STATE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF

CONNECTICUT

THE BEDROCK GEOLOGY OF THE CORNWALL QUADRANGLE With Map

Open Map

By

ROBERT M. GATES

QUADRANGLE REPORT NO. 11

1961

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OF CONNECTICUT

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Middletown

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State Geological and Natural History Survey of Connecticut

TABLE OF CONTENTS

	Page
Abstract	1
Introduction	1
Location	1
Physical features	3
Acknowledgments	3
Previous work in the area	3
General geology	4
Gneiss complex of the Housatonic Highlands	5
General statement	5
Lithology	7
Gray banded granitic gneiss (Rock type 1)	7
Petrography	9
Origin	10
Felsic gneiss (Rock type 2)	11
Petrography	12
Origin	12
Amphilibolite and mafic gneiss (Rock type 3)	13
Petrography	14
Origin	15
Graphitic gneiss and diopsidic rocks (Rock type 4)	16
Origin	16
Summary	17
Proposed stratigraphic subdivisions	17
Unit V	18
Unit IV	18
Unit III	18
Unit II	19
Unit I	19
Stockbridge marble	20
Waramaug formation	20
General statement	20
Lithology	21
Quartzo-feldspathic biotite gneiss	21
Petrography	22
Sillimanite-quartzo-feldspathic biotite gneiss	23
Petrography	24
Migmatitic gneiss	25
Amphibolite	25
Petrography	25
Summary	25
Tyler Lake granite	26
General statement	26
Petrology	26
Relations between formations	28
Gneiss complex and Stockbridge marble	28
Gneiss complex and Waramaug formation	29
Structure	29
Metamorphism	31
References	33
Appendix	34

ILLUSTRATIONS

Page

Figure 1. Map of Connecticut showing location of the Cornwall quadrangle and of other published quadrangles 2

2. Generalized geological map of northwestern Connecticut 6

3. Banded granitic gneiss of the Gneiss complex 8

4. Modal composition of quartzo-feldspathic biotite gneiss of the Waramaug formation 22

5. Modal composition of sillimanitic quartzo-feldspathic biotite gneiss of the Waramaug formation 24

Plate 1. Geological map of the Cornwall quadrangle, Connecticut .... in pocket

TABLES

Table 1. Modal analyses of banded granitic gneiss of the Gneiss complex 9

2. Modal analysis of rusty, quartzo-feldspathic biotite gneiss of the Gneiss complex 11

3. Modal analysis of amphibolite and mafic gneiss of the Gneiss complex 13

4. Chemical compositions of the Waramaug formation, the Gneiss complex and related rocks 23

5. Modal analyses of Nonewaug, Mine Hill, and Tyler Lake granites 28

The Bedrock Geology of the Cornwall Quadrangle

by

Robert M. Gates

ABSTRACT

The Cornwall quadrangle is divided diagonally into two parts by a sinuous valley marking the contact between the Gneiss complex of the Housatonic Highlands (Pre-cambrian) and the Waramaug formation (Cambro-Ordovician?). The Stockbridge marble (Cambro-Ordovician?), which commonly lies between the above formations, does not outcrop throughout the greater part of this valley. It is considered to be missing throughout two-thirds of it, where locally the other two formations appear to be gradational. The youngest rock unit is the Tyler Lake granite (probably Paleozoic) which intrudes the Waramaug as a large irregular mass and probably intrudes the Gneiss complex to a minor extent.

The most significant result of the mapping is the recognition of stratigraphic units in the Gneiss complex of the Housatonic Highlands. The stratigraphic units are parallel to the contact with the Waramaug. The key rock type which enables the stratigraphic subdivision to be made is a banded granitic gneiss believed to have been an acid volcanic rock prior to metamorphism.

INTRODUCTION

LOCATION

The Cornwall quadrangle is located in the western Connecticut Highlands, approximately 15 miles south of the Massachusetts border and 10 miles east of the New York State border (figure 1). The Western Connecticut Highlands, the southern extension of the Green Mountain Plateau, are bounded on the east by the Triassic rocks of the Connecticut Valley and on the west by the lower Paleozoic rocks of the Hudson River valley. More specifically, the quadrangle includes the eastern part of the Housatonic Highlands and extends eastward toward the Berkshire Highlands (Rodgers and others, 1956, 1959).

In this quadrangle the nature and relationship of the Gneiss complex of the Highlands and the Waramaug formation may be studied in an area where the normally intervening Stockbridge marble is absent. Furthermore, the Cornwall quadrangle provides an opportunity to study the core of a part of the Appalachian mountain system, with the hope of learning more about the geologic processes associated with mountain building.

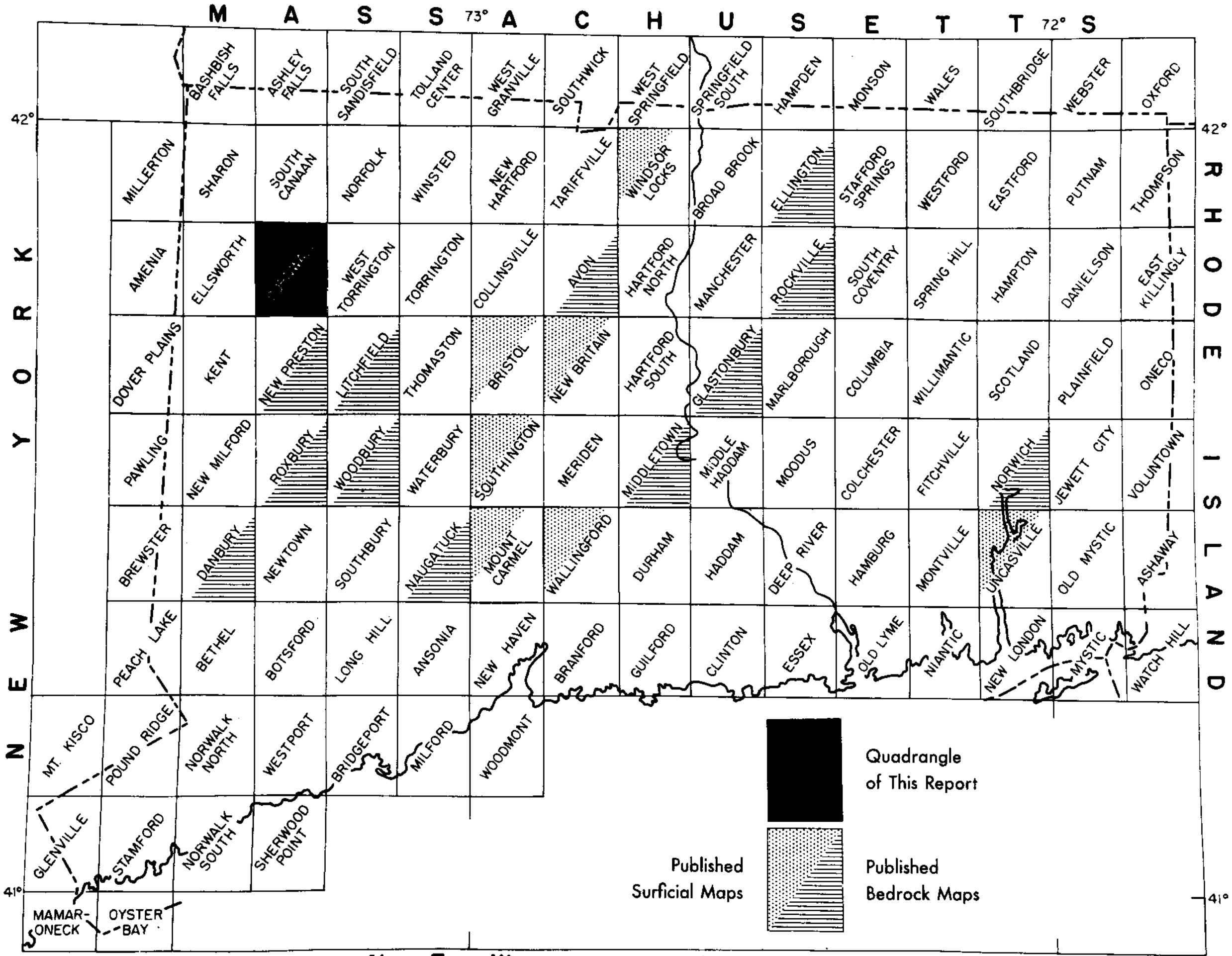


Fig. 1. Index map of Connecticut showing the location of the Cornwall quadrangle, and of other published quadrangle maps. For list of published maps see Appendix.

PHYSICAL FEATURES

The most prominent topographic feature in the quadrangle is the range of mountains which resembles a major dextral drag fold in structure. This range has no collective name, but is composed of Bald, Coltsfoot, Woodbury, The Hogback, Mohawk, Red, and Sedgewick Mountains. They are the major drainage divide and also control to a large extent the highway arteries.

The drainage south and east of the divide is through the Marshepaug, West Branch Shepaug, and Shepaug Rivers. The Shepaug ultimately flows into the Housatonic River about 25 miles south of the quadrangle. Northwest of the divide the area is drained by the small tributaries of the Housatonic River, such as Furnace Brook, Beaver Brook, and Hollenbeck River. The Hollenbeck River flows about 8 miles northwest to join the Housatonic north of Falls Village.

The quadrangle is wooded except for a few small cultivated fields located largely on the drumloidal hills along the eastern border and in the southeast section. The effects of the last glacial advance are well shown by the shaped outcrops on most hilltops, the rock-cored drumloidal hills, and the glacio-fluvial deposits left in the valleys by the stagnating ice sheets.

The only population concentrations are the ones located around Tyler Pond at West Goshen, Cornwall (Plains), and Cornwall Bridge and West Cornwall on the Housatonic River along the western border of the quadrangle.

ACKNOWLEDGEMENTS

The geological mapping of the Cornwall quadrangle was done during the summers of 1956 to 1960 under the direction of the Connecticut Geological and Natural History Survey. The Wisconsin Alumni Research Foundation has supported part of the field work, and all the petrographic, mineralogic, and other laboratory work.

The writer gratefully acknowledges the assistance of the following graduate students who have been engaged in this project. Mr. Thomas Vogel assisted in the mapping of the Gneiss complex during the summer of 1959. Mr. Robert M. Cassie assisted the writer in petrologic and mineralogic studies of the Goshen granite and the Gneiss complex during 1959-60. Mr. Nikolas Christensen assisted the writer in petrologic studies of the Waramaug formation. Mr. Robert Serbiak assisted in preparation of the maps.

PREVIOUS WORK IN THE AREA

Since the classic work of Percival (1842), only W. H. Hobbs and William Agar have contributed materially to the geology of the Cornwall area. W. H. Hobbs and his assistants prepared a manuscript of the Litchfield Folio for the U. S. Geological Survey. It was never published, but most of the information on the Western Highlands reported by Rice and Gregory (1906), and Gregory and Robinson (1907), in Bulletins

No. 6 and 7, respectively, of the Connecticut Geological and Natural History Survey, was drawn from the unpublished Litchfield Folio. More recently Agar (1929, 1932, 1934) contributed materially to the geology of western Connecticut with his reports on the Becket gneiss and the granites. The geology of the Cornwall area, as reported by Rodgers and Gates (1959) in Bulletin 84 of the Connecticut Geological and Natural History Survey, was taken principally from Agar's publications, modified in part by their own unpublished reconnaissance work.

