar, 1932, 1933) or those in eastern New York which are known to overlie the Stockbridge marble.

Although direct relationships between the Waramaug and the Stockbridge and Hartland formations cannot be observed, the Waramaug formation is considered much older than the other formations, and is probably pre-Cambrian. This conclusion was reached largely from the evidence that its structural and metamorphic history is much more complex than that of the other formations.

Waramaug Rock Types. The only two rock types sufficiently distinctive and extensive to warrant separate description are 1) a coarse, mica-quartz gneiss and 2) a gray, mica quartzite with streaks of biotite. The rock types are quite varied in texture and in the proportions of the various minerals, but mineralogically are relatively simple. The essential minerals are quartz, plagioclase, muscovite, and biotite. Garnet is almost invariably present. Other minerals commonly present in minor amounts are microcline, epidote, zoisite, sillimanite, magnetite, and apatite. Kyanite, staurolite, and titanite are occasionally observed. Many variations of both rock types are found particularly where the formation is intruded by pegmatites and granitic materials.

Mica-Quartz Gneiss: The typical mica-quartz gneiss is best exposed along the high ridges north of Highway 25 from Woodville to Marbledale. The rock at the road cut at Woodville is fairly typical except that it is more finely gneissic than most. Similar types, but with much less uniform foliation, occur around Wyantenock State Forest and in the region northward from Lake Waramaug. In the northwest section where the foliation in most outcrops is partly transposed, the rock appears very homogeneous. On weathered, glaciated outcrops the micaceous bands stand up in relief giving a rough corrugated surface typical of this member of the Waramaug formation (Plate I, fig. A).

Petrographic examination of this rock shows a wide range of textures and compositions best described as gneissic and composed essentially of quartz and biotite with lesser but varying amounts of muscovite, plagioclase, microcline, garnet, and epidote. The mica-rich bands range from less than one-tenth inch to one-half inch in width. The approximate range in composition is:

Quartz	50–85%
Biotite	10–35%
Muscovite	0–15%
Plagioclase	5–20%
Potash feldspar	0– 5%
Garnet	0– 5%
Epidote Sillimanite Staurolite	0– 2%

The gneissic structure is due primarily to the parallel orientation of the biotite and to a less extent to the parallel orientation of the quartz. The quartz grains have a wide range of size, but most are roughly equidimensional. Only in a few thin sections does the quartz show severe strain shadows or have an elongate form. The biotite, strongly pleochroic in dark brown and pale yellowish green, occurs along grain boundaries and in the interstices of the quartz grains. The biotite is bent and ragged in outline only around augen of garnet and sillimanite (fibrolite). The plagioclase ranges in composition from place to place generally within the limits of oligoclase. Most of it is in well twinned, anhedral grains interstitial to the quartz. Only a few specimens have zoned plagioclase. Microcline is nowhere abundant, but seems to be most common in cataclastic zones. A cataclastic texture, though seen in several thin sections, is not characteristic of the rock. The sillimanite needles occur in felted aggregates around augen, where deformation was most intense. Highly contorted biotite is associated with the garnet-quartz-sillimanite knots. Figure B of Plate I shows a typical augen of quartz-garnet-biotite-sillimanite. Epidote and zoisite give ample evidence of the contact and hydrothermal metamorphism everywhere present.

Mica Quartzite: The more quartzitic type of Waramaug is well exposed around Mt. Bushnell and south and west of Lake Waramaug. This variety of mica quartzite can be traced from Mt. Bushnell eastward along the north side of the Pinnacle to Rabbit Hill. More quartzitic types are common between Above All State Park and Warren. In hand sample the rock appears to be a quartzite that contains irregular streaks of biotite and various amounts of feldspars. The essential minerals are quartz, oligoclase, and biotite. Epidote, apatite, and garnet are usually present and titanite and sillimanite less commonly so. The amount of feldspar ranges from about 5% up to 50% as the mica quartzite grades into granite gneiss. A modal analysis of the rock is as follows:

Quartz	50–90%
Biotite	2–10%
Plagioclase	2–20%
K Feldspar	5–30%
Epidote Apatite Titanite	2– 3%

The gneissic structure is not readily apparent microscopically because the biotite is neither abundant nor well oriented. The banding is due to quartzitic layers alternating with quartz-feldspar layers. The quartz layers are relatively free of other minerals, the bulk of the biotite and of the accessories occurring in the feldspathic zones. The quartz and feldspar grains range in size from less than 0.1 mm. to more than a centimeter. The texture of the individual bands is best described as xenomorphic granular. There is some evidence of cataclasis, but generally neither quartz, feldspar, nor biotite show signs of strain. The biotite in the more feldspathic quartzite is strongly pleochroic, ranging from green to colorless, in contrast to the brown biotite in the mica-quartz gneiss. Also, the biotite is in well formed flakes instead of ragged, irregular aggregates as in the gneiss. The mica quartzite seems to have been injected in various degrees by feldspathic material, sodic in the formation generally, but predominantly potassic in the granite gneiss areas. The gradation between the mica quartzite and the granite gneiss will be discussed in the following section.

Petrographic as well as field study indicates that the Shepaug Reservoir is an area of more than average structural activity. The Waramaug formation in this vicinity is a very complex mixture of mica-quartz gneisses and feldspathic mica quartzites all highly injected and cut by granites and pegmatite dikes. Mortar structure, granulation, and undulatory extinction of many minerals are common features of these rocks. It is the area where the regional trend of the Waramaug changes abruptly as it borders the dioritic gneiss and the norite intrusive complex of Mt. Prospect.

In summary, the principal rock types of the Waramaug formation are mica quartzites and mica-quartz gneisses which contain normally about 10% plagioclase and lesser, indefinite amounts of garnet, epidote, sillimanite, staurolite, and apatite. All types are injected and intruded to a greater or less extent by granites, pegmatites, and granitic materials. The amount of injection is generally indicated by an increase in the potash feldspar content and the elimination of some of the metamorphic minerals.

Structure. All evidence of bedding has been completely obliterated. The only usable structural feature of the Waramaug formation is its foliation and even that is significant only locally. Although recognizable lithologic rock types are present and probably represent different sedimentary members, nowhere can they be traced far enough to indicate any major structures.

The foliation of the Waramaug, wherever reasonably uniform in an outcrop, has been plotted on the accompanying map. Along the southern border it is exceptionally uniform in attitude and parallel to the strike of the Stockbridge and Hartland formations, but is consistently vertical in contrast to them. It is roughly parallel to the borders of the Mt. Prospect complex. Elsewhere the foliation is so varied locally as well as areally that its relation to any simple structural history is not obvious.

Many features of the foliation indicate that the Waramaug formation has undergone at least two and possibly more stages of deformation. Except along the borders, an earlier foliation appears to have been folded, crumpled, or transposed. The earlier foliation is considered to be represented by the biotite-rich streaks and layers. These layers almost invariably have small-scale crenulations. In many outcrops the biotite folia occur in large folds and swirls. Some of the folds are dragged out and breached at the crests and troughs. In the northwest corner of the area partial transposition of the biotite folia has essentially destroyed the gneissic structure. The later shear plane, which cuts the earlier foliation plane at nearly right angles, has sliced up and drawn out the biotite folia into discontinuous 'Z' shaped streaks. The rock now appears massive rather than gneissic. Further evidence for two or more stages of deformation is presented in the section on granites and related rocks associated with the Waramaug formation.

The development of exceptionally good and uniform foliation along the borders and its absence elsewhere are explained most simply by considering the Waramaug as part of an upthrust block with the border foliation developing during upthrusting. The development of this type of foliation has been described and illustrated by Balk (1936).

Granites, Granitic Gneisses, and Pegmatites in the Waramaug Formation. Granitic rocks are quantitatively an important part of the Waramaug formation in certain areas but are essentially absent in others. They all are composed primarily of quartz, microcline, and sodic plagioclase with small amounts of muscovite, biotite, garnet, and the usual accessories. The rocks of the Waramaug formation which are not extensively injected by granitic dikes and sills do, however, contain moderate quantities of granitic materials, mainly feldspars.

The granites which intrude the Waramaug are distinguished mainly by lithology and their degree of metamorphism. The recognizable types are 1) an old, highly sheared and metamorphosed granite, 2) granitic gneisses, not deformed (Becket?), and 3) granites that are correlated with the Woodbury granite occurring in the Woodbury quadrangle (Thomaston granite, Agar, 1934)[1]. The highly metamorphosed granites and pegmatites intimately mixed with the Waramaug formation are apparently the oldest intrusives. The intermixing of the granites, pegmatites, and schists and the development of boudinage structures from some of the sills are due in large part to deformation following intrusion and consolidation. The area around the Shepaug Reservoir contains the greatest concentration of this old granite. The abundance of granitic material is at once evident from traverses along the hills surrounding the reservoir. Also Agar (1927) measured 600 feet of pegmatites in the first 3000 feet of the aqueduct tunnel exclusive of the small pegmatites only a few inches wide. The sediments around the intrusives have been granitized on a local scale.

Much of the confusion concerning the granites of western Connecticut arises from the difficulty of distinguishing a granite primarily of magmatic origin from one produced by granitization of sediments. Granites and granitic gneisses of metamorphic origin are likely to reflect the textural and mineralogical variations of the original sediments and hence may be quite varied in lithology. Also, granitic gneisses intruded by massive granite may be sediments metamorphosed by contact with the massive granite. Thus, despite intrusive relationships, the granite and granitic gneiss may be considered essentially of the same age, or at least phases of the same intrusion.

This seems to be the case in the two granite gneiss areas in the New Preston quadrangle. The granite gneisses around Town Hill on the northern border and between New Preston Hill and Marbledale

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[1] The type occurrence of the Woodbury granite is in the northern half of the Woodbury quadrangle west of Watertown. It is intrusive into the Hartland formation and is empirically associated with many granitic gneisses. Agar (1934) has referred to the granite and the granite gneisses as the Thomaston granite. The name Woodbury is restricted here to the intrusive granite and excludes the granitic gneisses. (*Ref. Litchfield Quad. Report.*)

along the western border are thought to be mainly granitized mica quartzites of the Waramaug formation. A few dikes and sills of a granite identical to the Woodbury granite are found in these areas and may have the same relationship to the granite gneisses as that described in the above paragraph. The granite gneiss at Town Hill was called Thomaston granite (Agar, 1929) and later changed to Becket (Agar, 1934). The granite gneiss exposed on New Preston Hill, which is the northeast tip of the Sharon Mountain quartz diorite (Agar, 1934), is very similar to the granite gneiss at Town Hill except in color. Therefore, for the present it seems advisable to map both of these areas simply as a granitic gneiss which is younger than the highly sheared granites of the Shepaug Reservoir area and older than or related to the granite dikes and sills (Woodbury) which cut it. The relations of the granite gneisses, the Woodbury-type granite, and the Waramaug formation will be discussed below.

On the hill 4000 feet west of Town Hill where the Waramaug, the granite gneiss, and the granite of the Woodbury type are found in contact, the Waramaug mica-quartz gneiss predominates with the granite and granite gneiss occurring as sill-like injections. The Woodbury-type granite and pegmatite have clearly intruded the Waramaug formation, but the granitic gneiss bands could be granitized layers of the Waramaug. The foliation of the granite gneiss and the contiguous Waramaug formation is everywhere parallel. Although the granite gneiss may be an injected granite or a sediment granitized during an earlier period, it is just as probable that it is genetically related to the Woodbury-type granite intrusion.

The granite gneiss around Town Hill differs from the gneiss on New Preston Hill primarily in its texture. It is generally considered a biotite granite gneiss even though the amount of sodic plagioclase in many places exceeds that of microcline. The essential minerals are quartz, microcline, sodic plagioclase, and biotite. Minor constituents are epidote, apatite, muscovite, and zircon. The most distinctive textural features are myrmekitic intergrowths of quartz and plagioclase along zones of apparent granulation and the replacement of microcline by plagioclase, or less commonly by quartz. Agar (1934, p. 375) used these features to distinguish the Becket granite gneiss from other granitic intrusives. The amount of granulation is difficult to determine due to development of myrmekite and to replacement, but it probably was not great. Large crystals of microcline show no signs of crushing and biotite commonly occurs in euhedral, undeformed flakes. The gneissosity was probably largely inherited from the Waramaug formation.

Better outcrops and a more continuous section between the granite gneiss and the Waramaug mica quartzite are found along the western border between New Preston Hill and Marbledale. An essentially complete gradation exists across strike between a gray, slightly feldspathic mica quartzite and a medium-grained, gneissic quartzose granite. The structure changes very little in the passage from the mica quartzite into the granite gneiss. Both have feldspathic bands alternating with quartzitic ones, the bands ranging in width from microscopic to one-quarter inch. The granite gneiss is pink in contrast to the gray meta-sediment.

The mineralogical and textural changes from the mica quartzite to the granite gneiss are much more apparent microscopically than in the hand sample. The mica quartzite is composed primarily of quartz with oligoclase and biotite making up 10 to 40 percent of the rock. The biotite is strongly pleochroic, being almost opaque parallel to the cleavage, and gives emphasis to the gneissosity of the feldspathic bands. Potash feldspar is present only in traces in the most quartzitic types. Garnet is commonly present in small rounded, pink grains. The texture of the individual bands is xenomorphic granular with considerable variation in grain size (Figure A of Plate II).

The gradation into granite gneiss is first shown by the presence of epidote, titanite, and microcline along zones showing slightly cataclastic texture. Magnetite and muscovite also make an early appearance. The quartz bands become much more pronounced, much coarser grained, and appear almost like vein quartz. They show only a very moderate amount of strain and no crushing or fracturing. Passing into the more granitic types the microcline and magnetite increase and the biotite and epidote decrease. The microcline and magnetite may have been derived in part from the breakdown of the biotite (Figure B of Plate II).

In the most granitic type the rock is a white and pink, finely banded gneiss. The white bands are almost pure quartz, and the pink bands consist of microcline and quartz with a small amount of oligoclase and magnetite. The texture of the individual bands is still xenomorphic granular but the average grain size is two to three times that in the mica quartzite. Quartz is the predominant constituent, composing 40-50 percent of the rock (Figure A of Plate III).

In summary, the Waramaug formation has undergone two and possibly three periods of granitic intrusions. The oldest, highly deformed granite probably was intruded and deformed prior to the deposition of the Stockbridge and Hartland formations, since no granites with a comparable degree of metamorphism have been reported in them. The granite gneisses and the Woodbury-type granite may be the same age as similar rocks in the Hartland formation. The age of the Woodbury granite is not known, but since it apparently postdates the deformation of the Hartland formation, it is tentatively considered here to be Devonian or younger. On the basis of granitic intrusions alone the conclusion can be drawn that the Waramaug formation is older, probably much older, than the Hartland formation and if the Hartland and underlying Stockbridge formations are generally accepted as Cambro-Ordovician, the Waramaug is most probably pre-Cambrian.

THE STOCKBRIDGE LIMESTONE

General Statement. The Stockbridge limestone or marble belt extends from Vermont southward along the Housatonic Valley of Massachusetts into western Connecticut and eastern New York. Moore

(1935) divided the limestones in western Connecticut into four areas: 1) Northern area—Canaan Valley, 2) Central area—the Housatonic Valley, 3) Southern area—Woodville, New Milford, Danbury, and 4) Ridgefield area. The northeastern tip of the southern area is included in the New Preston quadrangle.

