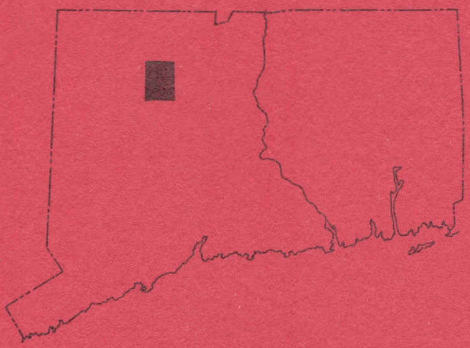
The Bedrock Geology of the Torrington Quadrangle

WITH MAP

Open Map

CHARLES W. MARTIN



STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

A DIVISION OF THE DEPARTMENT OF AGRICULTURE
AND NATURAL RESOURCES

1970

QUADRANGLE REPORT No. 25

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Earlham College

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FOREWORD

This quadrangle report represents another contribution to the bedrock geology of Western Connecticut started in 1948 with the mapping of the Litchfield quadrangle by Robert M. Gates who subsequently mapped the New Preston, Woodbury, Roxbury, Cornwall, and West Torrington quadrangles, and collaborated with Charles W. Martin in the Waterbury quadrangle. Rolfe S. Stanley has mapped the Collinsville quadrangle (Quadrangle Report 16). Contiguous quadrangles that have been mapped but not yet published are New Hartford, Thomaston, and Bristol. The cooperation between the various geologists has been excellent, but because of the complexity of the geology there is by no means full agreement on the interpretation of the structure, stratigraphy, and geologic history. The differences are not entirely between the geologists involved. Individuals have in many cases re-interpreted their own earlier work. For example, Stanley (1968) has revised some of his previous interpretations in Quadrangle Report 16. Martin shows in figure 7 of this report correlations of the formations he has mapped with those previously mapped by Stanley in the Collinsville quadrangle and by Gates and Martin in the Waterbury quadrangle.

Figure 9 of this report is Martin's interpretation of the regional geology of the Torrington and nearby quadrangles. This interpretation differs significantly from that recently presented at the meeting of the Northeast Section of the Geological Society of America in February 1970, by Norman Hatch and Rolfe Stanley. The stratigraphy of the metamorphosed and deformed unfossiliferous rocks is very complex and it is not surprising, therefore, that differences in interpretation still exist. Martin's views presented in this report should serve as a basis for discussion of the problems and be a challenge to others to develop sufficient additional evidence for a clearcut resolution of the problems.

The different interpretations of structure and geologic history have little or no bearing on the utility of a geologic map for many purposes for it shows distribution of rock units with described mineral composition and physical properties. In this report the author briefly discusses the properties of the rock units as they relate to environmental problems. Surficial geology has an even more direct relationship to water supply, waste disposal, construction and other environmental problems. The surficial geology of this quadrangle has been mapped by Roger Colton of the U.S. Geological Survey in cooperation with the State Survey. His map will be published as GQ-936 by the U.S. Geological Survey in 1971.

The U.S. Geological Survey in cooperation with the State Water Resources Commission is making an inventory of the water resources of the State on a basin basis rather than a quadrangle basis. Their work in this quadrangle is underway. The bedrock and surficial maps together with the water inventory studies will furnish important fundamental geological information which can be applied to environmental problems.

Joe Webb Peoples, Director
Connecticut Geological and Natural
History Survey

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The Bedrock Geology of the Torrington Quadrangle, Connecticut

by

Charles W. Martin

ABSTRACT

The Torrington quadrangle lies at the southeast edge of the Berkshire Highlands and contains a sequence of metavolcanic and metasedimentary rocks intruded by two kinds of granite. The major units, in order of decreasing age, are 1) the Gneiss Complex of the Berkshire Highlands (Precambrian?), 2) the Waramaug Formation (Lower Paleozoic?), 3) the Hartland Formation (Lower Paleozoic), 4) the Tyler Lake Granite (Middle Paleozoic), and 5) the Nonewaug Granite (Middle Paleozoic). Subordinate amounts of granite, pegmatite, amphibolite, and calc-silicate rocks are found in the Gneiss Complex and the Hartland and Waramaug formations. Mafic gneiss is interlayered in some parts of the Gneiss Complex.

The Gneiss Complex of the Berkshire Highlands consists primarily of well-banded to streaked, gray, granitic gneiss; biotite-streaked pink granitic gneiss; and nubby-weathering muscovite-microcline-quartz-plagioclase-biotite gneiss with sillimanite and kyanite. The first two rock types are interpreted as metavolcanics, the last as metasedimentary. The distribution and associations of these rock types and the less abundant amphibolite, mafic gneiss, and calc-silicate rocks define three mappable stratigraphic units in the Gneiss Complex. The Waramaug Formation is a heterogeneous mixture of muscovite-biotite-plagioclase-quartz gneiss and sillimanite-kyanite-muscovite-plagioclase-quartz-biotite gneiss. Attempts at stratigraphic subdivisions have not yet been successful. The Hartland Formation is divided into three stratigraphic units in the Torrington quadrangle. The lowest, unit I, is predominantly muscovite-biotite-plagioclase-quartz granulite and granulitic gneiss. Unit II, which is here correlated with The Straits Schist, is a lustrous, medium-grained, biotite-muscovite-plagioclase-quartz schist with porphyroblasts of plagioclase, garnet, staurolite, and kyanite. The Straits Schist is of very limited extent in this quadrangle and is mineralogically similar to unit II, with which it is correlated. Unit III is a mixture of schist, granulite, and granulitic gneiss characterized by its slabby nature and the presence of two distinctive rock types: 1) fine-grained, dark gray, graphitic granulite and schist, and 2) medium-grained, poorly foliated, silvery, schist with coarse kyanite and randomly oriented, blocky biotite.

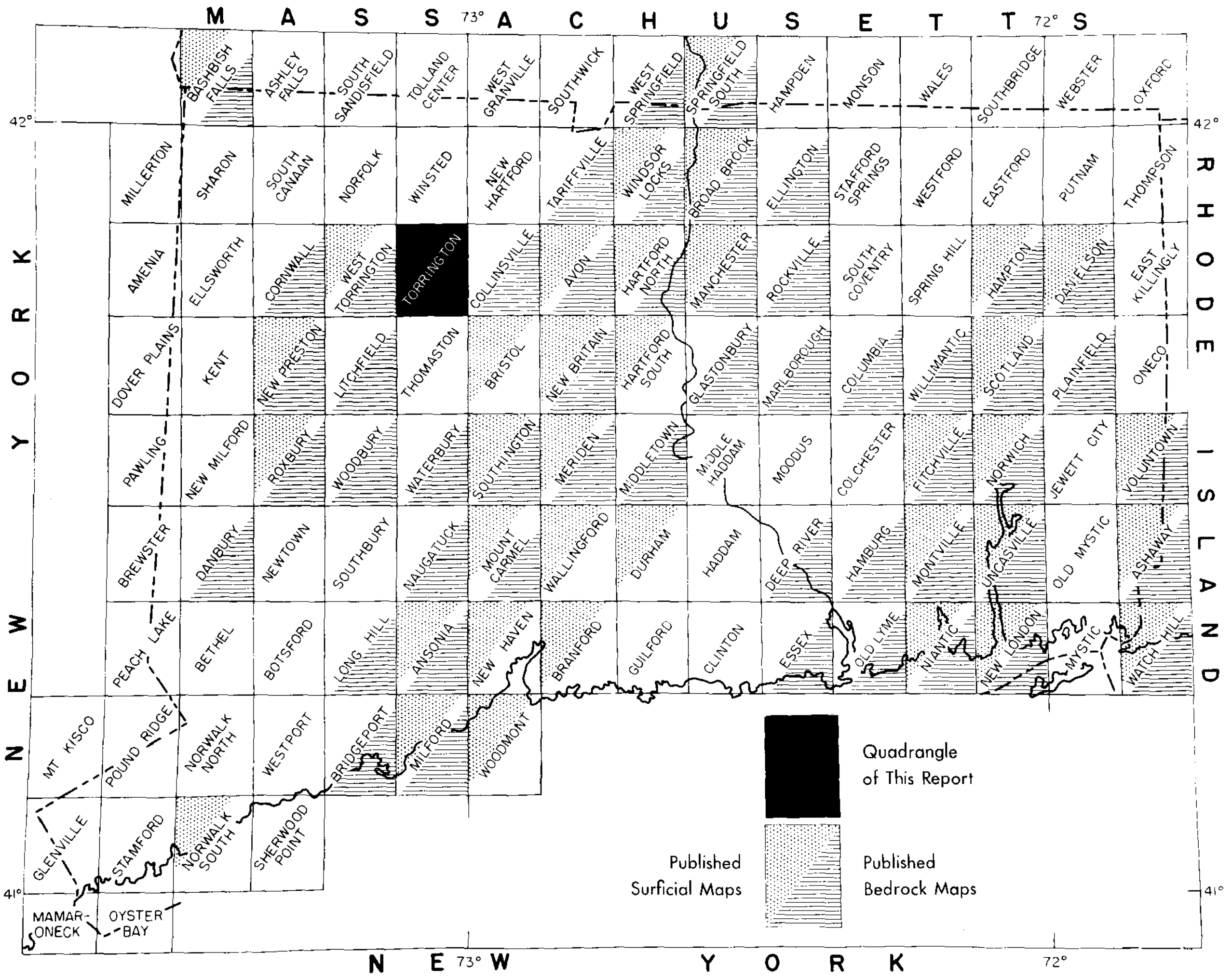

Fig. 1. Index map of Connecticut showing the location of the Torrington quadrangle and of other published quadrangle maps.

Only a small amount of Tyler Lake Granite occurs in the Torrington quadrangle. It ranges from medium-grained to pegmatitic, and from massive to gneissic, and is considered a syn- to posttectonic intrusive. The Nonewaug Granite is fine-grained to pegmatitic and is characterized by textural layering and the presence of coarse graphic granite crystals. The lack of foliation indicates it is late- to posttectonic.

Structure is dominated by a southward-plunging anticline in the Gneiss Complex with successively younger rocks exposed to the southeast into an overturned, isoclinal syncline whose axis is in unit III of the Hartland Formation. Small folds are found in all parts of the quadrangle and in the Hartland Formation give evidence of at least two periods of deformation. Conclusive evidence of major faulting has not been found. Metamorphism to the amphibolite facies accompanied deformation, and at least the last episode probably occurred during the Acadian Orogeny.

INTRODUCTION

Location

The Torrington quadrangle is located in northwestern Connecticut and is bounded by latitudes 41°45′ N and 41°52′30″ N and longitudes 73°00′ W and 73°07′30″ W (fig. 1). Major highways serving the city of Torrington at the western edge of the quadrangle and numerous local roads provide ready access to most areas.

Physical features

The topography of much of the Torrington quadrangle is dominated by elongate drumloidal hills between 900 and 1,200 ft in elevation. The direction of elongation of these hills is about N 20° W, or nearly perpendicular to the prevailing trend of the bedrock units. Maximum relief is 835 ft; Walnut Mountain is the highest point at 1,325 ft and the Naugatuck River at the southern boundary of the quadrangle is the lowest at 490 ft. Average local relief is less than 350 ft.

The abundance of outcrops is variable and is related at least in part to the underlying bedrock. The gneiss of the Berkshire Highlands and the schist of Hartland Formation unit II are best exposed. On the drumloidal hills, bedrock, if it is exposed at all, is most commonly found either as low pavement outcrops at the summit or in ledges projecting from the southeast or down-ice side of the hill.

Drainage is divided between the basins of the Naugatuck River, which flows through the southwestern part of the quadrangle, and the Farmington River, outside the quadrangle to the east. The Nepaug River and its tributaries in the northeastern and eastern parts of the area flow into the Farmington River, whereas the rest of the streams ultimately enter the Naugatuck River.

About two thirds of the quadrangle is wooded; the remainder consists of urban areas in and around Torrington, the only major city, and cultivated or pasture land mostly on the drumloidal hills, where the presence of till permits agricultural use.

Acknowledgments

The quadrangle was mapped during the summers of 1965, 1966, and 1967 under the sponsorship of the Connecticut Geological and Natural History Survey, which also provided the funds necessary for thin sections. During the summer of 1966 the writer was assisted by John Hill and Craig White, who undertook a study of the complicated structure of the southwestern corner of the quadrangle supported by National Science Foundation Undergraduate Research Participation Grant GY-994. Joseph Cohen, Christopher Drexler, Karen Felmlee, and Michael Finegan mapped portions of the Berkshire Highlands Gneiss Complex in the Torrington and adjacent Winsted quadrangles during the summer of 1967 with support from National Science Foundation Undergraduate Research Participation Grant GY-2682. To all of these students and both sponsoring organizations the writer expresses appreciation.

Joseph Gonthier kindly made available his map of the northern portion of the Torrington quadrangle, prepared as part of a Master's dissertation at the University of Massachusetts, and Roger B. Colton similarly provided helpful information obtained while mapping the surficial geology of the quadrangle. Rolfe Stanley and Robert Cassie mapped adjacent quadrangles, and numerous discussions and field trips with them have contributed to the understanding of the Torrington quadrangle.

Over several years the writer has benefited greatly from numerous discussions with Robert M. Gates. Without his support and encouragement it is unlikely that the writer would have mapped this quadrangle.

Previous work

The pioneer geological work in the Torrington area was done by Percival (1842), whose subdivision into major rock types still has validity. Rice and Gregory (1906) and Gregory and Robinson (1907) included the unpublished work of W. H. Hobbs in their reports of Connecticut geology. The 1907 map of Gregory and Robinson shows most of the Torrington quadrangle consisting of Becket and Waterbury gneisses, terms that are no longer applicable. Agar (1929) considered both the rocks now called the Berkshire Highlands Gneiss Complex and the Waramaug Formation to be Becket Gneiss. In a later work on the granites of western Connecticut, Agar (1934) considered most of the granites in the quadrangle to be Thomaston Granite gneiss, a name now much more restricted in usage. In recent years, three of the adjacent quadrangles have been mapped by R. S. Stanley (1964, Collinsville), R. M. Cassie (1965, Thomaston) and R. M. Gates and N. I. Christensen (1965, West Torrington). Joseph Gonthier (1964) mapped a portion of the Torrington quadrangle for a Master's dissertation. Most recently the surficial geology was mapped by R. B. Colton (in preparation) and an aeromagnetic map was prepared by P. W. Philbin and C. W. Smith (1966).