GENERAL GEOLOGY

Three major rock units underlie the bulk of the Cornwall quadrangle. They are the Gneiss complex of the Housatonic Highlands, the Stockbridge marble, and the Waramaug formation. In addition to these are the omnipresent, but not separately mappable, amphibolites, and the large amoeboid mass of the Tyler Lake granite.

Confusion has been brought about by the use of the name Thomaston for all "late" granites regardless of lithological, structural, and textural dissimilarities. Therefore, the name Tyler Lake granite is here proposed for the related granite masses located in the Cornwall and West Torrington quadrangles near Tyler Lake. These granite masses have previously been included with the Thomaston granite and granite gneiss in maps and publications prior to 1950. (A small part of this granite extends into the northern part of the New Preston quadrangle where it was not named.) The name Tyler Lake was chosen because of the exposures east of Tyler Lake, for although the larger mass of granite is south of Mohawk Mountain, it is not so well exposed. The Mine Hill granite gneiss in the Roxbury quadrangle and the Nonewaug granite in the Woodbury and Litchfield quadrangles are two other "Thomaston" granites which have been renamed (Gates, 1954, 1959; Rodgers, Gates, and Rosenfeld, 1959).

The Gneiss complex of the Housatonic Highlands (formerly Becket gneiss in reports prior to 1956) is one of a series of gneiss masses extending from the Green Mountains in Vermont to the Hudson Highlands in New York and probably still farther south. The Gneiss complex of the Housatonic Highlands is partially mantled by the Poughquag quartzite (generally considered Cambrian), not, however, in the Cornwall quadrangle, but 10 miles farther south near Kent, and 5 miles northward, south of Falls Village (Rodgers and others, 1959). The Gneiss complex, for this reason, is generally considered Precambrian (figure 2).

The Stockbridge limestone is an extensive formation which flanks the Precambrian core of the Green Mountains in Massachusetts on the west side, overlying the Cheshire quartzite (equivalent to the Poughquag in Connecticut and New York). It is generally considered Cambro-Ordovician. The Stockbridge is thought to wrap around the Gneiss complex of the Housatonic Highlands at its southern end and extend in a narrow belt up the Housatonic River to Cornwall Bridge, there flanking the Gneiss complex on the east. In the belt between Bulls Bridge and Cornwall Bridge the Stockbridge limestone lies between the Poughquag quartzite and/or the Gneiss complex to the west and the Waramaug formation to the east. The relationships between all these formations are in doubt. If the rocks mapped here as Stockbridge are part of a Cambro-Ordovician sequence overlying the Gneiss complex (Rodgers and others, 1959), certain problems are introduced in the Cornwall quadrangle. The Poughquag quartzite-Stockbridge marble-Waramaug are supposed to overlie the Precambrian Gneiss complex unconformably (Balk, 1936). In the Cornwall quadrangle, however, the Poughquag and Stockbridge are absent and the Gneiss complex is not only conformable to the Waramaug but appears to grade into it in the two areas where contacts are exposed (figure 2).

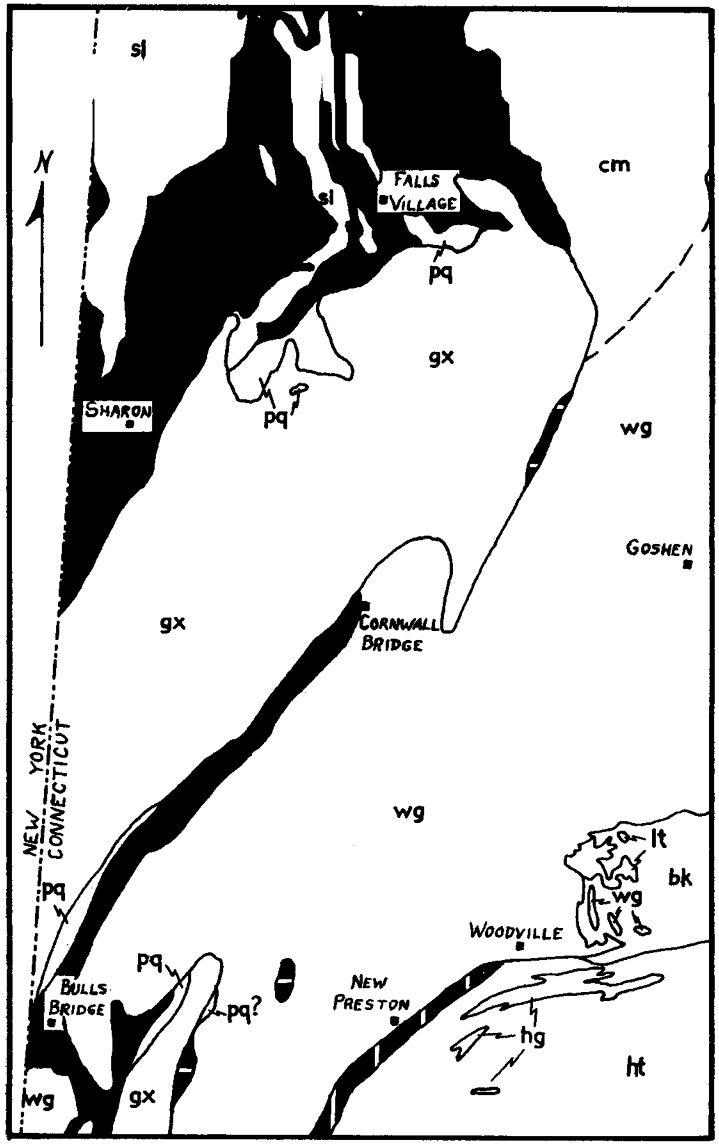
The Waramaug formation (commonly correlated with the Berkshire, or called Berkshire prior to 1952) is metasedimentary. It has ill-defined stratigraphic and structural relations with the adjacent formations. It is flanked by the Woodville marble, the Mt. Prospect complex, the Hartland formation, and the Gneiss complex of the Berkshire Highlands on the east and southeast, and by the Stockbridge marble, the Gneiss complex of the Housatonic Highlands, and the Canaan Mountain schist on the west and north. The Waramaug has been considered part of the Cambro-Ordovician sequence of Poughquag quartzite-Stockbridge limestone-Waramaug (Berkshire), comparable with the Poughquag-Stockbridge-Salisbury schist (Agar, 1929, p. 204; 1932, p. 32). It is not clearly separable from the Canaan Mountain schist or the Gneiss complex of the Berkshire Highlands. The possible correlation of the Waramaug with the Manhattan formation north of Danbury (Clarke, 1958) further complicates the picture.

The Tyler Lake granite is a young granite intrusive into the Waramaug formation. It intimately penetrates and is mixed with the Waramaug but has reacted only slightly with it. This is one of the many young granite bodies previously included with the Thomaston granite and granite gneiss.

GNEISS COMPLEX OF THE HOUSATONIC HIGHLANDS

GENERAL STATEMENT

The crystalline mass of the Housatonic Highlands has been referred to as a gneiss complex merely because it has not been subdivided, not because it is more complex than the Waramaug and Hartland formations in this same general region. It is generally considered Precambrian because of the disjointed carapace of the Lower Cambrian Poughquag quartzite, which occurs mainly on the west side and to a lesser extent on the southern end near Schaghticoke Mountain (Balk, 1936). Agar recognized inhomogeneities in the Gneiss complex (Becket) and proposed subdivisions (Agar, 1929, pp. 201-203). He did not define units in the Cornwall quadrangle but on a small scale map of the area he used a compound pattern to indicate a mixture of Grenville metasediments, Barrack Mountain granite gneiss and Mixed gneiss. The Mixed gneiss was interpreted as Grenville injected and altered by the Barrack Mountain granite gneiss and the Sharon Mountain quartz diorite. In the course of the writer's mapping, several distinctive stratigraphic or lithologic units were recognized and traced across the northwest quarter of



One inch equals four miles
Black = Stockbridge marble
Black with vertical stripes = Woodville marble
Black with horizontal stripes = Marble (Stockbridge?)

gx = Highlands Gneiss complex
wg = Waramaug formation
sl = Salisbury schist
pq = Poughquag quartzite
cm = Canaan Mtn. schist

lt = Litchfield mafic intrusives
ht = Hartland formation
hg = Hornblende gneiss
bk = Brookfield diorite gneiss

Fig. 2. Sketch map showing generalized geology of northwestern Connecticut, taken from Preliminary Geological Map of Connecticut, 1956 (Rodgers, Gates, Cameron, and Ross).

the quadrangle and about a mile into the adjoining Ellsworth and South Canaan quadrangles. Instead of using old names or proposing new ones the writer feels that it is best to designate these subdivisions of the Gneiss complex by numerals until they are better established by the mapping now in progress.

Contacts between the Gneiss complex and the Stockbridge marble are not exposed in this quadrangle and hence the relationship must be inferred from other areas. Agar (Balk, 1936) suggests a thrust fault along the east side of the Housatonic Highlands between the Gneiss complex and the Stockbridge. The contact of the Gneiss complex and the Waramaug formation appears to be exposed at two places in the quadrangle. At these localities, described below, the contact seems to be a normal, sedimentary contact.

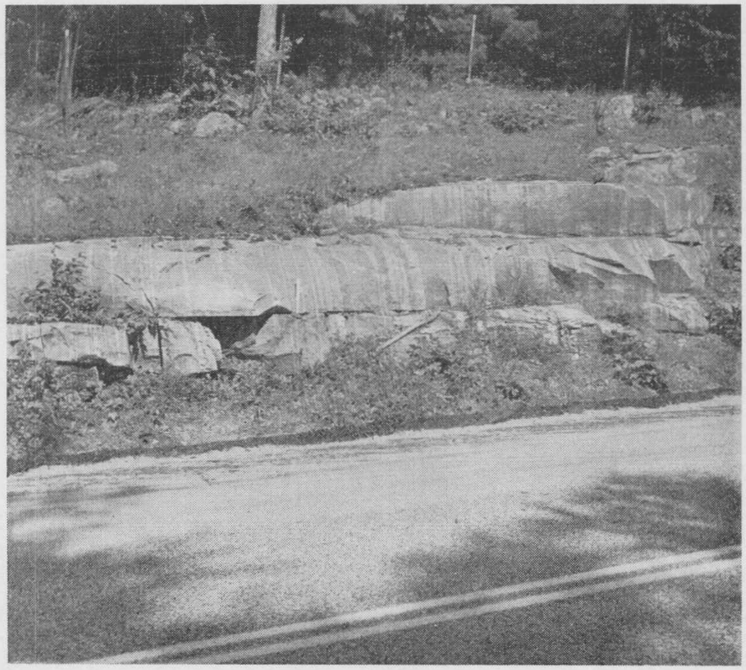
LITHOLOGY

The Gneiss complex may be conveniently described in terms of four rock types, all of which tend to be interlayered and to intergrade. They are 1) gray, banded granitic gneiss, 2) rusty weathering, quartzo-feldspathic biotite gneiss, 3) amphibolite to quartz-biotite-hornblende-andesine gneiss and 4) graphitic quartzo-feldspathic gneiss. In addition to these there is quartz-diopside granulite[1] and, of course, granite and pegmatite. The granite bodies in the Gneiss complex are small, irregular, and not generally mappable on the scale used. Their locations are indicated by a symbol "x" on the map. In occurrence and petrography they are similar to the Tyler Lake granite and thus not separately described here. The detailed descriptions of the various rock types and their distribution follow.