The marble here is massive, white to gray, dolomitic, and contains numerous micaceous layers. Some layers contain an abundance of pure white tremolite crystals which range in length from microscopic to more than an inch.

In the New Preston quadrangle the marble is found only along the valley floor between Woodville and Marbledale and nowhere in contact with the Waramaug or Hartland formations. However, about one mile east of Marbledale in a tributary valley on the south side of Highway 25 the marble and the Hartland outcrop within 50 feet of each other. The formations appear conformable in every respect and show no indications of unusual deformation in the contact zone. If the Hartland formation is overturned, the marble is stratigraphically lower. Moore (1935, p. 32) concluded that the marble was "....younger than, and unconformable upon the adjacent gneisses" (Waramaug), but found no clear cut relations between it and the Hartland formation. The simplest interpretation is that the marble is part of the quartzite-marble-schist series of northwestern Connecticut although here the quartzite is missing. Only further areal mapping will show, however, whether this interpretation is correct.

Structure. The bedding of the marble, which strikes N30–40E and dips steeply northwest, is everywhere conformable to that of the Hartland. It is essentially the same as the foliation of the adjacent Waramaug except for the westward dip. Moore (1935, p. 32) commented on the structure of the southern marble area as follows:

> "One of the most striking features of the southern area is the persistent westward dip of the marble. This is contrasted to the usual eastward dip of the central and northern areas. ...This reversal of dip from east, in the central area, to west in the southern area, takes place through an airline distance of only five miles between the two belts. This structure of the marble throughout this belt is interpreted as being a series of isoclinal folds which have been overturned to the east, resulting in the persistent westward dip."

The compressional NW–SE forces mentioned previously as causing the upthrusting of the Waramaug block would account satisfactorily for the westward dip of the rocks on the south side of the block and the eastward dip on the north side.

The wedging out of the marble tongue near Woodville is most easily explained by stratigraphic thinning of the formation. The Stockbridge marble is not found on the northern side of the Mt. Prospect complex where the Waramaug and Hartland formations again have parallel trends. Other explanations for the disappearance of the marble such as plastic flow during isoclinal folding, faulting, or southeastward thrusting of the Waramaug block are considered satisfactory but lack supporting field evidence.

THE HARTLAND FORMATION

General Statement. The Hartland formation is known to extend along the eastern half of the Torrington quadrangle southwestward across the eastern and southern halves of the Litchfield quadrangle (Gates, 1951) and westward across the southern half of the New Preston quadrangle. In the New Preston quadrangle its northern contact roughly parallels Highway 25 from the western border to Mt. Tom Pond.

The regional metamorphism has produced an isoclinally folded series of interbedded mica quartzites and schists over the entire southern half of the quadrangle. Staurolite, cordierite, and kyanite bearing varieties of the Hartland formation are usually related to the intrusive Mt. Tom hornblende gneiss.

Hartland Rock Types. The Hartland formation includes a variety of rock types ranging from mica quartzites with 5 percent muscovite and/or biotite to mica-quartz schists with 50 percent mica. The color ranges from a metallic silvery gray to a dark brownish-black, depending upon the amount and proportions of muscovite and biotite in the rock. The numerous rock types, probably representing different original sediments, are interlayered on a scale of inches and feet. Individual beds a few inches thick are no less common than those 10 to 100 feet thick. All the rocks have a marked fissility, even where the mica is in minor quantity and does not occur in continuous streaks.

The Hartland formation is characterized locally by crystals of garnet, staurolite, and kyanite. Magnetite, cordierite, and tourmaline are commonly associated with the coarser staurolite-bearing rocks, but are rarely visible megascopically. Cordierite was observed in the field only at one locality, but was found in moderate amounts in several thin sections of the staurolite-bearing rocks. Tourmaline is present only in traces. Magnetite occurs in numerous, very small grains and is much more apparent in thin section than in hand sample.

Of the megascopically obvious minerals the following assemblages are standard in this area: 1) Kyanite-staurolite-garnet, 2) staurolite-garnet, and 3) garnet. Garnet commonly occurs alone in the mica-quartz schists and is the only one of these minerals which has a regional distribution. The staurolite-kyanite-bearing rocks are of a strictly local nature empirically related to the Mt. Tom hornblende gneiss. The size and abundance of the staurolite crystals (kyanite is relatively rare) seem to be more dependent on a favorable host rock than on the size or proximity of the hornblendic intrusive. The Hartland in contact with the hornblendic bodies usually does not have staurolite or kyanite developed in it. Several outcrops of staurolite-bearing mica-quartz schists are found around the major intrusive at Mt. Tom, but the more spectacular occurrences are near much smaller bodies of hornblende gneiss. The large pendant of coarse garnetiferous mica-quartz schist near the top of Mt. Tom contains few, but large, staurolite crystals. The genesis of the staurolite and the associated cordierite and magnetite is discussed in the section on the metamorphism of the Hartland.

Kyanite, the least common of the three minerals discussed above, is abundant only in a narrow zone ½ mile long about one mile northwest of Carmel Hill in the southeast corner of the quadrangle. The zone is south of the cluster of three small hornblende gneiss bodies. Pale blue kyanite crystals are scattered throughout the Hartland formation here giving the weathered outcrops a studded aspect. Most of the crystals are less than one-half inch long, but crystals from one to eight inches are not rare. The largest crystals generally occur in quartz augen in a random orientation. Staurolite and garnet are also present in moderate amounts.

The occurrence of staurolite in the vicinity of the hornblendic bodies is so common that the association is expected except where the composition or texture of the Hartland formation is unfavorable to its development. The staurolite crystals, ranging from 1/16 to 4 inches in length, may be sparsely distributed throughout the rock or may compose 20 to 25 percent of it. The largest staurolite crystals in the Hartland formation occur 2000 feet east of the Pinnacle (near New Preston Station) where several small lenses of the hornblende gneiss crop out. Locally the crystals average over one inch in length and make up 30 percent of the rock. Although this is the most spectacular staurolite occurrence in this quadrangle, it does not compare in quantity or coarseness with that in the northeast corner of the Litchfield quadrangle (Gates, 1951). Unusually large staurolite crystals are found in the Hartland formation on the hill between Washington golf course and Wykham Mill Road and on the knob on the east side of the Shepaug River ½ mile east of Mt. Rat.

An additional rock type in the Hartland formation is a dense, fine-grained carbonaceous quartzite with considerable pyrite and muscovite. Anhedral porphyroblasts of microcline are fairly common in this rock. The only exposures of the rock are in the road cut 2000 feet north of Washington Depot and in the bed of Mallory Brook 2000 feet east of the road cut along the strike of the schistosity.

Microscopic examination has added little information on the mineralogical composition of the Hartland formation to that obtained in the field. Cordierite, associated with staurolite, was found to be much more common than expected from the field observations. Nor was the concentration of magnetite in the staurolite-rich rocks fully appreciated. Tourmaline was observed only in thin sections of the Hartland formation containing staurolite and cordierite. The minerals generally present in trace amounts are pyrite, magnetite, apatite, microcline, and albite. In summary, the Hartland formation is composed primarily of quartz, muscovite, and biotite with garnet commonly present, staurolite much less so, and kyanite only rarely.

The rocks range from fine- to coarse-grained and from nearly massive to very schistose. The range of textures is exhibited in places in a single outcrop, but there are also variations from place to place in the quadrangle. The quartz in most specimens is in an irregular mosaic pattern; muscovite and biotite occur scattered throughout the rock in uniform orientation. The micas are distributed uniformly through the rock in some places, but in others are concentrated in certain layers. The distribution of the micas probably reflects original differences in the sediments. There are few exposures in which the segregation of the quartz into separate bands might be interpreted as due to metamorphic differentiation. Figure B of Plate III is a photomicrograph of the standard mica quartzite of the Hartland formation. The quartz is usually free of strain and in roughly equidimensional grains. The garnet and staurolite are irregular in outline and poikilitically enclose considerable quantities of impurities.

Metamorphism of the Hartland. The Hartland formation has undergone a relatively simple set of changes in this area, i.e., regional folding and intrusion by the Mt. Tom hornblende gneiss. A later deformation produced minor crenulations on the foliation planes only locally. The granites and pegmatites which occupy the major part of the Woodbury quadrangle and are fairly common in the Litchfield quadrangle are almost absent here.

The original sediments have been completely recrystallized and have had a schistosity developed parallel to the bedding. It is most likely that the micas and at least some garnet were formed and the quartz recrystallized during the regional deformation which isoclinally folded and overturned the beds to the southeast. The schistosity probably was developed at the same time. No cataclastic texture or strain shadows are present to indicate deformation after the development of the crystalloblastic texture. Another significant feature is the uniform grade of regional metamorphism in this formation in the New Preston quadrangle and in the adjoining ones. Except for local variations due to intrusives the Hartland formation has the same metamorphic grade for over fifteen miles across the strike of the schistosity.

The empirical association of staurolite, kyanite, and garnet concentrations with the hornblendic intrusives implies a hydrothermal rather than a dynamic metamorphic origin. Further indications of late or post deformational hydrothermal metamorphism are the association of cordierite with staurolite, the presence of tourmaline, the poikiloblastic texture of the staurolite (Fig. A, Pl. IV), and the development of biotite porphyroblasts across the schistosity of the Hartland. Many of these features can be observed near a hornblendic sill on the west side of the Shepaug River one mile south of Washington Depot.

Another aspect of the staurolite-rich rocks which merits further discussion is the apparent migration and concentration of iron and to a lesser extent magnesium. As previously mentioned, magnetite and cordierite occur with the staurolitic rocks in sufficient quantity to produce a rock unusually high in iron and magnesium. Although some rock types of the Hartland formation are fairly rich in biotite, it seems unlikely that they could produce by simple thermal metamorphism the amount of staurolite, cordierite, and magnetite found in these small areas. Also, the development of magnetite in muscovite and the replacement of muscovite by staurolite are indications of active iron-bearing hydrothermal solutions. Thus, on the basis of mineralogical and petrological studies the conclusion is drawn that the staurolite-cordierite-magnetite-bearing Hartland represents a local concentration of mafic constituents.

The mafic accumulations may have been derived from two or more sources. The hornblendic intrusives are the most apparent sources of the hydrothermal solutions and may have furnished part, or possibly all, of the mafic materials. However, it is equally possible that a large part of the iron and magnesium was derived locally from the biotite in the Hartland immediately adjacent to the staurolitic rocks. The local migration and concentration of mafics in the Hartland formation under the influence of hydrothermal solutions from the hornblendic intrusives seems to fit the field observations better and is the preferred explanation. The sharp contacts across strike between the staurolite-bearing and standard mica quartzites indicate that the migration of mafics took place more readily along the planes of schistosity.

Structure. The schistosity and commonly the bedding of the Hartland are the guiding structural features. The rocks with highly contorted schistosity occur for the most part in zones parallel to the regional schistosity and are considered to be the eroded crests or troughs of the isoclinal folds.

Along the northern contact the schistosity strikes generally northeast as do the Stockbridge limestone and the adjacent Waramaug formation, but the dip averages 65-75 degrees north in contrast to the vertical dip of the Waramaug. With increasing distance from the contact the dip, consistently northwestward, decreases from about 70 degrees to 35 degrees. In the southeast corner the trend of the schistosity changes from slightly east of north to west of north. This variation of the general trend is a reflection of a major flexure related to the Woodbury granite in the quadrangle to the southeast. In general, the schistosity follows the trend of the outcrop belt. The major flexures in the trend are located around the intrusive masses like the Woodbury granite and the Mt. Prospect diorites and norites.

Linear elements and the plunge of minor folds are seen only in a few exposures and show no recognized pattern.

The bedding of the Hartland formation is parallel to the schistosity wherever they are observed together. The bedding can be identified with a fair degree of confidence in about half of the outcrops. Only in about a third is it essentially obliterated. Although the formation is well exposed, particularly in the southeast quarter of the quadrangle, no repetition of recognizable horizons was found. In fact, in a cross section from Washington to Waterbury, a distance of 15 miles, the regional changes in lithology are no more marked than strictly local ones. Throughout western Connecticut the Hartland formation lies in a continuous belt ranging in width from five to twenty-five miles uninterrupted by any other formation except those of an intrusive nature. Several explanations are possible for the persistent west or northwest dip of the foliation and/or bedding of the Hartland formation in this area, but the most obvious ones are that 1) the formation is exceptionally thick, 2) it is isoclinally folded and overturned to the southeast, or 3) it is one limb of a major anticline. The more reasonable interpretation is that the formation is relatively thin and it is tightly folded by a northwest-southeast compression. The rising block of the Waramaug formation—probably a consequence of the northwest-southeast compression—may account for the overturning of the Hartland formation to the southeast. It is also possible that the entire Hartland formation has been overthrust to the northwest after folding or that the Waramaug has been thrust over the younger formations.

The only estimate of the thickness of the formation was made by Agar (1927, p. 23). He assigned it a minimum thickness of 3250 feet which was based on a continuous 2¾ mile section in the Shepaug Tunnel.

The amplitude of folding apparently was not great since no underlying formations are found interlayered with the Hartland.

Comparison of Waramaug and Hartland Formations. These formations have rock types which are sufficiently similar in appearance that difficulty is sometimes encountered in separating them. This difficulty does not exist in the New Preston quadrangle since the formations are almost completely separated by the Stockbridge marble and the Mt. Prospect diorite gneiss. However, they do outcrop in parallel belts in the quadrangles to the northeast and the difficulty mentioned is very real. The comparison given in the table below may be of value in future work on these formations.

Hartland	*Waramaug*
1. Fissle, friable, splits readily	1. Well crystallized, compact, gneissic. Will break across foliation without splitting
2. Bedding commonly present	2. Bedding completely obliterated
3. Micas distributed through rock or in beds	3. Mica segregated into discontinuous folia
4. Micas usually undeformed	4. Micas usually deformed
5. Contains only trace of plagioclase	5. Usually contains minimum of 10% plagioclase
6. Garnet commonly shows crystal form	6. Garnet drawn out, or in augen
7. One direction schistosity	7. Foliation developed and early foliation frequently transposed by later deformation
8. Intrusive granites and pegmatites not deformed	8. Two or more periods of granite intrusives; early granites & pegmatites highly sheared; late granites relatively undeformed.
9. Usually plucked by glacial action (see Part II of report)	9. Usually polished and shaped by glacial action (Part II, Plate II)

From the above comparison it seems clear that the Waramaug formation has undergone considerably more granitic intrusion than the Hartland formation and has been involved in at least two major periods of deformation. The Hartland formation, on the other hand, has been involved in only one major deformation and a later minor one which slightly crumpled some of the early planes of schistosity. The major deformation of the Hartland formation must have been earlier than the undeformed granites and pegmatites and was probably during the Taconic disturbance. Therefore the early deformation or deformations of the Waramaug formation would have taken place during the pre-Cambrian. The ages of deformations are difficult to fix precisely and thus the very real possibility exists that the early deformation of the Waramaug was during the Taconic disturbance and the folding of the Hartland formation was during the Acadian disturbance or even later. The Waramaug mass could have been thrust southeast during the folding of the Hartland formation.