Petrographic methods

Modal analyses were made of all rocks using the method of Chayes (1956), counting 1,000 points per thin section. Staining was done to identify plagioclase and potash feldspar in those thin sections where they could not otherwise be positively distinguished. Plagioclase compositions were determined in thin section on the universal stage using the five-axis method (Emmons, 1943).

GENERAL GEOLOGY

The Torrington quadrangle is underlain by the crystalline rocks of the Western Connecticut Highlands, an area of metamorphic rocks bordered on the west by sedimentary and low-grade metamorphic rocks of the Hudson River valley and on the east by Triassic igneous and sedimentary rocks. Within the Western Highlands are three major belts of rock, all of which are represented in the Torrington quadrangle. The oldest of these consists of several similar, but separated gneisses making up the Berkshire Highlands of Massachusetts and the northern part of western Connecticut, the Housatonic Highlands in northwestern Connecticut, and the Hudson Highlands in southwestern Connecticut and adjacent parts of New York (fig. 2). These rocks are the southern extension of the core of the Green Mountain anticlinorium in Vermont and are presumed to be Precambrian. Between and east of these gneiss complexes is a belt of high- to middle-grade metasedimentary gneisses of the Waramaug Formation. This unit has been traced southwest as far as New Preston, and the possibility of it being correlative with the Manhattan Formation north of Danbury has been mentioned by Clarke (1958). East of the Waramaug Formation is a heterogeneous assemblage of medium-grade schists, granulites, and granulitic gneisses of the Hartland Formation which partially or completely wrap around a series of gneiss domes extending from the Chester dome in Vermont to the Waterbury dome in west-central Connecticut. The Waramaug and Hartland formations presumably correlate with rocks on the eastern flank of the Berkshire Highlands in Massachusetts and Green Mountain anticlinorium in eastern Vermont, but detailed correlations must at least await completion of work now in progress in the intervening areas. The Waramaug and Hartland formations are presently considered Cambro-Ordovician in age.

The Torrington quadrangle is at the southeastern edge of the Berkshire Highlands and contains rocks of the Berkshire Highlands Gneiss Complex in the northwestern corner and the belts of the Waramaug and Hartland Formations successively to the southeast. The rocks of the Gneiss Complex are predominantly thinly layered to massive, mica-streaked, biotite-microcline-quartz-plagioclase gneiss. Interlayered are subordinate amounts of calc-silicate rocks, amphibolite, mafic gneiss, and quartz-plagioclase-biotite gneiss with abundant sillimanite and kyanite. Distribution of these rock types and structural evidence indicate that the Gneiss Complex forms a large southward-plunging anticline.

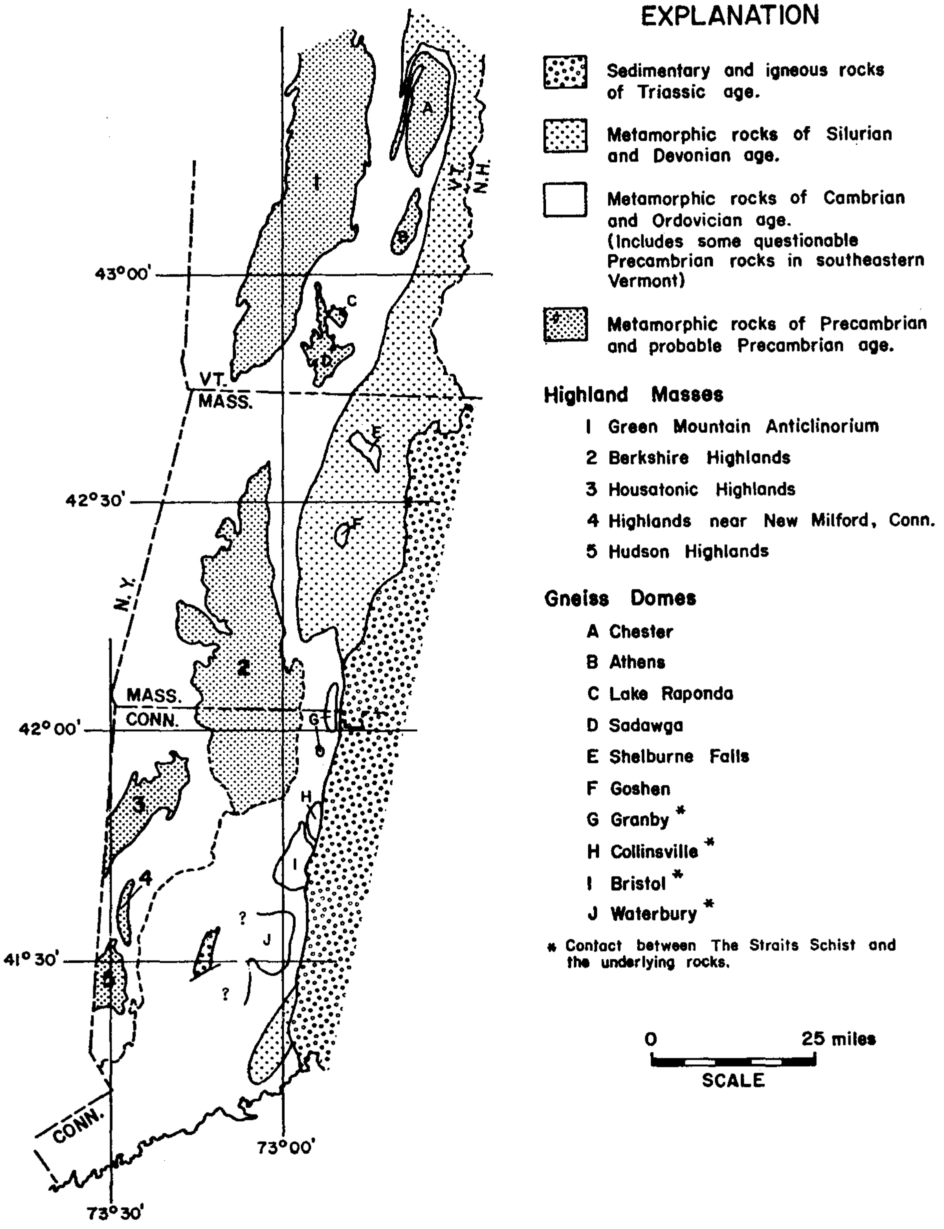

Fig. 2. Generalized geologic map of southern Vermont, western Massachusetts, and western Connecticut (after Stanley, 1964).

The Waramaug Formation overlies the Gneiss Complex with apparent structural parallelism. The nature of this contact is discussed in the following section. The Waramaug Formation consists of a heterogeneous mixture of granulitic gneisses in which no stratigraphic subdivisions can as yet be established. Its complex structural style and evidence of intense deformation indicate that it is older than the structurally more simple Hartland Formation. On this evidence alone, the contact between the two formations could be either a fault or an unconformity. In other areas, truncation of the Hartland Formation and localization of ultrabasic bodies along the contact have led to interpretation of a fault contact (Gates and Bradley, 1952; Gates and Christensen, 1965; Martin, 1962). In the Torrington quadrangle the evidence is inconclusive.

Three subdivisions of the Hartland Formation are present in this quadrangle. Unit I, the oldest, is a massive mica-plagioclase-quartz granulitic gneiss with subordinate interlayered schist. Plagioclase-quartz-mica schist dominates unit II, and in the upper half is characterized by coarse porphyroblasts of staurolite, kyanite, and plagioclase in various combinations and proportions. The uppermost member, unit III, consists of two distinctive rock types, plagioclase-quartz-mica schist with abundant very coarse kyanite porphyroblasts, and graphitic granulitic gneiss and schist with variable proportions of quartz, plagioclase, and mica.

Two large masses of Nonewaug Granite intrude all three units of the Hartland Formation, and smaller bodies of pegmatite, amphibolite, and altered ultrabasic rocks are contained within the formation. The edge of a large body of Tyler Lake Granite barely enters the western side of the quadrangle.

THE GNEISS COMPLEX OF THE BERKSHIRE HIGHLANDS

General statement

The Gneiss Complex of the Berkshire Highlands is exposed in the northwestern corner of this quadrangle, where it forms the eastern half of a southward-extending prong, the remainder of the prong being in the adjacent West Torrington quadrangle. The Preliminary Geologic Map of Connecticut (Rodgers and others, 1956) shows the Gneiss Complex bordered by the Hartland Formation, but mapping in both the West Torrington quadrangle (Gates and Christensen, 1965) and this quadrangle shows the Waramaug Formation to lie between these units. Two small areas of the Gneiss Complex are shown on the map as separated from the main body. The northernmost of these may be continuous with the main Gneiss Complex, but the connection, if present, is to the north and must await detailed mapping of the Winsted quadrangle. In the absence of any indication of faulting, it is interpreted as an anticlinal crest. The southern small patch splits into three eastward-extending prongs. The northern and southern of these prongs appear in roadcuts to be anticlinal crests; the center one is faulted along its south side. Thus a combination of folding and faulting is responsible for bringing the Gneiss Complex to the surface in this area.

The Gneiss Complex contains several distinct lithologic types which are essentially the same as rock types described by Gates and Christensen (1965) in the West Torrington quadrangle. These rock types are 1) gray, banded to massive but mica-streaked granitic gneiss; 2) nubby-weathering quartz-feldspar-biotite gneiss containing kyanite and sillimanite; 3) biotite-streaked pink granitic gneiss; 4) amphibolite and mafic gneiss; and 5) calc-silicate rocks. Granite and pegmatite are present throughout the Gneiss Complex and locally convert the rocks to migmatites. Field mapping revealed that several of the Gneiss Complex rock types are widespread, but the areal variation in association and relative abundance of the individual rock types allowed subdivision of the Gneiss Complex into three mappable units. These subdivisions (bgcb, bgcs, and bgcl), based on the assemblages and abundances of the five rock types, are shown on the geologic map (pl. 1, in pocket). In the following section on lithology, the five rock types found in the Gneiss Complex will be described. The section on stratigraphic units will present the characteristics of the map units.

The upper contact of the Gneiss Complex with the Waramaug Formation is not well exposed in this quadrangle; the best outcrops are along the tributary to Still River 4,000 ft south of Burrville and in the roadcuts along new Route 8, both 2,000 ft north of Besse Park Pond and about 2,000 ft east of the Armory in Torrington. It is significant that in each of these contact zones gray quartz-feldspar gneiss typical of the Gneiss Complex and biotitic gneiss typical of the Waramaug are interlayered, the layers ranging in thickness from about 1 in. to 40 ft. Gates (1961) reports a similar type of contact between the Gneiss Complex of the Housatonic Highlands and the Waramaug Formation in the Cornwall quadrangle. Interlayering of Waramaug-type rocks is found less commonly elsewhere in the Gneiss Complex; and interlayering of gray gneiss is unknown in other parts of the Waramaug Formation. For this reason, the contact is placed at the first appearance of gray, quartzo-feldspathic gneiss. Traceable units in the Gneiss Complex parallel the contact, as do the foliations in both formations adjacent to the contact. Based on these exposures, the contact would appear to be a normal gradational one representing a transition from volcanic to sedimentary deposition, although the evidence is far from conclusive. Two possible alternatives have been suggested by Gates (1961), and neither can be ruled out for the rocks in the Torrington quadrangle. They are 1) that the interlayering of rock types represents an unusual basal section of the Waramaug, and 2) that the conformity is produced structurally and the interlayering results from slabs being torn off along a fault and subsequently being recrystallized. The suggestion of a fault contact appears to be supported by the aeromagnetic map of the Torrington quadrangle (Philbin and Smith, 1966), which shows a pronounced north-south magnetic trend in the Gneiss Complex ending rather abruptly along an almost east-west line in the north-central part of the quadrangle. A fault was noted at the contact between the Gneiss Complex and the Waramaug Formation on the south side of the middle prong of the Gneiss Complex east of the Torrington Armory. Except for one other small area extending about 50 ft across strike, exactly 1,000 ft S 50° E of the outlet of Goodwin Pond, where the rocks show slickensides and cataclastic textures, no evidence of faulting near the contact was found, either in the field or in thin sections. The writer feels that the nature of the Gneiss Complex–Waramaug Formation contact has not yet been conclusively established. It is hoped that mapping in progress in other areas will provide additional evidence.

Lithology

GRAY, BANDED TO MASSIVE GRANITIC GNEISS

General statement. The Gneiss Complex can conveniently be described in terms of the five rock types listed in the previous section. The reader should recall that the map units in the Gneiss Complex are based upon the assemblages and relative abundance of these rock types, and that some lithologically identical rocks occur in more than one map unit. The detailed descriptions of the various rock types are given in this section and the assemblages of those rock types which characterize and define the map units are described in a following section.

Fine- to medium-grained, gray, banded to massive granitic gneiss is the most abundant rock type in the Gneiss Complex in this quadrangle. It is found in nearly all parts of the area mapped as Highlands Gneiss and is interlayered with all the other rock types of the Gneiss Complex. The same rock type was recognized by Gates and Christensen (1965) in the West Torrington quadrangle, where they called it rock type 1 of the Gneiss Complex of the Berkshire Highlands and noted that it is similar to rocks found in the Housatonic Highlands Complex of the Cornwall quadrangle.

As the name implies, the gray gneiss ranges from a strikingly banded rock with adjacent layers differing in proportion and/or arrangement of felsic and mafic minerals (fig. 3) to a more massive, homogeneous rock in which foliation is defined mainly by uniformly distributed, discontinuous streaks or wisps of biotite rather than by layers of contrasting mineralogy (fig. 4). (The main characteristic of a streak, as the term is used in this report, is that it is discontinuous and extends no more than a few inches to 2 or 3 ft on the rock surface, whereas bands or layers are continuous across an outcrop.) It is not uncommon to find the massive gneiss forming individual layers in a banded gneiss sequence. The thickness of layers in the banded gneiss ranges from a fraction of an inch to 10 ft or more, with most thinner than about 2 ft. In some exposures the banding is remarkably straight and regular; in others it is intensely deformed, with multiple isoclinal and flow folds and small faults present (figs. 3 and 5). Medium-to coarse-grained stringers and patches of white and pink granite and pegmatite are abundant in the more highly deformed gray granitic gneiss, and locally the rock is best described as migmatitic.

