STATE GEOLOGICAL AND
NATURAL HISTORY SURVEY
OF CONNECTICUT

THE BEDROCK GEOLOGY of the WOODBURY QUADRANGLE

With Map

Open Map

By

ROBERT M. GATES, Ph.D.

Quadrangle Report No. 3

1954

State Geological and Natural History Survey of Connecticut

QUADRANGLE REPORT NO. 3*

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With Map

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By

Robert M. Gates, Ph.D.
Associate Professor of Geology,
The University of Wisconsin

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by

R. M. GATES

ABSTRACT

The Nonewaug[1] granite is a body of magmatic origin with associated granitized and feldspathized metasediments. It is a roughly elliptical mass which cross-cuts the mica quartzites and mica-quartz schists of the Hartland formation. The granite is characterized by a fine to coarse textural layering, graphic granite crystals, and plumose muscovite. Granitic gneisses, feldspathized metasediments, and dikes and sills of the Nonewaug granite characterize the border zone.

The Hartland formation south of the granite body, in sharp contrast with that north of it, is much more intricately folded and contains feldspathic or pegmatitic material intimately intermixed with it. The suggestion is made that this feldspathic material is produced locally and illustrates a possible source for the Nonewaug granite. The mineralogical changes in the Hartland required to produce a granitic extract are discussed.

A down-faulted outlier of Triassic basalt and sediments in the Pomperaug valley accounts for the rough topography of the valley floor.

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[1] The granite called Nonewaug in this report was originally included with the Thomaston granite and granite gneisses by the earlier workers (Percival, J. G., 1842; Hobbs, W. H., unpublished Litchfield folio; Rice, W. N. and Gregory, H. E., 1906; Gregory, H. E. and Robinson, H. H., 1907; and Agar, W. M., 1934). It was called Woodbury in the Litchfield and New Preston quadrangle reports (Gates, R. M., 1951; Gates, R. M. and Bradley, W. C., 1952). The change to Nonewaug was made to avoid confusing it with the Woodbury granite in Vermont. The reasons for separating it from the Thomaston granite are discussed in this report in the section on Previous Work in the Area.

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INTRODUCTION

The major interest in this quadrangle is the relationship of the Nonewaug granite intrusive to the surrounding metasediments of the Hartland formation. The Nonewaug granite of magmatic origin may be compared with the granite gneisses which have originated through the metamorphism of the mica quartzites and schists. Of almost equal interest is the petrology of the Nonewaug granite itself and the significance of the feldspathized metasediments which make up over half of the area.

The Woodbury quadrangle is located (Figure 1) in the Western Connecticut highlands at the southern end of the Green Mountain Plateau. The highlands are bounded by the Housatonic valley on the west and the Connecticut valley on the east. The Weekeepeemee and Nonewaug rivers provide the principal drainage in the northern half of the area. They join near North Woodbury to form the Pomperaug river which enters the Housatonic a few miles to the south. The only population center, Woodbury, is located in the Pomperaug valley.

The mapping of this quadrangle was started in 1942 by Dr. E. N. Cameron in the course of a reconnaissance study of the Hartland formation, when he mapped the central part of the main body of the Nonewaug granite. In 1948, at his suggestion, the writer undertook to delimit the granite mass and to study several of its unusual features. Most of the main body was found to lie in the northern one-third of the Woodbury quadrangle but it extends northeastward into the Litchfield and Thomaston quadrangles (Gates, 1951). The writer completed the mapping of the quadrangle during the summer of 1952. Preliminary U. S. Geological Survey topographic maps on a scale of 1:24,000 were used as base maps. All the mapping was done under the direction of the Connecticut Geological and Natural History Survey.

The financial support of the Connecticut Geological Survey during the summers of 1948 and 1952 is gratefully acknowledged. The writer also wishes to thank Dr. E. L. Troxell for his continued interest in the mapping of western Connecticut. The work during the summer of 1952 was supported in part by a grant from the Wisconsin Alumni Research Foundation. The writer is indebted to Drs. R. C. Emmons and E. N. Cameron for their helpful criticism of the manuscript. Special thanks are due to Dr. Cameron for the use of his 1942 field notes on the Nonewaug granite and for his interest in this problem.

Previous Work in the Area

The earliest recorded work in this quadrangle was a very broad reconnaissance survey by James G. Percival (1842). Rice and Gregory (1906) prepared the "Manual of the Geology of Connecticut" which was published as Bulletin No. 6 of the Connecticut Geological and Natural History Survey. The data on the crystallines of the Western Connecticut highlands west of longitude 73 were obtained in large part from the unpublished U.S.G.S. Litchfield Folio of W. H. Hobbs (Rice and Gregory, p. 84, 1906). Hobbs had grouped many of the younger granites and granitic gneisses of western Connecticut under the name of Thomaston granite gneiss. The granite body in the Woodbury quadrangle was included in this group. The granite in the Woodbury quadrangle is considered sufficiently unusual in several aspects to merit a separate name and is called Nonewaug in this report. Some of the reasons for separating this granite from the Thomaston follow. The type Thomaston granite occurs in an abandoned quarry at Reynold's bridge south of the city of Thomaston. It is a small dike-like body which is quite different from the granite in the Woodbury quadrangle as well as from the granites and granite gneisses elsewhere also mapped as Thomaston. The Thomaston includes such a variety of granites, pegmatites, granitic gneisses, and feldspathic metasediments that it has a different meaning in every area. Agar (1934) in his discussion of the granites of western Connecticut included the granite of the Woodbury quadrangle with the Thomaston granite, although no specific mention was made of the occurrence. His petrographic description of the Thomaston granite is related more to the type Thomaston at Reynold's bridge than to some of the other Thomaston granites. The granite in the Woodbury quadrangle is quite different from the Thomaston granite he describes and from other Thomaston granite gneisses. The writer hopes to avoid, not add to, confusion by introducing the name Nonewaug for the granite in the Woodbury quadrangle.

The Triassic rocks of the Pomperaug valley were first mapped by J. G. Percival (1842) during his reconnaissance survey of the state of Connecticut. Few changes have been made in his original map of the trap ridges. Davis (1888, 1898) studied these rocks in connection with his work on the structure of the Triassic of the Connecticut valley. In 1901, W. H. Hobbs published a detailed report on the Pomperaug valley. Krynine (1950) included the Pomperaug basin in his study of the Triassic stratigraphy of Connecticut.

General Geology

The Nonewaug granite and the Hartland formation are the principal bedrock units in the Woodbury quadrangle. The Nonewaug granite is a lenticular, east-west trending body in the northern third of the quadrangle, bounded on the south by a zone of mixed granite, granite gneiss, and Hartland rock types. Highly metamorphosed Hartland rocks containing widely varying amounts of feldspar and granitic or pegmatitic material underlie most of the southern half of the area. Several small lenses and dikes of a hornblende gneiss similar to that of Mt. Tom (Gates and Bradley, 1952) were found in the Hartland formation, but they are barely large enough to be shown on the map of the quadrangle. In addition, granite and pegmatite dikes and sills are fairly common throughout the Hartland. A large granite gneiss area occurs west of Woodbury. A third major rock unit is an infaulted block of Triassic basalt and sediments which occurs as a narrow tongue along the Pomperaug valley.

The Nonewaug granite is only one of several intrusives in the Hartland formation (Agar, 1934). The intrusives range in composition and texture from quartz diorites to granites and pegmatites. Their relationships to the Hartland formation are, however, remarkably similar. In spite of many indications of a common age, these intrusives in the Hartland cannot be correlated definitely at the present time.

The geologic position of the small lenses of hornblende gneiss can only be inferred from occurrences in the adjoining quadrangles (Gates and Bradley, 1952). The present conclusion is that they are intrusive into the Hartland formation, but are older than the Nonewaug granite.

The basaltic lavas along the Pomperaug valley are considered part of the down-faulted western edge of the Triassic sedimentary wedge of the Connecticut valley (Krynine, 1950).

Although the sequence of geologic events can be determined fairly well in this area, the geologic age of the major structural disturbances as determined elsewhere in this general region must be accepted. The Cambro-Ordovician sequence of Poughquag–Stockbridge–Hartland formations was deposited on Pre-Cambrian metasediments, gneisses, and granites. These formations were isoclinally folded and overturned toward the east probably during the Taconic disturbance or later. In any event, the rocks were metamorphosed to quartzite, marble, and mica quartzites and schists prior to any intrusions. The Mt. Tom hornblende gneiss was intruded during and after the last stages of the isoclinal folding (Gates and Bradley, 1952). The granitization and feldspathization of the Hartland and the emplacement of the Nonewaug granite are closely related in time and can be considered only as post-Hartland and pre-Triassic. (The Nonewaug granite has not undergone any major deformation.) The Triassic lavas were infaulted either in late or post-Triassic time (Hobbs, 1901; Wheeler, 1937; Krynine, 1950).