THE MT. TOM HORNBLENDE GNEISS

General Statement. The Mt. Tom hornblende gneiss and similar hornblendic rocks are reported (Agar, 1927; Rice and Gregory, 1906) in the metamorphic rocks throughout western Connecticut. They occur in tabular or lens shaped bodies whose dimensions range from a few inches to several hundred feet. They are generally referred to as gneisses even though the textures vary greatly. In the New Preston and Litchfield quadrangles, in spite of the lithologic variations, the bulk of the hornblendic bodies are considered related genetically. The variations are generally no greater from outcrop to outcrop than they are in single large bodies. The rocks are composed essentially of hornblende, chlorite, and andesine with minor amounts of epidote, titanite, magnetite, and quartz. The majority of these rocks found in the Woodbury, Litchfield, Torrington, and New Preston quadrangles are intrusive into the older metamorphics. The intrusions are thought either to post date the regional folding or to take place during the late stages of the major deformation. The late deformation, which slightly crumpled some of the foliation planes of the Hartland formation probably followed the intrusions of the hornblende gneiss. The hornblende gneisses have, at least to a minor degree, hydrothermally metamorphosed the enclosing sediments and have produced some hybrid rock types.

Occurrence. With very few exceptions the hilltops, knobs, and ridges in the New Preston quadrangle south of Highway 25 are composed of the Mt. Tom hornblende gneiss. The largest mass of the hornblende gneiss extends in a discontinuous series of outcrops from Mt. Tom and Little Mt. Tom westward to Mt. Rat and Baldwin Hills. Its maximum width is about one-half mile and its length can be considered four to six miles depending on whether the scattered lenses of the Baldwin Hills are included. Numerous other hornblende gneiss sills, lenses and dikes are found in the southern half of the area and a few are found in the Waramaug formation and the dioritic gneisses.

The evidence for an intrusive origin for the hornblende gneiss is good in this area where exposures reveal the contacts with the sediments, but in other quadrangles where only isolated outcrops are found the arguments for a sedimentary and metamorphic origin are equally valid. Some observations supporting an intrusive origin are:

1. Slab-like mica quartzite inclusions from the Hartland formation are fairly common in the Mt. Tom hornblende gneiss. They have been modified to varying degrees by the hornblende, quartz has been recrystallized and coarsened, and plagioclase, epidote, and titanite have been added. The characteristic tabular nature of the inclusions indicates that the foliation was developed before their incorporation by the hornblende gneiss. A typical inclusion of the Hartland formation in the hornblende gneiss can be seen in an outcrop at New Preston Station. Inclusions of this type can be found in at least one-third of the hornblende gneiss outcrops.

2. A similar type of evidence is the interlayering of the Hartland formation and the hornblende gneiss. Sills 1 inch to 100 feet wide commonly alternate with layers of the Hartland formation of similar dimensions. Especially good examples of the multiple swarms of sills may be seen on all four knobs of the Baldwin Hills, on the western extremity of the ridge of Mt. Rat, and on the twin knobs 4500 feet south of the easternmost peak of the Baldwin Hills.

3. In general the hornblende gneiss is a concordant intrusive and does not cross cut the regional foliation of the Hartland formation. However, there are two clean cut exceptions to this generalization and numerous occurrences where the spatial relations of the Hartland formation and the hornblende gneiss indicate a cross cutting relationship. On the nose one-quarter mile north-northwest of Robin Hill a hornblende gneiss dike 800 feet in length cuts directly across the foliation of the Hartland formation which, though not in contact, is exposed only a few feet away on both sides of it. Near one end of the dike a garnetiferous mica-quartz schist 'disappears' into the dike as a coarse garnet- and quartz-bearing hornblende gneiss with the same foliation. Presumably this pendant of the Hartland formation has been hornblendized by the Mt. Tom intrusive. The foliated hornblende gneiss occurs at the two extremities of the dike; elsewhere the dike is much more massive and unfoliated.

The east hill of the twin knobs 4500 feet south of Baldwin Hills is another example of a hornblende gneiss dike. The interfingering of the dike and the Hartland formation is well exposed on the west knob.

The hornblende gneiss outcropping on Little Mt. Tom probably is a dike also which has fingered out abruptly into the adjacent Hartland formation. Numerous quartzite inclusions and hybrid 'hornblendized' Hartland rocks occur in the Little Mt. Tom exposure.

4. Locally rocks which are neither a hornblende gneiss nor mica quartzite or schist can be recognized. Microscopic examination of these hybrids shows them to be mica quartzites or schists injected on a

microscopic scale by the hornblende gneiss. Alternating bands of quartz and hornblende-andesine are very common. Usually the micas have been altered to chlorite or hornblende and the quartz recrystallized. Other types of the hornblende gneiss carry unusually large quantities of quartz and may have originated by the 'hornblendization' of the mica-quartz schist. One of the best exposures of the hybrid types is found on the western end of the Mt. Rat ridge. Agar's (1927) conclusion that the Mt. Tom hornblende gneiss was an intrusive was based largely on this outcrop.

5. As mentioned in a previous section, the association of the hornblende gneiss with the staurolite-cordierite-kyanite-bearing Hartland suggests a cause and effect relationship.

6. Although it is not possible to prove that the hornblende gneiss in the Waramaug formation and the Mt. Prospect diorite are of the same origin as the Mt. Tom hornblende gneiss, the two groups of hornblendic rocks are very similar in lithology and occurrence. If they are related, those in the Waramaug must be intrusive.

7. The foliation of the Mt. Tom hornblende gneiss usually is developed best in the small sills and along the borders of the larger lenses and always is parallel to the borders of the enclosing sediments. The central parts of all the major bodies and numerous isolated outcrops show little or no foliation. The foliation is considered to have developed in part during emplacement and in part to be inherited from the 'hornblendized' mica-quartz schists.

The evidence given above for an intrusive origin for the hornblende gneiss is not intended to deny the possibility that hornblendites in the Hartland and Waramaug formations elsewhere may be of sedimentary origin.

Petrology. The Mt. Tom hornblende gneiss is a dark greenish-black or mottled black and white rock composed essentially of hornblende and plagioclase. Other minerals usually present are, in order of decreasing abundance, chlorite, common epidote, zoisite, quartz, titanite, magnetite, and garnet. In a selected sample any of the above minerals except titanite or magnetite may predominate. The textures range from massive to foliated and lineated, and from coarse- to fine-grained. The gneissic structure, where present, is due to parallel bands or discontinuous streaks of plagioclase and hornblende.

The following discussion of the individual minerals and textures is based on a petrographic study of more than forty samples of the hornblende gneiss from the New Preston quadrangle.

Hornblende. This mineral makes up 50 to 75 percent of the hornblendic rocks exclusive of the hybrid varieties. It is usually only weakly pleochroic, light green to colorless, except where the hornblende gneiss is mixed with or has altered the Hartland formation. There the hornblende is strongly pleochroic in blue-green to yellowish-green colors and has originated at least in part from chlorite. The sequence of alteration of biotite and muscovite to chlorite and chlorite to hornblende cannot be seen in a single hand sample, but can be observed in selected specimens. The incomplete alteration of chlorite to hornblende is apparent in all hybrid rocks. The replacement of biotite and muscovite by chlorite can be seen where the Hartland formation is injected in a lit-par-lit manner by the hornblende-plagioclase rock (Figure A of Plate V). Iron appears to be mobilized by the hornblendic intrusions as indicated by the introduction of magnetite in the hybrid Hartland rocks and the chloritization of muscovite. This is similar to the iron and magnesium migrations in the staurolite- and cordierite-bearing rocks associated with many of the hornblendic bodies.

The hornblende ranges from euhedral, lath-shaped crystals to irregular, ragged flakes with a poikilitic or sieve-structure. It is fairly certain that the bulk of the hornblende was crystallized, or possibly recrystallized, after the last major deformational stresses. It is unlikely that the usual poikilitic texture of the hornblende could have withstood any severe shearing. In the hybrid rocks, particularly at the west end of Mt. Rat ridge, the hornblende grains have developed across the foliation of the Hartland. This is shown by trains of magnetite crystals, parallel to the foliation, continuing uninterrupted through the hornblende flakes. The foliation of the hornblende is developed best along the borders of the large intrusives and in the smaller sills. Lineation of hornblende needles is well developed only in the smaller bodies and may be related to the last deformation which crenulated some foliation planes of the Hartland formation. Equigranular textures are found in the dikes, but the central parts of many sills also lack any pronounced foliation.

Plagioclase. The plagioclase occurs as bands, streaks, or augen and also is poikilitically enclosed in the hornblende. It is always fine-grained, rarely twinned, and frequently progressively zoned. Oscillatory zoning is also found, but only rarely. The anorthite content of the plagioclase ranges from 35 to 50 percent and averages about 40 percent.

The feldspar streaks have an irregular, granular mosaic texture which Agar (1927) described as protoclastic. The plagioclase does appear to be granulated or crushed, but the individual grains usually have smooth, sharp contacts with one another and lack the sutured, irregular boundaries, strain shadows, and fracturing associated with cataclastic action. It seems likely that recrystallization of the plagioclase may have followed any crushing. Hornblende needles and epidote and zoisite grains developed in the plagioclase mosaic tend to show that crystallization (or recrystallization) of these minerals followed any granulation of the plagioclase. The progressive and oscillatory zoning indicate lack of equilibrium and at least partially liquid conditions. The texture of the plagioclase seems to have little relation to the texture of the hornblendic rocks as a whole. Figure B of Plate V shows a typically zoned plagioclase mosaic.

Epidote and Zoisite. These minerals are present in minor quantities in all parts of the Mt. Tom hornblende gneiss. Locally bands of epidote 6 to 12 inches thick occur with the gneisses. The zoisite is almost invariably associated with the plagioclase and in many samples makes up 50 percent of the felsic bands. Epidote is most prominent in the areas where the Hartland formation and the hornblende gneiss are in contact. A typical contact hybrid is a gneissic quartz and epidote or zoisite rock (Figure A of Plate VI).

Quartz. Quartz is present in amounts ranging from 0 to 20 percent in the standard hornblende gneiss. It is usually associated with the feldspar in bands or lenses, although it sometimes forms separate layers. It always occurs in much larger grains than the plagioclase and, except for the occasional augen structure or strain shadow, shows no sign of granulation. Most of the quartz is thought to have come from the assimilation and incorporation of the mica-quartz schists of the Hartland formation. Remnant quartz layers in a small hornblende gneiss sill are shown in Figure B of Plate VI. The amount of quartz present is considered a rough measure of the contamination of the hornblende gneiss by the Hartland formation.

The accessory minerals titanite and magnetite are always present, but seldom more than a few grains. In the hybrid rocks at the west end of the ridge of Mt. Rat, however, magnetite constitutes 5 to 15 percent of the rocks locally. The magnetite, which is in too great quantity for the standard rocks of the Hartland formation, was introduced prior to the hornblende and plagioclase. It occurs as streaks and strings of grains parallel to the foliation and occasionally extends uninterrupted in a helicitic structure through hornblende and plagioclase crystals developed across the foliation. The magnetite probably represents the first stage in the hydrothermal metamorphism of the Hartland formation by the Mt. Tom hornblende gneiss.

The origin of the Mt. Tom hornblende gneiss is an unsolved petrogenic problem. The unusual amount of hornblende is an accumulation of mafic constituents which cannot be explained readily in bodies of this type. The principle of "the basic front", a concentration of mafic constituents, described by D. L. Reynolds (1946) was considered in the course of field mapping. However, in the absence of a recognizable field pattern, no justification for this interpretation was found. Still, the lack of surface evidence does not deny the possibility that the mafic constituents could have accumulated from the metasediments below the observed hornblendic bodies.

THE MT. PROSPECT COMPLEX

The Mt. Prospect complex, which is located in the northeast corner of the quadrangle, is composed of a series of dioritic gneisses intruded in turn by a series of norites and younger basic rocks. Cameron (1951, pp. 13-16) has described the dioritic gneisses as follows:

> "The essential constituents of the dioritic gneisses, where unaffected by the younger mafic intrusives, are oligoclase-andesine, hornblende, and biotite. Quartz and clinopyroxene are present in minor amounts in some facies, and garnet, apatite, sphene, allanite, epidote, pyrite, pyrrhotite, zircon, and scapolite are common accessories.
>
> The gneisses show a broad range of textures, structures, and mineral proportions. They show two principal types of planar structures; one a small-scale foliation due

to parallel orientation of mineral constituents or groups of mineral constituents, the other a gross layering due to juxtaposition of layers of contrasting lithology. The whole assemblage is a pile of contrasting layers interrupted by innumerable partings and inclusions of rocks of the Hartland and Berkshire (Waramaug) formations. Foliation and gross layering, with rare exceptions described below, are parallel to each other and to contacts and foliation of the schist and gneiss enclosures. Contacts of dioritic gneisses and inclusions or partings are sharp, and neither rock shows variations related to the contacts.

The prevailing types of gneisses are fine-grained to medium-grained hornblende, biotite, and hornblende-biotite diorite gneisses consisting essentially of the minerals named, together with oligoclase-andesine and minor amounts of other minerals. All are foliated, distinctly to indistinctly; some have linear structure due to parallel arrangement of hornblende prisms. The various types form layers fractions of an inch to more than 200 feet thick. Individual layers commonly extend with uniform thickness across the full width of an outcrop. Across strike, layers pass gradually or abruptly into one another; with very rare exceptions discussed below there are no true contacts between lithologic types."

The essential features of the younger mafic intrusives are given below (Cameron, 1951, pp. 29-30).

"The younger mafic intrusives range from granodiorite to peridotite but norites and pyroxenites predominate... The principal members of the series, in order of decreasing age, are olivene norite, quartz norite, hypersthene pyroxenite, and dike rocks.

The younger mafic intrusives outcrop irregularly over a roughly quadrilateral area approximately 8,000 feet in length and breadth, in the northwestern part of the Mt. Prospect complex. The intrusives lie mostly within the diorite gneiss assemblage, but to the west they extend across the boundary of the dioritic rocks into the Berkshire (Waramaug) gneiss. . . .

Structurally the younger mafic intrusives are in striking contrast to the older series of rocks. The boundaries of the younger rocks are markedly discordant to the structure of the older series. The younger rocks range from massive to foliated, but foliation in them is clearly related to the forms of their boundaries, not to the structural trends of the older rocks, and with certain exceptions discussed below, is evidently related to movements within the intrusive bodies during consolidation. Among the members of the series, ordinary intrusive relationships prevail—diking, inclusion of fragments of older rocks, and contact metamorphism and assimilation of rocks invaded."

The geology of the Mt. Prospect complex is discussed in a separate bulletin by Dr. E. N. Cameron (1951) and will not be discussed further here.

Summary and Conclusions

The following conclusions have been drawn from this study of the New Preston quadrangle.

1. The Berkshire formation in this area should not be correlated with the rocks called Berkshire elsewhere. It has, therefore, temporarily been renamed the Waramaug formation.

2. The Waramaug formation is the oldest rock in the quadrangle and is probably pre-Cambrian.

3. The Stockbridge marble conformably underlies the Hartland formation and overlies the Waramaug formation.

4. The Hartland formation overlies the Stockbridge formation. Its correlation with the other mica-quartz schists known to overlie

the Stockbridge marble—i.e., the Canaan Mountain schist, the Salisbury schist, and possibly the Hudson River pelites,—is suggested.

5. The Hartland formation with unusual amounts of staurolite-magnetite-cordierite represents a local migration and concentration of mafic constituents due to hydrothermal metamorphism by the Mt. Tom hornblende gneiss.

6. The Mt. Tom hornblende gneiss is a basic intrusive which was emplaced late in the major deformation of the area. Its gneissosity is due, in part, to emplacement and, in part, inherited from the hybrid or 'hornblendized' Hartland mica-quartz schist.