Excellent scattered outcrops of banded gray granitic gneiss with interlayered amphibolite and mafic gneiss, biotitic gneiss, and calc-silicate are present on the summit and eastern slope of the hill 1,000 ft southwest of Goodwin Pond and on the slope southeast and east of Goodwin Pond. Fresh exposures of the same rock types, somewhat

Fig. 3. Banded, gray granitic gneiss of the Gneiss Complex of the Berkshire Highlands from roadcut on new Newfield Road at eastern end of the Newfield dry dam. Faulting and multiple deformation are visible. Scale is given by 7-in. pencil.

complicated by minor structural features, are abundantly displayed in the spillway of the Newfield dry dam across the east branch of the Naugatuck River, 1,800 ft north of the intersection of Newfield and Guerdat roads, and in the new roadcuts along relocated Newfield Road east of the dam. Massive, streaked, gray granitic gneiss is found mixed with pink gneiss and subordinate banded gneiss on the summits and west slopes of both the hill 1,000 ft east of the intersection of Meyer and Guerdat roads and the hill 2,000 ft south of the intersection. An excellent, readily accessible exposure of streaked gray gneiss occurs 2,900 ft southwest of Burrville at the western edge of the unnamed road just west of old Route 8.

Petrography. Mineralogically and texturally the gray granitic gneiss is a simple rock. The essential minerals include quartz, plagioclase, microcline, biotite, and muscovite, with zircon, apatite, and magnetite present in accessory amounts in all thin sections studied. Epidote, hornblende, carbonate, sphene, and chlorite are present in trace amounts in some sections. The rocks are dominantly fine- to medium-grained, although some contain a few coarse microcline grains and there are augen of coarse quartz and plagioclase. The texture ranges from

Fig. 4. Biotite-streaked granitic gneiss of the Gneiss Complex of the Berkshire Highlands from the unnamed road adjacent and parallel to Route 8, 0.75 mi. south of Burrville. Scale is given by 4.5-in. pencil.

lepidoblastic in the more biotitic layers to xenomorphic-granular in some felsic layers. Foliation (gneissosity) is defined both by the segregation of biotite and quartz-feldspar into layers and streaks and by the parallel orientation of the biotite flakes.

The average composition of the gray gneiss determined by point counting, given in table 1, reveals that the rock is similar to granodiorite. Comparisons of modes of well-banded and more massive biotite-streaked varieties show no significant differences. In half of the thin sections examined, plagioclase is more abundant than quartz, and in one section microcline is the most abundant mineral. Biotite is the dominant mica, but muscovite, although never abundant, is present in all but one sample.

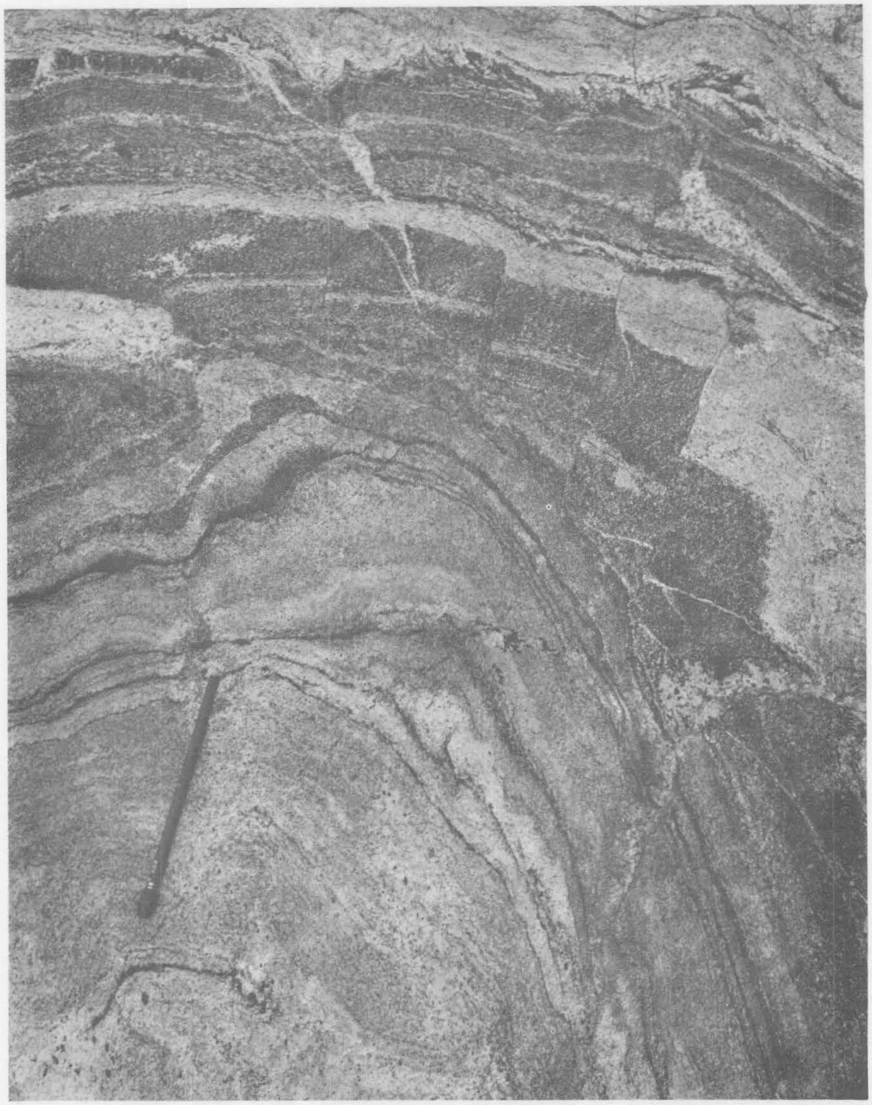

Fig. 5. Folded and faulted, interlayered banded gray granitic gneiss, biotite-streaked gray granitic gneiss, mafic gneiss, and subordinate amphibolite from the Gneiss Complex of the Berkshire Highlands along new Newfield Road at the eastern end of the Newfield dry dam. Scale is given by 7-in. pencil.

Table 1.—Petrographic data,[1] granitic gneisses and granites of the Gneiss Complex of the Berkshire Highlands

		Plag.[2]	Quartz	Micro.	Bio.	Mucs.	Epidote	Mag.	Other
A[3]	Average	33.5	36.9	10.0	13.8	1.9	0.6	2.0	1.3[4]
	Range	16–48	16–52	0–39	3–25	0–10	0–4.5	0–9.5	—
B[3]	Average	36.5	30.7	22.9	6.3	2.4	T[5]	0.7	0.5[6]
	Range	25–46	26–39	17–36	2–17	T[5]–7	0–0.1	0–2	—
C[3]	Average	21	29	38.7	8.4	1.5	T[5]	1.2	0.2[7]
	Range	12–29	17–44	25–52	2–14	0.1–4	0–0.1	0–3	—
D[3]	Tn-69	14	55.7	28.5	T[5]	1	—	0.5	0.3[8]

[1] Modal analyses in volume percent. Part of the data for A and B taken from Felmlee (1968).

[2] Plagioclase data:

	Average composition	Number of determinations	Range
A	An 26.6	23	An 21–38
B	An 19	11	An 10–30
C	—	—	—
D	An 9.3	3	An 8–10

[3] Composition and number of samples:

A. Gray, banded to streaked granitic gneiss (14 samples)
B. Pink, biotite streaked granitic gneiss (10 samples)
C. Pink granite lenses and augen in granitic gneiss (3 samples)
D. Young, cross-cutting pink granite (1 sample)

[4] Carbonate, zircon, apatite, sphene, chlorite, hornblende, garnet.

[5] T = trace.

[6] Sphene, zircon, apatite, chlorite, garnet, staurolite.

[7] Zircon, apatite.

[8] Garnet.

Quartz and plagioclase typically occur as fine to medium anhedral grains, most with irregular shapes. Strain shadows are abundant in the quartz. Twinned plagioclase is present in all samples studied, but many grains are untwinned. Most plagioclase shows sericitization either around grain borders or along cleavage or selective twin lamellae. Plagioclase composition ranges from An 21 to 38 but most grains fall in a more limited range An 22 to 26. A few plagioclase grains contain scattered small patches of microcline, all having the same optical orientation. This type of texture has been interpreted by Gates and Scheerer (1963) as evidence of microcline replacement by plagioclase. In many places where plagioclase is in contact with microcline, myrmekitic intergrowths of quartz and plagioclase are well developed along the contact.

Microcline has two distinct types of occurrence in the gray gneiss; as small rounded grains in the felsic layers with quartz and plagioclase, and as large grains in lenses with coarse quartz and plagioclase. The coarse microcline os poikilitic, containing inclusions of quartz, plagioclase, and mica. Many grains are also perthitic, with the plagioclase in the form of irregular, discontinuous stringers, commonly with twinning parallel to adjacent microcline twinning. There is a suggestion that microcline grains are least perthitic where there is abundant myrmekite along the grain border.

Biotite occurs as straight-sided flakes having a moderate to high degree of parallelism. In some rocks they are concentrated into biotitic layers; in others they form discontinuous streaks; and in a few there is no tendency toward biotitic segregation. Muscovite forms coarse, blocky flakes oriented transverse to the foliation. The flakes are highly corroded where in contact with plagioclase, and their texture ranges from vermicular intergrowths to feathery looking masses of very fine flakes that appear to be pseudomorphic after coarse blocky flakes. The total mica content is less than 25 percent, and biotite is the dominant mica in all thin sections studied.

Magnetite is a common accessory in the biotitic layers of the gray gneiss. In a few localities grains reach 0.5 in. in diameter.

PINK GRANITIC GNEISS

General statement. The pink granitic gneiss is largely restricted to map unit bgcs in the central portion of the Gneiss Complex in the Torrington quadrangle. In addition to color, it differs from the gray gneiss by being a massive to streaked rock without pronounced banding. Where it is in association with the gray gneiss, the latter is of the massive to streaked variety. Typically the boundary between the two types of gneiss is gradational over a few inches, although there are places where it is sharp. It should be noted that texturally the pink gneiss is very similar to the biotite-streaked gray gneiss, but mineralogically it contains significantly more microcline and less biotite than the gray gneiss, which accounts for the color differences. Point-count analyses of 10 samples of pink gneiss are shown in table 1.

Foliation in the pink gneiss depends primarily upon the biotite, its abundance, orientation, and concentration into thin, discontinuous streaks, and there are all variations from well-foliated to essentially massive and unfoliated rocks. Biotite streaks, where they are present, are generally less than 1 in. thick and range from 0.5 in. to several feet in length. In many outcrops they are bifurcating. Deformation of the streaks is common and varies from gentle undulations to complex structures showing evidence of multiple folding. In a few places crude layering results from the presence of lenses of coarse quartz and feldspar.

The pink granitic gneiss is best exposed in the east-facing cliffs extending southwest for 3,000 ft from a point 2,000 ft east of the intersection of Meyer and Guerdat roads. Other good, scattered outcrops are abundant on the summit of Walnut Mountain.

Petrography. The pink gneiss is a fine- to medium-grained rock that consists mostly of quartz, plagioclase, and microcline. There is less total mica than in the gray gneiss, and muscovite and biotite are about equal in abundance. Accessory minerals found are zircon, magnetite, epidote, apatite, and chlorite. Based upon the average of the modal analyses, the pink gneiss is mineralogically granitic (table 1).

The texture of the pink gneiss ranges from xenomorphic-granular to gneissic, depending upon the total mica content. In most samples the granular minerals quartz, plagioclase, and microcline constitute at least 90 percent of the rock. Quartz is generally strained and tends to be slightly elongate parallel to the mica orientation. Plagioclase occurrence is similar to that in the gray gneiss, although it is somewhat more sodic. The compositional range is from An 10 to 30; however, a frequency diagram of plagioclase compositions shows two peaks, one at about An 11, the other at An 28. This is not evident from the average composition of An 19. Some plagioclase grains contain oriented microcline inclusions, and in two thin sections myrmekite is present at the contact between plagioclase and microcline, but both of these features seem less abundant than in the gray gneiss. Microcline occurs both as small, rounded, and as coarse, poikilitic grains. The latter contain inclusions of quartz and plagioclase and are restricted to coarse-grained quartz-feldspar lenses. Except for the lower biotite content, micas show the same features as in the gray gneiss.

The most notable difference between the pink gneiss and streaked gray gneiss is the increase in fine, granular microcline. This apparently is responsible for the pink color, and where microcline content decreases, pink gneiss grades into massive or streaked gray gneiss.