THE HARTLAND FORMATION

General statement. Regionally the Hartland formation lies on the east flank of the Green Mountain anticlinorium and is thought to extend from Vermont through Massachusetts and Connecticut to Long Island Sound. It is correlated with the Hoosac and Rowe formations in Massachusetts. It enters Connecticut in a narrow belt near Hartland, attains its maximum width at Woodbury where it extends from New Milford to east of Waterbury, and again narrows at Long Island Sound. The Hartland formation is generally considered part of the Cambro-Ordovician sequence of Poughquag quartzite, Stockbridge limestone, and Hartland schist, although the quartzite is not present in this area and definite correlation has not been made. The nearest Stockbridge limestone is in the narrow belt from Woodville in the New Preston quadrangle to New Milford in the New Milford quadrangle (Moore, 1935; Gates and Bradley, 1952).

The Hartland formation has been traced by detailed mapping from the eastern half of the West Torrington quadrangle southward through the Litchfield quadrangle and westward across the southern half of the New Preston quadrangle. The Nonewaug granite almost separates the Hartland in the Woodbury quadrangle from that in the Litchfield quadrangle. The Hartland is continuous around the granite body, however, in the Thomaston and Waterbury quadrangles to the east and in the Roxbury quadrangle to the west. Thus, there is little doubt that the highly metamorphosed and feldspathized rocks in the southern half of the Woodbury quadrangle are modified parts of the Hartland formation.

The early regional metamorphism of the Hartland produced an isoclinally folded series of interbedded mica quartzites and mica-quartz schists. These were later modified in various ways to granitic gneisses, feldspathic mica quartzites and schists, and metasediments containing granitic and pegmatitic material, i.e., banded gneisses or 'injection' gneisses.

Structure. The general structural features of the Hartland formation are revealed mainly by its foliation and to a lesser extent by the bedding. The bedding is seen much less commonly than the foliation, but where they are observed together they are parallel. The foliation has a general north to northeast trend except where massive intrusives are present. The dip is westward with only a few local exceptions.

Two quadrangles north of Woodbury, the foliation trends approximately south and continues southward along the east side of the Litchfield quadrangle to the Nonewaug granite, where it changes abruptly to N40°-70°E, parallel to the northern border of the granite and also to the mass of the Mt. Prospect complex (Cameron, 1951; Gates and Bradley, 1952). The foliation again changes abruptly in the southeast and northeast corners of the New Preston and Roxbury quadrangles where it swings around the west end of the Nonewaug granite. Along the west side of the Woodbury quadrangle the foliation ranges from N10°-40°W with a persistent westward dip. The foliation outlines a westward-plunging anticline at the west end of the Nonewaug granite.

A similar deflection of the foliation occurs on the east side of the Woodbury quadrangle. Here the trend is generally north up to the southern boundary of the granite where it changes to almost east. East of the granite in the Waterbury and Thomaston quadrangles, the foliation again becomes north to northeast.

South of the granite the Hartland seems to have deformed plastically to acquire an extremely variable foliation. In a general way it appears that the north-trending foliation divides south of the granite, part swinging to the northwest and part to the northeast around the two ends of the granite. The foliation in the intervening area reflects turbulent, plastic deformation.

Hartland rock types. The normal Hartland rock types are composed primarily of muscovite, biotite, and quartz in varying proportions. The common accessory minerals are garnet, staurolite, kyanite, feldspar, and magnetite. Feldspar, usually plagioclase, is commonly present in amounts of 10 to 15 per cent, probably as a primary constituent. Near granite and pegmatite bodies the plagioclase may have been introduced. The micas range from 5 to 50 per cent of the rocks and the quartz from 50 to 90 per cent. These mica quartzites and schists, which represent different original sediments, are interlayered in beds ranging from less than an inch thick to more than 100 feet. These normal rock types are modified locally in response to different grades and types of metamorphism. Garnet, which is fairly common in much of the Hartland, particularly in the more micaceous layers, is the only medium grade (epidote-amphibolite facies) metamorphic mineral developed on a regional scale. Staurolite and kyanite are much less common and are very local in their occurrence (Gates, 1951; Gates and Bradley, 1952).

The mica quartzites and schists that characterize the Hartland in the Litchfield and New Preston quadrangles are not particularly abundant in the Woodbury quadrangle, probably because of different metamorphic conditions related to the origin and emplacement of the Nonewaug granite. The modifications of the Hartland formation bordering the granite and in the southern half of the quadrangle are discussed below as a sequence of increasing metamorphism.

The first indication of increased dynamic metamorphism and metamorphic differentiation in the mica-quartz schist is the separation of the quartz into thin layers, stringers, and augen. Continued metamorphic differentiation results in a banded rock with alternate quartz and mica-quartz lamellae. Normally the layers are less than one-half inch wide and quite regular, but larger lenses and veins of quartz are rather common. The mica quartzites with a small amount of mica do not appear banded although lamellae of relatively coarse grained quartz are present. Garnet in minor quantity is seen fairly often in the mica-quartz schists; staurolite is observed occasionally and kyanite rarely. In the region of Hooppole and Peacock hills these aspects of the Hartland are the dominant rock types.

The second stage of the increased metamorphism is revealed by the presence of feldspar in some of the mica quartzites and schists. In the mica-quartz schists the feldspar is most obvious in the quartz-rich lamellae where its chalky white appearance contrasts with the vitreous luster of the quartz. The micaceous lamellae also contain feldspar and normally small red garnets in fair quantity. Generally the garnet and the feldspar are visible only with the hand lens owing to the coarseness of the micas. The mica quartzites in this stage become more feldspathic but do not appear much different. The grain size may increase, but not so much as in the mica-quartz schists. The feldspar requires a hand lens for identification in the mica quartzite, but is visible to the naked eye in the quartz-rich layers in the mica-quartz schist. The area northwest of Transylvania pond is typical of these slightly feldspathic types.

The Hartland formation in the southern section east of the Pomperaug valley is much the same as that mentioned above except for having more feldspar and an increasing frequency of pegmatitic stringers, dikes and sills. Also, kyanite and staurolite, usually seen only in thin section, characterize the mica-rich layers in this area. The pegmatitic stringers and the quartz lamellae containing feldspar are essentially identical in their occurrence and grade into each other, indicating a common origin. These modified (feldspathized) mica-quartz schists may be described as banded gneisses or, in some places, "injected" (Figure A of Plate I). The banding is normally even if the original metasediment was a mica-quartz schist with no quartzitic layers. The mica quartzite beds generally become more feldspathic, but yield to metamorphic differentiation and "injection" less than do the schists. The beds generally had reacted as competent rocks and in places are broken and appear as "boudinage" in schists and gneisses. The many variations of thick- and thin-bedded mica quartzites and mica-quartz schists and the intermediate types, where feldspathized, produce a complex of rock types which can be mapped only in a general way. The red dots on the Hartland formation color of the accompanying map indicate the feldspar content. Where pegmatitic or granitic dikes or sills are present in mappable quantity, they are represented by red lines. Irregular masses of pegmatitic material are represented by an 'S'-shaped red symbol.

As the first stage grades into the second, so does the second into the third which is marked by the increase in the feldspar content of the rocks. This is less noticeable in the banded gneisses themselves than in the size and number of pegmatitic and granitic sills, dikes, and irregular masses in them. The pegmatitic material generally takes the form of narrow, irregular stringers and patches (Figure B of Plate I) but may occur as thin sills (Figure A of Plate II). There are also larger and coarser-grained granite and pegmatite dikes and sills and some isolated outcrops where the relationships to the metasediments are not known. An additional feature which becomes rather pronounced in this stage is the apparent plastic deformation of some of the rocks. This results in a rock best described as an intimate mixture of metasediments, gneisses, pegmatite, and granite. Summarizing, these three stages are interpreted as a continuous series produced by increasing dynamic metamorphism accompanied by increasing hydrothermal activity and feldspathization.

Ideas on the source of the feldspathic or pegmatitic material are, of course, highly speculative. A nearby granite, the Nonewaug, or an underlying granitic magma are possible origins usually accepted. However, some field observations suggest that at least some and possibly a great deal of the feldspathic or pegmatitic materials are of very local origin. Some pertinent field observations supporting this suggestion are: 1) the common association of garnet and feldspar or pegmatitic material, 2) the ubiquitous occurrence of feldspar and small pegmatitic and granitic bodies, 3) the thin, isolated stringers, lenses, and irregular patches of pegmatitic material, and 4) the apparent genetic relationship of the quartz lamellae, presumably produced by metamorphic differentiation, and the quartz-feldspar lamellae in the banded or "injection" gneisses.