7. The structural relations of all the rocks are explained best by compressional forces effective in a northwest-southeast direction and an upthrusting of the Waramaug block.

8. The possible interpretation that the Hartland formation could have been overthrust northwestward to its present position was considered and tentatively rejected for lack of supporting field evidence.

The conclusions given above are thought to fit the observations made during the detailed mapping of the New Preston and Litchfield and parts of the Torrington and Woodbury quadrangles. These conclusions may be revised later as the mapping is extended in western Connecticut.

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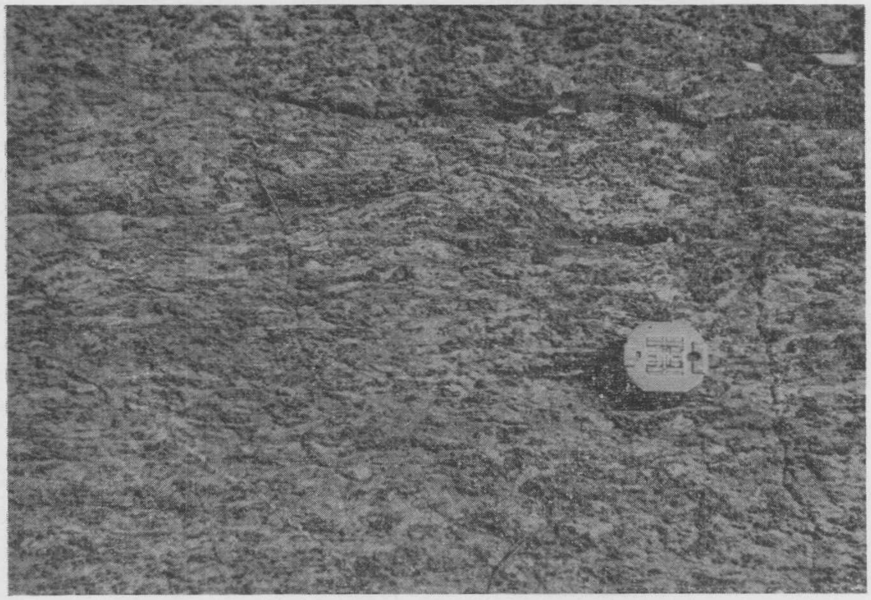

Figure A Waramaug mica-quartz gneiss showing corrugated surface resulting from differential weathering of micaceous and quartzose layers. This surface is characteristic of the mica-quartz gneiss.

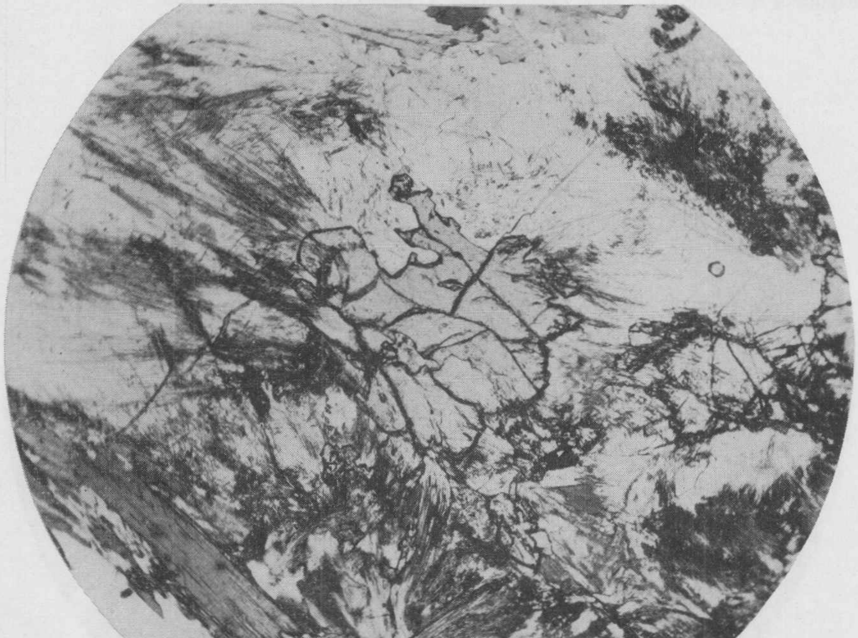

Figure B Augen of quartz and garnet in the Waramaug mica-quartz gneiss showing development of sillimanite (fibrolite). Uncrossed nicols; 90X (H-719).

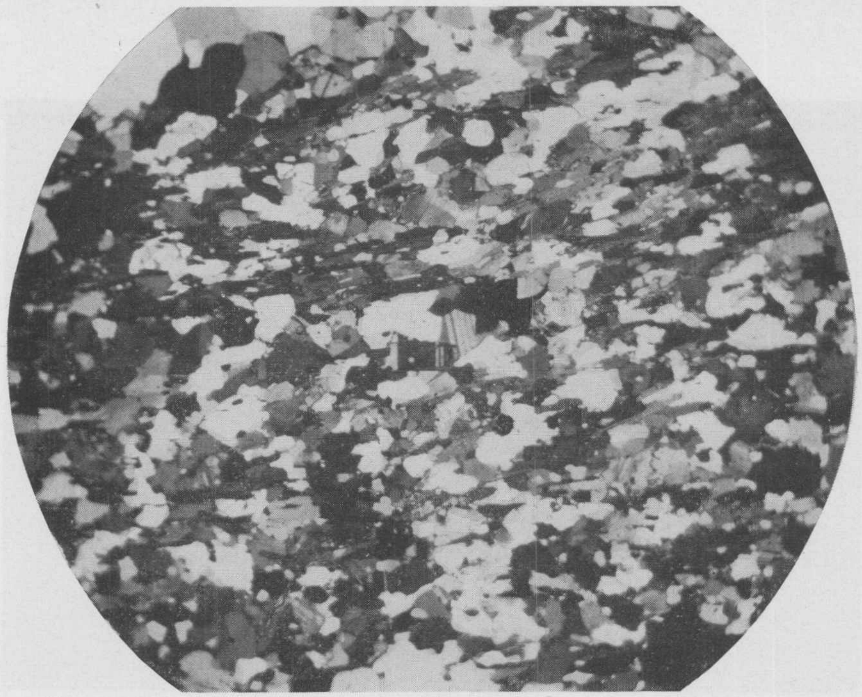

Figure A Feldspathic mica quartzite (Waramaug formation). This mica quartzite grades into a granitic gneiss with the addition or development of microcline. Minerals present are quartz, oligoclase, and biotite. Compare with Figure B of Plate II and Figure A of Plate III. New Preston Hill; Crossed nicols; 30X (H-738).

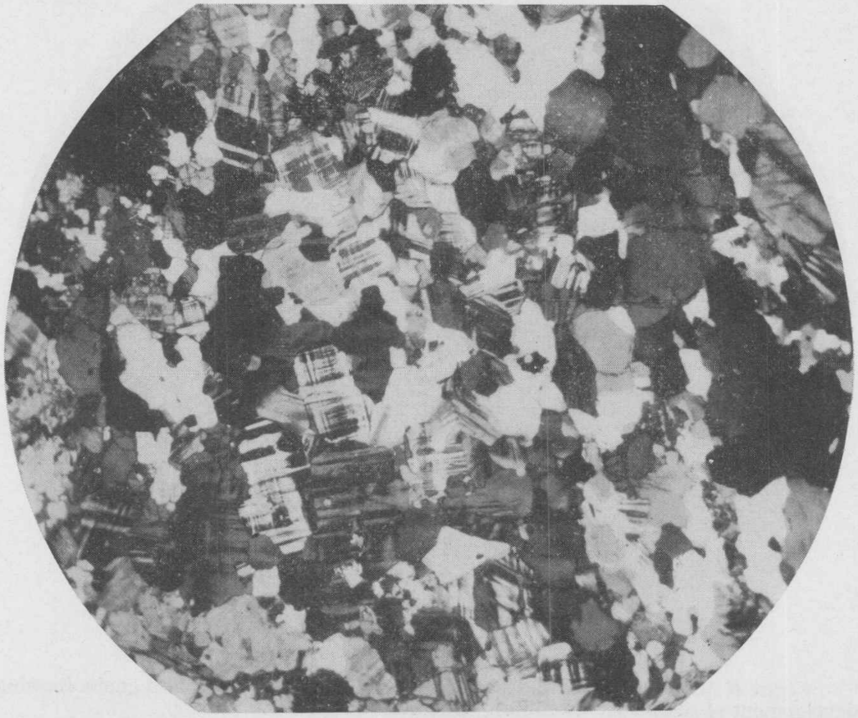

Figure B Intermediate rock type between mica quartzite and granitic gneiss. Notice increase in coarseness of texture and in amount of microcline. New Preston Hill; Crossed nicols; 30X (H-733).

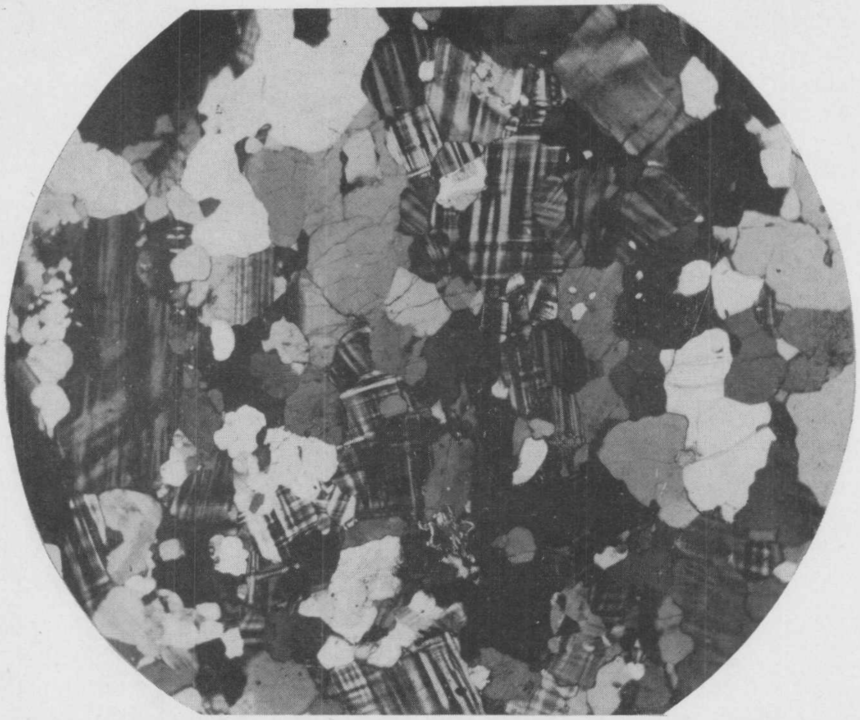

Figure A Granitic gneiss from top of knob south of New Preston Hill. Notice coarse texture and relative abundance of microcline and absence of biotite. Crossed nicols; 30X (H-737).

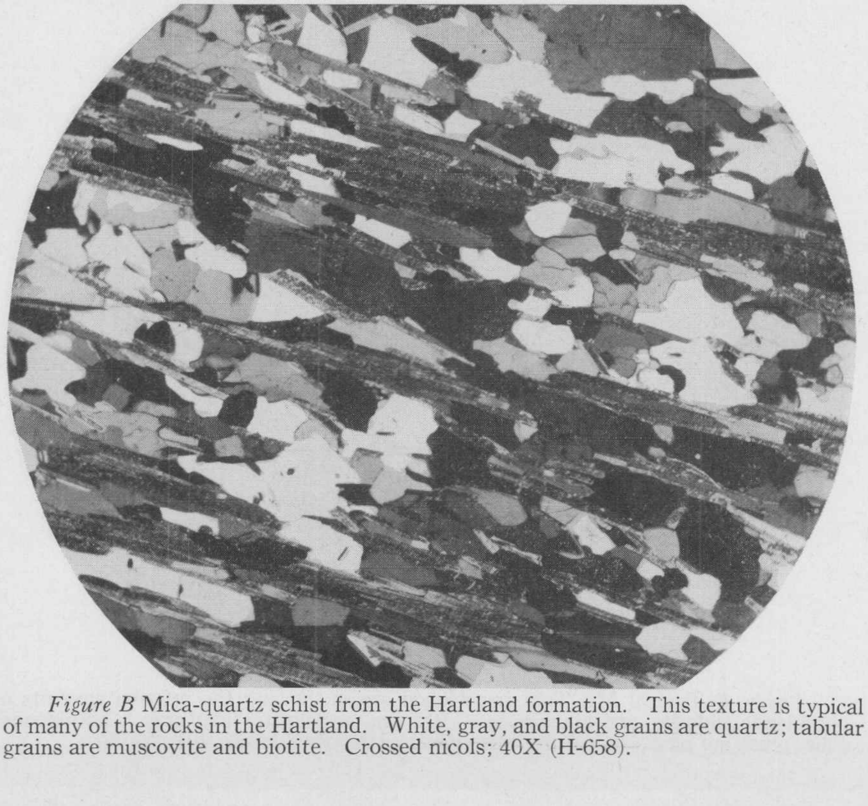

Figure B Mica-quartz schist from the Hartland formation. This texture is typical of many of the rocks in the Hartland. White, gray, and black grains are quartz; tabular grains are muscovite and biotite. Crossed nicols; 40X (H-658).

PART I — PLATE IV

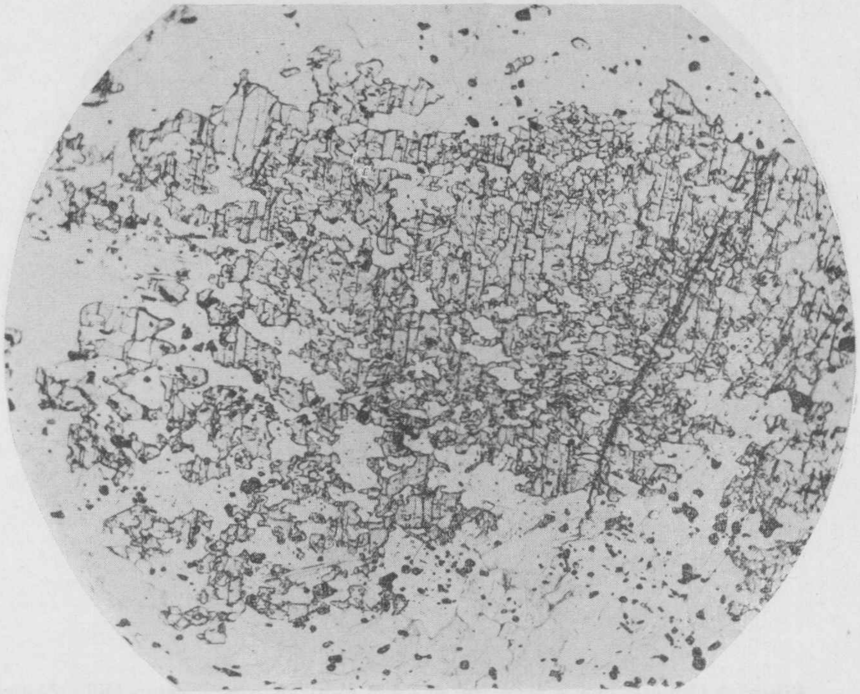

Figure A Staurolite porphyroblast in Hartland mica-quartz schist showing its poikiloblastic development. Uncrossed nicols; 40X (HO689).