BIOTITIC, QUARTZ-FELDSPAR GNEISS

General statement. The biotitic, quartz-feldspar gneiss is strikingly different from the granitic gneisses of the Highlands Complex. It is a fine- to medium-grained rock having quartz, plagioclase, biotite, muscovite, kyanite, and sillimanite as essential minerals. Microcline is also present in six of seven thin sections examined. Accessory minerals are zircon, rutile, apatite, garnet, and opaques. In the field its most obvious characteristic is a ribbed or nubby-weathered surface caused by the abundance of resistant kyanite and sillimanite (fig. 6). These min-

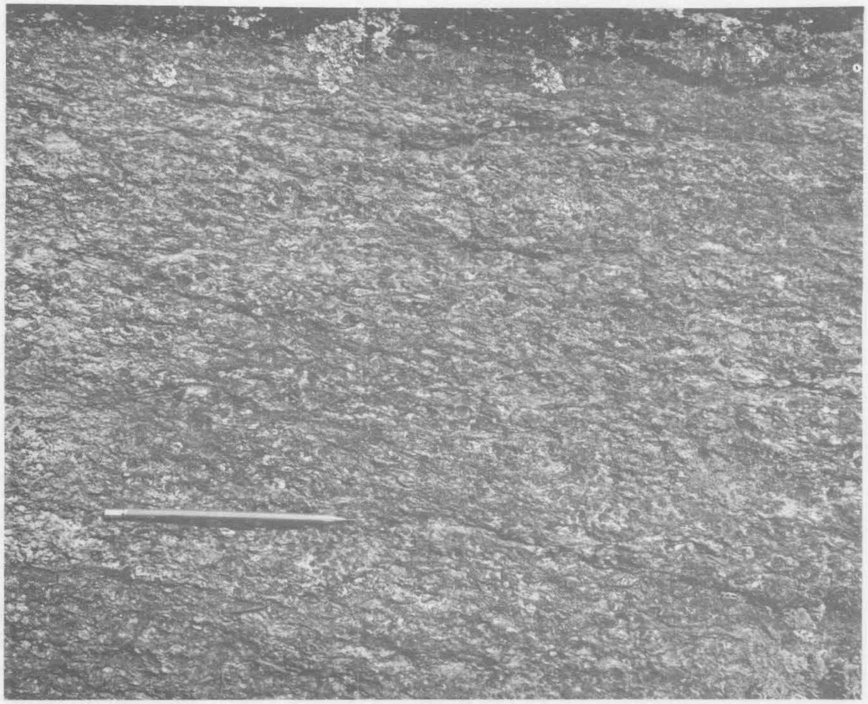

Fig. 6. Characteristic nubby-weathered surface on sillimanitic muscovite-microcline-quartz- plagioclase-biotite gneiss of the Berkshire Highlands Gneiss Complex from Burr Mountain Road at entrance to Burr Pond State Park. Scale given by 7-in. pencil.

erals also cause the rock to be distinctly coherent and to have a high specific gravity compared to the granitic gneisses. Weathered surfaces of the biotitic gneiss are rust-colored.

Typically the rock shows nearly perfect mineral segregation into thin, discontinuous streaks of quartz-feldspar and biotite, most of which are less than 0.5 in. thick and up to about 3 in. in length. The small and consistent dimensions of the streaks cause the overall aspect of the rock on an outcrop or larger scale to be one of uniformity and homogeneity. Close examination reveals that in some exposures quartz-feldspar streaks weather positively, whereas in others the biotite streaks weather positively, depending on which contain the most kyanite and/or sillimanite.

Table 2.—Petrographic data,[1] kyanite-sillimanite-quartz-feldspar-biotite gneiss of the Gneiss Complex of the Berkshire Highlands

	Bio.	Quartz	Plag.[2]	Musc.	Ky.	Sill.	Micro.	Gar.	Others[3]
Average[4]	35.2	18.1	18.1	5.4	12.3	4.1	3.7	2.0	1.1
Range	20–45	8–38	5–27	2–10	4–25	1–8	0–18	0–4.3	—

[1] Modal analyses in volume percent. Part of the data from Felmlee (1968).

[2] Plagioclase data: Average composition of 9 determinations = An 25.7; range of compositions An 16–38.

[3] Zircon, rutile, apatite, magnetite.

[4] Average of 7 samples.

Megascopically, the biotitic gneiss appears very similar to many rocks of the Waramaug Formation. Modal analysis (tables 2 and 4) reveals that although the two rock types are similar, the biotitic gneiss has somewhat more kyanite and sillimanite and less garnet than the Waramaug, and contains microcline, a mineral absent in the Waramaug Formation. Nevertheless, the environment of formation of the biotitic gneiss must have been very similar to that which subsequently gave rise to the sediments that now compose part of the Waramaug Formation.

The best and most easily accessible exposures of the biotitic gneiss are found in Burr Pond State Park, where they form large rounded outcrops in and around the main parking and picnic areas on the eastern side of the pond. The narrow peninsula extending into the southern end of Burr Pond is an almost solid outcrop of the biotitic gneiss. In this area the biotitic gneiss is exposed in a belt about 1,000 ft wide that terminates someplace in a region of no outcrop south of Burr Pond. The same kind of biotitic gneiss has been found as thin layers within gray, banded granitic gneiss sequences. All these occurrences are within 3,000 ft of the contact with the Waramaug Formation. The thickness of these biotitic gneiss layers ranges from a few inches to a maximum of probably less than 50 ft. Near Goodwin Pond two such layers (indicated on plate 1 by the symbol–X–X–) can each be traced for about 1,500 ft, and another layer along the western edge of the quadrangle can be followed for 1,000 ft before it passes into the West Torrington quadrangle. Gates and Christensen (1965) mapped two layers of the same kind of rock in the West Torrington quadrangle, and these, too, fall near the contact with the overlying Waramaug Formation.

Petrography. The muscovite-microcline-quartz-plagioclase-biotite gneiss of the Highlands Complex is an inequigranular rock with abundant kyanite and sillimanite. Grain size is variable, with quartz forming fine, rounded grains and biotite in coarse, poorly oriented flakes. Foliation is defined by the segregation of felsic minerals into distinct streaks. In addition to quartz, the felsic streaks contain fine to coarse grains of plagioclase and microcline. Plagioclase ranges in composition from An 16 to 18, with an average of An 26. In two thin sections there is minor vermicular quartz along the contact between plagioclase and microcline. A few microcline grains are perthitic.

Biotite is the dominant mica in all thin sections examined. It typically is concentrated into distinct, although discontinuous, streaks within which individual flakes show all gradations from parallel to random orientation. The biotite is dark brown to reddish brown and deeply pleochroic. Muscovite is sparingly present as small, ragged flakes with random orientation.

Of particular interest in this rock type is the abundance of kyanite and sillimanite, both of which are present in all samples studied, commonly in contact with each other. Kyanite forms small anhedral or subhedral grains that are concentrated in biotite streaks. Sillimanite is fibrolitic and occurs either singly or as clusters of fine needles. It is found included in quartz, plagioclase, and biotite, although it seems most abundant in the felsic streaks. In some places clusters of needles radiate outward from the border of kyanite grains, although in other areas of the same thin section the two minerals are not in contact. In one thin section, sillimanite is located along the border of bleached biotite flakes.

Garnet is present as medium to coarse, irregularly shaped grains containing wormy opaque inclusions. Minerals present in accessory amounts include zircon, rutile, apatite, and magnetite.

AMPHIBOLITE AND MAFIC GNEISS

Small unmapped layers and lenses of amphibolite and mafic gneiss are present throughout the Highlands Gneiss Complex, although they are most commonly associated with the banded to massive gray granitic gneiss. Thicknesses range from 1 to 2 in. to about 20 ft. These rocks are fine- to medium-grained and typically massive and homogeneous, although a few contain indistinct quartz-plagioclase lenses. In most outcrops foliation depends upon parallel alignment of hornblende needles and biotite flakes. The layers and lenses, some of which show boudinage structure, are parallel to the foliation of the associated granitic gneiss.

The mineralogy of the amphibolite and mafic gneiss is simple, the essential minerals being biotite, plagioclase, and hornblende with quartz, sphene, epidote, magnetite, apatite, garnet, and zircon present as accessories in some or all samples. The texture is most commonly xenoblastic, with coarse, irregularly shaped hornblende and fine, granular plagioclase and quartz. Biotite occurs as ragged flakes. Plagioclase has an average composition (based upon 10 determinations) of An 40 and a range from An 32 to 49. Amphibolite grades into mafic gneiss with a decrease in hornblende and an increase in plagioclase and biotite content. The modal analyses of three samples of amphibolite are shown in table 3.

Table 3.—Petrographic data,[1] amphibolites of the Gneiss Complex of the Berkshire Highlands

	Hbl.	Plag.[2]	Quartz	Mag.	Sph.	Epidote	Biotite	Others[3]
Tn65[4]	55.4	24.9	8.5	5.5	2.2	2.0	1.3	0.2
Tn-91[4]	31.6	48.5	6.5	7.4	3.4	0.1	2	0.5
Tn-117[4]	62	24.2	T[5]	0.4	6.1	3.2	2.6	1.5

[1] Modal analyses in volume percent.

[2] Plagioclase data: Average composition of 10 determinations = An 39.8; range of composition An 32–49.

[3] Carbonate, apatite, garnet, zircon.

[4] Samples from layers and pods in gray granitic gneiss.

[5] T = trace.

It is possible to examine amphibolite and mafic gneiss in many scattered localities in the field. The spillway of the Newfield dry dam provides a readily accessible area where these rock types are well exposed.

CALC-SILICATE ROCKS

Rocks containing varying amounts of calcium-bearing silicate minerals are widely scattered in certain parts of the Highlands Gneiss Complex. They occur in sizes ranging from small pods or layers a few inches thick to large masses constituting entire outcrops. Calc-silicate rocks are commonly associated with gray granitic gneiss, mafic gneiss, and amphibolite but have not been found in the area underlain by pink granitic gneiss. None of the calc-silicate bodies are large enough to be mapped separately at a scale of 1:24,000.

Calc-silicate rocks are very fine-grained and are everywhere massive and unfoliated. Weathered surfaces are pale gray or brown, commonly with a greenish tint, and if carbonate is present solution pits are abundant. The texture is best described as granoblastic. Minerals found in the calc-silicates include diopside, actinolite, zoisite, epidote, scapolite, sphene, carbonate, garnet, biotite, microcline, plagioclase, and quartz. Most of these minerals are present in most exposures of calc-silicate rocks, but the relative proportions of them is quite variable. In order to describe adequately the calc-silicate rocks, modal analyses of considerably more samples than are presently available will be necessary.

The area of the Newfield dry dam provides the best place to examine the calc-silicate rocks. In a large roadcut on new Newfield Road about 1,000 ft north of the east end of the dam, diopside-zoisite-epidote rock is well exposed. A similar rock type, but containing sufficient pink and yellow calcite to be locally considered marble, is present in the first roadcut on new Newfield Road north of the intersection with Guerdat Road. Scapolite is found in calc-silicate pods at the southern end of the spillway of the dam.

GRANITE AND PEGMATITE

Nearly all large outcrops, and many small ones, in the Highlands Gneiss Complex contain granite and pegmatite. The proportion of granite and pegmatite varies from rocks containing only a few discrete stringers, lenses, or dikes to those in which granite is sufficiently pervasive to form migmatitic assemblages with the host gneiss. The lenses and pods are conformable and average a few inches in length, although it is not unusual to find stringers of the same material several feet in length in the same outcrop. Many of these stringers parallel the foliation of the host rock for several feet, only to change orientation and abruptly cross the foliation. In some localities younger dikes and masses of granite up to 50 ft in thickness cross-cut the migmatitic granite. None of these bodies are large enough to be shown on the geologic map.

Most of the granite and pegmatite is distinctly pink, apparently because of the potash feldspar, but in a few places it is gray. All of the granitic material is massive and unfoliated. Grain size ranges from fine to coarse with the pods and stringers medium- to coarse-grained and the younger dikes and granite masses fine- to medium-grained. Most of the lenses and stringers are coarser than the host rocks in which they occur.

Microcline, plagioclase, and quartz are the major minerals in all the granites. Muscovite and biotite are subordinate in the lenses, but only muscovite is found in the younger granite. Accessory minerals include garnet, apatite, zircon, and magnetite. Modal analyses of pink granite lenses from three samples are shown in table 1. In each instance the lens contains significantly more and coarser microcline and less plagioclase than the host rock in which it occurs. Specimen Tn-69 (table 1) is representative of the finer grained, younger cross-cutting granite, and the point-count analysis shows it to differ mineralogically from the granite lenses as well as from the Nonewaug and Tyler Lake granites (table 9) found in other parts of the quadrangle.

Stratigraphic units

The Gneiss Complex has been subdivided into three stratigraphic units (bgcb, bgcs, and bgcl), shown on the geologic map (pl. 1). The V-shaped pattern formed by these units is compatible with the attitudes of foliation and layering and the meager lineations available, all of which indicate that the Gneiss Complex along the Torrington–West Torrington quadrangle boundary is a southward-plunging anticlinal prong. These stratigraphic units are characterized by the combinations and relative abundance of the individual rock types described above.

The unit at the center of the anticline (bgcb) consists entirely of nubby- and rusty-weathering biotitic gneiss, and is the most distinctive of the stratigraphic units. Granitic gneiss, amphibolite, and calc-silicate rocks have not been found in this unit, and granite and pegmatite are scarce. This is presumably the oldest unit of the Gneiss Complex exposed in the Torrington quadrangle. The contact between this unit and the overlying bgcs is not exposed in this quadrangle, but in the adjacent Winsted quadrangle there is a gradational zone about 200 ft thick in which biotitic gneiss is interlayered with biotite-streaked granitic gneiss typical of unit bgcs. The contact there is placed at the highest biotitic gneiss layer.

Adjacent to the biotitic gneiss is a V-shaped belt characterized by biotite-streaked pink and gray granitic gneiss (bgcs). Minor amphibolite, calc-silicate rocks, and mafic gneiss are interlayered, but well-banded gneiss is extremely rare. Biotitic gneiss has not been found in this unit. Pink granitic gneiss is dominant in the area south of Walnut Mountain, with gray gneiss most abundant elsewhere in the unit. Although this unit is not exposed along the western side of Burr Pond, outcrops of the same kind of biotite-streaked gneiss are abundant along strike just across the Winsted quadrangle boundary. The distinction between this unit and bgcl is largely a textural one, and the contact has been placed where streaked gneiss gives way to predominately well-layered granitic gneiss.

What is apparently the uppermost stratigraphic unit of the Gneiss Complex (bgcl) consists mainly of well-layered gray granitic gneiss with widespread, but subordinate, interlayered amphibolite, mafic gneiss, biotitic gneiss, and calc-silicate rocks. Pink granitic gneiss was found in only three localities in this unit: east of old Route 8 about 1.5 mi. north of Torrington; in the fault zone 1,000 ft southeast of Goodwin Pond; and in the southernmost outcrop in the area of Gneiss Complex near West Hill Pond. Two 10- to 50-ft-thick layers of biotitic gneiss can be traced in this unit near Goodwin Pond, and a layer of the same rock occurs in about the same stratigraphic position along the western boundary of the quadrangle. The ubiquitous, well-developed, and continuous banding and interlayering distinguish bgcl from bgcs, in which the foliation is defined primarily by discontinuous streaks and wisps of biotite rather than by continuous layers.