Tentatively, the writer takes the view that the metamorphic differentiation was accomplished by the following mineralogic changes which accompanied the structural activity. Muscovite and biotite, which are always present in adequate amounts, are the sources of the potassic and feldspathic solutions. The plagioclase is derived in part from that present in the original metasediment and in part from the soda usually present in the muscovite type micas (Schaller and Stevens, 1941; Winchell, A.N., 1951). The breakdown of biotite will produce garnet, potash feldspar, and excess potash, if adequate quartz is present and some of the iron is oxidized. Also, kyanite and staurolite, which are observed commonly in thin sections of the micaceous layers, may have been formed from the breakdown of the micas, releasing still more potassic (and sodic) material. The excess potash and soda migrating in response to pressure differentials will react with muscovite to produce more feldspar. At least some of the plagioclase in the gneisses appears to have originated through the replacement of muscovite or biotite.[1]

The quartz-feldspathic materials so generated in a hydrothermal environment could well be fluid and able to respond to differential pressures. They may in one case feldspathize a mica quartzite and in another fill fissures, fractures, or any other opening to form pegmatitic stringers or dikelets. The more feldspathic and pegmatitic areas are considered zones of relatively intense structural activity in which the quartz and feldspar so produced were dilatantly concentrated. In general the southeastern quarter of the quadrangle may be regarded as such an area with the pegmatitic content of the metasediments increasing northward toward the granite.

ROCKS BORDERING THE NONEWAUG GRANITE

General statement. The Nonewaug granite is a lens-shaped body nine miles long and three miles wide which apparently fills a structurally produced opening in the Hartland formation. Its average trend is N60°E with a steep southeasterly dip. The border rocks are the normal Hartland metasediments, feldspathized metasediments, granitic gneisses and granite pegmatite dikes and sills. The metamorphism of the border rocks seems to depend in large part on their structural relations to the granite and on their original metasedimentary texture. The foliation of the Hartland north of the granite is parallel to the northern border, in contrast to the strike on the southern border which is roughly normal to the trend of the granite. The dip of the foliation is generally to the northwest, north of the granite (opposite to that of the granite), and to the southwest, south of the granite. The metamorphism and structure

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[1] The formation of garnet from chlorite in response to higher grade metamorphism without the production of feldspar or the release of potash is generally recognized. The writer does not intend to dispute this reaction.

of the border rocks become increasingly complex from the northwest side of the granite to the southeastern side.

The northern border. The rocks in the northwest corner of the quadrangle where the relations are relatively simple are fairly typical of the entire northern border and provide a good starting point. The predominant rocks are the rather normal mica quartzites and schists. Their foliation strikes N45°–75°E and dips approximately 50° northwest. This northwest dip of the metasediments is nearly opposite to that of the granite which is 60° southeast. A granite lens and several granite and pegmatite sills occur in the Hartland formation near the border of the main granite body. Small concordant granite-pegmatite bodies are very common along the northern border of the granite in the Litchfield quadrangle (see structure section AA^1 on map). Granitic gneisses and feldspathic mica quartzites occur primarily as roof pendants in the granite and as granitized metasediments in the Hartland formation, but are not particularly abundant along the northern border. In all cases the foliation of the granitic gneisses is the same as that of the nearest Hartland.

The west end. The west end of the Nonewaug granite and its border rocks are well exposed in Kavanaugh hill. Here the foliation of the Hartland changes rather abruptly from northeast to N10°–30°W, dipping southwest. As the map shows, the granite ends in three major tongues and many dikes and sills. The dikes normally trend northeast and dip southeast like the main granite. Some dikes terminate as sills by spreading out parallel to the foliation of the Hartland. The Hartland metasediments, which are more mica-quartz schist than mica quartzite, are little affected by their proximity to the granite. Contacts are sharp with no apparent contact metamorphism. Some mica-quartz schists contain thin stringers of pegmatitic material in very minor amounts, but most are the normal schist.

The southern border. The southern border is a complex mixture of granitic gneisses, granite, pegmatite, feldspathic metasediments, and some standard Hartland rock types. A combination granite-Hartland symbol has been used to represent this mixture where it is impractical to map the rock types separately. In the mixed rock granitic rocks predominate in outcrop, but there are indications that the mica-quartz schist, which is relatively soft, may underlie the valleys and covered areas and be quantitatively more abundant than the outcrops suggest.

The structural relationships between the main granite and the rocks of the western half of the southern border are very much the same as those at the western end of the granite. The major granite body and its associated granite and pegmatite dikes trend N35°–65°E and dip southeast. Granite dikes are very common in the mixed rock zone and cross-cut all other rock types. Granite sills are also common particularly at the southern end of Church hill. The granitic gneisses are structurally part of the Hartland metasediments from which they presumably originated. They and the more normal Hartland metasediments strike N20°–50°W and dip southwest.

The western half of the southern border zone includes: 1) the two granitic gneiss lobes of Hogpen hill and the south end of Brushy hill, 2) the Hartland mica-quartz schist tongues between the granitic gneiss and the ridge between Meadow and Gaipin brooks, and 3) interlayered granitic gneiss, metasediments, and granite and pegmatite south of Church hill.

The muscovite-biotite granitic gneiss of Hogpen hill is the largest single area of the gneiss. It is crosscut by several small granite and pegmatite dikes trending northeast and dipping southeast. The foliation of the granitic gneiss strikes N10°–30°W and dips steeply southwest. This granitic gneiss is separated from the gneiss of Brushy hill by a thin wedge of mica-quartz schist. The schist is coarser grained than normal and contains an unusually large number of small garnet crystals. Only a few, small outcrops of the normal Hartland formation were found in this area.

The southern end of Brushy hill, though similar in many respects to Hogpen hill, has many more granite and pegmatite dikes and sills, more normal mica-quartz schist, and feldspathic mica quartzites.

The schist ridge between Meadow and Gaipin brooks is characterized by an abundance of granite and pegmatite dikes and sills at the southern end, and by the occurrence of kyanite at the northern end. The larger kyanite crystals are found in random orientation in quartz augen in the schist. This development of kyanite must be regarded as unusual in many respects since the metasediments normally do not have excess alumina. The kyanite may have resulted from the loss of an unusual amount of potash during the breakdown of the micas. Of course, it is also possible that the excess alumina was received from the granites and pegmatites nearby.

The intermediate members of the metasediment-granitic gneiss series are best exposed in the rocks on the south end of Church hill. By selection, it is possible to show a complete series from mica quartzite to feldspathic mica quartzite to granitic gneiss. The foliation of the rocks is not so uniform here as elsewhere, but generally trends N20°W to N20°E and dips westward. The relations of the granite and pegmatite to the other rocks are also well exposed in this area. The granite dikes consistently strike northeast and dip steeply southeast.

The eastern half of the southern border, extending from the Nonewaug river to Watertown, can be described only as a mixture of granite, pegmatite, granitic gneiss, feldspathic metasediments, and mica quartzites and schists. The granite, pegmatite, and granitic gneisses predominate. The structural relations are quite complex if any consistent pattern is sought, but are very simple if the metasediments are considered as having yielded plastically. This area seems to be one where the metasediments have been thoroughly 'soaked', feldspathized, and kneaded together with the granite and pegmatite. The variations in the foliation of the metasediments shown on the map indicate the degree of crumpling.

The eastern end of the Nonewaug granite in the Thomaston quadrangle is similar to the western end. There are, however, an unusual number of granite and pegmatite sills in the Hartland formation in the region between Watertown and Thomaston.

The granitic gneisses. It is appropriate to discuss here the origin of the granitic gneisses since this section shows their best development. The granitic gneisses are considered to have originated through the metamorphism of the Hartland metasediments during the emplacement of the Nonewaug granite. There is abundant field evidence for this conclusion.

1. Full gradations are found between the normal mica quartzites and schists and the granitic gneisses. The type of gradation depends largely upon the texture of the original metasediment. Mica quartzites, for example, change only slightly, the major changes being the increase in feldspar content and a general recrystallization of the minerals present. Most of the muscovite-granite gneisses show in thin section that much of the biotite has been replaced by muscovite. This replacement muscovite has slightly higher refractive indices[1] than the muscovite in the contiguous granite and is also slightly magnetic. The feldspars may be sodic plagioclase or microcline or both. In general, plagioclase is more abundant, but microcline tends to predominate in the coarser-grained gneisses.

The mica-quartz schists tend to become banded during granitization and to develop into augen gneisses. Mica-rich bands with plagioclase the dominant feldspar alternate with felsic bands in which microcline is more abundant. The plagioclase is commonly untwinned or has only a few twin lamellae in the mica-rich layers. It is usually more normally twinned in the felsic layers. In the augen gneisses microcline tends to be partly replaced by plagioclase.

2. The foliation of the granitic gneisses and that of the Hartland formation are consistently parallel indicating a common structural history. Although the main granite has a textural layering, nowhere has it or its related dikes and sills any foliation.

3. The granitic gneisses and the Hartland formation are intruded by dikes and sills in exactly the same way (Figure B of Plate II and Figure A of Plate III).

4. The spatial relations of the granitic gneisses and the granite indicate a genetic relationship. The gneisses are found mainly as roof pendants in the granite or in the contiguous border zones.

5. The granitic gneisses do not show the cataclastic textures or granulation that might be expected in an early granite sill.