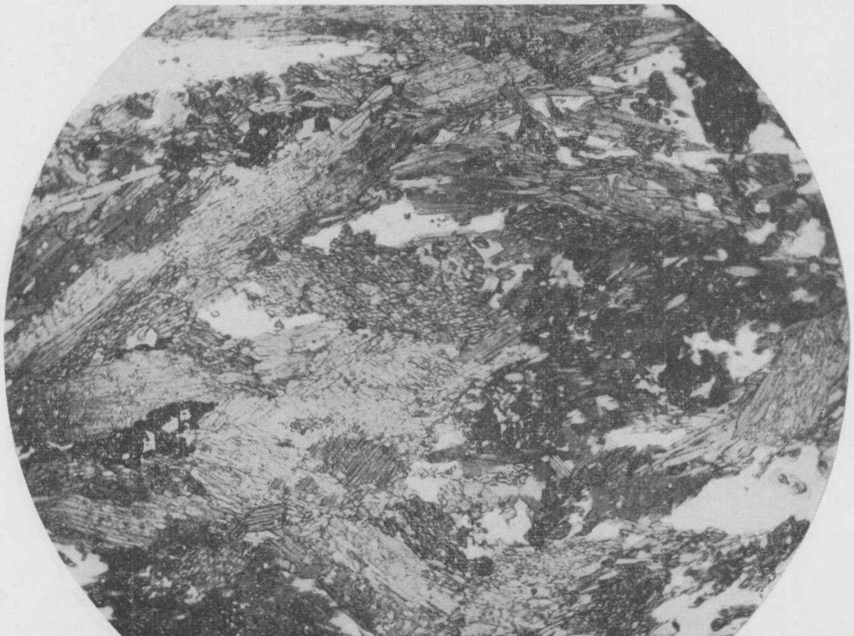

Figure B Typical Mt. Tom hornblende gneiss showing the relative amounts of hornblende, chlorite, and plagioclase. Dark gray is chlorite; light gray is hornblende; white areas are plagioclase with some quartz. Uncrossed nicols; 40X (H-701).

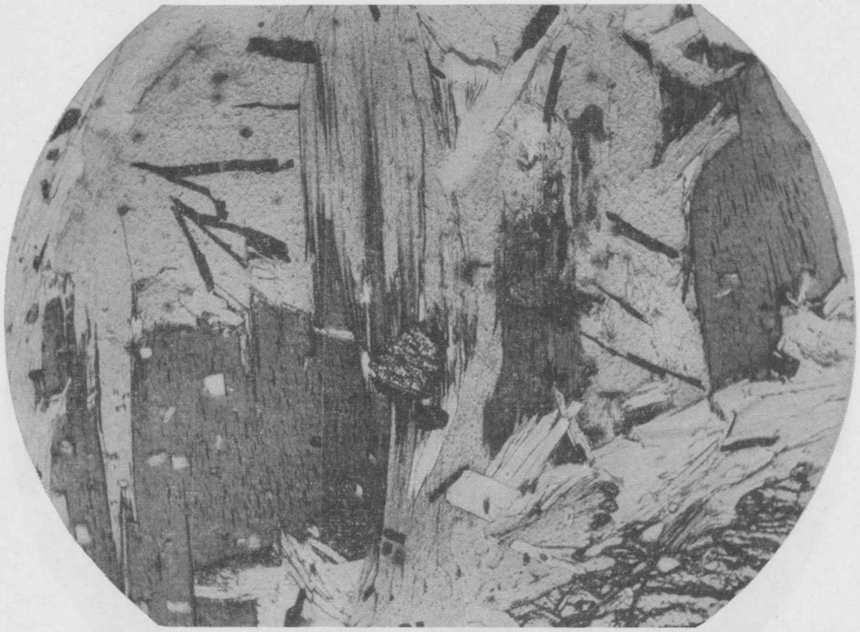

Figure A Biotite partially altered to chlorite and magnetite in Hartland formation near Mt. Tom hornblende gneiss. Dark gray is biotite; light gray is chlorite; and black streaks are magnetite. Uncrossed nicols; 90X (H-720).

Figure B Typical plagioclase mosaic in Mt. Tom hornblende gneiss. Notice zoning of some grains and sharp, regular grain boundaries. Grains with high relief are epidote and zoisite. Crossed nicols; 90X (H-691).

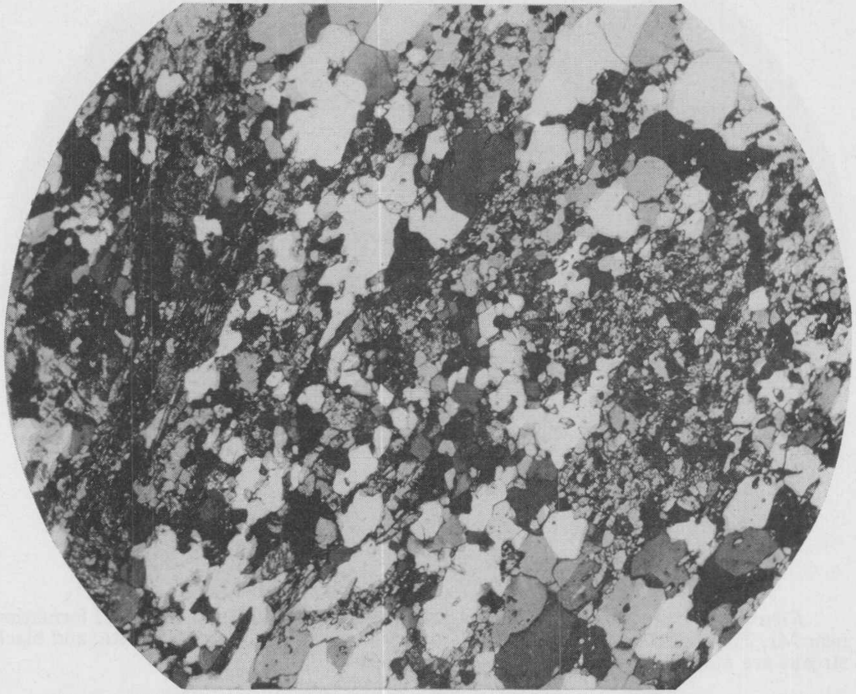

Figure A Mica quartzite in contact zone with Mt. Tom hornblende gneiss. Epidote, titanite, and hornblende are important constituents of this rock. Crossed nicols; 40X (H-696).

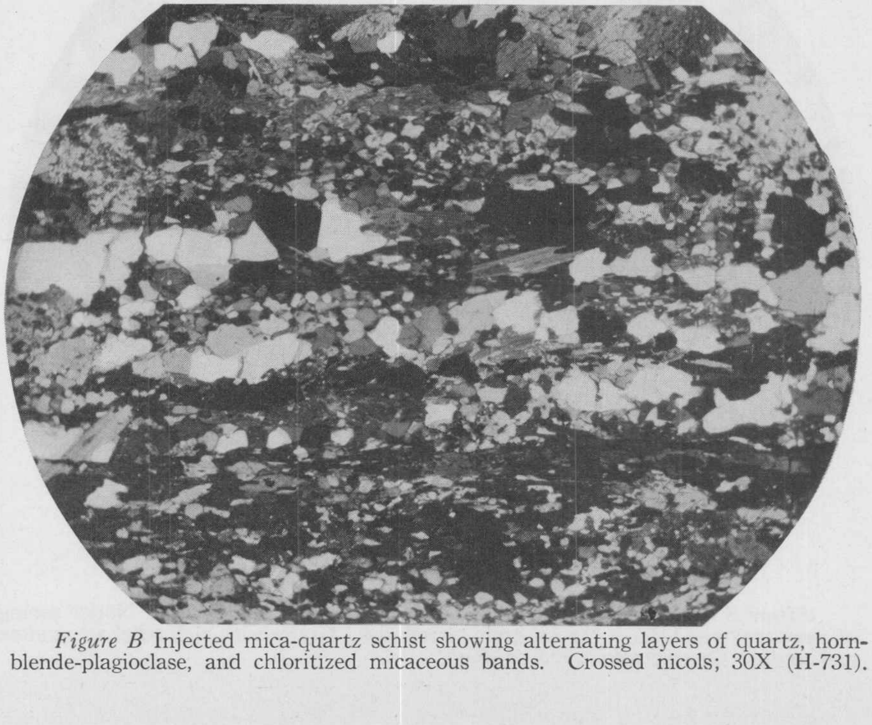

Figure B Injected mica-quartz schist showing alternating layers of quartz, hornblende-plagioclase, and chloritized micaceous bands. Crossed nicols; 30X (H-731).

Part II

THE GLACIAL GEOLOGY

by

William C. Bradley

INTRODUCTION

During the mapping of the bedrock geology in the New Preston quadrangle, observations were made on the Pleistocene geology of this area and, to a more limited extent, of the adjoining Litchfield quadrangle to the east. These observations, recorded on the following pages, are of necessity incomplete and must be considered a by-product of the main study. It is hoped that they may serve as a guide for further, more detailed studies in the area.

The accompanying map shows the Pleistocene geology in the New Preston quadrangle. A map of the drumlins in the New Preston and Litchfield quadrangles is shown in Plate III.

Flint (1930) published a bulletin on the glacial geology of Connecticut, which included the New Preston-Litchfield area. This was the only major work done in the area. Later Flint (1932) modified some of the theories he had presented in his earlier paper; although no re-study of this area was made, his modified interpretations are applicable to the New Preston and Litchfield quadrangles.

GENERAL PHYSIOGRAPHY

The New Preston quadrangle is a part of the western Connecticut uplands. Elevations vary from approximately 450 feet to over 1450 feet. It includes parts of three important preglacial rivers: the Shepaug and its tributary the Bantam, and the East Aspetuck. All are a part of the Housatonic River drainage. Other preglacial drainage exists but much of it has been so confused by glaciation that the area is dotted with small swamps. Considerable drainage which is consequent upon the glacial drift also is recognizable. The overall topography is in part controlled by bedrock, in part controlled by drift, with all gradations in influence between the two types.

GENERAL STATEMENT

Glacial striae, roches moutonnees, and drumlins all show that the last ice sheet to cover this area moved in a S20° E direction. Further evidence from drumlins indicates that the ice then stagnated briefly and rejuvenated in a S2° E direction. While the effects of glacial abrasion, in the form of striae and polish, are in evidence, the chief manner of glacial erosion was plucking. Both abrasion and plucking were so guided by bedrock lithology and structure that they created two distinct types of rock-controlled topographies in the area, one associated with the Waramaug formation, the other with the Hartland formation. The differences between the two topographies arise directly from differences between the two formations. There have been some drainage changes as a result of glacial erosion, glacial deposition, and ice dams. The close association of bedrock with many, if not most, of the drumlins in the area shows up in the abundance of rock drumlins and half-drumlins. Crevasse fillings, kame terraces, and eskers substantiate the theory that the ice wasted into stagnant masses.

Glacial Erosion

Glacial erosion is discussed under the following headings: 1) Glacial Polish, 2) Striae, 3) Roches Moutonnees, 4) Plucking, and 5) Valleys.

Glacial Polish. Original glacial polish of any extent is rarely exposed in this quadrangle. Undoubtedly it is still abundantly preserved beneath glacial drift, but once it is exposed it weathers rapidly. One of the few good examples is an outcrop where Angevine Road ascends the hill (Plate I, Fig. A).

Tiny patches of original polish, however, are common. They are found on quartz stringers in the Waramaug and Hartland formations, on feldspar crystals in the Waramaug, and on parts of the Mt. Tom hornblende gneiss. These residual patches have resisted weathering much as slickensides do, and frequently give a knotty aspect to the surface of the bedrock. In addition they furnish information concerning postglacial weathering. They show that in many parts of the quadrangle the general rock surface has been removed to a depth of at least one-fourth inch. The occurrence of pavement outcrops, discussed below, substantiates this observation.

Near-replicas of original polish, in the form of pavement outcrops, are also common. In these cases the bedrock has obviously been smoothed by glaciation, essentially in its present flat to undulating condition, yet the surface polish has been destroyed by weathering. Pavement outcrops are particularly abundant in areas of the Waramaug formation, although they also exist in areas of the Hartland formation, the Mt. Tom hornblende gneiss, and the Mt. Prospect complex. There is a direct relationship between the occurrence of pavement outcrops and the nature of the bedrock; this relationship is discussed below under "Plucking".

Striae. Striae, like glacial polish, do not long survive when exposed to direct weathering at the surface. Only where recently uncovered, or where the bedrock is especially quartzitic, are they well preserved. Excellent examples are found at the Warren ball park (Plate I, Fig. B), on the drumloidal hills just north of Mt. Tom Pond, and along Angevine Road. Occasionally they occur on pavement outcrops, in spite of the fact that weathering has destroyed all glacial polish. In these cases only the deepest grooves now remain. Some of the grooves are channel-sized: one to two feet in width, and six inches to a foot in depth.

In general, most of the striae trend along a S21° E average, similar to most of the drumlin axes. Of twenty-five outcrops where striae were measured, twenty follow this trend, five follow an average trend of S40° E, and two follow an average trend of S12° E. One of these outcrops (on the west flank of Rabbit Hill), and a second doubtful one (in New Preston), bear striae of two types: the S21° E group and the S40° E group. No consistent striae which were gradational between these two groups were observed anywhere in the quadrangle.

The evidence suggests that the last ice sheet to reach this far south moved in a direction generally S21° E across this area, and that it underwent a minor fluctuation to roughly S40° E while the front advanced. The two examples of striae trending S12° E (along Angevine Road and along the road which ascends Tanner Hill from Lake Waramaug) are explained as deflections of the advancing ice front by hills. At the Warren ball park there is definite evidence of ice deflection. The problem of the movement of the last glacier is discussed again under "Drumlins".

On any good exposure of striae, some do not conform to the regional trend, or to any secondary trend, representing a fluctuation in the direction of ice movement, or to each other (Plate I, Fig. B). Were they a part of a secondary trend, more of them would be expected to occur. Inasmuch as a stria is formed by a rock held at the base of the ice, a possible explanation for an errant stria is that the rock turned over while the ice advanced, giving a slight lateral component to the forward movement.

Unquestioned striae were found only in areas of the Waramaug formation and the Mt. Prospect complex. No doubt the Hartland formation and the Mt. Tom hornblende gneiss also bore striae at one time, but their destruction on these formations, like the destruction of pavement outcrops, was related to the nature of the bedrock, and is discussed further under "Plucking".

Roches Moutonnees. Commonly associated with pavement outcrops are roches moutonnees. All gradations exist between crudely shaped rock knobs and perfectly streamlined forms. One of the best examples lies on the east nose of Rabbit Hill (Plate II, Figs. A, B).

Referring to origin, two types of roches moutonnees exist. 1) One was formed in the standard way, i.e. by abrasion of the stoss side of a knob and plucking of the lee side. 2) In the other no plucking was involved. Both ends show abrasion, but the stoss end was abraded much more than the lee so that it became ramp-shaped. This second type is usually smaller than the other and often well streamlined (Plate II).

The axial directions of three extremely well formed roches moutonnees were measured. Like most of the striae they followed the S21° trend.

Plucking. There is a type of rock-controlled topography which is characteristic of the Waramaug formation. It features pavement outcrops, roches moutonnees, glacial striae, and occasionally glacial polish. A good example of an area where this kind of topography prevails is found north of Highway 25.