Summary

The Gneiss Complex of the Berkshire Highlands in the Torrington quadrangle is an interlayered assemblage of granitic gneiss, biotitic gneiss, mafic gneiss, with subordinate amphibolite and calc-silicate rocks. In the adjacent West Torrington quadrangle, where many of the same rock types are present, Gates and Christensen (1965) postulated that the assemblage was formed by the metamorphism of acid and basic volcanic rocks and shale. The writer supports this conclusion for the same rocks in the Torrington quadrangle. The pink granitic gneiss, a rock type not present in the West Torrington quadrangle, has some characteristics that may suggest a different type of origin for it. In contrast to the gray granitic gneiss it contains no interlayered biotitic gneiss or calc-silicate and is not commonly banded. In addition, although pink gneiss has been found elsewhere, it is most abundant in a relatively small part of the banded gneiss unit extending from Walnut Mountain south to a point about 1,000 ft east of Guerdat Road and 1,600 ft north of Goodwin Pond. This area lies along the crest of a major anticline. These features suggest that it may be a pre- or syntectonic intrusive, or perhaps represents mobilized granitic material concentrated along an already existing anticlinal crest. The final answer requires more detailed field and petrographic examination of this rock type.

The calc-silicate rocks are interpreted as metamorphosed impure carbonate-bearing sediments, and along with the biotitic gneiss are the only rocks in the Gneiss Complex considered to be metasedimentary. This assemblage of impure carbonates, shale, and volcanics is suggestive of a eugeosynclinal environment. The upper contact of the Gneiss Complex with the Waramaug Formation is not well exposed, and although the two units appear to be at least structurally conformable and perhaps interlayered, the possibility of a fault contact cannot be ruled out. The Gneiss Complex is generally considered to be Precambrian and to be related to the core rocks of the Green Mountain anticlinorium.

THE WARAMAUG FORMATION

General statement

The name Waramaug was first used by Gates and Bradley (1952) for rocks that previously had been called Berkshire. Subsequent mapping of the Cornwall and West Torrington quadrangles (Gates, 1961; Gates and Christensen, 1965) extended the Waramaug Formation belt to the northwestern edge of the city of Torrington, about 0.5 mi. from the west border of the Torrington quadrangle. At this point the Waramaug Formation is truncated by the younger Tyler Lake Granite. The present mapping of the Torrington quadrangle reveals that the Waramaug Formation continues east of the Tyler Lake Granite as a northeast-trending belt up to 3 mi. wide between the Gneiss Complex of the Berkshire Highlands and the Hartland Formation. Most of this area is shown on the Preliminary Geological Map of Connecticut (Rodgers and others, 1956) as part of the Gneiss Complex.

The Waramaug Formation is a metasedimentary gneiss consisting primarily of quartz, oligoclase, and biotite. Two distinct lithologies are readily discernable, although intermediate types are common. They are 1) muscovite-biotite-plagioclase-quartz gneiss, and 2) sillimanite-kyanite-muscovite-plagioclase-quartz-biotite gneiss. The interlayering of these two types plus the generally poor exposure of the Waramaug Formation in the Torrington quadrangle has prevented the establishment of any stratigraphic subdivisions. Subordinate granite and pegmatite are present within the Waramaug Formation, and one granite lens in the northeastern corner of the quadrangle is of mappable extent. Numerous small layers and lenses and several mappable bodies of amphibolite are found. All appear to be conformable.

The contact between the Waramaug Formation and the overlying Hartland Formation is not exposed. Elsewhere, this contact has been interpreted as a major fault, but the evidence in the Torrington quadrangle is inconclusive. Foliation in both formations near the contact seems to be generally parallel, and there is no evidence that the contact truncates either unit. In only one outcrop near the contact, 1,000 ft southeast of the intersection of Behrens and East Pearl roads, is there any suggestion of intensive deformation. Textural comparisons of the two formations, however, do reveal some important differences. Relic bedding, which is common in the Hartland Formation, is largely obliterated in the Waramaug. In the Hartland, long, slender, well-oriented mica flakes are common; in the Waramaug micas tend to be ragged appearing and randomly oriented. In the Hartland Formation, most quartz is unstrained and garnets typically show crystal faces; in the Waramaug, quartz is strained and garnets are anhedral and highly drawn out. These features, plus the generally coherent nature of the Waramaug compared to the slabby or friable nature of the Hartland, indicate that the Waramaug has undergone more periods of deformation than has the Hartland, and require the contact to be either a fault or an unconformity. Gates and Christensen (1965) pointed to brecciation of the Waramaug Formation along the power line just east of Breezy Hill Road as evidence of faulting along the contact, but the writer considers these rocks to be Hartland Formation more than 0.5 mi. from the contact.

Lithology

MUSCOVITE-BIOTITE-PLAGIOCLASE-QUARTZ GNEISS

General statement. This is a fine-grained rock that occurs in scattered outcrops throughout the Waramaug Formation in the Torrington quadrangle. Weathered surfaces are mostly light to dark gray, although some are distinctly rusty colored. Unless kyanitic or sillimanitic rocks are interlayered, outcrops are rounded and massive. The more quartzo-feldspathic types are commonly sandy and friable. Foliation ranges from poor to good and depends both upon the presence of thin biotite and diffuse quartz-plagioclase streaks, and on parallel orientation of the biotite flakes.

Although the muscovite-biotite-plagioclase-quartz gneiss is a distinctive rock type, it is interlayered and intergradational with the sillimanite-kyanite-muscovite-plagioclase-quartz-biotite gneiss and cannot be mapped separately. It can be seen interlayered with the sillimanitic variety in most parts of the Waramaug Formation but is abundant at the southern end and on the southeastern slope of West Hill.

Petrography. Mineralogically and texturally the muscovite-biotite-plagioclase-quartz gneiss is a simple rock. Quartz, plagioclase, and biotite are the dominant minerals, making up over 90 percent of the rock. Muscovite is present in most samples, but is everywhere subordinate to biotite, averaging about one fourth of the total mica. Garnet, zircon, apatite, and magnetite are ubiquitous accessory minerals.

Other minerals found in some thin sections include kyanite, sillimanite, sphene, and tourmaline. Table 4 shows the modal analyses of 9 samples of the muscovite-biotite-plagioclase-quartz gneiss. The texture varies from gneissic in those rocks where there are quartz-plagioclase and biotite segregations, to either lepidoblastic, where biotite is oriented but not segregated, or, in a few cases, granoblastic, where biotite is neither segregated nor oriented.

Table 4.—Petrographic data,[1] Waramaug Formation

	Quartz	Plag.[2]	Bio.	Musc.	Gar.	Ky.	Sill.	Mag.	Others
A[3] Average	33.7	32.7	25	6.1	1.7	0.2	T[4]	0.4	0.2[5]
Range	12–49	23–48	16–40	0–15	T[4]–5	0–2	—	T[4]–3	—
B[3] Average	24.6	22	30.4	10	5.1	4.7	1.1	1.3	0.8[6]
Range	14–36	12–47	22–41	0–21	T[4]–8	0–9	0–2	T[4]–2	—
C[3] Average	50	18	18	11	2	—	—	<1	—
D[3] Average	33	18	23	16	3	1	1	2	3[7]
E[3] Average	45	24	26	2	1	—	—	2	T[4, 8]
F[3] Average	37	19	25	10	5	—	2	1	1[9]

[1] Modal analyses in volume percent.

[2] Plagioclase data:

	Average composition	Number of determinations	Range
A	An 33.4	31	An 23–42
B	An 35.6	23	An 23–53

[3] Composition and number of samples:

A. Plagioclase-quartz-biotite gneiss (9 samples)
B. Sillimanite-kyanite-plagioclase-quartz-biotite gneiss (7 samples)
C. Quartz-plagioclase-biotite gneiss (7 samples) from the West Torrington quadrangle (Gates and Christensen, 1965)
D. Sillimanite-garnet-quartz-plagioclase-biotite gneiss (20 samples) from the West Torrington quadrangle (Gates and Christensen, 1965)
E. Quartz-plagioclase-biotite gneiss (28 samples) from the Cornwall quadrangle (Gates, 1961)
F. Sillimanite-garnet-quartz-plagioclase-biotite gneiss (34 samples) from the Cornwall quadrangle (Gates, 1961)

[4] T = trace.

[5] Zircon, apatite, tourmaline, sphene.

[6] Chlorite, staurolite, zircon, apatite, tourmaline, sphene.

[7] Staurolite, tourmaline, microcline.

[8] Microcline.

[9] Staurolite, apatite, tourmaline.

Quartz occurs as small grains which are either equidimensional or slightly elongated parallel to the foliation. Strain shadows are common. Plagioclase forms either small, rounded grains or medium to coarse poikilitic grains with inclusions of quartz. Composition determination of 31 grains shows a range of An 23 to 42, with the average at An 33. A distribution curve suggests the presence of two peaks, one at An 32, the other at An 40. Biotite typically occurs as stubby flakes concentrated in many rocks into vaguely defined streaks. It is deeply pleochroic from dark brown to pale brown or straw yellow. Muscovite, where present, tends to be in coarse flakes oriented transverse to the foliation. It is concentrated in micaceous layers and streaks with biotite. Garnets are small, irregularly shaped grains. Most occur in biotitic streaks and are elongated parallel to the streak. Abundant inclusions in garnet are mostly quartz and magnetite, but biotite, plagioclase, and sillimanite were also noted. Kyanite is present in a few samples of the muscovite-biotite-plagioclase-quartz gneiss as aggregates of small grains in biotitic streaks.

SILLIMANITE-KYANITE-MUSCOVITE-PLAGIOCLASE-QUARTZ-BIOTITE GNEISS

General statement. This type of gneiss is readily distinguished in the field from the muscovite-biotite-plagioclase-quartz gneiss by its nubby or corrugated weathered surfaces. These result from the presence of resistant streaks or clusters of sillimanite or kyanite which tend to weather positively. Typically the weathered surfaces are rusty colored. This rock ranges from uniform and homogeneous to containing abundant quartz-plagioclase lenses up to 0.5 in. thick and several inches long in a dark biotitic groundmass. The relative abundance of biotite, sillimanite, and kyanite cause it to be dense and tough. Granitic and pegmatitic material are common constituents of the biotitic gneiss and locally interpenetrate the foliation sufficiently to form migmatitic mixtures. With a decrease in the content of biotite, kyanite, and sillimanite, and an increase in quartz and plagioclase, the biotitic gneiss grades into the quartzo-feldspathic gneiss of the Waramaug Formation described previously. It should be noted that this sillimanite- and kyanite-bearing biotitic gneiss of the Waramaug Formation is not greatly different from the biotitic, quartz-feldspar gneiss of the Berkshire Highlands Gneiss Complex.

The sillimanite-kyanite-muscovite-plagioclase-quartz-biotite gneiss can be found in nearly any outcrop area within the Waramaug Formation either as layers or entire outcrops. Typical exposures include the roadcut on Torringford West Street 2,400 ft north of West Pearl Road; the roadcut on the southern side of East Pearl Road 2,500 ft east of the Torrington City boundary; and scattered outcrops on the hill just north of East Pearl Road and west of Behrens Road.

Petrography. This rock type does not differ greatly from the muscovite-biotite-plagioclase-quartz gneiss except for the abundance of biotite, garnet, kyanite, and sillimanite at the expense of quartz and plagioclase. It is typically medium- to coarse-grained, with the foliation varying from poor to good. Quartz, plagioclase, muscovite, and biotite are the major minerals, but garnet, kyanite, sillimanite, and opaques are common. Accessories include chlorite, staurolite, zircon, apatite, tourmaline, and sphene. Modal analysis based upon 7 thin sections is shown in table 4.

Quartz and plagioclase occur as irregularly shaped grains either equidimensional or slightly elongate parallel to the foliation. In streaked rocks they are concentrated to form felsic streaks and are coarser grained. Most quartz grains show faint strain, and some contain small sillimanite inclusions. Plagioclase is commonly twinned, and in some rocks it is selectively sericitized along twin lamellae or around grain borders. Some of the coarser grains contain inclusions of quartz, mica, garnet, and sillimanite. Plagioclase shows a wide range of composition, from An 23 to 53. The average is An 35, and there is no pronounced peak in the distribution curve.

Muscovite and biotite constitute about 40 percent of the rock with biotite dominant. Both tend to be concentrated in micaceous streaks or layers. Biotite is typically blocky and irregular in shape with at least vague parallelism in most rocks. Flakes of biotite range from fine to coarse and are deeply pleochroic. In some rocks there is minor replacement of biotite by chlorite. The less abundant muscovite occurs most commonly as small, blocky to elongate, essentially unoriented flakes.

Sillimanite and kyanite are the minerals that give the rock its most distinctive characteristics. Most of the sillimanite is fibrolitic and occurs either as clusters of needles or as scattered individual needles. The distinctive association of sillimanite with "bleached" biotite noted by Gates and Christensen (1965) in the West Torrington quadrangle is not present in these rocks. Sillimanite is most commonly associated with and included in quartz and plagioclase, and even where adjacent to or included in biotite, the mica shows no change in pleochroism. Kyanite forms small subhedral or anhedral grains scattered through the rock or strung out along biotitic layers. There is no apparent reaction where it is in contact with sillimanite.

Garnet occurs as fine to coarse, highly irregular shaped, poikilitic grains. Most of the inclusions are opaque, but quartz, plagioclase, sillimanite, mica, and staurolite are also found. Typically garnet is concentrated in biotitic layers, and the distribution and shape of the garnet grains suggest it has formed at the expense ot biotite.

AMPHIBOLITE

Thin lenses and layers of amphibolite are present in many parts of the Waramaug Formation, and in a few places mappable bodies occur. One of these bodies is well exposed in an abandoned quarry 1,200 ft west of the intersection of West Pearl Road and Torringford West Street. More typically the amphibolite forms lenses a few inches to a few feet thick conformable with the surrounding rock. Most of the amphibolites are fine- to medium-grained, dark green to black, and slabby. Hornblende forms mats, although it is not lineated, and this combined with segregation of plagioclase into streaks in some amphibolites gives them a distinctly planar aspect.

Summary

The interlayered varieties of gneiss in the Waramaug Formation are considered to have formed by the metamorphism of a series of impure sandstones and shales. A comparison of the rocks of the Torrington quadrangle with those mapped by Gates (1961) and Gates and Christensen (1965) in the Cornwall and West Torrington quadrangles (table 4) indicates that the Waramaug Formation of the Torrington quadrangle contains less quartz, somewhat more plagioclase and biotite, and significantly more kyanite. This suggests some lateral variation in the composition of the original sediments to the northeast.