6. The Nonewaug granite proper is rather uniform in composition, varying mainly in the microcline-plagioclase ratio. The granitic gneisses show a considerable range of texture and composition.

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[1] Oral communication, T. O. H. Patrick.

7. Even the most granitic gneisses contain more quartz and mica than a normal granite.

Summary of the border rocks. The rocks surrounding the Nonewaug granite are the various types of the Hartland metasediments and their granitized and feldspathized equivalents. Granite and pegmatite dikes and sills are prominent features in the border metasediments, particularly along the southern border. The spatial relations of the granitized rocks and the associated granitic dikes and sills indicate a genetic relationship to the Nonewaug granite. It is quite clear, however, that the main granite was emplaced during the late stages of the granitization of the metasediments. It seems likely that the granite now occupies the enlarged opening which was the initial channel for the early granitic solutions. The effect of the advancing solutions on the enclosing rocks seems to have been controlled equally by the structural relations of the metasediments to the channel and by the texture of the rocks. Apparently the initial openings served as solution channels until the emplacement of the last of the main granite mass.

THE NONEWAUG GRANITE

General statement. The Nonewaug granite has several unusual features which originally focused attention on the granite and later upon the surrounding area. The most prominent feature is a textural layering or banding of the granite, consisting of layers which range in thickness from a fraction of an inch to several feet and in texture from very fine-grained granite to coarse pegmatite. A second prominent feature is the occurrence of graphic granite crystals, locally in great quantity, which range up to two feet across in a matrix of relatively fine-grained granite. Associated with the graphic granite crystals is plumose muscovite in "plumes" up to 18 inches long. These special features will be discussed more fully in the following sections.

The main granite mass lies in the northern one-third of the quadrangle. Its eastern end extends a short distance into the Litchfield, Thomaston, and Waterbury quadrangles. In all, the granite body is about nine miles long and three miles wide; it is roughly elliptical in plan and is thought to be lens shaped. Although the main granite mass can be sharply outlined, its borders are characterized by numerous dikes and sills in the Hartland metasediments. The eastern and western ends of the elongate body are very similar in their relations to the surrounding metasediments.

Texture. The textural variations of the granite observed during field mapping seemed to fall naturally into four groups which are, at least in part, intergradational. These groups are: 1) layered granite, 2) patchy granite and pegmatite, 3) "plum pudding" type, and 4) massive granite.

The layered nature of the granite is due mainly to variations in the coarseness of texture—the compositions are essentially constant. The layers range in texture from fine-grained to pegmatitic (Figure B of Plate III and Figure A of Plate IV) and from a fraction of an inch in width to several feet. As a rule, where the textural variations are slight, the granite is fine-grained and the layers narrow, and where the textural variations are marked, the layers are much thicker. This layering can be observed best on slightly weathered, glacially polished surfaces. The fine layering is most common along the borders of the main granite and especially in the narrow tongues at the east and west ends. The coarse layering is also more common near the borders, but is found in the central part usually near roof pendants of mica-quartz schist and mica-granite gneiss.

The general attitude of the main granite was determined on the basis of the layering shown on the map by the strike and dip symbols in the main granite area. The average trend is N60°E with dips ranging from 35° to 80° southeast. The numerous dikes in the border rocks have the same general attitude.

The patchy granite and pegmatite is the most common type in the central part of the intrusive. The granite ranges from fine-grained to pegmatitic with no sharp boundaries between the different textures. Nor is there any regular distribution of the fine- or coarse-grained types. The general pattern is that of a brecciated mush with the finer-grained granite forming the blocks and the more pegmatitic granite the host. The patchy granite and pegmatite is similar in its textural variations to the layered granites. The fundamental difference is in the distribution of the various textures.

The "plum pudding" type is characterized by porphyritic graphic granite crystals in a fine- to coarse-grained granite. The graphic crystals range from less than an inch to more than two feet across (Figure B of Plate IV). Usually the graphic crystals are scattered in a random manner as the type name implies. However, occasionally they do have a linear or planar distribution in the layered granite. The "plum pudding" type does not occur outside the main granite body, but has no regular distribution in it.

Massive granite is the least common type in the granite mass proper. The only sizable area of massive granite is found on the west side of the hill between Upper road and Guernsey town road just west of Watertown. Many of the dikes and sills in the border rocks, however, are massive, medium-grained granite.

Composition. The essential constituents of the Nonewaug granite are microcline, sodic plagioclase, quartz, muscovite, and biotite. The accessory minerals are mainly apatite and garnet. Microcline and albite normally compose 65 per cent of the rock, quartz 30 per cent, and the micas about 5 per cent. Microcline may predominate in one sample and plagioclase in another, to provide all proportions between a nearly pure potassic feldspar granite and a nearly pure sodic plagioclase granite. In general, however, plagioclase is more abundant and the granite is properly called a soda granite. Muscovite is the predominant mica.

Graphic granite and plumose muscovite. The graphic granite and the plumose muscovite present one of the most interesting problems in the Nonewaug granite. The graphic granite crystals have three general types of occurrence—1) in pegmatites and pegmatitic layers, 2) as porphyritic crystals in random distribution in relatively fine-grained granite (Figure A of Plate V), and 3) in linear or planar structures in granite. Plumose muscovite has an empirical association with the graphic granite crystals. Although graphic granite may occur without plumose muscovite, the reverse is seldom found. The best development of plumose muscovite and graphic granite is in a broad zone trending N60°E through the central part of the main granite. Specific interesting occurrences are 1) along the Weekeepeemee river west of Brushy hill, south of the power line, 2) at the intersection of Flanders road and the power line northeast of Brushy hill, 3) east of the road and south of the power line near the north end of Church hill, 4) in the area near the power line southwest of the big bend in Highway 61, and 5) in the hills just east of Paradise Valley road in both the Woodbury and Litchfield quadrangles.

The graphic granite crystals range in size from a fraction of an inch to more than two feet (Figure B of Plate IV). They are normally intergrowths of microcline and quartz, but plagioclase and quartz occur. Graphic plagioclase and quartz are particularly common near plumose muscovite. The graphic microcline and quartz crystals are invariably perthitic, the albitic element occurring as irregular, disconnected patches (Figure B of Plate V). The quartz in the graphic intergrowths ranges considerably in amount, orientation, and shape. The percentage of quartz in the intergrowths is estimated to range from about 5 to 30 per cent. Two or three different optical orientations of the quartz are commonly present in a single crystal, although one orientation will predominate. However, the most common orientation in one crystal will be different from that in another. The regular, cuneiform pattern of the typical graphic granite is not so typical in the Nonewaug granite. More commonly the quartz occurs in irregularly shaped rods which have only one straight-line boundary or, in some cases, none.

A particularly significant feature of the graphic plagioclase and quartz associated with the plumose muscovite is the serrated border between the quartz rods and the plagioclase. The serrated border (Figure A of Plate VI) seems to result, at least in part, from the selective replacement of alternate twin lamellae by quartz. The replacement nature of the quartz is thought to be critical in any explanation of the origin of the graphic granite and plumose muscovite.

Other pertinent features of the graphic granite crystals are the poikilitically included flakes of biotite and muscovite and patches of fine-grained granite. The inner parts of the larger crystals are relatively free of inclusions whereas the outer parts generally contain much fine-grained granitic material. The subhedral and anhedral crystals have vague outlines and tend to blend into the surrounding granite. The outer zones of some crystals look little different from the granite except for the single reflection of the microcline cleavage. The bulk composition of the graphic granite crystals with their included material seems to be the same as that of the granite itself.

Field observations indicate that the graphic granite crystals in the fine-grained granite are a porphyroblastic development in a partly crystallized granite. Structural activity during the last stages of crystallization and a consequent local concentration of the interstitial liquid in sheared and brecciated zones could explain both the planar and "plum pudding" type distribution of the graphic crystals. The graphic granite crystals in the more pegmatitic layers may originate quite differently.

The plumose muscovite occurs similarly to the graphic granite except in the standard pegmatites where it is in books. Actually, it is an intergrowth of muscovite and quartz in which quartz is the matrix poikilitically including innumerable small muscovite flakes (Figure B of Plate VI). In a "plume" the muscovite flakes are aligned roughly like the barbs of a feather in quartz of a single orientation. A group of the muscovite-quartz plumes forms a plumose aggregate which may be spherical, hemispherical, or "feather duster"-like (Figure A of Plate VII). They range in size from less than an inch in their longest dimension to more than 18 inches. They are more resistant to weathering than the enclosing granite and stand out prominently on the weathered surface. The graphic granite contiguous to the plumose muscovite is commonly composed of plagioclase and quartz instead of the usual microcline.

Petrology of the Nonewaug granite. The magmatic origin of the Nonewaug granite is apparent from its structural relations to the surrounding metasediments and the metamorphic granitic gneisses. Its discordant attitude essentially precludes its being a product of granitization in situ. Many of the textural features of the granite may be explained by continued structural activity along the fault zone which it now occupies. The coarse layering in the central part reflects major movement with the dilatant introduction of new material and the emplacement of interstitial liquid in zones of low relative pressure. The patchy granite and pegmatite are regarded as the breccia of partly crystallized granite, and the fine layering, particularly near the border, the result of relatively slight movement when the rock was nearly crystallized.