The Hartland formation also has a typical rock-controlled topography, which is strikingly different from that of the Waramaug formation. It features jumbled and irregular outcrops which control a confusion of knobs and ridges. There is little obvious evidence of glacial abrasion. Pavement outcrops are rare, glacial striae and roches moutonnees are practically non-existent. Preglacial drainage lines exist, yet they have been modified to the extent that swampy areas are plentiful. Ground moraine is thin and of mainly local derivation. A good example of such an area is that just northwest of Carmel Hill. But much larger areas are found all around Pitch, Morris, and Wigwam reservoirs in the Litchfield quadrangle. All of these areas are bedrock islands amid drumloidal topography; this characteristic is discussed further under "Drumlins".

The contrast between the rock-controlled topographies of the two formations is directly related to differences in lithology and structure between the two. Difficult as it often is to tell the two formations apart in the field, these differences were fundamental enough to guide erosion by the ice. The Waramaug formation is coarsely gneissic, sometimes rather homogeneous, and has a relatively variable direction of foliation. It is a well crystallized rock type which will break across foliation without splitting, and therefore is not easily plucked by the ice. The Hartland formation is bedded and very well foliated, qualities which render it susceptible to large-scale plucking. No doubt both formations were polished and striated as the ice first advanced. Later, under deeper ice, the Hartland was thoroughly plucked and lost its polished outcrops, whereas the Waramaug effectively resisted that type of erosion. The obstructed drainage lines in the Hartland are probably due both to rock basins and to ground moraine dams of the quarried material.

The exceptional cases follow the pattern. In the vicinity of Washington Depot there are pavement outcrops on the Hartland formation; here, the formation displays highly contorted structure. On the hill in Woodville the Waramaug formation has a good foliation, and has been plucked.

Valleys. In accordance with the observations of others in Connecticut (Flint, 1930) the stream valleys show little evidence of glacial erosion. A possible exception is that part of the East Aspetuck River now occupied by the southeast end of Lake Waramaug. As seen from Church Hill Road west of Church Hill, this valley has a definite U-shape. Since it lies generally parallel to the ice movement, erosion would have been feasible.

Lake Waramaug as a whole appears like a flooded part of the East Aspetuck River. There is glacial drift in New Preston, which may be partly responsible for blocking the valley to form the lake.

But there is also bedrock in New Preston, so that Lake Waramaug may also occupy a rock basin formed by differential deepening by the ice.

GLACIAL DEPOSITION

Glacial deposition is discussed under the following headings: 1) Drumlins, 2) Boulder Fields, and 3) Erratics.

Drumlins. The drumlins of the New Preston and Litchfield quadrangles, shown in Plate III, have these general characteristics. 1) Their distribution is patchy, unsuggestive of any overall pattern of deposition. 2) Generally they occur on upland areas, but they are also found in lowlands, as around Lake Waramaug and Bantam Lake. 3) Both single and compound forms are common. 4) Many are closely associated with bedrock. 5) Most have axes which follow a S20° E trend, although there is a small group whose axes follow a S2° E trend. 6) Postglacial erosion of drumlins has not been great. These last three characteristics are of sufficient importance to be discussed in detail below.

An outstanding characteristic of many of the drumlins is their close association with bedrock. The large drumlin fields in central Wisconsin are in plain-like areas of little relief. But here the drumlins are built on the rougher western Connecticut uplands, and this change in the basement topography is reflected by a difference in the nature of the drumlins. Here rock-controlled drumlins abound. Of sixty-eight drumlins recorded in the New Preston quadrangle, forty are known to be rock-controlled. Of one hundred drumlins in the Litchfield quadrangle, twenty-two are known to be rock-controlled. Many of the others are undoubtedly also rock-controlled, but fail to display their nature surficially. For example, the upland area west of Washington Depot is mainly capped by drumlins. Yet there are a number of outcrops of bedrock scattered along the crestal areas, indicating that the till is but a thin veneer over a bedrock upland, and that almost all of the drumlins are rock drumlins.

No unquestioned all-till drumlins are known to exist in this area. However, those drumlins which may be of this type are: 1) Lower Church Hill, 2) the three Carmel Hill drumlins, 3) the drumlin on the north shore of Lake Waramaug, 4) Plumb Hill, and 5) the drumlins on the sandy plain around Bantam Lake in the Litchfield quadrangle.

The close association of bedrock with many of the drumlins has caused two characteristics of these drumlins. 1) Standard rock drumlins (those with rock cores) are common. But there are also half-drumlins, in this report called drumlin-heads and drumlin-tails. A drumlin-head is a shaped ridge of till banked against a rock promontory (Plate IV, Fig. A). A drumlin-tail is a similar ridge trailing off a promontory. In material, shape, and trend they are identical to other drumlins; yet they are only half-formed. A half-drumlin is not a hill in itself, as other drumlins are; it is merely a ridge connected to a rock upland. Drumlin-heads and -tails grade on the one hand into rock drumlins, and on the other into unshaped masses of till banked against rock promontories (as the northwest flank of Mt. Rat). This half-drumlin concept readily explains drumlins with reverse profiles, i.e. those whose lee sides are steeper than their stoss sides, for a reverse profile is achieved in a rock drumlin by the combination of a long drumlin-head and a short drumlin-tail.

An example of a drumlin-head is found just north of Camp Washington. Several drumlin-tails are found on the north shore of Lake Waramaug and just north of Mt. Tom Pond.

2) Rock drumlins frequently lack the perfection in streamlining that other drumlins have. Their trend is just as accurate, and the presence of shaped till demonstrates their nature, but the bedrock may still manifest itself in the shape of the drumlin. For example, the second rock drumlin to the northwest of Above All State Park is clearly a drumlin, yet the contour map shows how irregular in outline it is, due to the close bedrock control. Just north of Mt. Tom Pond is a rock drumlin which trends S21° E; but the top of it, where the Waramaug formation crops out, trends a little west of south, which is just the strike of the Waramaug foliation there. The rock drumlin constituting New Preston Hill is similar; the southern hill, where the Waramaug formation crops out, trends west of south in response to the foliation of the Waramaug.

The abundance of rock-controlled drumlins strongly suggests they were formed by deep, plastic ice which plastered the till against or over rock buttresses. And yet the simple plastering of till against a protuberance could not have been the whole story, because there are large areas where rock knobs abound but till is scanty (as around the Pitch, Morris, and Wigwam reservoirs in the Litchfield quadrangle), and there are numerous rock promontories which lack drumlin-heads or -tails. Observation shows that there are extensive bedrock island areas surrounded by drumloidal topography with no apparent differences in lithology, structure, or basement topography between the adjacent contrasting areas. The reason for this patchy distribution of drumlins is unknown to the writer.

The graphical record of the axial trends of 158 drumlins measured in both quadrangles (Plate IV, Fig. B) shows two peaks in the occurrence of trends: one at S20°E, the other at S2°E. The S20°E trend is the major one, and it checks with the major trend of the glacial striae. The S2°E drumlins have no counterpart in glacial striae. There is no record of drumlins with axes between S7°E and S11°E. This indicates that the S2°E group is a definite group in itself, separate from the S20°E group. And the lack of complete gradation between the two groups suggests that in this area the glacier ceased movement briefly, and then was rejuvenated with a slightly different trend.

Drumlins of the two groups occur side by side, as the two rock drumlins west of City Hill. They also occur in combination, as Church and Fenn hills.

Dating the age relationship of the two groups is difficult. In east-central Wisconsin there is an area containing drumlins of two ages, where some of the older have tails reshaped to the younger trend (Thwaites, 1948). There are a few such examples in this area, which indicate that the S20°E group was earlier than the S2°E group. The drumlin just southwest of Romford and the rock drumlin east of the Shepaug Reservoir both have tails which bend toward due south. In the Litchfield quadrangle, the drumlin just east of Big Meadow Pond, the drumlin just northeast of Magnolia Hill, and Plumb Hill all have tails reshaped to the south. No drumlins of the S2°E group bear tails which show reshapement in the reverse direction.

In summary, the axial trends of drumlins indicate that the last glacier to cover this area moved in a S20°E direction, that it stagnated briefly, and was rejuvenated in a S2°E direction. Further detailed investigation in adjacent areas is necessary to verify this hypothesis.

The Apple Hill drumlin at the southeast end of Bantam Lake in the Litchfield quadrangle has been called an east-west drumlin (Flint, 1930), or contrary to the general trend. While it is true that the long dimension of Apple Hill is east-west, the drumlin is actually a compound form whose several members all follow the proper trend. It may also be a rock drumlin.

One final observation on drumlins deserves comment. Postglacial erosion has been so slight that in only a few places is it noticeable. The New Preston Hill rock drumlin has been cut into two parts. This was probably largely accomplished by proglacial streams. Three drumlins in the Litchfield quadrangle have similarly been severed: one just south of East Morris, one just west of Guernsey Hill, and Marsh Point in Bantam Lake. On the northwest flank of the drumloidal uplands west of Washington Depot, parallel consequent streams have incised the till slightly: up to twenty feet in places. On the east slope of these uplands the headward growth of preglacial streams re-excavating their till-plugged valleys is visible. This suggests that drumlins formed on rough uplands last a relatively short time. Some of the drumlins at the south edge of the Litchfield quadrangle bear consequent streams which have incised headward and have dissected the slopes of the drumlins to such an extent that the drumlins have an odd lobate appearance.

Boulder Fields. Small boulder fields which are not uncommon in the quadrangle, generally, although not always, occur on the sides of and in the bottoms of valleys. There is little reason to suspect a difference in till between these areas and other areas. A more probable explanation is that the boulders were concentrated by the removal of the finer materials from the till by consequent streams.

Erratics. Erratics on the whole are too commonplace to discuss. There are two in this quadrangle, however, which deserve mention. 1) One is a fifteen foot boulder of granite gneiss which lies on the west flank of the second rock drumlin to the southwest of City Hill. It probably came from the granite gneiss area northwest of Town Hill.

2) The other is a five foot boulder of white marble, studded with tremolite, which rests on the top of the Pinnacle, just north of Washington Depot. The Pinnacle is dark Mt. Tom hornblende gneiss. The contrast between the two rock types couldn't be greater. This erratic is notable on two counts: a) its location on the top of a high bluff overlooking the Shepaug River; b) the nature of the rock. It is remarkable that a boulder of material of this incompetence could last during movement. It must have come from the Stockbridge marble belt along Highway 25, a distance of two and one-fifth miles.

GLACIO–AQUEOUS DEPOSITS

Glacio-aqueous deposits most commonly occur along the sides of valleys, particularly main valleys. Such a linear distribution suggests deposition at the edges of residual tongues of ice which lay in the valleys during the wastage of the ice sheet. This is in accordance with the theory of wastage of the ice sheet in New England proposed and modified by Flint (1930, 1932). The perfection of some of these deposits attests to the fact that in these areas, at least, the ice was stagnant.

Crevasse Fillings. 1) There is a cluster of crevasse fillings on the south flank of Mt. Tom and on the west side of the valley southwest of Little Mt. Tom, where deposition took place in crevasses at the edge of the ice tongues during wastage, the material being carried in by streams off the land and off the ice. With one exception, the crevasses were not open all the way to the valley sides during deposition. Thus the crevasse fillings are separated from the valley sides, rather than connected by terraces. The depressions between the crevasse fillings and the valley walls are not due to postglacial erosion; it is more likely that they represent ice slivers separated from the main ice body. All the crevasse fillings are similar in appearance (Plate V, Fig. A).

Some of the crevasses paralleled the ice border, some cut into it. This combination isolated blocks of ice, and these later produced kettles. Being on the valley side, the meltwater from these ice blocks flowed directly downhill, eroding gaps in some of the crevasse fillings to leave amphitheater-shaped kettles.

The large crevasse filling southwest of Little Mt. Tom had a slightly more complex history. The conical hill at its southern end contains delta foreset bedding; but above the foresets, and throughout the rest of the crevasse filling, the deposits are glacio-fluvial. Apparently a two-stage history was involved. The conical hill is a form of moulin kame, representing a short crevasse which impounded water in which the delta was deposited. Then the long longitudinal crevasse opened, draining the pond and leaving a channel open for glacio-fluvial sediments.

2) There is a crevasse filling linked to a kame terrace at West Morris, where a tributary joins the Bantam River. It represents a crack which opened between the Bantam River ice tongue and the smaller tributary ice tongue. The combined deposits constricted the

tributary to form a pond, now a swamp, just across the road (east) from Little Mt. Tom.

3) The large crevasse filling west of Little Mt. Tom is similar to the one just described, except it is not joined to a kame terrace.

4) The crevasse filling 1250 feet southwest of BM 845 (northeast of Emmons Pond) represents a crack at the edge of the ice into which a stream from the hill flowed and deposited its load.

5) The crest of the crevasse filling 3500 feet east of Romford is in three step-like levels. It may represent the pulsational opening of the crack during deposition, or it may represent three stages of deposition in a crack in the ice, as the ice shrank westward.

6) The small crevasse filling on the east flank of Mt. Tom is a form of moulin kame.

Eskers. Inasmuch as eskers and crevasse fillings form an isomorphous series, differentiation between the two forms was not easy. In general, most of the ridge-shaped deposits of this form are found on valley sides, where crevasse fillings seem the best explanation. Most of these deposits, then, were put in this category. Eskers were differentiated on this basis: 1) where the ridges were especially sinuous, and 2) where the ridges were branching (as the one north of Sprain Brook).

Kame Terraces. 1) A kame terrace containing glacio-fluvial deposits of all kinds is found southwest and west of Camp Washington. Both glacio-fluvial and glacio-lacustrine sediments are closely associated. Rapid, local variations in the sediments are the outstanding characteristic. The following deposits were observed: a) poorly varved clays, and fine well-sorted sands, indicating relatively quiet impounded water, b) delta cross-bedding, c) shoreline sands and gravels, d) stream cross-bedding, and e) coarse fluvial gravels. They all indicate rapidly changing depositional conditions in a gap between the ice tongue and valley side, conditions under which sedimentation constantly see-sawed between lacustrine and fluvial. In general, the highest deposits are fluvial.

Erratics occur in the deposits. They may be due to ice rafting or were sloughed off the ice tongue. Small-scale normal faulting is visible, perhaps due to differential settling. Local crumpling of deposits is found, attributed to ice berg drag or slumping.

2) The kame terrace 3250 feet west of Mt. Tom lies in a basin of accumulation which was held in by an ice dam at its northern end. In this basin lay an ice sliver (now a swamp) which was separated from the main ice mass. Sedimentation occurred along the western edge of the ice sliver to form the kame terrace.

Other Glacio-Aqueous Deposits. There are two deposits banked against two drumlins, 3500 feet north of Camp Washington. Both deposits rise to the same level. The western one is a true terrace. The eastern one is also a terrace, most of which has been rendered irregular by two kettles. Delta cross-bedding is exposed in the eastern one, with the foreset beds dipping toward the south. This evidence suggests the history depicted in Plate VI. As the ice tongue in the Bantam River tributary wasted, it impounded water between it and the two drumlins. Into this pond a compound delta was built, part coming from a stream flowing south between the drumlins, part coming from a stream off the ice. Two ice bergs were entrapped in the process. Further wastage of the ice tongue opened an outlet in the main valley, draining the pond. The stream between the drumlins, no longer base leveled by the pond, began to incise the delta. Ultimately, only the terraces remained.