The Waramaug Formation has recently been considered Lower Paleozoic in age (Gates, 1961). This is consistent with its position above the Berkshire Highlands Gneiss Complex and with its possible correlation with the Manhattan Formation north of Danbury (Clarke, 1958).

THE HARTLAND FORMATION

General statement

The Hartland Formation extends as a belt of mixed metasedimentary rocks from Massachusetts to Long Island Sound. In the past the Hartland Formation generally has been correlated with the Hoosac-Rowe-Savoy sequence in Massachusetts, but work now in progress near the state line is expected to redefine these correlations. From a narrow outcrop width of about 2 mi. at the Massachusetts line, the formation widens to about 15 mi. at the latitude of Waterbury, Connecticut. Throughout most of its extent in northwestern Connecticut the Hartland Formation is bordered on the west by the Waramaug Formation along what is generally considered to be a major tectonic break (Rodgers and others, 1956, 1959). Along its eastern margin, at least as far south as Waterbury, the Hartland Formation borders a series of gneiss domes or is in fault contact with the Triassic rocks of the Connecticut River valley. A Lower Paleozoic age is probable for the Hartland Formation because it is intruded by pegmatites determined to be about 360 million years old (Rodgers, 1952; Wasserburg and others, 1956).

Gates (1959) subdivided the Hartland Formation into four units. Three of these (units I, II, and III) are traceable into the West Torrington quadrangle. Unit I was originally considered the oldest of the four Hartland units because 1) it is located in the center of foliation domes and anticlines within the Hartland Formation; 2) it is the unit of the Hartland Formation most nearly adjacent to a series of gneiss domes along the eastern edge of the Hartland belt; and 3) it occurs at the eastern edge of a sequence of rocks in which the foliation dips consistently to the west or northwest. Subsequent mapping in the Waterbury quadrangle (Gates and Martin, 1967) substantiated this interpretation by revealing that unit I is the lowest unit mantling the core of the Waterbury dome. Stanley (1964) raised the Hartland Formation to group status and assigned four formations to it based upon his mapping in the Collinsville quadrangle. Units I, II, and III are present in the Torrington quadrangle, and the following correlations with Stanley's units are indicated (fig. 7). Unit I of the Hartland Formation in the Torrington quadrangle and quadrangles to the southwest is equivalent to the Taine Mountain Formation of the Collinsville quadrangle. The evidence for this correlation is based largely upon mapping in the Waterbury quadrangle (Gates and Martin, 1967), where unit I of the Hartland Formation underlies the equivalent of the Collinsville Formation, the Hitchcock Lake Member of the Hartland Formation. Thus, in addition to their lithologic similarity, both the Taine Mountain

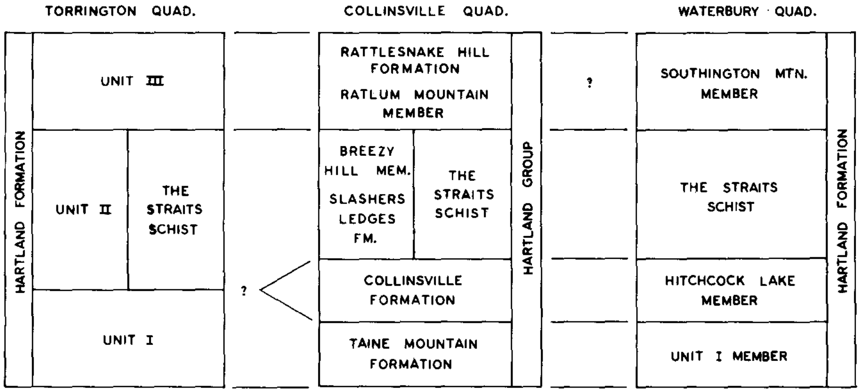

Fig. 7. Proposed correlations of stratigraphic sections in the Torrington, Collinsville, and Waterbury quadrangles.

Formation and unit I occupy the same stratigraphic position. The Collinsville Formation and the Hitchcock Lake Member are both absent in the Torrington quadrangle and quadrangles to the southwest. Instead, unit II directly overlies unit I, and in the Torrington quadrangle unit II can be traced eastward into the upper member (Breezy Hill Member) of the Satans Kingdom Formation and the Slashers Ledges Formation. If the absence of Collinsville-Hitchcock Lake equivalents in the Torrington quadrangle is attributed to nondeposition—a reasonable conclusion given the probable volcanic origin and variable thickness of the Hitchcock Lake Member in the Waterbury area—unit II in the Torrington quadrangle and The Straits Schist of the Waterbury and Collinsville quadrangle occupy the same stratigraphic position above unit I. Unit II thus becomes correlative with The Straits Schist as well as the Breezy Hill Member of the Satans Kingdom Formation and the Slashers Ledges Formation. More will be said about this in a subsequent section. The area mapped as unit III in this report occupies the same position as, and undoubtedly correlates with, both the lower member (Ratlum Mountain Member) of the Satans Kingdom Formation and the Rattlesnake Hill Formation in the Collinsville quadrangle.

The Hartland Formation occupies most of the southern half and eastern edge of the Torrington quadrangle, forming a northeast-trending belt that is nearly truncated by the intrusive Nonewaug Granite. The three units comprising the Hartland Formation in the Torrington quadrangle are quite distinctive, although similar to identical rock types can be found in all of them. The differences between them are not so much in the kinds of rocks they contain but in the relative abundance of these rock types. Unit I is predominantly mica-plagioclase-quartz granulite or granulitic gneiss. (The term granulite is used in this paper to indicate those rocks containing at least 80 percent equigranular minerals, mostly quartz and plagioclase, and in which platy minerals are uniformly disseminated.) Subordinate schist is interlayered. Unit II is a garnet-staurolite-biotite-muscovite-plagioclase-quartz schist containing subordinate granulitic layers. The upper part of unit II tends to be coarsely porphyroblastic and less biotitic than the lower part. Unit III, which is poorly exposed in the Torrington quadrangle, is an interlayered assemblage of mica-plagioclase-quartz granulite and kyanite-bearing schist. Both types are graphitic, which imparts to the rocks a distinctive purple-gray to black color. Layers and pods of amphibolite and irregularly shaped patches and lenses of pegmatite are abundant throughout the Hartland Formation. A few of these are large enough to be mappable. Several outcrops of highly altered ultrabasic intrusives are located in unit II and are indicated on the geologic map.

Lithology

UNIT I

General statement. Unit I is typically fine-grained, gray, muscovite-biotite-plagioclase-quartz granulite or granulitic gneiss. It is designated granulite where the micas are uniformly disseminated, and granulitic gneiss where they tend to be concentrated in streaks or pin-stripe layers.

Interlayered schist from 0.5 in. to several feet thick is common but consistently subordinate in total amount to the granulitic rocks. Micas are everywhere well oriented, whether streaked or disseminated. Layering is believed to represent original bedding and is generally parallel to the foliation except at the crest of some small isoclinal folds, where it crosses the foliation. Outcrops of unit I range from rounded and massive to spindled or slabby, depending upon the total amount of mica present and the extent to which it is segregated into layers. The more granulitic rocks are commonly sandy and friable.

A distinctive and unusual rock type occurs in the upper part of unit I near the contact with unit II; it is shown on the map as a sinuous band, about 700 ft wide, in the eastern part of the quadrangle, and as three isolated areas in the same stratigraphic position farther to the southwest. It differs from more normal unit I rocks by containing kyanite, staurolite, and more abundant muscovite at the expense of quartz and plagioclase. The kyanite causes the rock to be tough and coherent and to weather with prickly or nubby surfaces not unlike sillimanitic and kyanitic varieties of the Waramaug Formation. The rock is considered part of the Hartland Formation rather than Waramaug because of the high muscovite content and ubiquitous presence of staurolite as well as its apparently conformable and interlayered stratigraphic relationship with unquestioned Hartland units. This type rock is not known to occur in unit I southwest of the Torrington quadrangle. Stanley (1964) has mapped it as a probable equivalent of the upper member of the Rattlesnake Hill Formation in the Collinsville quadrangle.

Minor folding is much in evidence in unit I and ranges from tight isoclinal folds to broad, open folds. In several outcrops the earlier isoclinal folds have been subsequently refolded into open folds with amplitudes and wavelengths of several feet. Small crenulations of the foliation surfaces give many exposures a washboard-like appearance.

The band of unit I in the Torrington quadrangle continues into the West Torrington quadrangle in what was interpreted by Gates and Christensen (1965) as an isoclinal anticline. They correlated unit I rocks of the West Torrington quadrangle with lithologically similar rocks in the eastern part of the Litchfield quadrangle and northwestern part of the Thomaston quadrangle. The latter rocks can be traced south as far as the Waterbury quadrangle, and southwest to the Roxbury quadrangle.

Typical unit I with interlayered schist and amphibolite can be seen at East Litchfield, both in the railroad cut and roadcuts along new Route 8 (fig. 8). Other areas of good exposure include the small knobs around the western end of the swamp southwest of Lake Harwinton, and in the lower slopes of Town Hill 1,800 ft west of Camp Trinita. The kyanitic variant can best be observed on the small knobs on either side of Surdam Road 3,200 ft south of Bakersville.

Petrography. Unit I is a simple rock both texturally and mineralogically. The texture ranges from lepidoblastic to gneissic, where micas are concentrated in thin streaks or layers. Muscovite, biotite, plagioclase, and quartz are the dominant minerals, with the total mica content generally

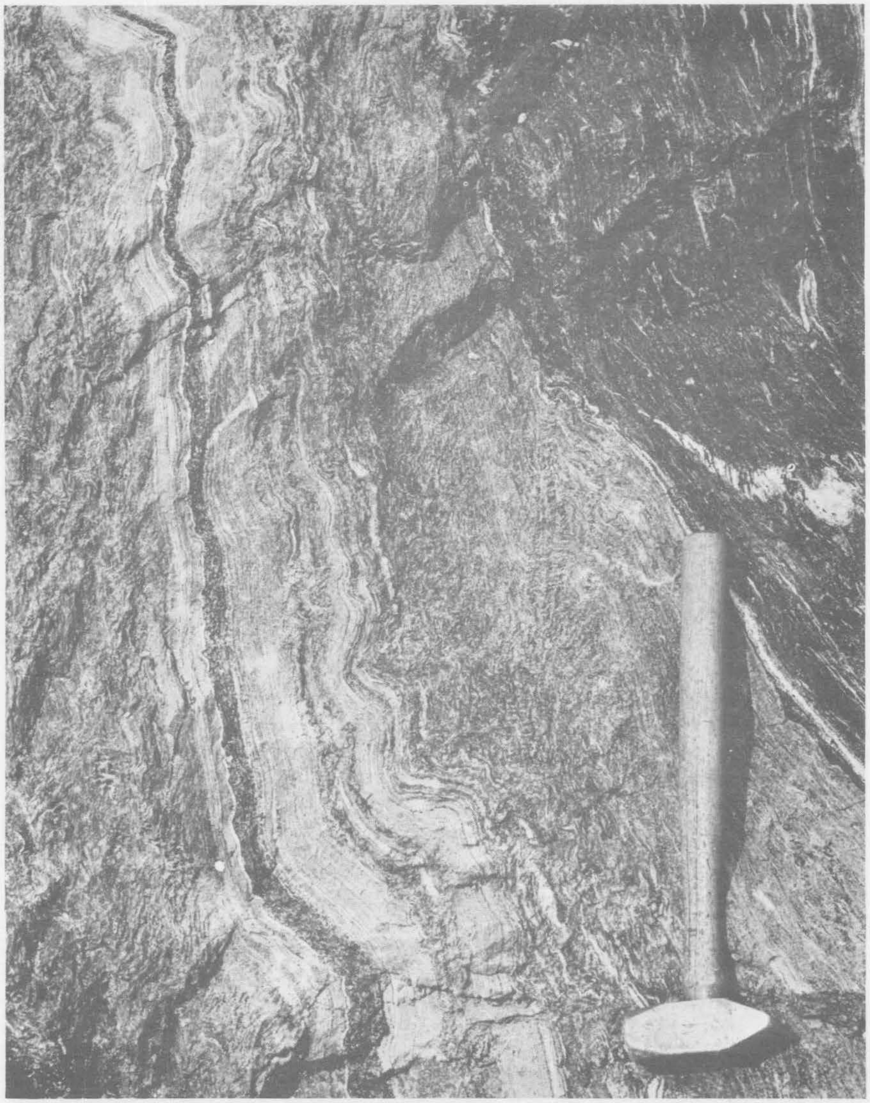

Fig. 8. Interlayered granulitic gneiss, schist, and amphibolite in Hartland Formation unit I in the railroad cut immediately south of East Litchfield. Scale given by 14-in. hammer.

less than 20 percent except in thin schist layers. Overall, biotite is the predominant mica, but many rocks are found in which muscovite is more abundant. Garnet and magnetite are found in small amounts in all samples. Minerals present in trace amounts include chlorite, tourmaline, zircon, apatite, sphene, and, rarely, kyanite. Modal analysis is shown in table 5.

Table 5.—Petrographic data,[1] Hartland Formation unit I

		Quartz	Plag.[2]	Bio.	Musc.	Gar.	Ky.	Staur.	Mag.	Others[3]
A[4]	Average	44.6	22.3	18.1	11.9	1.0	T[5]	—	1.4	0.7
	Range	31–70	9–46	7–28	0–30	0–4.4	0–0.8	—	T[5]–3.6	—
B[4]	Average	27.7	10.1	24.6	24.1	3.9	5.2	0.8	2.6	1.0
	Range	19–38	1–21	15–38	12–37	0–6.5	T[5]–17	T[5]–3.3	1–5.2	—

[1] Modal analyses in volume percent.

[2] Plagioclase data:

	Average composition	Number of determinations	Range
A	An 26.7	43	An 13–40
B	An 22.8	16	An 12–36

[3] Chlorite, tourmaline, zircon, apatite, sphene, sillimanite.

[4] Composition and number of samples:

A. Fine-grained, gray, mica-plagioclase-quartz granulite and granulitic gneiss (14 samples)
B. Kyanitic, mica-plagioclase-quartz gneiss (8 samples)

[5] T = trace.