The graphic granite crystals in the granite are a special problem which requires a detailed petrographic study for its solution, but pending completion of this study the writer would like to speculate on an explanation suggested by field observations. It seems reasonable to relate the graphic granite crystals to structural activity late in the crystallization history of the granite, since their composition is essentially that of the granite. The interstitial liquid, concentrated locally, might crystallize as graphic granite and facilitate recrystallization of the fine-grained granite present to give the porphyroblastic appearance of the crystals. Shearing may account for the common planar distribution of the crystals, and brecciation for the "plum pudding" type granite. In summary, repeated movements of varying magnitude during different stages in the crystallization of the granite would account for the coarse and fine layering and also for the unusual occurrence of the graphic granite crystals.

The crystallization sequence of the Nonewaug granite, and the mutual mineral reactions reflect a changing, pulsating physicochemical environment during crystallization. Microcline was one of the first minerals to form since it is replaced in greater or less amounts by plagioclase (Figure B of Plate VII and Figure A of Plate VIII). In some rocks the microcline has been almost completely replaced by plagioclase. Muscovite commonly shows a vermicular reaction border with plagioclase (Figure B of Plate VIII) and seems to be completely replaced locally. Quartz appears to replace both microcline and plagioclase, but neither to any great extent. Serrated borders between plagioclase and quartz (Figure A of Plate VI) show clearly that the quartz is the last to crystallize. The selective replacement of alternate twin lamellae in the plagioclase indicates a physical or chemical difference in contiguous lamellae (Emmons and Gates, 1943). Figure A of Plate VI is intended to illustrate the replacement of microcline by plagioclase and the replacement of plagioclase by quartz. Each of the points of the serrated contact contains a narrow plagioclase twin lamella. These twin lamellae are probably inherited from the albite twinning of the microcline (Gates, 1953) (Figure B of Plate VII and Figure A of Plate VIII), which may account for their apparent difference in composition. Some quartz rods in the graphic granite crystals show textures indicating replacement of the microcline. Also, plagioclase replaces microcline in the graphic granite crystals. The apparent instability of the essential minerals in association with each other is one of the most significant features of the Nonewaug granite. The tentative conclusions expressed above are based mainly on field observations and on only limited petrological study. A detailed petrological study of the Nonewaug granite now in progress will be offered later.

THE TRIASSIC ROCKS

General statement. The Triassic rocks of the Woodbury quadrangle are a part of the Upper Triassic Newark system which extends in a series of narrow, discontinuous belts from Nova Scotia to South Carolina (W. H. Hobbs, 1901). They are included in the Pomperaug basin, a small, down-faulted outlier of the main Connecticut Valley basin. This outlier is separated from the Connecticut Valley basin by 13 miles of the crystalline and metamorphic rocks of the Western Connecticut highlands. Although over half of the Pomperaug basin lies in the Woodbury quadrangle, most of the Triassic sediments outcrop in the vicinity of Southbury and South Britain in the Southbury quadrangle. The lava flows form the prominent topographic features throughout the basin and are the major interest in the Woodbury quadrangle.

Stratigraphy. The Triassic rocks of Connecticut are predominantly clastic sediments with three interlayered basalt flows and some basic intrusives. P. D. Krynine (1950, pp. 5-6) has summarized the general distribution, structural history, and division of the sediments as follows:

> "The Connecticut Valley area is bordered on the east by a north-south trending major fault, the Great Fault, downthrown on the western side and with a displacement

of from 17,000 to 35,000 feet. The Pomperaug basin is a downfaulted outlier disposed thirteen miles west of the main area. The Triassic section dips 10°–15° east and is broken up into numerous fault-blocks.

"The Triassic sediments form a wedge-shaped sedimentary prism built up of ancient coalescing alluvial fans which radiate westward from the Great Fault. The thickness of the section near the Great Fault reaches 16,000 feet; in the Pomperaug area, 32 miles to the west, it decreases to less than 1,500 feet.

"The Triassic section can be divided into three formations:

"1. A lower unit, the New Haven arkose, up to 8,500 feet thick, a relatively coarse fluvial sediment, consisting of gray and pink arkoses, conglomerates, red feldspathic sandstones and subordinate red siltstones and shales.

"2. A middle unit, the Meriden formation, up to 2,800 feet thick, a fine-grained series of lacustrine and swamp deposits consisting of variegated or dark-colored siltstones, shales, limestones, light feldspathic sandstones, subordinate coarser clastics, and three basaltic lava flows.

"3. An upper unit, the Portland arkose, up to 4,000 feet thick, a fluvial deposit similar to the New Haven arkose."

The reader is referred to Krynine's excellent report (1950) for a detailed discussion of the Triassic sediments and a critical review of the literature. Attention will be restricted in this report to the basalts of the Meriden formation which are the only Triassic rocks to crop out well in this quadrangle.

The basalts. The striking topography of the Pomperaug valley, which is produced by the aphanitic, erosion-resistant basalt flows, was used extensively by the earlier workers (Davis, 1888, 1898, and Hobbs, 1901) in their interpretation of the stratigraphy and structure of the region. This was especially true in the northern half of the basin since outcrops of the Triassic sediments are very scarce. In the Woodbury quadrangle the basalt outcrops in a continuous series of parallel ridges from Bates rocks northeastward to the Orenaug hills east of Woodbury. These ridges are part of the Main or Middle basalt flow of the Meriden formation. The Lower (Anterior) flow, which is a thin, vesicular, severely weathered basalt, is observed only near South Britain (Hobbs, 1901, p. 43). The Upper or Posterior flow of the main Connecticut valley is apparently not present in this area. No contacts of the main basalt and the Meriden sediments were found although poor outcrops of conglomerate occur on the northern slopes of the twin Orenaug hills. Sandstone crops out on the slope of Bates rocks and near the river one-half mile north of Pomperaug village.

The outcrops of sandstone shown on the road in Woodbury village (Hobbs, 1901) have been completely covered by a later asphalt surface. Water wells recently drilled along this road have "red rock" close to the surface which extends to a depth of at least 127 feet. Basement excavations east of the road have uncovered a red till with large, angular blocks of sandstone and conglomerate up to three feet across. The outcrops of sandstone and conglomerate north of the west Orenaug hill (Hobbs, 1901) are somewhat concealed by farm buildings and a turkey ranch.

The presence of the sediments below the basalt flow on the east side of the Orenaug hills was learned only from conversation with the local drillers. Drill holes for blasting and for water in the trap rock quarry on the east flank of Orenaug hills gives us the most recent and reliable information. Drill holes for blasting at the present working face of the quarry encountered "red rock" at a depth of 120 feet or about 10 feet below the quarry floor. The "red rock" was encountered at 54 feet in a drill hole starting at the quarry floor level. This hole is located about 350 feet southwest of the drill hole mentioned above. A third drill hole located about 500 feet east of the working face of the quarry and about 20 feet below the quarry floor entered the red rock at 170 feet. Minor faulting which is apparent in the quarry walls makes it difficult to use this information structurally. In any case, the presence of the sediments under the basalt of the Orenaug hills is unquestioned.

The topographic features of the basalt ridges are rather consistent throughout the valley. From Bates rocks to Orenaug hills the ridges have basalt crests, west-facing scarps from 10 to 100 feet high, and comparatively gentle east slopes. Orenaug hills are an exception in that they have some east-facing scarps. The western ridges are usually higher and longer than those on the eastern side of the range. The longest ridge (1¼ miles) extends from the crest of Bear hill southward to the highway north of Bates rocks. The eastern group is an interrupted series of ridges ranging in length from ¼ to ½ mile.

The main basalt is a compact rock, dark gray or black on the fresh surface and reddish brown in outcrop. It is uniform in composition (Hobbs, 1901, pp. 72–77) but somewhat variable in texture and mineralogy. The lower portions of the flow are denser than the upper parts, locally porphyritic and composed of labradorite and pyroxene with minor amounts of magnetite or ilmenite and chlorite. The upper portions are different mainly in being more vesicular, apparently more weathered, and show minor propylitic alterations. Also, tachylite blebs are occasionally seen, particularly in the eastern Raglands area.