Drainage Changes

Mt. Tom Area. Mt. Tom Pond drains southeastward through a narrow gorge into the Bantam River, and thence into the Shepaug River. Yet the west end of the pond is separated from a direct westward outlet to the Shepaug River by a narrow divide less than ten feet high. This divide is composed of till, and is an extension of the drumloidal hills immediately north of the pond. It is believed that the drumlins blocked a tributary of the Shepaug River to form Mt. Tom Pond (Plate VII, Figs. A, B). The impounded water spilled over a divide to the southeast where, with the assistance of glacial waters, it cut a short channel to an older Bantam River tributary; this combined channel is the present Mt. Tom gorge. In the middle of the gorge a part of the older tributary is preserved as an abandoned channel. The present stream is separated from it by a narrow monolithic ridge. Traces of glacial polish are found at the bottom of the abandoned channel, proving its older age. Probably an ice block prevented the Mt. Tom Pond overflow from entering the older tributary farther upstream, and led to the cutting of the bypass. Mt. Tom gorge is thus seen to be partly preglacial and partly postglacial.

Warren-Tanner Hill Area. Sucker Brook, 4750 feet southeast of Warren, is joined by a south-flowing tributary which drains only 4500 feet of its broad valley. The rest of the valley to the north is drained by a stream which swings eastward through a narrow rock gorge to enter a north-flowing stream. But this valley with the split drainage is a single valley. Furthermore, its broadness bespeaks its age. Evidently at one time it was drained entirely by the Sucker Brook tributary (Plate VII, Figs. C, D). Then an ice block, where the swamp is today, diverted the northern part of the drainage over the divide to the east. Glacial meltwater must have reinforced the diverted stream, for its gorge through the divide is too deep for its own cutting ability.

An elongate rock hill, 2000 feet northeast of BM 998, is separated from the uplands to the west by a narrow, deep rock gorge containing Sucker Brook. On the east side of the hill is a relatively broad, nearly abandoned valley. It is likely that Sucker Brook once flowed through this broad valley (Plate V, Figs. B, C), and that it was diverted by till and/or ice to its present course. In the gorge the Waramaug formation displays a shattered appearance, as if there were a fault zone here; such an interpretation would explain the easy divergence of Sucker Brook and youthful aspect of the gorge.

The large swamp, 4500 feet northeast of Tanner Hill, was at one time a lake, which originated when the Sucker Brook drainage was constricted by the till on the north flank of Tanner Hill and the drumlin-tails beneath BMs 998, 931 (Plate V, Figs. B, C).

Highway 25 Area. State Highway 25 follows a broad marble valley from Woodville to the western border of the New Preston quadrangle (and on to New Milford). From New Preston on, the valley contains the East Aspetuck River. Northeast of New Preston it contains Meeker Swamp, which drains through Bee Brook to the Shepaug River. Yet the marble valley is a single valley. It is believed that at one time a tributary of the East Aspetuck River extended almost to Woodville (Plate VIII, Figs. A, B), and that its upper part was disrupted by two deposits of till: 1) the drumlin-tail which extends to BM 110 diverted the stream to the Shepaug River drainage, and 2) the till composing the hill 2626 feet northeast of BM 664 dammed the stream to form a lake which is now Meeker Swamp. Inasmuch as there is marble here, Meeker Swamp may be in part a rock basin.

Economic Aspects

All glacio-aqueous deposits, such as crevasse fillings, eskers, kame terraces, etc. are potential sources of sand and gravel. Many of these deposits shown on the map are being worked now or have been at one time. Many of the others have been test pitted. The best potential area is the cluster of crevasse fillings on the south flank of Mt. Tom; most of these are untouched.

General Summary

1) Glacial polish and striae weather rapidly when exposed. But near-replicas of glacial polish, in the form of pavement outcrops, have lasted a long time, and are characteristic of certain types of bedrock.

2) Glacial plucking, guided by differences in bedrock lithology and structure, has controlled the rock topography of the area.

3) There was no widespread valley glaciation.

4) Many, and probably most, of the drumlins have close bedrock control. Rock drumlins abound. Not uncommon are half-drumlins, in this report called drumlin-heads and drumlin-tails.

5) Drumlins, striae, and roches moutonnees indicate that the last ice sheet to cover this area advanced in a S20°E direction, that it stagnated briefly, and that it was rejuvenated in a S2°E direction.

6) Postglacial erosion has not been great.

7) Crevasse fillings, eskers, and kame terraces indicate stagnant conditions. Their distribution adds weight to the theory that the ice wasted into stagnant valley tongues (Flint, 1930, 1932).

8) There have been some drainage changes due to glaciation.

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Figure A Glacial polish on the Waramaug formation along Angevine Road. Striae show the ice moved in a direction away from the observer. The hammer handle indicates the foliation of the formation.

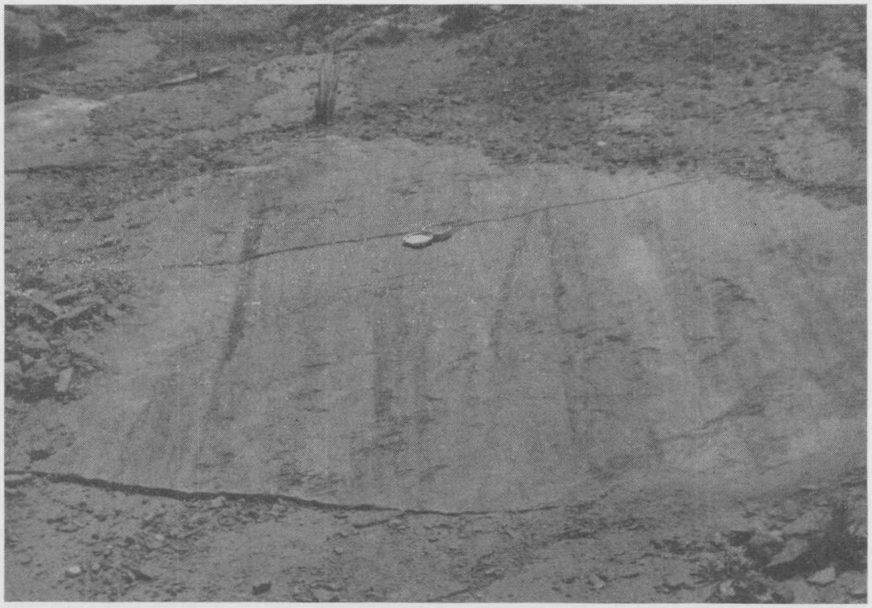


Figure B Glacial striae on the Waramaug formation at the Warren ball park. Note the errant stria in the center of the photograph. It may be due to the rolling over of a stone as the ice advanced. The compass indicates the foliation of the formation.

Figure A Side view of a roche moutonnee on the Waramaug formation at Rabbit Hill. Ice moved from left to right. Hammer gives the scale.

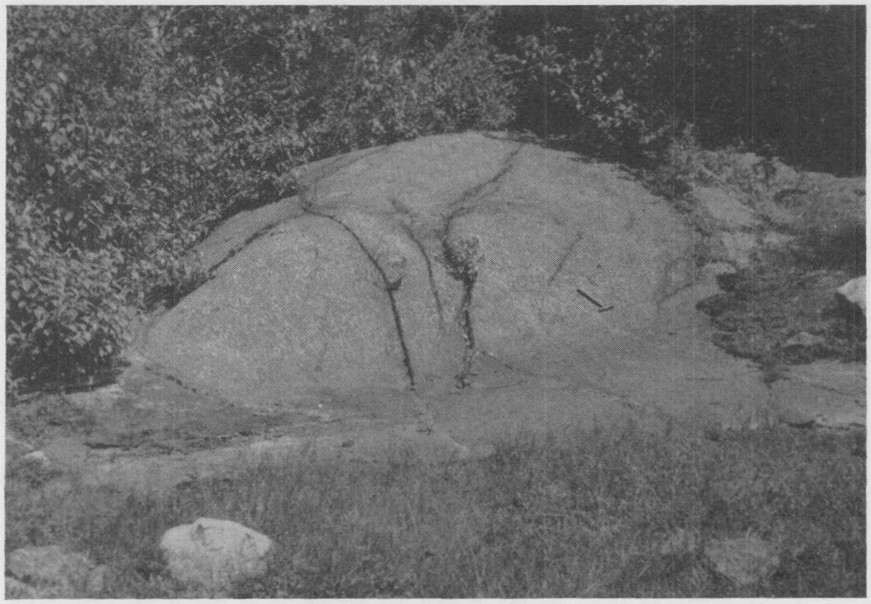
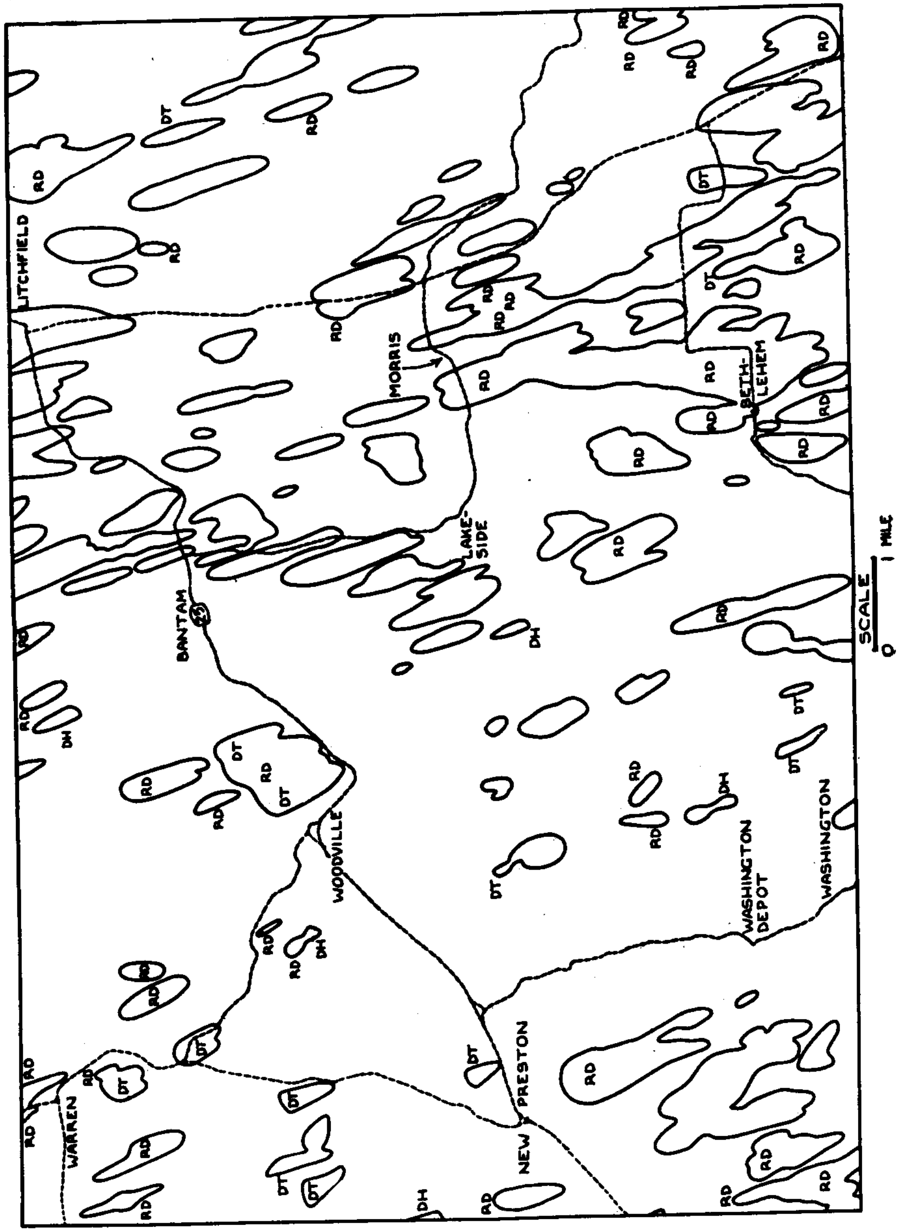


Figure B Nearly end-on view of the same roche moutonnee, looking in the direction of ice movement.



Map of the drumlins of the combined New Preston and Litchfield quadrangles. Dotted lines are main highways. RD is rock drumlin, DH is drumlin-head, DT is drumlin-tail.

PART II — PLATE IV

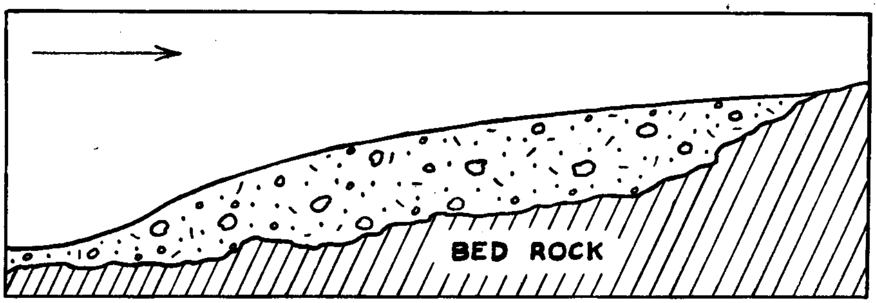


Figure A Diagram of a drumlin-head, side view. Arrow shows the direction of ice movement. Half-drumlins are ridges rather than hills.

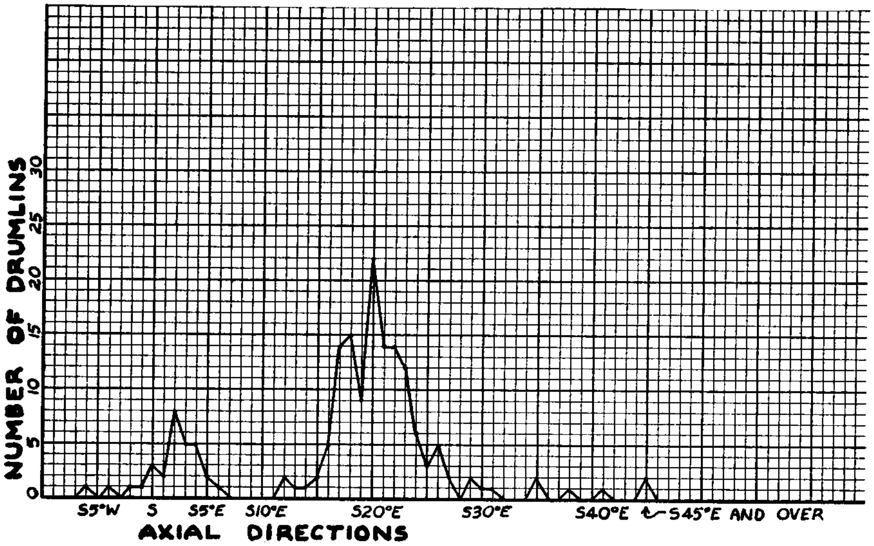


Figure B Graph of the axial trends of 158 drumlins measured in the New Preston and Litchfield quadrangles. Note the two peaks, at S2°E and S20°E, with a lack of complete gradation between.