Gray Banded Granitic Gneiss (Rock Type 1)

The field characteristics of the granitic gneiss are a) smooth, gray weathered surface, b) light and dark gray banding ranging from a fraction of an inch in width to several feet (figure 3), and c) fine-grained, granular texture. The layering is due in large part to variations in the biotite content of alternate bands. The biotite normally is in discrete, but parallel, flakes, but it may form discontinuous, coarser grained streaks. In fact, in places the disseminated fine-grained biotite grades into coarser grained biotite streaks forming what might properly be called a biotite-streaked granitic gneiss. The layers range from sharply defined, "sedimentary-like beds" to irregular, discontinuonus, thin biotite streaks. Aggregation of the biotite into streaks makes the rock more homogeneous in appearance. The banded granitic gneiss is the predominant rock type, but the coarse biotite-streaked gneiss is a subordinate textural variant of it. Subordinate layers in the banded granitic gneiss are biotite amphibolite to quartz dioritic gneiss (quartz-biotite-hornblende-andesine gneiss) which, except for the darker color, are indistinguishable from the granitic gneiss. These layers are rich in biotite, hornblende, and plagioclase, relatively low in quartz, and virtually devoid of microcline.

[1]Granulite is used throughout this report as a textural term.



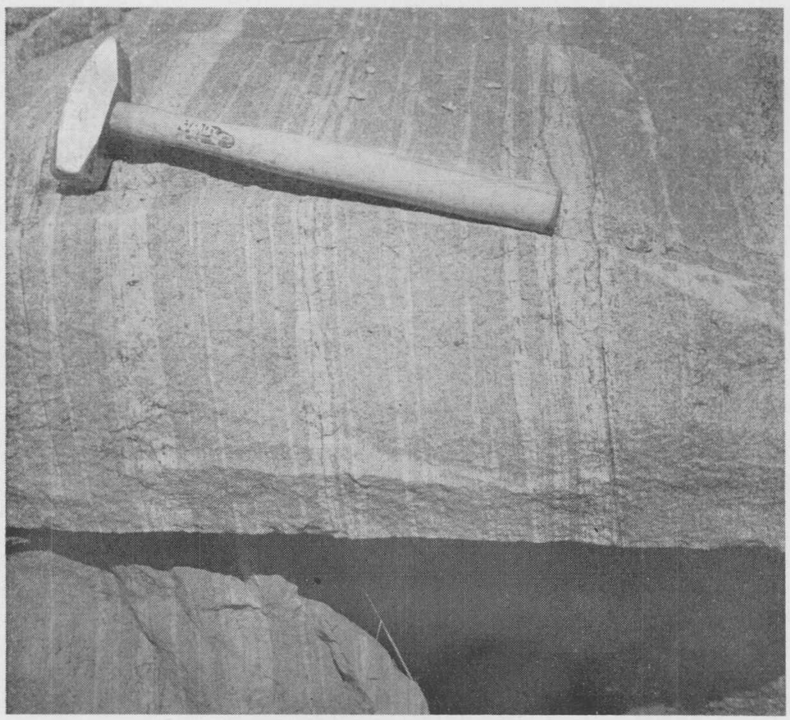


Fig. 3. A. Road cut on Coggswell Road showing banded granitic gneiss of the Gneiss complex of the Housatonic Highlands.

B. Detailed view of the above.

PETROGRAPHY

The banding of the granitic gneiss makes any individual mineralogical analysis of limited value in determining the over-all composition of the gneiss. In general, however, two types of bands – gray or biotitic ones and light, felsic ones – are rather uniform in composition. Representative specimens of the biotitic bands and of the felsic bands were selected and point-counted to show the typical variations in composition. These point-count analyses are shown in table 1. It is apparent from this table

TABLE 1

Percent by volume, based on point count						
	Dark band, granitic gneiss		Light band, granitic gneiss		Average Composition[2]	21 Samples[3]
	H-1069B	H-1134	H-1133	H-1135		
Quartz	28.6	30.7	20.4	21.6	26.8	30.0
Oligoclase	43.1	47.2	8.7	21.3	35.1	32.0
Microcline	15.9	11.1	62.0	52.6	28.1	25.0
Biotite	8.5	8.4	0.1	0.4	5.7	8.0
Muscovite	2.4	1.5	1.2	0.4	1.6	2.0
Myrmekite	1.5	1.1	6.8	3.7	2.6	3.0

[1]Accessories: epidote, sphene, apatite, zircon, and magnetite.

[2]A weighted average, assuming 2:1 ratio of dark bands:light bands.

[3]Estimated mineralogic composition, based on 500 point analyses of each of the 21 samples.

Table 1. Modal analyses of the light and dark bands of the banded granitic gneiss of the Gneiss complex, estimated modal analysis of the gneiss, and estimated mineralogic composition of 21 samples of gneiss.[1]

that plagioclase predominates over microcline in the biotitic layers and microcline over plagioclase in the felsic layers. The average composition of the granite is based on the writer's estimate that the dark layers are approximately twice as abundant as the felsic layers. Limited 500 point analyses of 21 additional thin sections of the granite gneiss, modified by visual estimates of the light to dark ratio, gives the composition shown in the last column of the table. By all estimates and analyses the rock falls in the compositional range of granite as defined by Tuttle and Bowen (1958).

The granitic gneiss is fine to medium grained, equigranular to inequigranular with interlocking grains. Cataclastic zones, granulation of larger grains, and strained quartz are common features. The textural differences between the biotitic layers and the nearly pure felsic layers are mainly minor. Typically, the darker layers are finer grained and equigranular whereas the felsic layers are coarser grained and inequigranular. The micas are disseminated but have a common orientation; however, in some localities the thicker biotitic layers are very massive in appearance.

Microline occurs as irregular, interstial grains in the darker bands and is non-perthitic. Locally, discrete micro-seams of pure microcline are present in an otherwise microcline-poor biotitic layer. In the felsic layers the microcline tends to be in coarser grains and to contain a few perthitic albite stringers. Milky-appearing plagioclase and myrmekite, which tend to rim and embay the microcline, are generally associated with the larger grains of microcline. Some microcline crystals contain numerous very small, ovoid or spindle-like inclusions of a material of moderately high refractive index which is tentatively identified as muscovite. Though not common, they are found in many microcline grains in the granitic gneiss. Whether they represent alteration of the microcline, remnants of incompletely assimilated material, or were formed in another way, is not clear.

Plagioclase occurs in three different ways. 1) The most common type of plagioclase is as in the plagioclase-quartz mosaic in the biotitic or dark gray layers. Here the oligoclase is untwinned or has only a few poorly defined lamellae and is in small, semi-rounded grains with sharp boundaries against the quartz. 2) Larger crystals of plagioclase are found in both the biotitic layers and in the felsic bands. They are characterized a) by clear twinning, often according to parallel and complex twin laws, b) by sericitic alteration of selected twin lamellae or patchy alteration, c) by "reaction" rims of variable thickness in contact with microcline, which are more sodic (about An_7) than the main part of the grain, and d) by irregular, embayed borders with microcline occupying the embayments. 3) The third type of plagioclase is quantitatively subordinate. Typically milky in appearance, untwinned, and myrmekitic, it is associated with the larger microcline grains in the felsic bands as interstitial material or as unoriented, ovoid grains clustered around the microcline grains. This microcline is perthitic and the associated milky plagioclase may be a result of deformation and unmixing (Gates, 1953; Tuttle, 1952) but the textural evidence is obscure. Cataclasis is commonly associated with the larger grains which makes any interpretation of the textures difficult.

Biotite predominates over muscovite in the dark layers and, along with the light and dark layering, provides the gneissic texture of the rock. The biotite is strongly pleochroic, deep reddish brown to pale yellow and commonly contains zircon crystals with dark halos.

Origin

As the granitic gneiss is the rock that has been most useful in subdividing the Gneiss complex, it is appropriate to consider its origin here. However, a separate study of its origin is currently underway, and hence conclusions presented now are preliminary and tentative. The observations which bear on its petrogenesis may be briefly summarized. The gray, banded granitic gneiss is chemically, mineralogically, and texturally a granite in the strictest sense. Though heterogeneous in detail, it is the most distinctive and homogeneous rock type in the Gneiss complex. It occurs principally in several layers 300 to 850 feet thick which, except for very subordinate layers of amphibolitic and sillimanitic gneiss, are homogeneous, mappable units. Subordinate layers 10 to 20 feet thick and of limited extent, do occur in all units of the Gneiss complex. In spite of the mineralogic similarity of the contiguous rocks, the granitic gneiss is readily separated from them by textural and weathering features. There are no dikes, or other of the usual intrusive features associated with granites. Gradational contacts, also, are absent.

Three explanations are being considered and doubtless others will suggest themselves as the work progresses. The working hypotheses being tested are: 1) The granitic gneiss is an intrusive, sill-like granite. 2) A particularly favorable pre-existing metasediment has been granitized by the introduction of the appropriate constituents. 3) Rhyolitic or other acid volcanic material deposited with the other sedimentary rocks has been recrystallized during regional metamorphism. Each hypothesis has serious weaknesses, but the third alternative seems to explain things best.

Felsic Gneiss (Rock Type 2)

This rock type is without question the most abundant in the Gneiss complex in the Cornwall quadrangle. It is most likely the type Agar (1929, p. 205) referred to as Grenville, though he included with the Grenville the hornblende schists to be described below. Its characteristics as observed in the field are a) pale yellow or tan to dark brown rusty-weathered surface, b) rough, ribbed or knotty surface compared to the smooth weathered surface of the granitic gneiss, c) irregular, coarse, continuous to discontinuous biotite-rich streaks or layers. The rough surface is due mainly to differential weathering of quartz-feldspar layers and biotite-rich layers. Sillimanite tends to produce a knotty or warty surface as it commonly occurs in small fibrolitic clusters. In general, the gneiss ranges from one with a few, narrow, discontinuous biotite-rich streaks to a striking black and white gneiss with biotite-rich streaks 1 to 2 inches in width.

Table 2 shows the range of mineralogic composition of the rusty, quartzo-feldspathic biotite gneiss in the Gneiss complex. It is notably different from the banded granitic gneiss in its general lack of microcline

Table 2

Mineral	Minimum percent by volume	Maximum Percent by Volume	Mode, percent by volume	Remarks
Quartz	18	78	20-45	2/3 of Samples in Mode
Plagioclase	2	70	20-40	2/3 of Samples in Mode
Biotite	3	45	10-25	2/3 of Samples in Mode
Muscovite	0	30	2-3	1/2 of Samples less than 3 percent
Microcline	0	25	0-5	1/2 of samples contain no microcline; 1/10 of samples contain more than 7 percent microcline.