In general, the writer agrees with Davis's (1888) interpretation of normal strike faults to account for a repetition of the basalt ridges, but disagrees with his statement that the Orenaug hills consist of two basalt flows separated by shales (pp. 472–473). Relatively minor faulting followed by glacial erosion can easily explain the topographic features observed. A similar type of topography in the granites and metasediments may be seen elsewhere in this quadrangle as well as in the quadrangles to the north where major faulting is unlikely. Evidence for major faulting was observed only in the crystallines a half mile east of the Pomperaug valley. The scattered outcrops in the stream valley west of the Woodbury reservoir show rather intense brecciation, fracturing, and shearing. The writer tried unsuccessfully to trace this fault northward beyond the Pomperaug valley. It is certainly possible, if not probable, that the fault does continue northward along the Nonewaug river to the Watertown pumping station. Its presence is inferred mainly by the lack of outcrops and the slight change in the rock types on the opposite sides of the river. However, no direct evidence of faulting was found in the rocks in this area. It is unlikely that the fault can extend north of the pumping station since the continuity of the Nonewaug granite and the border rocks across the strike of the fault is certain. Minor faulting is evident in the trap rock quarry in Orenaug hills where a prominent set of joints is developed. The joints trend approximately N10°E and dip steeply west. Some of the joint planes show hydrothermal alteration and slickensides. The displacement appears to be very slight. The Pomperaug valley, therefore, appears to be a small graben in the early Paleozoic metasediments. Hobbs's (1901) theory on deformation and faulting is much more complex than is necessary to explain the present topography, and his criteria for faulting are open to question.

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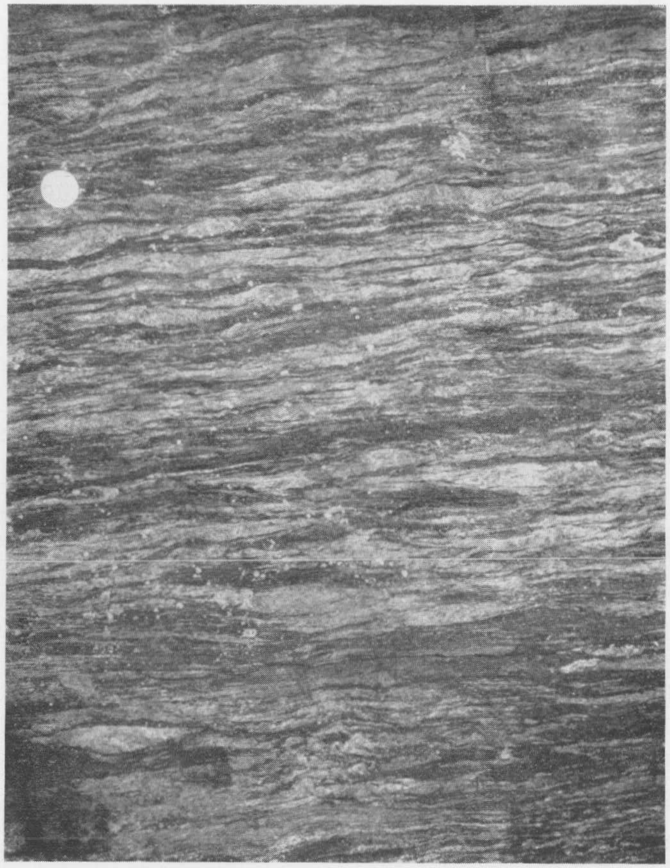

Plate 1, Fig. A. Banded gneiss considered to have developed from mica-quartz schist. Dark bands are mica-garnet-quartz with some kyanite and staurolite. Light bands are quartz and feldspar.

Plate 1, Fig. B. An irregular patch of pegmatitic material in finely banded Hartland formation.

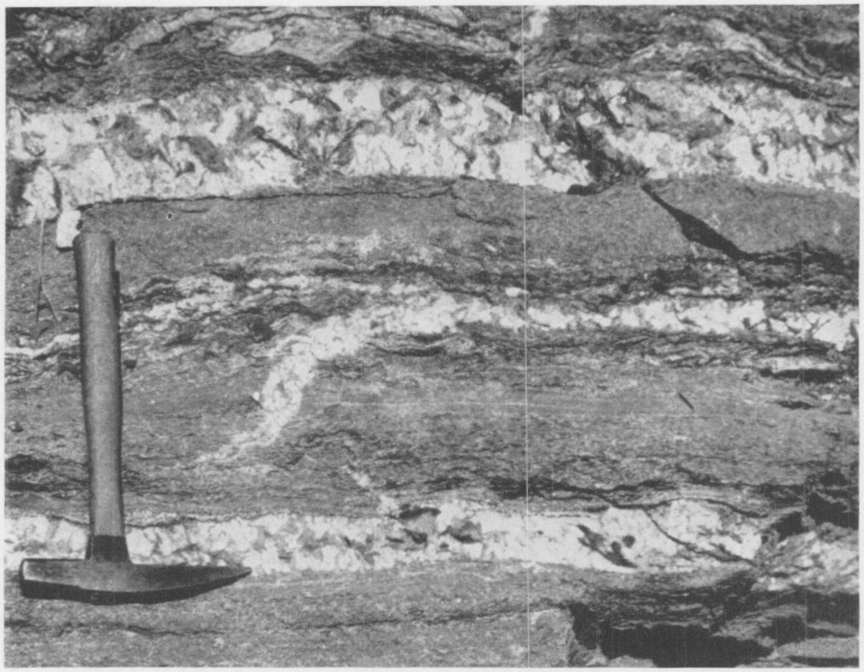

Plate II, Fig. A. Thin, pegmatitic sills in Hartland formation. These sills are coarser grained and more feldspathic than the pegmatitic patch in Figure B, Plate I.

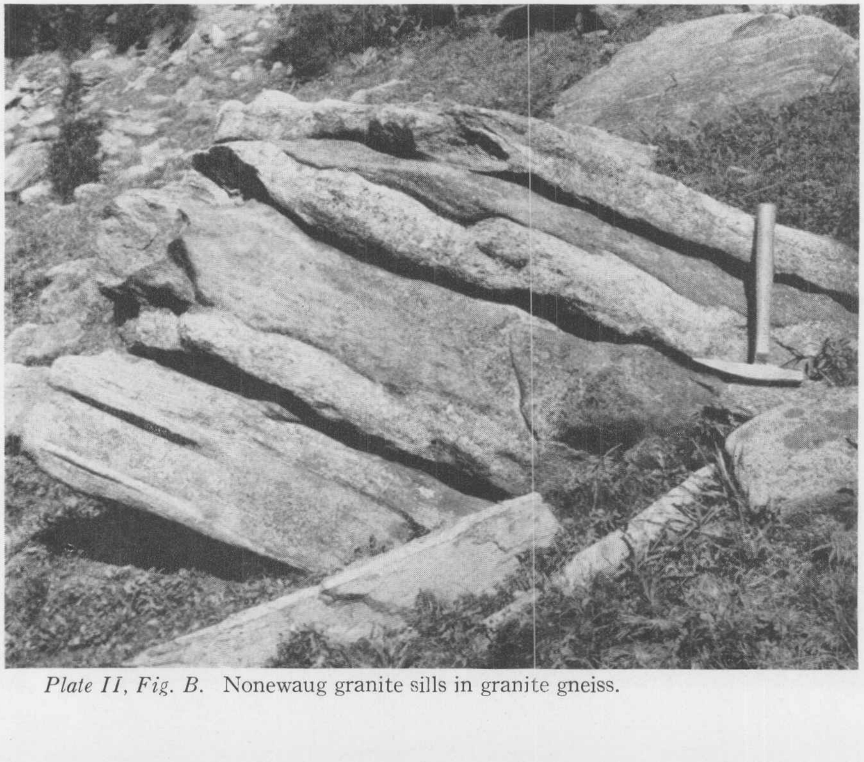

Plate II, Fig. B. Nonewaug granite sills in granite gneiss.

Plate III, Fig. A. Nonewaug granite dike cutting granite gneiss. Notice the fine-grained border and the graphic granite crystals in the granite.

Plate III, Fig. B. Layered granite. Two fine-grained granite layers with a coarse-grained granite layer between lie to the left of the hammer. A narrow fine-grained granite layer lies to the right of the hammer. The rest of the rock in the photograph is very coarse-grained.

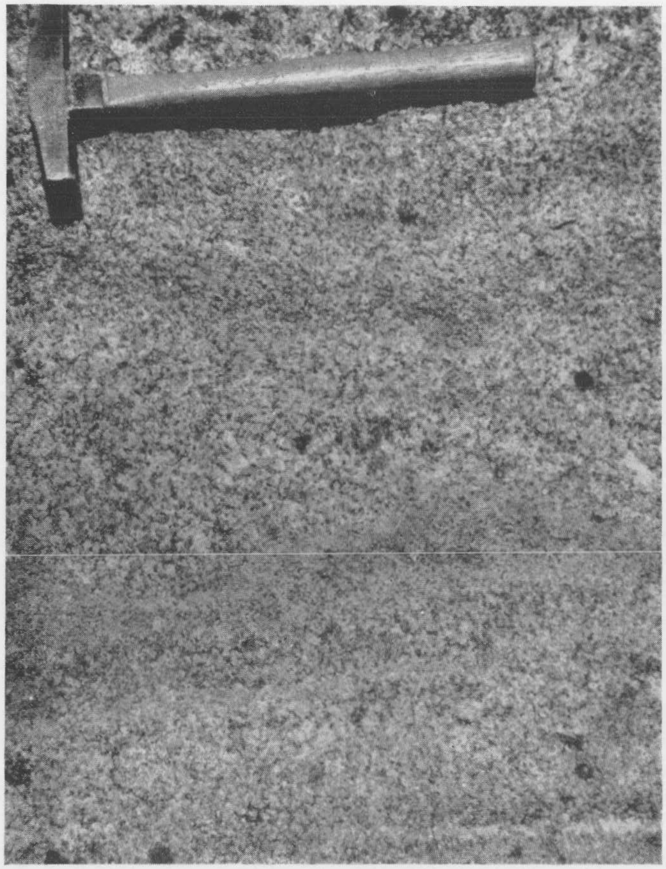

Plate IV, Fig. A. Fine textural layering in fine-grained granite.