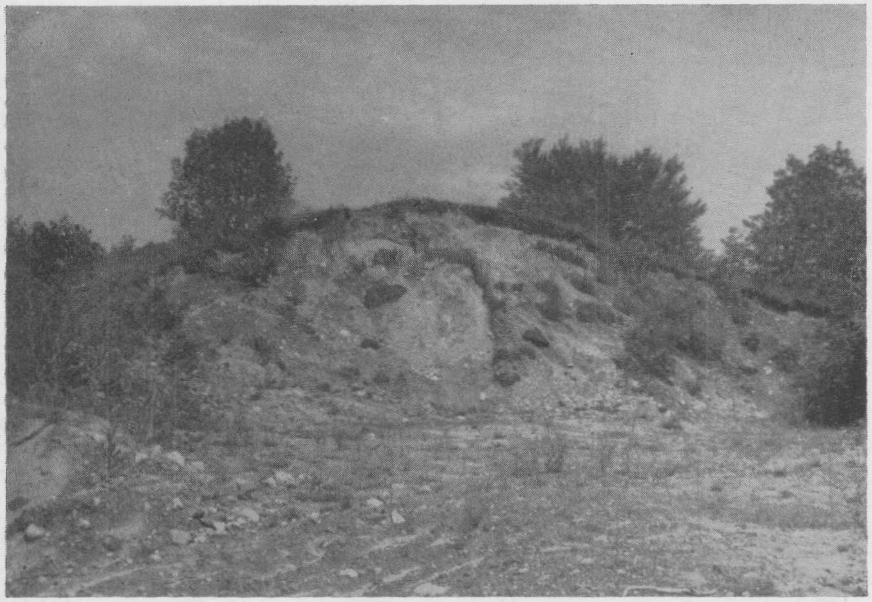


Figure A Cross section of the long crevasse filling southwest of Little Mt. Tom.

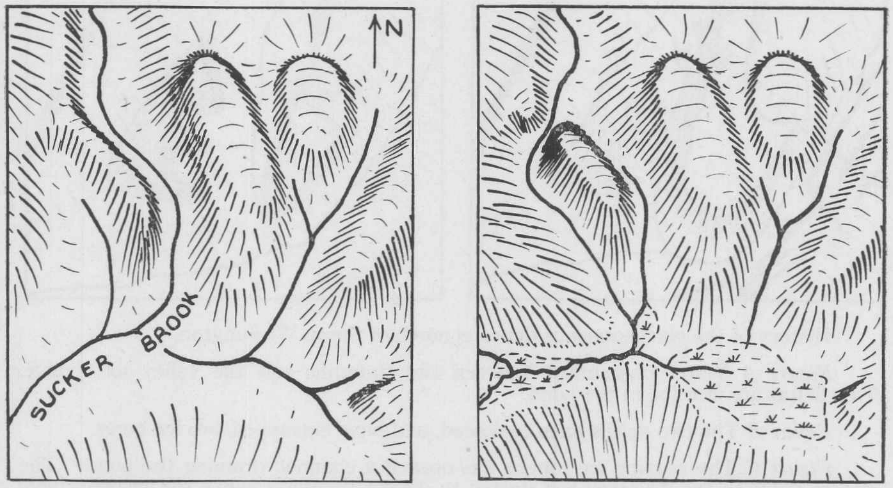
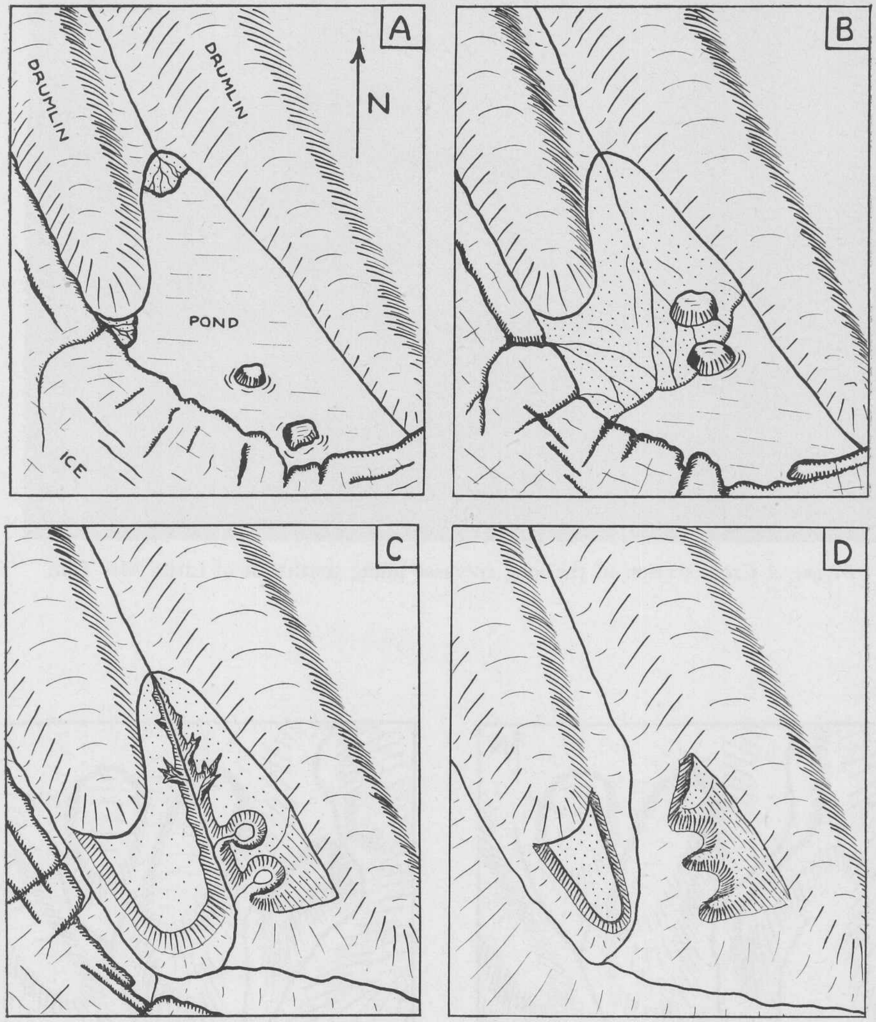


Figure B Preglacial Sucker Brook drainage north of Tanner Hill.

Figure C Present Sucker Brook drainage north of Tanner Hill. Ice or drift deflected Sucker Brook over a spur, where it cut a gorge, and the deposition of till constricted it to form a swamp.

PART II — PLATE VI



History of the glacio-aqueous deposits north of Camp Washington.

Figure A Water impounded between two drumlins and the valley ice tongue. Two deltas are forming in the pond.

Figure B The two deltas have coalesced, and have entrapped two ice bergs.

Figure C The wasting ice tongue has opened a channel, draining the pond. The stream between the drumlins has started to dissect the delta, while the ice bergs have melted to form kettles.

Figure D The present remains of the delta.

PART II — PLATE VII

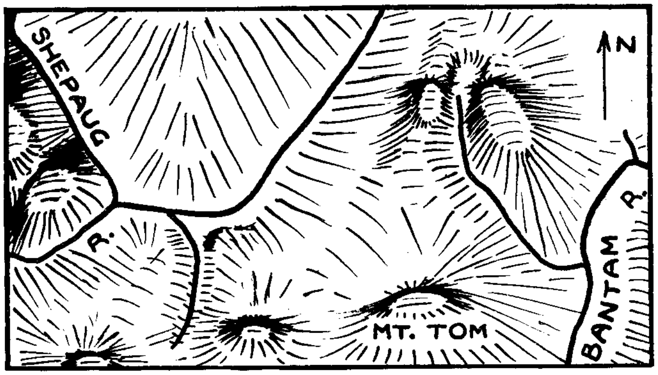


Figure A Preglacial drainage north and northwest of Mt. Tom.

Figure B Present drainage north and northwest of Mt. Tom. Deposition of till blocked a Shepaug River tributary to form Mt. Tom Pond, and the pond overflowed into an older Bantam River tributary.

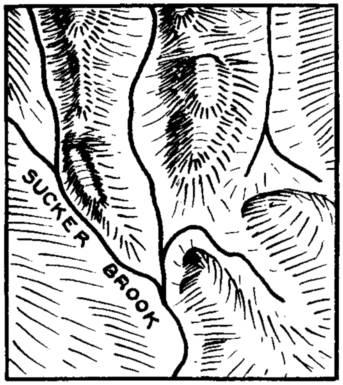


Figure C Preglacial drainage of a Sucker Brook tributary east of Warren.

Figure D Present drainage of a Sucker Brook tributary east of Warren. Ice deflected the headwaters of the tributary over a divide to the east, where it cut a gorge, leaving the tributary valley with split drainage.

PART II — PLATE VIII

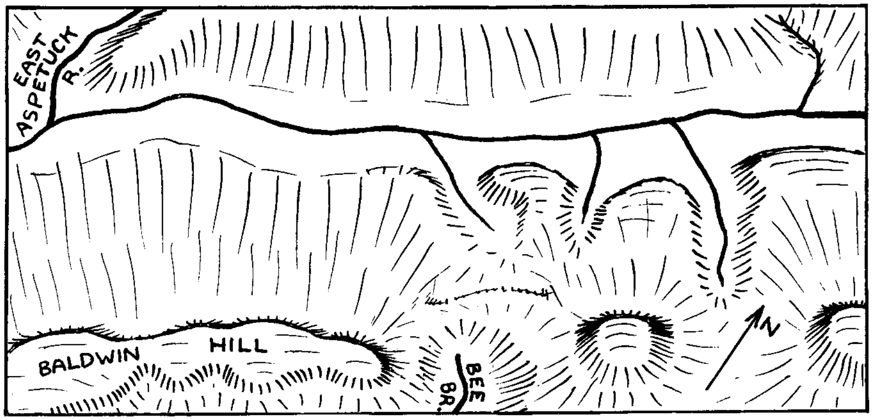


Figure A Preglacial drainage of an East Aspetuck River tributary northeast of New Preston.

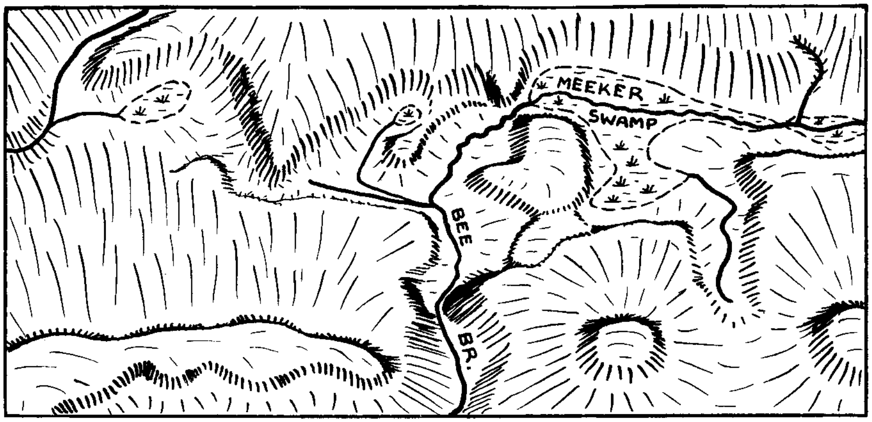
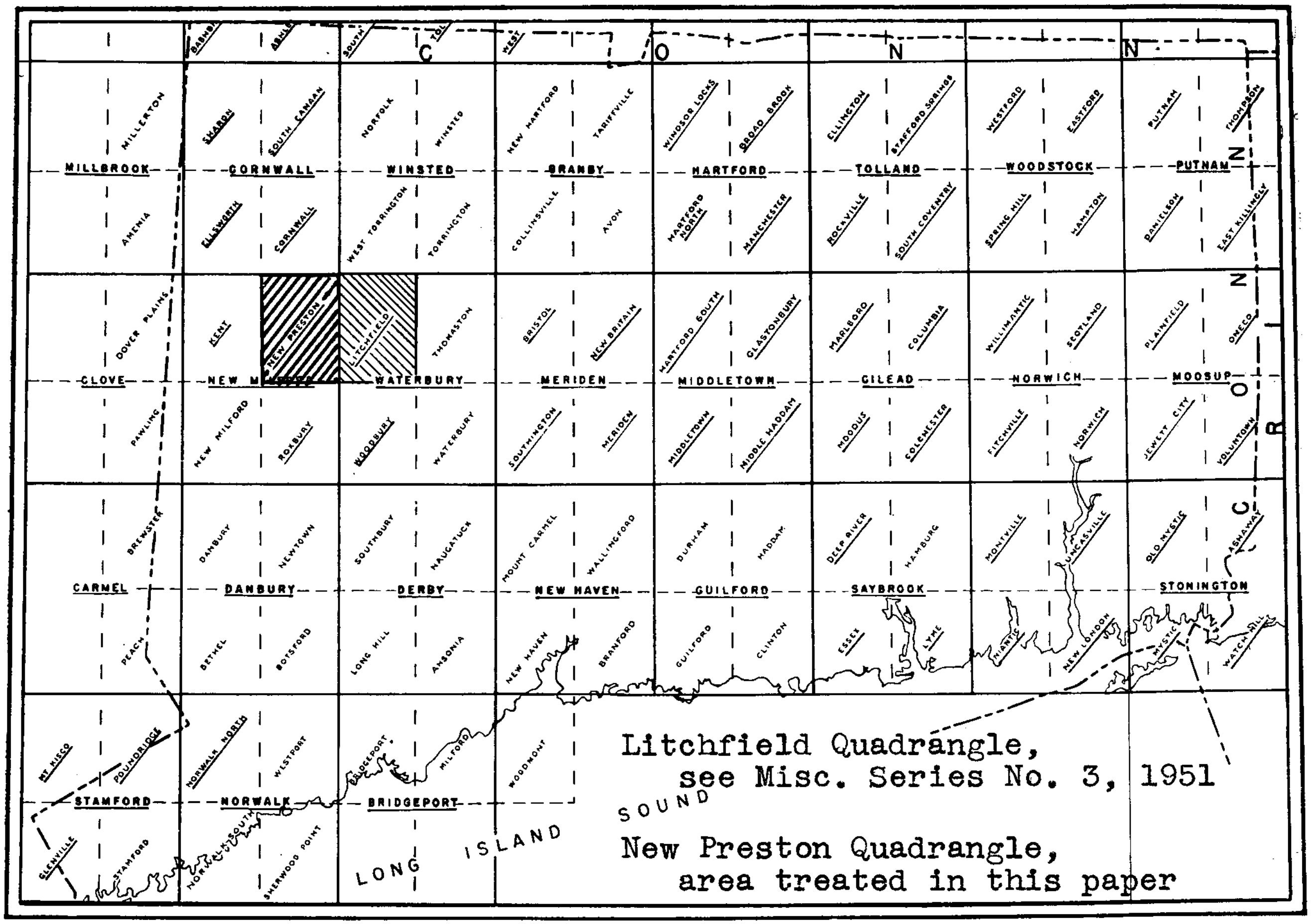


Figure B Present drainage northeast of New Preston. The deposition of till blocked the tributary to deflect the stream over a divide to Bee Brook, and to form Meeker Swamp.

C
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WINDSOR LOCKS
HARTFORD NORTH
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ROCKVILLE
STAFFORD SPRINGS
SOUTH COVENTRY
WESTFORD
SPRING HILL
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HAMPTON
PUTNAM
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THOMPSON
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SHERWOOD POINT
BRIDGEPORT
MILFORD
WOODMONT
LONG ISLAND SOUND
Litchfield Quadrangle,
see Misc. Series No. 3, 1951
New Preston Quadrangle,
area treated in this paper

GLACIAL GEOLOGY OF THE NEW PRESTON QUADRANGLE