Table 2. Modal analysis of the rusty-weathering, quartzo-feldspathic biotite gneiss of the Gneiss complex. Totals are based on 33 samples.

and in the common occurrence of sillimanite and garnet in amounts ranging from a trace to 3 percent. In overall chemical composition, the biotite gneiss is deficient in potash compared to the granitic gneiss (column D, table 4).

Petrography

Attempts to determine the bulk chemical composition of the quartzo-feldspathic biotite gneiss inevitably end in frustration as the relative amount of the biotite-rich streaks or layers and the felsic layers is not known nor readily estimated. Biotite amphibolite layers, which range from a few inches to more than 20 feet in thickness, complicate the picture further. The division between the quartzo-feldspathic biotite gneiss and the amphibolitic rocks described in the next section is drawn on the basis of significant amounts of hornblende. From table 2 it is apparent that the extreme ranges of composition reflect the variations between mica-rich and felsic layers. The modes also range widely, as the proportions of micaceous and felsic streaks vary from sample to sample.

Texturally the quartzo-feldspathic gneiss ranges widely, not only between different samples but in a single thin section. Fine-grained and aplitic textures are found adjacent to coarse-grained ones. In a single specimen the various minerals range from fine-grained, equant crystals to coarse anhedral ones. There is abundant evidence of cataclasis; quartz is commonly strained and mortar structure is apparent around large grains of microcline. The gneissosity is produced mainly by the mineralogic banding and by the rude parallelism of the micas.

In general the plagioclase is variable in composition and texture. It ranges from fine granular clusters or streaks with little twinning to large poikiloblastic grains with better developed twinning. A striking feature of many sections is the interlayering or intermixing of the fine granular plagioclase and quartz with coarse, strained vein-like quartz. The plagioclase in these irregular patches or streaks ranges from An_{30} to An_{77} anorthite in different samples.

Microcline is generally absent, but, where present, also ranges from small interstitial grains to large metacrysts. Not uncommonly the microcline includes abundant, very small, rounded to angular grains of a higher refractive index mineral tentatively identified as muscovite, similar to the "inclusions" found in microcline in the granitic gneiss. Myrmekite is present but very subordinate.

Biotite is the major mica and is the coarsest grained material in the rock. The muscovite present is interleaved with it. The biotite is typically pleochroic in pale yellow to foxy-red colors. Zircon is present in the biotite and shows the usual black halo.

The minor constituents are garnet, sillimanite, magnetite, and graphite. Sillimanite is usually associated with biotite and muscovite and appears to be growing or developing at their expense. The biotite is bleached wherever it contains appreciable sillimanite.

Origin

The rusty, quartzo-feldspathic biotite gneiss is very heterogeneous and its chemical analysis as given in column D, table 4 was calculated from the modal analyses of 33 samples. The over-all chemical composition indicates that the parent rock was something between a sandstone and shale. It is not significantly different from the Waramaug formation in bulk chemistry. However, the typical felsic layer in the Gneiss complex has a K_2O : Na_2O ratio of less than 1 whereas in the mica-rich layers the ratio approaches 2. Except for excessive quartz, the mica-poor layers have a composition similar to the average graywacke given in column G, table 4. They are generally comparable to the paragneiss of Engel and Engel (1953) (column E, table 4). If the layering is a primary sedimentary feature, the parent rocks would be alternating quartzose graywacke and shale. The assumption that the layering is primary seems valid. The layering is very irregular, and hence not readily explained by metamorphic differentiation, although doubtless metamorphism accentuated it. The mafic gneiss and amphibolite described below, which are interlayered with the quartzo-feldspathic biotite gneiss, are in geologic harmony with this assemblage.

Amphibolite and Mafic Gneiss (Rock Type 3)

Throughout the Gneiss complex are layers of dark gray to black rock, which range in thickness from a fraction of an inch to approximately 30 feet. In the field the biotite-hornblende gneiss is distinguished from the other rocks mentioned above by definitely darker color, ranging from black to mottled black and white to dark gray. Typically, it forms thin layers in the granitic gneiss and in the quartzo-feldspathic gneiss. Nowhere are the layers of mappable thickness or extent, but they tend to be present in the same stratigraphic positions. For convenience the dark gneiss containing quartz, biotite, plagioclase, and hornblende is here referred to as mafic gneiss.

The mineralogic composition of the amphibolite and mafic gneiss is given in table 3. From a comparison of table 3 and table 2 it is apparent

Table 3

Mineral	Minimum percent by volume	Maximum percent by volume	Mode, by volume	Remarks
Quartz	2	40	5-20	2/3 of Samples in Mode
Plagioclase	4	65	35-55	2/3 of Samples in Mode
Biotite	Trace	35	15-25	1/2 of Samples in Mode
Hornblende	Trace	80	10-35	1/2 of Samples in Mode
Sphene	Trace	6		
Magnetite	Trace	7		
Epidote and Clinozoisite	Trace	3		
Apatite	Trace	8		

[1]Diopside and Scapolite are present in some samples. Garnet, Carbonate, Zircon, Tourmaline, Chlorite, Microcline, and Muscovite are present in amounts ranging from a trace to 2 percent.

Table 3. Modal analysis of the amphibolite and mafic gneiss of the Gneiss complex. Totals are based on 24 samples.[1]

that there is no sharp break between the rusty, quartzo-feldspathic biotite gneisses and the mafic gneisses and that they must be treated as a complete series from a nearly pure felsic rock at one extreme to a nearly pure mafic one (80 percent hornblende) at the other. In the field the division between these gneisses is made primarily on the basis of hornblende and/or a dark gray to black color. The end member of the mafic gneiss series is a typical amphibolite containing hornblende and andesine-labradorite as its major constituents and minor amounts of quartz, sphene, magnetite, apatite, and epidote. The mafic gneiss grades into the felsic gneiss mainly by decrease in hornblende and also by decrease in the accessory sphene, apatite, and epidote. Some hornblende-free gneisses are included with the mafic gneiss if they contain abundant andesine-labradorite and the accessory sphene, apatite, magnetite, and epidote, which are not common in the rusty, quartzo-feldspathic biotite gneiss. It seems probable that the extreme compositional range of the mafic gneiss is produced at least in part by metamorphic differentiation accompanying deformation.

Petrography

Variability of texture is a major feature of the mafic gneiss as of the felsic gneiss. The gneiss ranges from poorly banded to well banded, massive to well foliated, equigranular to inequigranular, and fine to medium grained. Cataclasis and mortar structure are rather common features. The textures are most easily described in conjunction with the mineral discussions which follow.

Plagioclase is highly variable in composition, texture, and zoning. Its variability makes the interpretation of the original nature of these rocks inconclusive. In general the plagioclase can be divided into a) small grains with rounded outlines and little or no twinning and b) larger grains (1 mm and larger) with irregular outlines and well developed twinning. The larger plagioclase grains show progressive zoning which follows the irregular, amoeboid outline of the grain. The outer zone is typically more sodic than the core, but a reversal was found in one very calcic labradorite grain. Not uncommonly the larger grains show the effects of cataclasis and may be surrounded by finely granular plagioclase and quartz as in mortar structure. As in the rusty, quartzo-feldspathic biotite gneiss, there are rounded, irregular, or rectangular areas of granular plagioclase surrounded by coarser grained biotite and other minerals. The biotite tends to wrap around the finely granular areas. The granular plagioclase masses are tentatively considered to be porphyroblasts or even clastic plagioclase crystals which were granulated during deformation. The small, rounded grains of plagioclase predominate in the equigranular rocks in the lighter zones of the coarsely gneissic rocks. Granular mosaics of plagioclase and quartz or plagioclase-quartz-hornblende are common in rock relatively low in mafics.

The anorthite content of the plagioclase ranges from 12 to 80 percent as determined by the Five Axis method or by extinction angles measured in sections oriented normal to *a* (Emmons, 1943). In individual thin sections variations of 10 percent were measured but in general the variations are between different specimens or different bands in the coarsely gneissic rocks. In two-thirds of the rocks studied the plagioclase falls in the andesine range, and the bulk of the remainder in the labradorite range. However, the plagioclase in the rusty, quartzo-feldspathic biotite gneiss is 25 to 37 percent anorthite on the average; only two samples are more calcic and six are 10 to 25 percent anorthite.

Quartz is very erratic in its distribution and its associations. It is generally more abundant in the lighter colored mafic gneisses than in the darker ones. However, it is more abundant than plagioclase in two samples containing 55 to 70 percent hornblende and biotite. In one of these the plagioclase is bytownite. The quartz tends to occur in lenticular or irregular zones of finely granular material and in augen or discontinuous streaks of nearly pure quartz. There seems little doubt that the quartz has tended to segregate during metamorphism.

Hornblende occurs both in coarse poikilitic grains and as small euhedral to anhedral solid grains in all mafic gneiss specimens. Poikilitically included in the hornblende in order of decreasing abundance are magnetite, quartz, biotite, sphene, zircon, apatite, epidote, and plagioclase. In several specimens the hornblende contains a mass of finely disseminated magnetite or ilmenite in the central part of the grain such as is commonly found in hornblende formed from pyroxene. Most mafic gneiss specimens that contain biotite and hornblende show a replacement relationship between them, but the criteria as to which mineral is being replaced are inconclusive. For example, large anhedral hornblende grains commonly contain numerous small rectangular "inclusions" of biotite with a common orientation. The direction of replacement is not obvious.

Biotite is ubiquitous and associated with all other minerals. It is strongly pleochroic with the maximum absorption being deep brown to reddish brown. It occurs in large, long flakes with ragged terminations. Its intimate relationship with hornblende has been noted.

The remaining minerals found in the mafic gneiss are subordinate except in individual specimens. Pargasite with discontinuous rims of pleochroic common green hornblende is the common mafic mineral in one section. Cummingtonite and a carbonate are associated with hornblende in another gneiss. Diopside is abundant in one sample. Scapolite composes 4 to 7 percent of four separate specimens, in which it occurs as large poikiloblastic crystals or in small anhedral grains interstitial to plagioclase. Two of its occurrences are in rocks containing 15 to 20 percent epidote. Magnetite, sphene, and epidote (usually clinozoisite) are the common accessories in all mafic gneisses.

Origin

The amphibolite is the normal product of the metamorphism of basic igneous rocks or impure limestones. Sphene, apatite, and magnetite, which are rather abundant in the amphibolite favor a basic igneous parent. The mafic gneiss differs from the amphibolite mainly in the amount of biotite and quartz. The mafic gneiss, which is variable in composition, is most readily explained as mixtures of amphibolite and felsic gneiss or, in terms of parentage, basic volcanic material and graywacke shale. As the amphibolite, mafic gneiss, and felsic gneiss are interlayered and intergrade, it seems most reasonable that two primary source materials become mixed and interbedded during sedimentation. The additional possibility of acid volcanic material is suggested by the major layers of granitic gneiss and by the subordinate, thin layers throughout the felsic and mafic gneisses.