Quartz and plagioclase form a mosaic of small grains that are either equidimensional or slightly elongated parallel to the foliation. Plagioclase is typically untwinned and unzoned. It shows a compositional range of An 13 to 40, with the average An 27. A frequency-distribution curve of plagioclase composition, however, reveals two distinct peaks, one at An 15, the other at An 30. The reason for this distribution is not known, but it is worth noting that an almost identical pattern was found in unit I in the Waterbury quadrangle (Gates and Martin, 1967). Micas are typically well oriented, although a few flakes are transverse to the foliation. They are either disseminated uniformly through the rock or concentrated in discontinuous streaks. In most thin sections there is some replacement of biotite by chlorite. Garnet occurs as irregular, poikilitic grains mostly associated with biotite. In one thin section, trails of opaque inclusions indicate that the garnet crystals have been rotated about 70°.

The kyanitic layer in unit I does not differ appreciably from more typical rock types except for the abundance of kyanite and staurolite. Kyanite occurs as very fine grains clustered together in streaks or layers up to 1 in. thick. Small subhedral to euhedral staurolite grains are associated with the kyanite in most thin sections.

The schist layers in unit I are the same as the schist of unit II.

UNIT II

General statement. Unit II consists of lustrous mica-plagioclase-quartz schist, with or without porphyroblasts, and with subordinate interlayered granulite and granulitic gneiss. Pegmatite patches and lenses invade the rock in many places, and mappable amphibolite lenses are particularly abundant in unit II. The main variation in the schist is the presence in some layers of coarse porphyroblasts of plagioclase, garnet, staurolite, and kyanite in varying combinations. The distribution of these porphyroblastic layers is not uniform throughout unit II; they are clearly subordinate to nonporphyroblastic schist layers in the lower part of the unit nearest the contact with unit I but become dominant in the upper part, where they commonly constitute 90 percent or more of the total outcrop. This distribution has led to subdivision of the unit into nonporphyroblastic and porphyroblastic types, shown on the geologic map (pl. 1).

Point-count analyses (table 7) show that the two types of schist are mineralogically very similar, and that except for the presence of coarse crystals of one or more minerals, the porphyroblastic schist does not differ significantly from the nonporphyroblastic.

Except for the coarse porphyroblasts, the rocks of unit II are typically medium-grained. Most of the porphyroblasts average about 0.5 in. in length, but locally they are much larger. Staurolite reaches 2 in. in many places in the porphyroblastic schist; plagioclase up to 3 in. long occurs in roadcuts along Woodchuck Lane at the top of the hill 3,000 ft south of Townline Road; and kyanite is up to 6 in. long on the knobs east of Harmony Hill Road 3,000 ft south of the top of Harmony Hill.

Outcrops of unit II are generally rounded and have a uniform appearance. Foliation is defined by mica orientation and numerous lenses of quartz and plagioclase several inches long. Granulitic layers in the schist are typical of those in unit I and average 2 to 3 in. in thickness.

The unit II schist belt in the Torrington quadrangle apparently splits near the southwestern corner of the quadrangle. One band of it, repeated several times by folding along the Torrington–Thomaston quadrangle boundary, trends southeast toward the town of Thomaston (Cassie, 1965, and oral communication); the other can be traced continuously southwest to the Roxbury quadrangle (Gates, 1959; Gates and Christensen, 1965; Martin, 1962). To the northeast, unit II is equivalent to the Slashers Ledges Formation and to the Breezy Hill Member of the Satans Kingdom Formation (fig. 9).

Excellent exposures of both porphyroblastic and nonporphyroblastic unit II schist are easily seen in roadcuts along both new Route 8 and the railroad south of East Litchfield and on the slopes above them. Nonporphyroblastic schist can be seen on the small knobs 1,300 ft north of the intersection of Hill Road and Route 116. Porphyroblastic schist outcrops well and can be seen at many places along its outcrop belt, including the slope east of Highview Road, the knobs east of Harmony Hill Road, and along and west of Woodchuck Lane to the swamp.

Petrography. The rocks of unit II are medium-grained biotite-muscovite-plagioclase-quartz schist with porphyroblasts of plagioclase, garnet, staurolite, and kyanite. Chlorite and magnetite are found in nearly all samples, always in minor amounts. Accessory minerals present in some rocks include tourmaline, zircon, apatite, sphene, and rutile. Modal analyses of both the porphyroblastic and nonporphyroblastic type are given in table 6. The mineralogical similarity of the two types is readily apparent; the difference between them is textural, not mineralogical. The texture is lepidoblastic to porphyroblastic.

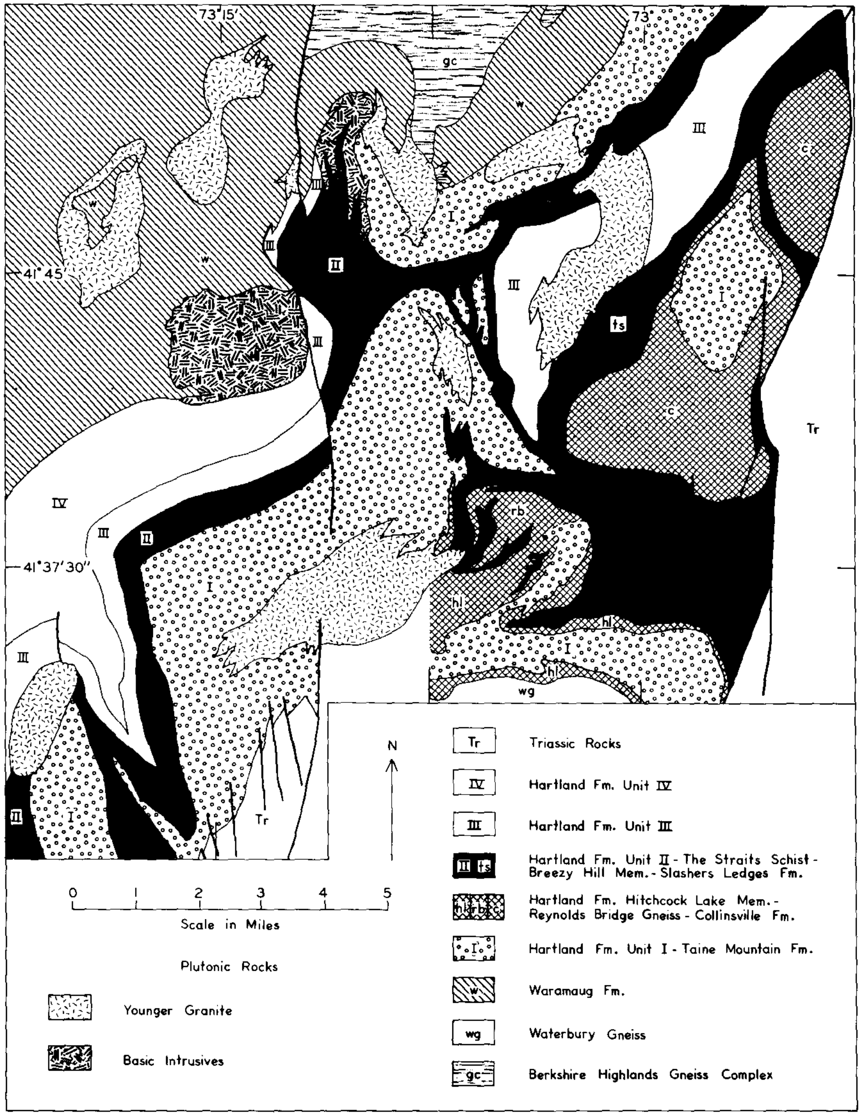

Fig. 9. Generalized geologic map of the Torrington quadrangle and adjacent portions of western Connecticut. Data from Cassie, 1965; Fritts, 1963; Gates 1954, 1959, 1961; Gates and Bradley, 1952; Gates and Christensen, 1965; Gates and Martin, 1967; Martin, 1962; Stanley, 1964.

Table 6.—Petrographic data,[1] Hartland Formation unit II and The Straits Schist

		Quartz	Plag.[2]	Musc.	Bio.	Staur.	Gar.	Ky.	Graph,	Others[3]
A[4]	Average	30.4	21.9	16.9	18.1	4.5	2	3.6	—	2.6
	Range	9–43	5–47	T[5]–44	11–25	0.5–9.5	T[5]–4.5	0–25	—	—
B[4]	Average	28.6	26.5	18.8	12.6	5.7	1.4	1.2	—	5.2
	Range	17–60	8–53	4–44	3–21	0–11	0–4.3	0–7.8	—	—
C[4]	Tn-27	45.8	6.8	19.1	16.8	1.5	6.0	0.9	—	3.1
D[4]	Average	41.9	10.1	23.7	15.0	T[5]	3.3	3.1	0.9	2.0
	Range	29–60	1–19	16–42	3–25	—	T[5]–8	T[5]–11	0–3.5	—

[1] Modal analyses in volume percent.

[2] Plagioclase data:

	Average composition	Number of determinations	Range
A	An 22.8	14	An 12–30
B	An 21.1	7	An 10–32
C	—	—	—
D	An 24.1	21	An 21–30

[3] Chlorite, tourmaline, zircon, apatite, sphene, rutile, magnetite.

[4] Composition and number of samples:

A. Nonporphyroblastic unit II schist (7 samples)
B. Coarsely porphyroblastic unit II schist (8 samples)
C. The Straits Schist (1 sample)
D. The Straits Schist (13 samples), Waterbury quadrangle (Gates and Martin, 1967)

[5] T = trace.

Quartz occurs both as medium and coarse grains, the latter restricted to quartz or quartz-plagioclase lenses. The coarse grains are equidimensional, whereas the finer ones in some rocks show elongation along the foliation.

Plagioclase is found both as small, anhedral grains associated with quartz and as porphyroblasts, both types present in some rocks. The small grains are untwinned; the porphyroblasts twinned, poikilitic, and sericitized. The range of plagioclase compositions is from An 10 to 32 and averages An 22. There is no peak in the distribution curve of composition and no appreciable difference in range, average, or distribution of compositions between the small grains and the porphyroblasts.

Muscovite occurs as straight-sided, fine to coarse flakes, typically well-oriented and concentrated in thin layers. Some rocks contain a few, nearly equidimensional, randomly oriented flakes. Biotite is generally slightly coarser grained and more randomly oriented and distributed than muscovite. In some rocks the two micas are interleaved. Minor replacement of biotite by chlorite is ubiquitous.

Garnet ranges from small, rounded to euhedral, inclusion-free grains to coarse, anhedral or subhedral, poikilitic masses. Small grains show a tendancy to occur in biotitic layers. Quartz and opaques are the main inclusions, but biotite, muscovite, tourmaline, zircon, and kyanite have also been found.

Staurolite is found in small and very coarse subhedral and anhedral grains. Many of the larger grains, and a few of the smaller ones, are poikilitic, with quartz and opaques the most common inclusions. The shape and distribution of the poikilitic grains indicate they have replaced mica.

Kyanite is locally present either as masses of very small grains clustered with quartz, or as porphyroblasts containing inclusions of quartz, magnetite, garnet, and tourmaline. In a few thin sections the type and pattern of inclusions suggest that kyanite has formed at the expense of mica. The evidence, however, is less convincing than is the case with staurolite.

THE STRAITS SCHIST

The Straits Schist is a medium- to coarse-grained plagioclase-biotite-muscovite-quartz schist with porphyroblasts of garnet, staurolite, and kyanite locally present. It is found in the extreme southeastern corner of the Torrington quadrangle, where it forms part of a major belt of The Straits Schist that can be traced continuously from the Collinsville quadrangle to the Waterbury quadrangle nearly 20 mi. to the south. For reasons noted above, and to be explained more fully in a subsequent section, The Straits Schist is tentatively correlated with unit II of the Hartland Formation.

The Straits Schist is a lustrous, silver-gray rock on fresh surfaces that weathers to a rusty color. Projecting edges of resistant muscovite and kyanite grains cause weathered surfaces to be prickly. Granite and pegmatite patches of variable size, and quartz and quartz-plagioclase stringers up to 1 in. thick and 6 in. long, are characteristic features. The texture of the rock is lepidoblastic.

Quartz, plagioclase, muscovite, and biotite are the essential minerals. Chlorite and garnet are generally present in subordinate amounts with kyanite and staurolite found locally. Accessory minerals include zircon, sphene, apatite, and opaques. The modal analysis of one sample, Tn 27, is shown in table 6 along with the figures for 13 samples of The Straits Schist from the Waterbury quadrangle for comparison. Quartz and plagioclase are concentrated in lenses and stringers of coarse, equidimensional grains. The micas show moderate to good parallel orientation and form layers around and between the quartz-plagioclase segregations. Biotite is replaced locally by penninite and other chlorites. Garnet forms irregularly rounded, coarse grains containing numerous small inclusions of quartz and opaques concentrated in the center of the crystal. Kyanite occurs in some rocks as blades up to 1 in. long. Sericitization around grain borders and along cleavage and fractures is common. Medium to coarse staurolite ranges from anhedral to euhedral, and from nonpoikilitic to sievelike with quartz inclusions.

The rocks in scattered outcrops along the northwestern side of The Straits Schist belt are finer-grained, apparently lack kyanite, and contain abundant layers of fine-grained, light gray, biotite-plagioclase-quartz granulite averaging about 1 in. in thickness. Although there is not enough exposure in the Torrington quadrangle to permit any definite conclusions, it is interesting to note that these are the same characteristics that identify the Southington Mountain Member of the Hartland Formation, which overlies The Straits Schist in the Waterbury quadrangle (Gates and Martin, 1967).

The Straits Schist is very limited in extent in the Torrington quadrangle, with the best exposures found on the hills in the extreme southeastern corner east of the swamp. The finer-grained possible Southington Mountain Member equivalent can be seen along the Thomaston quadrangle boundary in scattered outcrops extending about 1,000 ft both east and west of the Hartford-Litchfield County line.