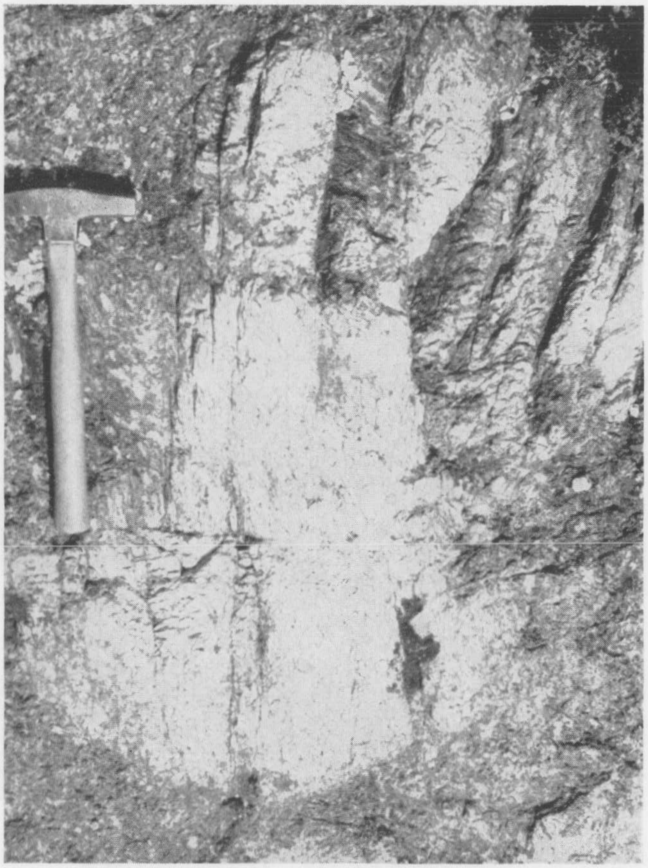

Plate IV, Fig. B. Large porphyritic graphic granite crystal in a matrix of coarse-grained granite.

Plate V, Fig. A. "Plum pudding" type Nonewaug granite. The large crystals are graphic granite; the matrix is fine- to coarse-grained granite.

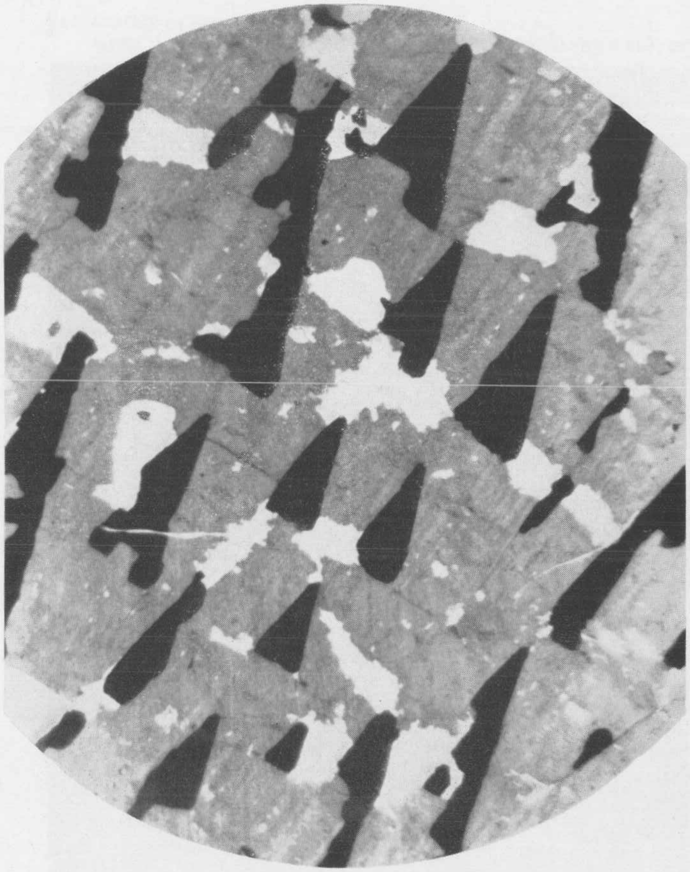

Plate V, Fig. B. Graphic granite crystal showing relations of microcline, quartz, and plagioclase. Quartz is black, microcline is gray, and plagioclase is white. Crossed nicols; X 26.

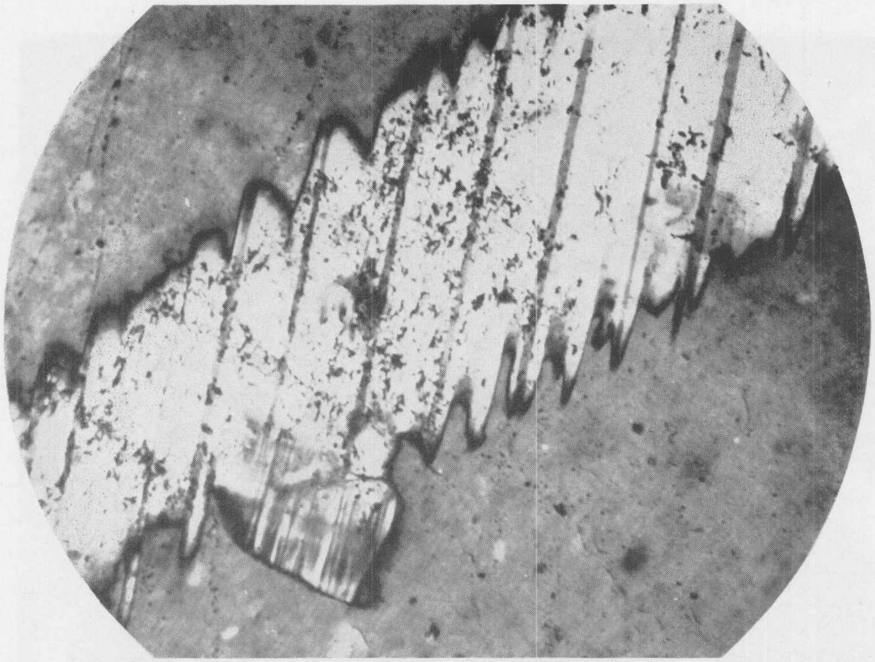

Plate VI, Fig. A. Serrated plagioclase–quartz border. Notice the twin lamellae in the center of each plagioclase point. A small microcline remnant occurs in the lower left corner of the photomicrograph. Plagioclase is white, quartz is gray, and microcline is crosshatched. Crossed nicols; X 90.

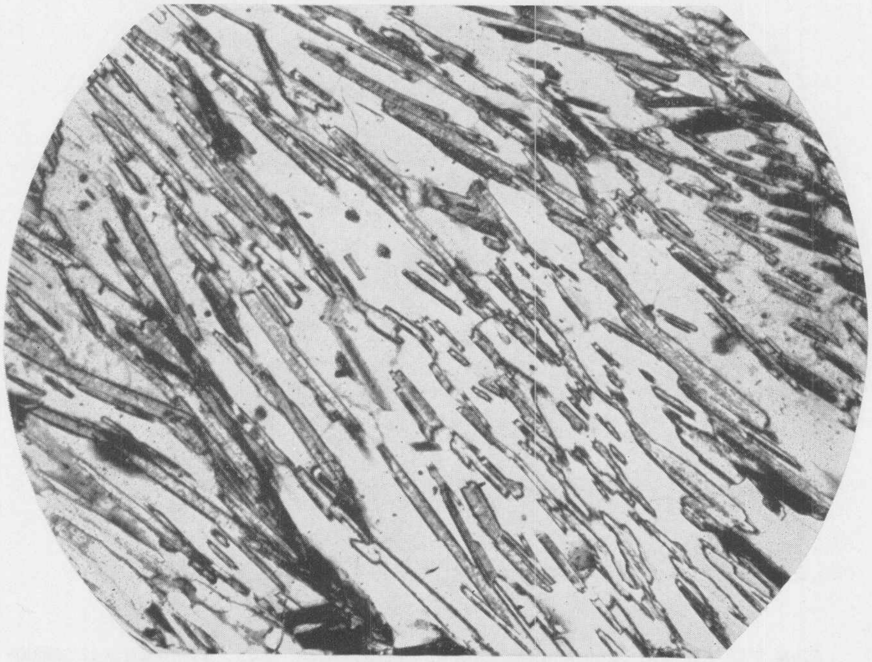

Plate VI, Fig. B. Plumose muscovite. This is a small part of a single plume of muscovite. The quartz has a single orientation (white) and poikilitically includes the flakes of muscovite. Crossed nicols: X 26.