Graphitic Gneiss and Diopsidic Rocks (Rock Type 4)

The rusty graphitic rock is separated from the rusty quartzo-feldspathic biotite gneiss mainly because it is much more rusty-appearing in outcrop and because of its graphite content. Although graphite is present in minor amounts locally in the Gneiss complex, the graphitic rocks constitute a readily recognizable belt in Unit II and merits separate description for that reason alone. Physically, the graphitic rocks in this belt tend to crumble under the hammer whereas the non-graphitic rocks tend to be hard and tough. The light yellow color appears to be produced by the weathering of pyrite. The intensity of the rusty weathering of the graphitic rocks seems to be related to the biotite (stilpnomelane?) content but it is not obvious why the biotite of the non-graphitic gneiss does not weather so much or, for that matter, why the biotite of the granitic gneiss seems not to weather at all.

The rocks containing readily visible graphite are composed on the average of quartz (50 percent) and of biotite, plagioclase, microcline, and graphite in nearly equal (11 to 12 percent) amounts. Muscovite generally makes up 1 to 4 percent. By a decrease in the graphite content and the degree of rusty weathering, the rock grades in all respects into the "normal" rusty, quartzo-feldspathic biotite gneiss. The graphite-rich rocks do not form a continuous layer but do occur discontinuously at approximately the same stratigraphic level.

The diopsidic rocks are here included with the graphitic rocks as they appear to be associated in field occurrence. Generally, the diopsidic rocks contain megascopic amounts of graphite and are in large part disconnected patches or pods in the major graphitic belt. Diopsidic rocks without graphite are found in two isolated occurrences outside that belt.

The diopsidic rocks range in texture from fine grained to very coarse grained. No valid mineralogic composition can be given for these rocks because of the extreme variability of grain size. However, the minerals typically associated with the diopside are graphite, microcline, and quartz. Other minerals commonly associated with these in minor quantity are biotite, muscovite, plagioclase, sphene, zoisite, hornblende, and carbonate.

Origin

The diopsidic and graphitic rocks are thought to represent pre-existing black shales with nodules, lenses, or pods of carbonate. The presence of pyrite is compatible with such an environment.

Summary

The rock types in the metasedimentary sequence of the Gneiss complex which must be accounted for are, in terms of composition, 1) granite, 2) quartz diorite, 3) basalt, 4) quartzo-feldspathic graywackes, and 5) shale. Except for relatively minor granite bodies, and the ubiquitous but minor quartz-feldspar veins, there is little indication of alteration or additions to the existing rocks. Assuming further that metamorphism has not caused major losses of constituents and that metamorphic differentiation has been local in extent, the existing assemblage of gneisses must be explained in terms of primary sediments and sedimentary processes. The amphibolite and granite gneiss are most easily explained as volcanic flows, ash, or reworked and redeposited acid and basic material derived from active volcanism or from rapidly eroded volcanic source rocks. Active volcanism is thought to explain best the thicker granite gneiss and amphibolite layers. The felsic gneiss and the sillimanite-bearing biotite-rich layers appear to be average graywacke and shale respectively. The mafic gneiss, which is intermediate in composition between the amphibolite and quartzo-feldspathic biotite gneiss, could result from sedimentary processes mixing basic volcanic debris and sandy shale or graywacke. The conclusion is drawn that the Gneiss complex is the metamorphic equivalent of sediments and volcanic rocks commonly found in eugeosynclines.

PROPOSED STRATIGRAPHIC SUBDIVISIONS

The Gneiss complex has been divided into five units, I to V, which are considered a stratigraphic sequence in spite of the fact that granitic gneiss provides the major basis for the subdivisions. The units are numbered from the top downward since mapping has not progressed far enough to find the lowest or basal unit where the numbering would begin conventionally. The gray banded granitic gneiss is a major component of Unit I and Unit V and the only rock of Unit III. Unit II is a complex assemblage bounded by the easily recognized banded granitic gneiss, which marks the base of Unit I and makes up all of Unit III. Unit IV similarly is a heterogeneous assemblage defined by Unit III and the banded granitic gneiss marking the top 500 to 700 feet of Unit V. There are other layers of the banded granitic gneiss in Unit V which will be separately designated when mapping is further along in the Ellsworth, Sharon, and South Canaan quadrangles.

The mapping of the Gneiss complex, begun in the Cornwall quadrangle, is as yet too incomplete to establish formal subdivisions. However, as a guide for further mapping in the adjoining quadrangles as well as for studies of the Gneiss complex elsewhere, certain mappable units, characterized by specific rock types or assemblages of rock types have been assigned to units indicated on the map by symbols I to V and separated by the intraformational boundary symbol. These units maintain their relative positions across the northwest corner of the Cornwall quadrangle and extend at least a mile into the adjoining quadrangles. They will be described from the apparently lowest, Unit V, upward to the apparently highest.

Unit V

This unit is not well defined; finding its lower boundary requires further mapping in the Sharon quadrangle. In general it can be divided into two parts, a lower one composed of the heterogeneous assemblage of light and dark banded or streaked gneisses (mainly rock types 2 and 3 above, interlayered) and an upper one of gray, rather uniform banded granitic gneiss (rock type 1 above); the latter has an apparent thickness of 500 to 700 feet. Typical of the lower part are the rocks exposed in the road cuts and the railroad cut along the east side of Housatonic River a quarter of a mile south of West Cornwall. The rocks range in composition from mafic gneiss to microcline-bearing quartz-plagioclase gneiss with subordinate muscovite and biotite. Quartz and plagioclase compose 50 to 80 percent of most layers, biotite and subordinate muscovite the remainder. Microcline is subordinate to plagioclase in all layers and absent in the layers rich in biotite or biotite and hornblende. Sphene, apatite, epidote, and magnetite are accessories in the hornblendic layers.

Unit IV

This is a heterogeneous assemblage of 1) rusty, quartzo-feldspathic biotite gneiss, 2) gray to white, biotite-streaked gneiss, 3) gray, granitic gneiss generally in thin layers, and 4) subordinate biotite amphibolite (mafic gneiss). In general these various gneisses occur in poorly defined layers ranging from a few feet to nearly 200 feet in width. The dominant gneisses are composed essentially of quartz, plagioclase, muscovite, and biotite in varying proportions and in varying distributions. For example, in one of the two gneisses of identical composition containing 30 percent biotite the biotite is concentrated in thin ⅛- to 2-inch layers, giving a coarse, black and white layered or streaked appearance, and in the other the biotite is disseminated, producing a dark gray gneiss of uniform appearance. All gradations are found from regularly banded through irregularly streaked gneisses to those in which the micas are uniformly disseminated. The mineralogic ranges of composition are: quartz 15 to 50 percent, plagioclase 15 to 60 percent, biotite 0 to 35 percent, muscovite 0 to 15 percent. The typical accessories are garnet, magnetite, sillimanite, apatite, and graphite. Microcline is absent or subordinate in all gneisses except the granitic gneiss. The mafic gneisses are those described as rock type 3 above.

Unit III

Gray, banded granitic gneiss (rock type 1 above) makes up this entire unit. It is one of the best defined units in the Gneiss complex and is readily traceable across the quadrangle. It can be observed 1) on Mine Mountain, 2) on the northern slope of Buck Mountain, 3) both east and west of Dibble Hill Road on the southern part of Green Mountain, 4) at Hitchcock Corners, and 5) on Coggswell Road just north of the quadrangle boundary. The Coggswell Road exposure is the most readily accessible and shows both fresh surfaces in a road cut and the normal glaciated and weathered surface (figure 3). Essentially complete sections of this unit are exposed on Mine Mountain and east of Dibble Hill Road on Green Mountain. The lithologic homogeneity of this unit is broken only by a 10-foot layer of the rusty, quartzo-feldspathic gneiss approximately 50 feet from the lower contact. The disseminated biotite locally gives way to biotite streaks. This unit ranges from 400 to 600 feet in outcrop width.

Unit II

Like Unit IV, this is a heterogeneous assemblage of quartzo-feldspathic gneisses bounded by the lithologically distinct granitic gneiss of Unit III and a similar granitic gneiss marking the base of Unit I. The most abundant rock types are the rusty to nearly gray-weathering, quartzo-feldspathic gneisses with graphite as a common accessory. Mafic gneisses are subordinate but present in layers 1 to 20 feet thick throughout the unit. The most striking characteristic of this unit is the belt of coarse graphite-bearing, sandy, quartzo-feldspathic gneiss (rock type 4 above), which is different from all other rocks in the area. This coarse graphite-bearing belt is well exposed on the east and southwest slopes of the triangular peak at the crest of Mine Mountain. More readily accessible exposures are found in the northeast-southwest trending knobs east and west of Dibble Hill Road on Green Mountain. Characteristically the graphite-rich gneisses weather pale yellow and crumble like a poorly cemented sandstone under the hammer. Furthermore, diopside-quartz granulite with graphite occurs in irregular pods or masses in this belt. The diopsidic rock ranges from a fine-grained rock to pegmatitic masses with crystals several inches across. Graphite occurs as an accessory in most of the rocks in Unit II and also in Unit IV, but only in Unit II does it occur in large flakes in amounts up to 10 percent. The coarse graphitic zone is not continuous but is pod-like or discontinuous in its distribution. It is, however, in the same stratigraphic position wherever it occurs.

Unit I

The base of this unit is a layer 300 to 850 feet thick of the gray, layered granitic gneiss with only one or two mafic gneiss layers in it. This layer and its contact with the underlying Unit II are well exposed about a mile northwest of Cornwall Bridge on the southwest slope of the southern end of Mine Mountain. Much of the outcrop is just west of the Cornwall quadrangle border in the Ellsworth quadrangle. The rather uniform granitic gneiss layer is succeeded upward by a poorly defined, possibly discontinuous zone 60 to 90 feet thick. This zone is a heterogeneous, thinly layered assemblage of rusty weathering quartzo-feldspathic gneiss, mafic gneiss, gray, granitic gneiss, and brick-red-weathering, granite-bearing, quartzo-feldspathic gneiss. The remainder of the section in this unit is poorly exposed in separated, discontinuous outcrops and, of necessity, must be patched together. Above the thin heterogeneous zone the gray granitic gneiss or the gray-weathering quartzo-feldspathic gneiss predominates. There are several rather thick layers or pods of dark quartz-biotite-hornblende-plagioclase gneiss (mafic gneiss) which contain the usual accessories, sphene, magnetite, and apatite, in amounts up to 8 percent. About 500 feet from the top of the section is a thin layer of a granular, tough, diopside-hornblende-microcline-plagioclase-quartz rock which is noteworthy mainly because it occurs in the same stratigraphic position in two places – one in the stream bed of Tanner Brook southeast of White Rock and the other on the small knob in the Ellsworth quadrangle near its eastern border just south of Highway 4.

STOCKBRIDGE MARBLE

The Stockbridge marble is in two closely spaced, isolated outcrops in the bed of Furnace Brook just east of Cornwall Bridge. These outcrops are the northernmost of a series in the Housatonic Valley floor extending from Bulls Bridge to Cornwall Bridge (see figure 2) (Moore, 1935). In spite of a diligent search for marble in the valley marking the contact between the Gneiss complex and the Waramaug formation, no additional outcrops were found in this quadrangle. (Nor did a search for information from well drilling reveal indications of limestone.) Three isolated outcrops of marble are in the valley floor just north of the Cornwall quadrangle between Johnson Hollow and Cornwall Hollow (in the South Canaan quadrangle). These also lie between the Gneiss complex and the Waramaug formation.

The extension of the Stockbridge marble northeastward into the Cornwall quadrangle for nearly three miles beyond the last outcrop is based on three considerations. 1) Glacial cover or deposits of one type or another mark the extension area indicating that it was a pre-glacial valley. Dean Hill has no outcrop, and is characterized by heavy glacial debris. 2) The thickness of Unit I of the Gneiss complex is readily measured in the area north of Cornwall Bridge on Mine Mountain and in the adjacent Ellsworth quadrangle near Silver Hill and Bread Loaf Mountain. The base of Unit I is well exposed in the area northeast of Cornwall Bridge and its top (i.e., the contact between the Stockbridge and Unit I) was determined by measurement from the base. 3) The outcrop width of the Stockbridge marble in the Housatonic Valley south of Cornwall Bridge is comparable with the width of the extension in the valley of Furnace Brook. The termination of the marble is based on structural considerations and the absence of marble in the crooked valley extending to Johnson Hollow.

In the vicinity of Cornwall Bridge the Stockbridge marble is a dense, medium-grained, impure calcitic marble. The impurities are mainly quartz, tremolite, muscovite, phlogopite, and a trace of microcline. The quartz is strained and has undulatory extinction. The impurities are in discontinuous streaks, giving the marble an ill-defined gneissosity.

WARAMAUG FORMATION

GENERAL STATEMENT

The Waramaug formation underlies the greater part of the eastern and southern halves of the quadrangle. It was previously called Berkshire schist and, in part, Becket gneiss (Gregory and Robinson, 1907; Agar, 1929). In 1952 Gates (Gates and Bradley, 1952) renamed it Waramaug to avoid confusion with the type Berkshire in Massachusetts.

Gregory and Robinson (1907) mapped a thin wedge of Becket gneiss along the west side of the Tyler Lake granite. Remapping showed no valid basis for separating this wedge from the surrounding rock, and it is here included with the Waramaug.

Regionally the Waramaug is separated throughout much of its extent from the Gneiss complex of the Housatonic Highlands by the Stockbridge marble and from the Hartland formation (5 miles south) by the Woodville marble (Gates and Bradley, 1952; Moore, 1935; Rodgers and others, 1956, 1959). In the Cornwall quadrangle, however, the Waramaug comes into direct contact with the Gneiss complex and in the adjoining quadrangle to the east (West Torrington) it is in contact with the Hartland. The limited exposures showing the relationship of the Waramaug and the Gneiss complex are described in the section on relations between formations. Any revision of the interpretation of a fault relationship between the Waramaug and the Hartland (Gates and Bradley, 1952) will have to await further mapping in the West Torrington quadrangle.

The Waramaug formation is composed of a variety of biotitic quartzo-feldspathic gneisses containing generally subordinate muscovite, garnet, sillimanite, and staurolite. Amphibolites (ortho-?), which range in size from a few inches across and several feet long to as much as 2000 feet thick, are abundant locally and present in minor amounts throughout the Waramaug. Most of the amphibolites are 5 to 100 feet thick and a few hundred feet in length. Generally they are discrete concordant layers but not of mappable size. Their occurrence in the Waramaug is indicated on the map by a special symbol. On Mohawk Mountain the strike of the contact between an amphibolite and the Waramaug diverges from the foliation by about 15 degrees. In only two outcrops are amphibolite and biotite gneiss mixed or intimately interlayered, in sharp contrast to the intimate interlayering and mixing of amphibolites and quartzo-feldspathic gneiss everywhere in the Gneiss complex.

LITHOLOGY

In the field it is possible to recognize three different rock types in the Waramaug, though there are intermediate and intermixed variants. A fourth rock type within the Waramaug formation is the amphibolite. Unfortunately, the rock types are not mappable units. Descriptions of these four rock types follow:

Quartzo-Feldspathic Biotite Gneiss

The major rock type is a gneiss of uniform appearance that weathers light brown and is composed principally of micas, quartz and oligoclase-andesine. It differs from the quartzo-feldspathic gneiss of the Gneiss complex in that the micas are uniformly distributed rather than in streaks and layers. The micaceous folia alternate with the felsic layers on the scale of a fraction of an inch, producing a foliated, but homogeneous-appearing rock. Post-glacially weathered surfaces of this rock are smooth. This rock type is well exposed several places along the road leading from Highway 4 to the top of Mohawk Mountain.

PETROGRAPHY

The quartzo-feldspathic biotite gneiss is rather simple in mineralogy and in texture. The range of composition is shown on the triangular diagram (figure 4). In general muscovite is subordinate to biotite, but it is more abundant in four of the 26 thin sections analyzed by point

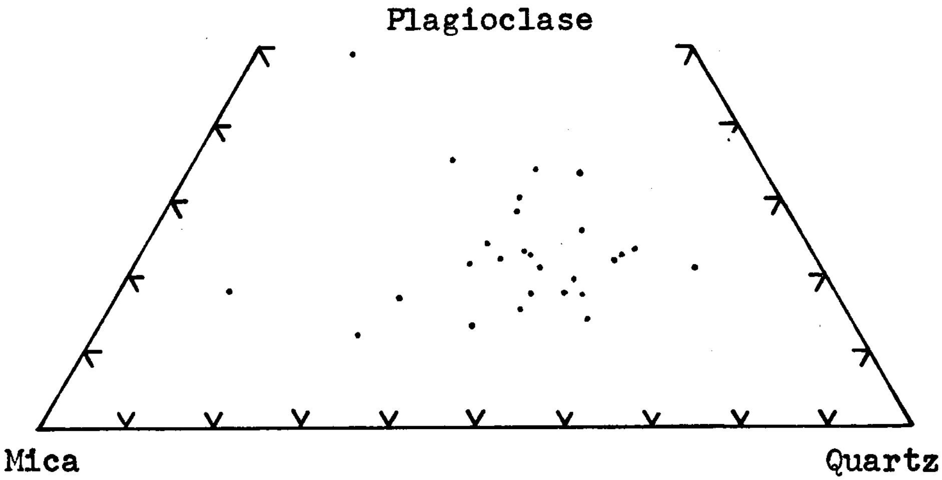


Fig. 4. Modal composition of the quartzo-feldspathic biotite gneiss of the Waramaug formation. Plagioclase averages An_{30}. Mica includes biotite and muscovite, but muscovite is subordinate.

counting. Microcline is present in very minor amounts in a few samples, the maximum present is 8 percent in one sample. Minor and accessory constituents are garnet (0-8 percent), magnetite, tourmaline, apatite, chlorite, epidote, sphene, sillimanite, staurolite, and zircon.

The chemical composition of the gneiss was calculated from the average modal analysis using a 24-oxygen cell for convenience in converting volumes to weight percents since the error introduced by ignoring specific gravity is not significant in this case. Table 4 gives the calculated chemical composition of the quartzo-feldspathic gneiss along with some selected sedimentary and metamorphic rock analyses for comparison.

Texturally the quartzo-feldspathic gneiss is fine- to medium-grained, gneissic to granoblastic. Quartz, the most abundant mineral, occurs in semi-equant grains and commonly shows strain shadows. There is little or no elongation parallel to the foliation. Plagioclase occurs in various forms from small equant grains to large poikiloblastic grains with inclusions of quartz, muscovite, biotite, and magnetite. The composition of the plagioclase as determined in thin section using the Five Axis method (Emmons and Gates, 1939; Emmons, 1943) ranges from An_{22} to An_{40}; the majority of the grains lie around An_{30}. Biotite, the major mica, ranges in amount from 13 to 37 percent; the mode is about 27 percent. It is typically pleochroic in reddish-brown to pale yellow colors.

TABLE 4

Constituents (Weight percent)	A	B	C	D	E	F	G
SiO_2	70.0	63.5	62.2	69.57	70.9	68.3	65.8
TiO_2	–	–	0.7	–	0.32	0.7	0.5
Al_2O_3	10.9	14.6	16.5	13.30	12.17	15.9	14.4
Fe_2O_3	8.1 (Fe₂O₃ + FeO)	11.3 (Fe₂O₃ + FeO)	4.3	–	1.31	1.1	1.0
FeO			2.6	6.31	4.12	5.7	4.3
MnO	–	–	tr	–	.04	0.1	0.1
MgO	4.0	3.7	2.6	3.04	2.32	2.6	3.0
CaO	1.6	1.24	3.3	2.23	1.55	1.9	3.6
Na_2O	2.0	1.6	1.4	2.65	3.74	2.1	3.5
K_2O	3.5	4.1	3.5	3.04	2.87	3.9	2.1
H_2O+	–	–	–	–	.21	.8 (H_2O+ and H_2O-)	–
H_2O-	–	–	–	–	.05		–
P_2O_5	tr	tr	.2	–	–	–	0.1
CO_2	–	–	2.7	–	–	–	1.6
SO_3	–	–	–	–	–	–	–
TOTAL	100.1	100.04	100.0	100.14	99.6	98.8	100.0

[1]A. Waramaug quartzo-feldspathic biotite gneiss. (Mode: quartz - 45; plagioclase An_{30} - 24.5; biotite - 26.7; muscovite - 2.6; garnet - 1.0; magnetite - 2.0)

B. Waramaug sillimanite quartzo-feldspathic biotite gneiss. (Mode: quartz - 37.2; plagioclase An_{30} - 18.8; biotite - 25.2; muscovite - 10; garnet - 4.8; magnetite - 1.0; sillimanite - 2.5; staurolite - .4; apatite - .1)

C. Chemical analysis of average shale, recalculated from Clarke, 1924, p. 30.

D. Rusty, quartzo-feldspathic biotite gneiss of Gneiss complex. (Mode: quartz - 40; plagioclase An_{32} - 33; biotite - 20; muscovite - 3; microcline - 2; garnet - 1.5; sillimanite - .5)

E. Grenville gneiss, modal analysis (Engel and Engel, 1953, p. 1039)

F. Chemical analysis of Manhattan schist (Scotford, 1956, p. 1184)

G. Chemical analysis of average graywacke (Pettijohn, 1949, p. 250)

Table 4. Chemical composition of Waramaug, Gneiss complex, and related rock types. Chemical compositions given in columns A, B, D, and E are calculated from modal analyses.[1]

SILLIMANITE-QUARTZO-FELDSPATHIC BIOTITE GNEISS

The second major rock type differs from the gneiss described above only in the presence of sillimanite and garnet as recognizable constituents. Sillimanite and garnet are revealed most obviously on post-glacial weathered surfaces where the sillimanitic and garnetiferous streaks and clusters stand up in positive relief. They produce a warty or nubby surface where the gneiss is relatively homogeneous; where it is well foliated a ribbed or corrugated surface results (see Gates, 1952, pl. I, fig. A). Both the warty and corrugated surfaces are in marked contrast to the smooth weathered surfaces of the quartzo-feldspathic biotite gneiss. Excellent exposures of this rock type are readily accessible from the Appalachian Trail on Red Mountain.

PETROGRAPHY

The mineralogy of the sillimanite-garnet gneiss is similar to that of the quartzo-feldspathic biotite gneiss with the obvious exception of the sillimanite and garnet. Minor constituents are staurolite, magnetite, apatite, tourmaline, chlorite, and microcline. The range of composition of the essential minerals is shown on the triangular diagram of figure 5.