Plate VII, Fig. A. Three "feather duster" type plumes of muscovite in coarse-grained granite.

Plate VII, Fig. B. Microcline remnants in plagioclase host. The matrix is plagioclase; small, cross-hatched fragments are microcline. The light streaks are indistinct twin lamellae (010) inherited from the microcline. Crossed nicols: X 60.

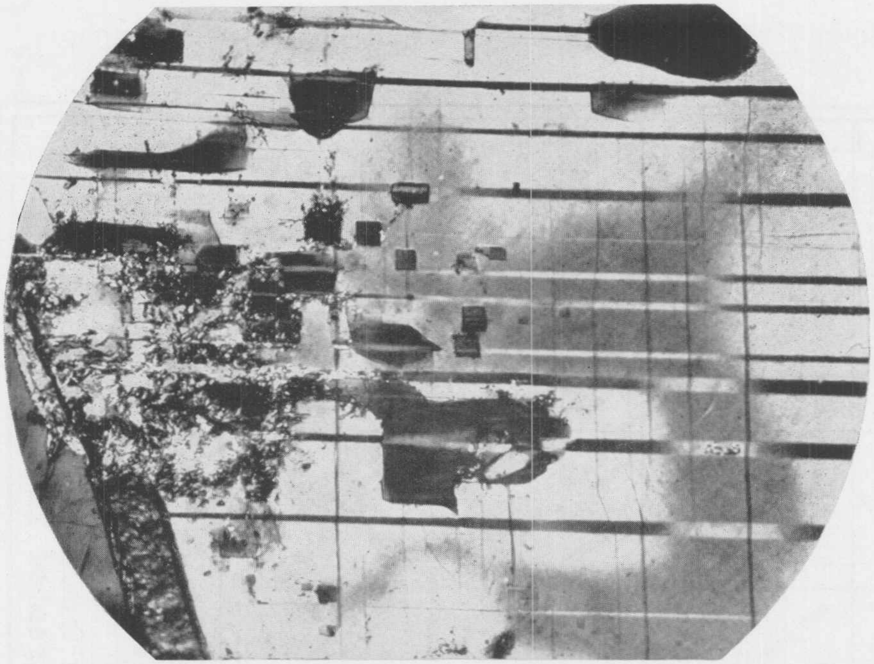

Plate VIII, Fig. A. Microcline almost completely replaced by plagioclase. The polysynthetically twinned material is plagioclase; small, dark, angular blocks are microcline. Light areas around microcline fragments are due to incomplete replacement. The albite twin lamellae are continuous in the plagioclase and the microcline. Crossed nicols; X 210.

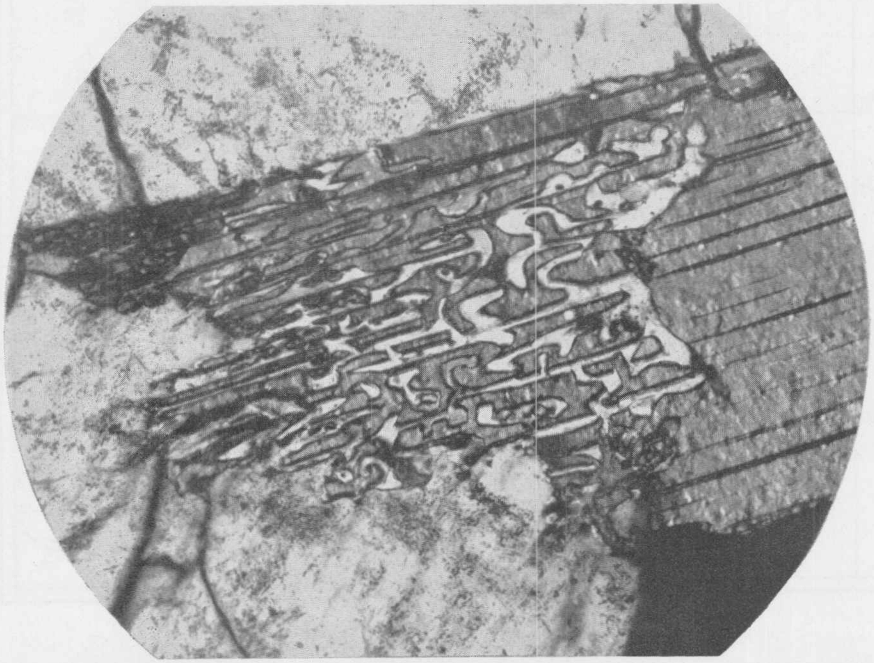

Plate VIII, Fig. B. Vermicular reaction rim of muscovite and plagioclase. Crossed nicols; X 60.

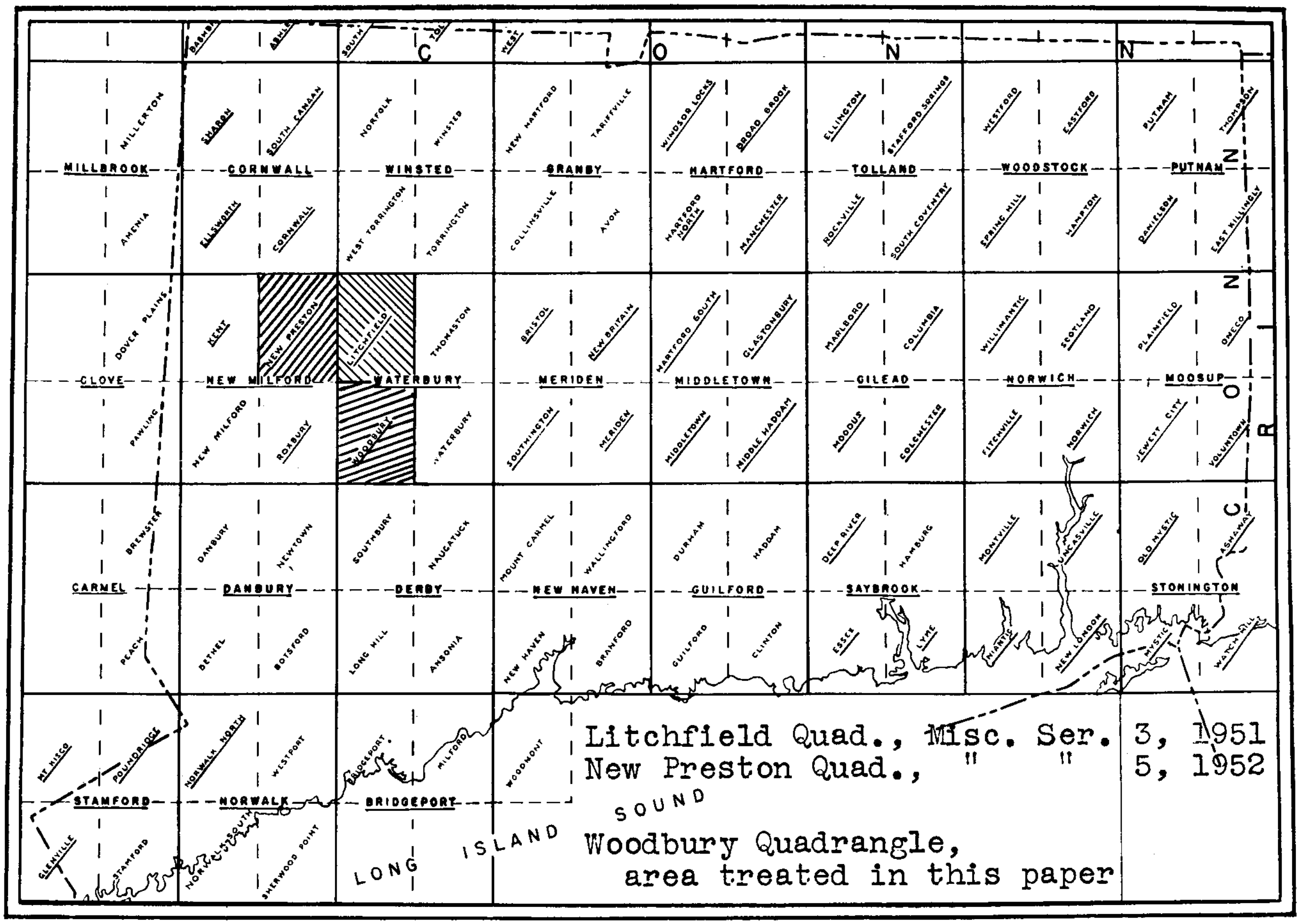

Figure 1. Index map of Connecticut showing location of Woodbury quadrangle.