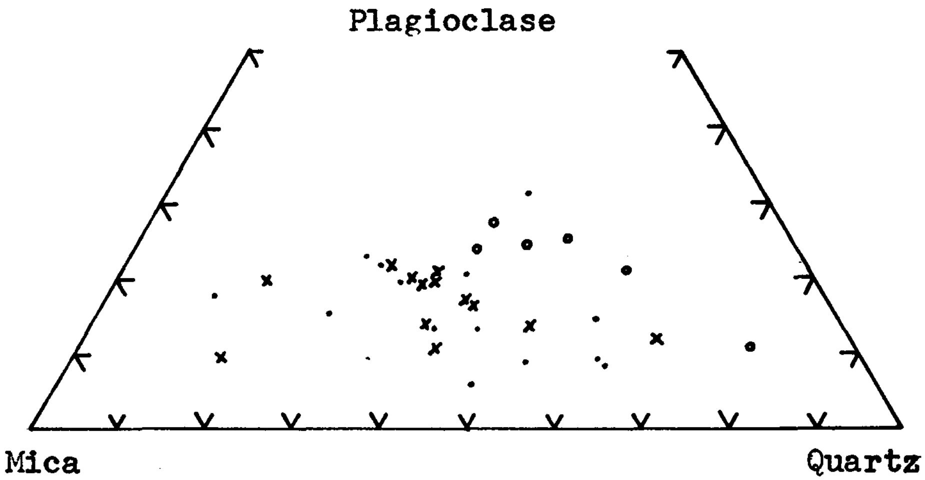


Fig. 5. Modal composition of sillimanitic quartzo-feldspathic biotite gneiss of the Waramaug formation recalculated to 100 percent in terms of mica, plagioclase, and quartz. Open circles indicate samples containing 0 to 1 percent sillimanite; "X" indicates 1 to 3 percent sillimanite; and a dot indicates samples with 3 to 6 percent sillimanite. Accessories are garnet, magnetite, staurolite, and apatite.

The chemical composition as calculated from the mode is shown in table 4.

The sillimanitic rocks range in texture from gneissic to granoblastic to lepidoblastic and are fine to coarse grained. Except for the knots of sillimanite and garnet, the over-all texture is similar to that of the quartzo-feldspathic gneiss. Plagioclase occurs in equant grains in large part, but large poikiloblastic crystals with abundant inclusions of all other minerals – such as micas, quartz, and tourmaline – are not rare. Its average composition is An_{30}, but ranges from An_{25} to An_{37}. Muscovite and biotite occur together; biotite generally predominates, but in some samples muscovite is abundant and the only mica present. Biotite is pleochroic in reddish brown to pale yellow colors with some flakes deep olive green and dark brown.

Sillimanite occurs 1) as knotted aggregates associated with biotite, 2) as slender fibres in biotite, the two intergrown parallel to foliation,

3) as clusters of needle-like crystals enclosed by quartz, and 4) as small aggregates at the boundaries of quartz, plagioclase and garnet. The most common association is with biotite. Biotite containing sillimanite is typically bleached and only slightly pleochroic. It appears that in large part the sillimanite has developed at the expense of the biotite. Thus small euhedral grains of staurolite are commonly intergrown with sillimanitic biotite or lie adjacent to it.

Migmatitic Gneiss

In the Waramaug the third rock type is actually a mixture of the two types of gneiss described above with granite and pegmatite. The granite and pegmatite intimately penetrate the Waramaug in the form of dikes, sills, and anastomosing stringers, but the Waramaug itself seems little changed, except for a small increase in microcline content. This mixed rock type is largely restricted to the southeast quarter of the quadrangle and to the borders of the Goshen granite.

Amphibolite

The amphibolite, typically dark green to black, and fine grained, forms sharply defined sill-like bodies in the Waramaug formation and is considered a part of it. However, the concentration of amphibolite bodies in the foliation anticline and syncline around Mohawk and Coltsfoot Mountains and their simple mineralogy make it reasonable to look upon them as pre- to syntectonic intrusives. In only two places were mixed Waramaug and amphibolite found.

Petrography

All the amphibolite is similar in mineralogy and texture. It is composed mainly of plagioclase (20 to 40 percent) and hornblende (50 to 70 percent) with minor amounts of quartz, biotite, magnetite, and sphene. The amphibolite is well foliated, and is lineated in some places where prismatic hornblende is present. The hornblende is blue green in color and pleochroic in pale green to pale yellow or colorless. Prismatic crystals and poikiloblastic hornblende are present in all samples. Plagioclase occurs primarily in equant grains which show some zoning and some strain shadows. Twinning is uncommon. The composition ranges from An_{42} to An_{65}.

SUMMARY

The several distinct rock types in the Waramaug do not form separate and mappable units; they are, rather, end members in a series of gneisses that includes all intermediate gradations. Originally, it seemed as though mapping the various rock types might reveal stratigraphic units, but lack of critical outcrops and of truly distinctive rocks dimmed this hope. The difficulty of tracing any rock type along strike of foliation is probably related to lack of parallelism of foliation and original bedding rather than facies changes. The amphibolite bodies are discrete lenses that have no obvious stratigraphic distribution.

The chemical compositions of the Waramaug rock types as calculated from modal analyses (table 4) indicate that the parent sediments were argillaceous sandstones and siliceous shales. The K_2O : Na_2O ratio of 2.5 in the sillimanitic gneiss corresponds to that in the average shale (column C, table 4). The relatively high MgO : CaO ratio can reasonably be expected from an argillaceous sediment lacking carbonate minerals. The original sediments are thought to be derived from an environment where chemical weathering predominated and brought about the removal of soda.

A comparison of the chemical composition of the Waramaug, the felsic gneiss of the Gneiss complex, and the Manhattan schist is provided in table 4. The felsic gneiss (column D, table 4) is the only rock type of the Gneiss complex comparable in any way to the Waramaug. Though the average Waramaug and felsic gneiss are not significantly different in chemical composition or mineralogy, they are markedly different in outcrop. The Waramaug is generally uniform, whereas the felsic gneiss is typically heterogeneous due to mica-rich streaks and layers. The variations in the rock types of the Gneiss complex as a whole are much more complex than in the Waramaug. The chemical composition of the Manhattan schist (column F, table 4) is remarkably similar to that of the Waramaug. The chemical, mineralogical, and textural similarity of these two formations is the basis for considering a common sedimentary antecedent and a common metamorphic history.

TYLER LAKE GRANITE

GENERAL STATEMENT

The Tyler Lake granite (see p. 4) forms an irregularly shaped mass within the Waramaug formation. It clearly intrudes the Waramaug, intimately penetrating it along its borders. The area mapped as granite contains no appreciable outcrop of Waramaug and is essentially massive granite, but the boundaries of the granite are ill-defined and in part arbitrary. A migmatitic mixture of Waramaug with granite and pegmatite characterizes the border, especially on the south and east where dikes, sills, and stringers of granite and pegmatite occur in moderate abundance within the Waramaug formation. The western border of the granite is much sharper.

PETROLOGY

The Tyler Lake granite is a structureless, massive, white, fine- to medium-grained granite. It is composed of quartz (35 percent), microcline (32 percent), plagioclase (25 percent), and muscovite and biotite (8 percent). Its most obvious and perhaps significant textural feature is its deformation. All the felsic minerals are granulated in varying degrees in all sections studied. The larger grains of quartz have a very wavy extinction. The texture is typically cataclastic, though some specimens are granitic and some are crudely foliated. Lenses of granulated quartz and microcline are apparent in the gneissic granite. The grain size is quite irregular; large megacrysts of quartz, microcline, and plagioclase are set in a fine-grained granular matrix of microcline, plagioclase, quartz, and myrmekite.

The microcline megacrysts are typically poikilitic with numerous inclusions of quartz and plagioclase, some perthitic. The plagioclase inclusions in the microcline are subhedral, and some show progressive zoning. The fine-grained microcline in the granulated material is not perthitic.

Plagioclase also occurs as megacrysts and in the fine-grained matrix. The megacrysts are generally anhedral, show progressive and/or oscillatory zoning, and contain muscovite flakes oriented parallel to either (001) or (010). It is not uncommon for the plagioclase grains to contain polygonal microcline "inclusions" of small size in crystallographic continuity with the plagioclase. The areas of plagioclase around the "inclusions" of microcline show irregular extinction different from the bulk of the crystal. The relationship has been interpreted as microcline replaced by plagioclase (Gates, 1953, 1954).

The composition of the plagioclase ranges from An_{10} to An_{20}. The forty-three determinations show a distinct concentration around 12 percent and around 17 percent anorthite. The range of composition between rim and core of one progressively zoned plagioclase is 10 percent to 19 percent An. In one sample the plagioclase is more sodic than An_{10}. This sample is unusual in that it is rather gneissic and does not contain either perthite or myrmekite. It is possible that the sodic plagioclase in this rock resulted from the complete unmixing of the microcline perthite due to extreme granulation (Tuttle, 1952).

Essentially all the features of the Tyler Lake granite indicate a magmatic origin. In mineralogical composition it falls close to "petrogeny's residua system" of equal parts plagioclase, microcline, and quartz. Biotite is very low, especially in comparison with the surrounding biotite gneiss. The granite is largely discordant and has no gradational contacts. Even in the migmatitic border the injected metasediments are not materially altered.

It is appropriate here to summarize briefly the differences between the Tyler Lake granite, the Mine Hill granite gneiss, and the Nonewaug granite, since they were previously called Thomaston granite or granite gneiss. The Nonewaug granite is characterized by extreme variability in grain size from fine to pegmatitic, by a textural layering parallel to the walls of the body, by high albite content, and by large graphic granite crystals. Typically the albite : microcline ratio is 1.6. It does not show any cataclasis, is structurally discordant, and is considered post-tectonic. By contrast, the Mine Hill granite is gneissic in texture, shows mineral segregation and excellent muscovite-rich foliation planes. It is concordant and considered pre-tectonic in large part. The textural characteristics of the Tyler Lake granite appear to place it in the syn- to post-tectonic category. It seems reasonable that these granites are related in general but have slightly different tectonic histories within the last major period of deformation. Table 5 gives the average composition of each of the granites.

TABLE 5

Granites			
Minerals (By volume percent, based on point count)	Nonewaug (10 samples)	Mine Hill (5 samples)	Tyler Lake (8 Samples)
Quartz	31	32	35
Plagioclase	38	40	25
Microcline	22	18	32
Biotite	1	2	4
Muscovite	8	8	4

Table 5. Modal analyses of several young granites in western Connecticut: Nonewaug (Woodbury-Litchfield quadrangles), Mine Hill granite gneiss (Roxbury quadrangle), and Tyler Lake granite (Cornwall-West Torrington quadrangles).

RELATIONS BETWEEN FORMATIONS

The relations between the Gneiss complex, the Stockbridge marble, and the Waramaug formation are of major interest to all workers in western Connecticut. But in this quadrangle, as elsewhere, they are amenable to more than one interpretation. The pertinent considerations in this matter are summarized below.

GNEISS COMPLEX AND STOCKBRIDGE MARBLE

The Cornwall quadrangle can shed no light on the relations of these two formations since there is no exposed contact. The last exposures along the Stockbridge marble belt, which extends along the Housatonic Valley from Bulls Bridge twelve miles northward, lie a few feet inside the western boundary of the Cornwall quadrangle (see figure 2 and foliation symbols on the geologic map, plate I, marking outcrops in Furnace Brook). Here, as almost everywhere in this belt, the relations of the Stockbridge to the adjacent formations are not revealed. However, the Stockbridge does lie between the Gneiss complex and/or the Poughquag quartzite on the west and the Waramaug on the east. The Poughquag quartzite is absent more commonly than it is present in this belt, and presumably the Stockbridge overlies the Gneiss complex directly. At the falls in Kent Falls State Park where the contact between the Stockbridge and the Waramaug is exposed, the two units appear conformable, dipping approximately 60-70 degrees east. The same relations are inferred from the outcrops of the Stockbridge and Waramaug in the Cornwall quadrangle although the contact is not exposed. Thus, one view is that the Stockbridge is part of a Cambro-Ordovician sequence of Poughquag-Stockbridge-Waramaug which overlies the Gneiss complex (Rodgers, 1959, p. 10-11). Balk (1936) proposes a fault between the Gneiss complex and all formations to the east.

The absence of the Stockbridge marble in the sinuous valley from Cornwall (Cornwall Center, junction of Highways 4 and 125) to Johnson Hollow may be due to stratigraphic pinch out, tectonic "squeeze out," or faulting. In the section on structure a fault is postulated along the west limb of the sinuous valley south of Cornwall Center.

Between the Crooked Esses and Johnson Hollow is an apparently conformable contact between the Gneiss complex and the Waramaug, indicating lack of deposition of the Stockbridge in this interval.

GNEISS COMPLEX AND WARAMAUG FORMATION

Where the Gneiss complex and the Waramaug formation are not separated by the Stockbridge marble, their relations are seldom clear. A major fault is considered to lie between the two units along the west side of the Quarry Hill-White Rock tongue of the Gneiss complex. This conclusion is based on stratigraphic and structural considerations to be taken up later. On the east side of this tongue, between North Corners and the Crooked Esses, these is no evidence of faulting.

The contact of the Waramaug formation and the Gneiss complex is exposed in two places: in the stream bed near the head of Tanner Brook, and on the slope between the tributaries of Birdseye Brook north of the Mohawk ski-lift trails. In both areas gray, quartzo-feldspathic to granitic gneiss is interlayered with rusty-weathering, quartzo-feldspathic biotite-rich gneiss (with or without sillimanite), the first typical of the Gneiss complex to the west and the second typical of the Waramaug formation to the east. The individual layers range from two feet to one hundred feet. The interlayered rocks are considered to represent the transition from a biotite-poor quartzo-feldspathic rock to a biotite-rich one. Thus, based on these two exposures alone (and there are no others where these two formations come close together) the conclusion would be drawn that the Gneiss complex has a normal, gradational sedimentary contact relationship to the Waramaug formation. As mentioned in the section on the Gneiss complex, biotite-rich gneiss lithologically similar to much of the Waramaug formation occurs in abundance as part of the Gneiss complex. It may be such an interlayering that we see here. However, the typical Gneiss complex rock type along this belt is the gray, quartzo-feldspathic to granitic gneiss. The typical Waramaug rock type east of the contact is the biotite-rich gneiss. Further, the normal thickness of Unit I of the Gneiss complex, as measured elsewhere, would place the upper contact on the east side of the valley. The possibility that the interlayering of rock types represents an unusual basal section of the Waramaug cannot be dismissed. The evidence for the transitional contact is far from conclusive, or to the skeptic even convincing, but it is all that is available in this quadrangle. An alternative conclusion would be a fault as suggested by Balk and Agar (1936) where conformity is produced structurally and the interlayering of rock types is a consequence of slabs being torn off along a fault zone and recrystallized. The writer feels that firm conclusions regarding the relations of the Gneiss complex to the Stockbridge limestone and the Waramaug formation should await further mapping and petrologic study.

STRUCTURE

The Cornwall quadrangle is located in the crystalline part of the major orogenic belt of the Appalachian geosyncline. The regional structure has the general northeast trend characteristic of the crystalline rocks throughout the system which is assumed to have been produced by northwest-southeast compression. The dominant structural feature of this area is a large dextral "drag" foliation fold with an amplitude of more than two miles. This fold is reflected in the major topographic features of the quadrangle – the sinuous valley which marks the approximate contact between the Gneiss complex and the Waramaug formation, and the range of mountains along the southeast side of the valley. The fold consists of a major foliation syncline in the Bald-Coltsfoot-Woodbury Mountain area and the complementary anticline reaching from Woodbury Mountain into Mohawk Mountain. On Mohawk Mountain itself, there appears to be a subordinate "drag" fold on the flank of the major one. The foliation and layering of the Gneiss complex parallels the foliation of the Waramaug except that, instead of simply folding into an anticline to match that in the Waramaug, a north-south fault sliced off the east limb which moved into the core of the anticline. The horizontal component of the displacement of the east limb on the fault is a little over two miles southward.

The foliation and layering in the Gneiss complex is parallel to the apparent stratigraphic units (I to V). The general trend of the foliation is to the northeast and the dip to the southeast except between Overlook and White Rocks. A fault is inferred along the west side of this belt from the repetition of the stratigraphic units in the Gneiss and the lack of parallelism of both foliation and units with the Waramaug to the west. From its mineralogy the Gneiss complex can be considered more competent than the Waramaug and might be expected to yield by faulting along the axial plane of a tight fold. Linear features are not readily seen in the Gneiss complex.

The Waramaug formation has well developed and consistent foliation only along its borders. Elsewhere the foliation has an average or general northeast trend, but is quite variable in the individual outcrop. Similarly in the New Preston quadrangle to the south, the Waramaug is consistently well foliated only along its border, where it is parallel to the trend of the Woodville marble (Gates and Bradley, 1952). In the south and east sections of the Cornwall quadrangle the foliation is more irregular, but still shows the regional northeast trend. Wherever a general trend of the foliation is apparent in an individual outcrop, it is indicated on the map by the conventional symbol. Commonly the foliation planes are intensely crumpled and convoluted locally and only a general trend is apparent. Transposition of mica folia can be seen in many areas to have produced a rock surprisingly homogeneous in appearance. Outcrop areas where the foliation is too irregular to determine a trend are indicated by a separate symbol (see map near Warren). The convolutions of the foliation planes and the nearly homogeneous rocks are considered the results of the second deformation. The conclusion drawn is that the Waramaug formation has undergone major deformation and metamorphism more than once and that the present border foliation and the foliation folds reflect the last deformation.

The lineation in the Waramaug is measured on the crenulations or folds of the foliation planes or on rod-like arrangement of quartz and feldspar grains. The lineation is best developed in the foliation syncline and anticline. In the core of the folds the lineation is the only measureable structural feature, as the foliation planes are crumpled so severely that the general trend is not apparent in most outcrops. In the area of Baldwin Cave the crenulation of the foliation planes has an amplitude of nearly a foot.

The structural relations of the Tyler Lake granite to the Waramaug are ambiguous. Along the west side of the main mass around Flat Rocks the Waramaug is well foliated and conformable to the contact of the granite which, here, is comparatively sharp. Elsewhere the granite appears to have invaded the Waramaug as if the Waramaug were an incompetent mass and deformed plastically. Here it seems likely that the foliation of the Waramaug along the western border of the granite was developed relatively late, probably after the granite was essentially rigid. The sharp border may be an extension of the fault which extends from the northern border of the quadrangle to the Crooked Esses. This would also account for the general cataclastic texture of the granite.

METAMORPHISM

In general the rocks of all formations in the Cornwall quadrangle fall in the sillimanite-almandine-muscovite subfacies of the almandine-amphibolite facies in metamorphic rank (Fyfe, Turner, and Verhoogen, 1958). Neither the Tyler Lake granite, which is unquestionably magmatic, nor the banded granite gneiss of the Gneiss complex, which is probably metamorphic, have had a noticeable metamorphic effect on their surrounding rocks. The intimate penetration of the Waramaug by the Tyler Lake granite has changed the mineralogy of the Waramaug screens by adding some microcline. Thus, the metamorphism in the quadrangle is attributed to regional metamorphism accompanying deformation in this orogenic belt. Although the Gneiss complex and the Waramaug are essentially of the same metamorphic facies, there are modest differences which need elaboration.

The granitic gneiss of the Gneiss complex has a mineralogic assemblage stable in all rocks of this composition from the greenschist to the granulite facies. However, intimately interlayered in and with the granite gneiss are rocks of mafic and pelitic composition which have mineral assemblages stable in the almandine-amphibolite facies (sillimanite-almandine-muscovite subfacies). The mafic rocks contain hornblende-andesine-quartz-biotite-epidote, minerals which are present in all subfacies of the almandine-amphibolite facies except the sillimanite-orthoclase subfacies. The quartzo-feldspathic and pelitic rocks typically contain sillimanite and garnet in addition to the essential muscovite-biotite-quartz-plagioclase. The presence of labradorite and oligoclase in adjacent rocks, and associated with quartz, is attributed to original differences in composition and lack of mobility of the constituents.

The significance of scapolite in some of the basic rocks of the Gneiss complex is not certain. It may indicate an approach to the granulite facies. However, the presence of sphene and epidote in all sections containing scapolite indicates that the scapolitization, though local, should be considered as due to regional metamorphism of a locally peculiar rock rather than to pneumatolitic or intrusive processes. The CO_2 and Cl are considered of local origin also.

The graphite found in trace amounts in the quartzo-feldspathic gneiss and in greater abundance in some diopside-quartz rocks and quartzose gneiss is also considered to be of local origin. The deep rusty or yellow weathering of the graphitic rocks suggests an association of graphite and iron sulfides. The chemistry of the development of these coarse graphite flakes and other graphite concentrations is under study and a conclusion now is premature. However, there are good indications of a general stratigraphic distribution of the graphitic rocks, and no indication of a source of external solutions. The apparent mobility of the graphite or carbon is tentatively attributed to conditions accompanying the regional metamorphism.

Essentially the same metamorphic conditions prevailed in the Waramaug formation as in the Gneiss complex. The major difference is that staurolite is in small grains with biotite, and sillimanite with muscovite-biotite-plagioclase-quartz-sillimanite gneiss in the Waramaug. The sillimanite (fibrolite) appears to form at the expense of biotite which is invariably bleached. There are no indications that the staurolite is unstable. Microcline is present in a few specimens but is attributed mainly to nearby granite and pegmatite rather than to muscovite and quartz reacting to form sillimanite and potash feldspar. It seems that the Waramaug exhibits slightly lower grade metamorphism than the Gneiss complex and is properly placed transitionally in the staurolite- to sillimanite-almandine-muscovite subfacies. The kyanite subfacies appears to have been passed over, perhaps due to rapidly rising temperature and/or slow reactions. The rocks in the Hartland formation about two miles east belong to the kyanite subfacies, indicating falling metamorphic rank from west to east.

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