UNIT III

General statement. Unit III is a thinly interlayered, heterogeneous assemblage of fine-grained muscovite-biotite-plagioclase-quartz granulite and muscovite-plagioclase-quartz-biotite schist, with many of the rocks unusually graphitic. All intermediate varieties between granulite and schist can be found, depending upon the relative abundance of mica versus quartz and plagioclase. Two very distinctive rock types not found elsewhere in the quadrangle are interlayered in varying amounts in almost every outcrop in unit III and, together with the consistently thin interlayering, serve to distinguish the unit. They are 1) fine-grained dark gray or purple-gray granulite and schist with abundant graphite, and 2) medium-grained, poorly foliated, silvery schist with randomly oriented, black biotite porphyroblasts and coarse kyanite blades. Both of these types are distinctive in the field, the graphitic rocks because of their fine grain size, dark color, and crumbly, rusty weathering; the schist because of its poor foliation, abundant kyanite, and spotted appearance caused by the black biotite. In many outcrops these are the only rock types present; in almost all they are the dominant ones. Other rocks interlayered in clearly subordinate amounts include very fine-grained, sandy to brittle, mica-feldspar-quartz granulite, and very minor nonkyanitic schist.

The interlayering, which is interpreted as relic bedding, ranges from 0.25 in. to several feet in thickness. Weathered surfaces are angular and ledgy because of the differing resistance of the thin layers, and crumbly and rust-colored where graphite is abundant.

The designation of these rocks as unit III has important regional geological implications, and it is necessary to examine the evidence on which this conclusion is based. Unit III is best known from the area south of Bantam Lake in the Litchfield quadrangle, where it is part of a belt that can be traced from the Roxbury quadrangle northeast to the West Torrington quadrangle, where it is truncated along a fault contact by the Waramaug Formation (Gates, 1959; Martin, 1962, Gates and Christensen, 1965). Unit III rocks of this belt are best characterized as a thinly interlayered, heterogeneous assemblage of schist, granulite, and granulitic gneiss which typically forms slabby outcrops. In these respects they are smilar to the rocks mapped as unit III in the Torrington quadrangle. They differ from the Torrington quadrangle rocks mainly by containing fewer kyanitic layers, and little, if any, graphite.

Stratigraphic and structural considerations also play a role in the designation of these rocks as unit III. Their stratigraphic position adjacent to unquestioned unit II rocks that can be traced continuously to the Roxbury quadrangle dictates that these thinly interlayered rocks are unit I or unit III, unless there is either faulting or a stratigraphic break along the contact. In the few places where exposures occur near the contact, it appears conformable, and perhaps even gradational, so the rocks in question would seem to be unit I or unit III. If they are unit I, they should be lithologically similar to unit I rocks exposed northwest of unit II, and they are not. Unit I is neither thinly interlayered and slabby, nor does it contain the distinctive graphitic or kyanitic rocks. Furthermore, this interpretation would require the presence of a synclinal axis within unit II which is difficult to reconcile with the asymmetrical distribution of the porphyroblastic and nonporphyroblastic schist in unit II. If these rocks are not unit I, the most reasonable explanation is that they are unit III, which is consistent with the thin interlayering and overall slabby aspect of the rocks.

Typical lithologies of unit III can be seen in a series of roadcuts along Route 116 from Harwinton School to the intersection with Route 72. Scattered small outcrops are found on the knobs between Kelly Pond and Whetstone Road and on the slopes both north and south of Swimming Hole Road, west of Leadmine Brook.

Petrography. Although a wide variety of individual rock types are found in unit III, two types characterize the unit and distinguish it from other rocks in the Torrington quadrangle. This discussion will be restricted to these two types, recognizing that many other kinds of rocks are interlayered in subordinate amounts. The distinctive rocks are 1) slabby, fine-grained, gray, muscovite-biotite-plagioclase-quartz granulite and schist, and 2) poorly foliated, medium-grained muscovite- plagioclase-quartz schist with coarse porphyroblasts of biotite and kyanite. Average modal analyses of these two rock types are shown in table 7. It is noteworthy that even the kyanitic schist contains appreciable graphite. The texture of the kyanitic schist is lepidoblastic with the foliation defined primarily by orientation of the muscovite; that of the graphitic rocks ranges from granoblastic to lepidoblastic, depending upon the abundance of mica.

Table 7.—Petrographic data,[1] Hartland Formation unit III

		Bio.	Quartz	Plag.	Musc.	Ky.	Gar.	Graph.	Chl.	Others
A[2]	Average	34.4	23.4	16.8	10.2	7.9	3.5	2.3	T[3]	1.5[4]
	Range	27–41	16–37	7–30	7–15	5–14	1–9	2–3	—	—
B[2]	Average	21.3	28.7	21.9	6.1	5.2	3.6	10.5	1.0	1.7[5]
	Range	10–26	15–57	3–37	0–13	0–26	0–10	5–15	0–3	—

[1] Modal analyses in volume percent.

[2] Composition and number of samples:

A. Kyanite-muscovite-plagioclase-quartz-biotite schist (4 samples)

B. Graphite-biotite-plagioclase-quartz granulitic gneiss and schist (6 samples)

[3] T = trace.

[4] Staurolite, tourmaline, zircon, apatite, sphene, rutile, magnetite.

[5] Tourmaline, zircon, apatite, sphene, rutile, magnetite.

Quartz and plagioclase typically form a mosiac of equidimensional fine to medium grains. Plagioclase is untwinned and its composition has not been determined. Biotite is the dominant mica in all samples examined. It is generally coarser-grained and more randomly oriented than the muscovite in the same rock. In the kyanitic schist it forms coarse, irregularly rounded, randomly distributed and oriented porphyroblasts. In a few samples there is segregation of micas, especially muscovite, into layers or discontinuous folia.

Kyanite is most abundant in, although not restricted to, the porphyroblastic schist, where it locally attains lengths of 1 in. or more. Blades are anhedral and most are poikilitic, containing abundant small, rounded, quartz grains. In many thin sections, kyanite appears as a mass of small grains over large areas, all of which have a common optical orientation.

Graphite is one of the distinctive minerals of unit III. It occurs as "clouds" of tiny flakes, some euhedral, that are either uniformly disseminated throughout the rock, or are concentrated into ill-defined layers or wispy streaks. They commonly are included in all other minerals of the rock, although they tend to be most abundant in micas.

Garnet is a common accessory mineral forming fine to coarse, subhedral grains, some containing inclusions of quartz and opaques. Coarse staurolite porphyroblasts were found in two samples of kyanite-bearing schist but are apparently absent in the graphitic rocks. Accessory minerals are chlorite, tourmaline, zircon, apatite, sphene, rutile, and magnetite.

AMPHIBOLITE

Amphibolite is found throughout the Hartland Formation, ranging from layers 1 in. or less in thickness to mappable bodies up to 0.75 mi. in length and several hundred feet thick. Thin layers are most abundant in unit I; larger bodies in both units I and II. Most of the amphibolites are fine- to medium-grained and well foliated. Hornblende needles show a planar, although not linear, orientation. Everywhere contacts could be observed, amphibolite is parallel to the adjacent metasediments.

The average modal analysis of three amphibolite samples is shown in table 8. Hornblende generally comprises from 50 to 80 percent of the amphibolite and forms anhedral to subhedral grains pleochroic in blue-green. In some rocks it tends to be segregated into streaks that alternate with streaks and lenses of plagioclase. Plagioclase occurs both as small, rounded grains scattered evenly throughout the rock, and also as coarse, twinned, in some places poikilitic, grains associated in layers and lenses with subordinate quartz. Composition ranges from An 32 to 54 and averages An 40. Garnet and epidote are not present in all amphibolites, but where they do occur they are apt to be relatively abundant, garnet as medium to coarse subhedral grains, and epidote as masses of fine anhedral grains associated with plagioclase. Accessory minerals are biotite, sphene, diopside, zoisite, apatite, and magnetite.

Table 8.—Petrographic data,[1] Hartland Formation amphibolite

	Hornblende	Plagioclase[2]	Quartz	Garnet	Magnetite	Epidote	Others[3]
Tn-6[4]	68.7	14.1	2	—	—	9.6	5.6
Tn-8[5]	47.8	16.8	14	19.2	1.9	—	0.3
Tn-12[6]	83.3	11.0	3.6	—	1.8	—	0.3

[1] Modal analyses in volume percent.
[2] Plagioclase data: average composition of 5 determinations = An 40.4; range An 32–54.
[3] Biotite, sphene, diopside, zoisite, apatite.
[4] Layer in unit II south of East Litchfield.
[5] Lens in unit I west of Clearview Road.
[6] Layer in unit I at East Litchfield.

Remarkably continuous layers of amphibolite from 0.25 to several inches in thickness can be seen interlayered with granulite in the first railroad cut south of East Litchfield (fig. 8). The most easily accessible large, mappable body of amphibolite is exposed in the valley of the Nepaug River at Maple Hollow. Any conclusions regarding the origin of these amphibolites would require more detailed sampling and petrographic study of both the amphibolites and the adjacent rocks than has so far been done. Gates (1967) attributed the amphibolites in neighboring areas to syntectonic intrusion of basaltic magma; however, for the very thin and continuous amphibolite layers it would seem that a metamorphosed volcanic origin should not yet be ruled out. The general absence of calcite, diopside, and tremolite argues against a metasedimentary origin.

GRANITE AND PEGMATITE

Granite and pegmatite are found in all units of the Hartland Formation, typically as small dikes, sills, or irregularly shaped, cross-cutting bodies. Only a few are large enough to be mapped. Of particular interest is a pegmatite immediately southwest of the intersection of Route 116 and Hill Road, which contains coarse tourmaline up to 6 in. in diameter.

Summary

The Hartland Formation in the Torrington quadrangle is a sequence of interlayered metasedimentary rocks that is divisible into three distinct units. The mica-plagioclase-quartz granulite and granulitic gneiss of unit I represent original clastic sediments that compositionally are similar to subgraywackes with subordinate interbedded shale. The presence of thin calc-silicate layers indicates that some beds were calcareous. The mica-plagioclase-quartz schist of both unit II and The Straits Schist are the rock types to be expected from the metamorphism of aluminous shale. The concentration of staurolite and kyanite in thin to thick layers indicates that their presence is largely controlled by original sedimentary composition. Unit III is a heterogeneous assemblage of mica-plagioclase-quartz granulite and schist which must be derived from a variety of thinly bedded quartzo-feldspathic and shaly sediments. Assuming that metamorphism results in an increase in grain size, many of the original sediments of unit III must have been quite fine-grained. The abundant graphite is presumed to be of organic origin.

In this report, The Straits Schist is tentatively correlated with unit II of the Hartland Formation, a correlation first suggested by mapping in the Waterbury quadrangle (Gates and Martin, 1967). Since the belt of unit II that extends continuously from Roxbury to the Torrington quadrangle can be traced into the Breezy Hill Member of the Satans Kingdom Formation and the Slashers Ledges Formation in the Collinsville quadrangle, this interpretation would require that all four units be considered correlatives or facies equivalents. The original correlation of unit II and The Straits Schist was based upon the discovery in the Waterbury quadrangle that The Straits Schist overlies Hartland Formation unit I with the Hitchcock Lake Member of the Hartland Formation, of presumed metavolcanic origin, between them. Thus both The Straits Schist and unit II occupy the same stratigraphic position above unit I. At that time (Gates and Martin, 1967) it was pointed out that there were two major arguments against the proposed correlation; 1) the two schists show some lithologic differences, although both were aluminous shale originally, and 2) there is nothing resembling the Hitchcock Lake Member between units I and II in the Roxbury, New Preston, Litchfield, or West Torrington quadrangles. These arguments are still valid, although the writer does not consider them compelling. The proposed correlation is supported by mapping in the Thomaston quadrangle (Cassie, 1965, and oral communication) where a band of schist can apparently be traced continuously from The Straits Schist near the town of Thomaston to the unit II belt in the extreme northwestern corner of the Thomaston and southwestern corner of the Torrington quadrangles (fig. 9). In the Torrington quadrangle, the position of The Straits Schist in the southeastern corner and its relationship to the sequence of units I, II, and III of the Hartland Formation must be explained. This could be done in several ways: 1) it could overlie unit III; 2) there could be a fault between it and unit III; 3) it could underlie unit III and thus be equivalent to unit II. If The Straits Schist is stratigraphically above unit III, it is at or near the top of the Hartland Formation and should correlate with unit IV. Lithologically, unit IV, where it is found in the Roxbury and New Preston quadrangles, and The Straits Schist are dissimilar. Furthermore, the position of The Straits Schist around the Waterbury, Bristol, and Collinsville domes makes this hypothesis, requiring The Straits Schist to be high in the Hartland sequence, unattractive. The actual contact between unit III and The Straits Schist is not visible in the Torrington quadrangle because of later intrusive granite, but the geological map of the adjacent Collinsville quadrangle (Stanley, 1964) shows no evidence of faulting in this position. The third alternative seems most attractive—that The Straits Schist and unit II are correlative in the Torrington quadrangle. This interpretation requires that a synclinal axis extend through unit III parallel to the strike. The suggestion that rocks similar to the Southington Mountain Member of the Hartland Formation may be present along the northwestern side of The Straits Schist in the Torrington quadrangle is consistent with this interpretation.

In the Torrington quadrangle, unit I, the lowest of the Hartland Formation sequence, is in contact with the Waramaug Formation with younger units exposed to the southeast. In quadrangles to the southwest, stratigraphically higher Hartland Formation units are exposed against the Waramaug Formation and lower units appear successively to the southeast away from the contact (Martin, 1962; Gates and Christensen, 1965). Thus the contact between the Hartland and Waramaug formations, which is best explained by a fault west of Torrington, could be an unconformity in this quadrangle, although the possibility of a fault cannot be ruled out.

THE TYLER LAKE GRANITE

Only a small area along the western margin of the quadrangle at the southern edge of Torrington is underlain by Tyler Lake Granite. Most of this granite body is in the adjacent West Torrington quadrangle (Gates and Christensen, 1965). The Tyler Lake Granite ranges from medium-grained to pegmatitic and massive to gneissic, but these variations cannot be mapped on a scale of 1:24,000. The color is white, gray, or pink. Pegmatite is abundant in most outcrops of granite either as parallel layers a few inches thick or as irregularly shaped patches. Discordant relationships between both granite and pegmatite and the adjacent metasediments are present in several places on the slope at the eastern edge of Hillside Cemetery.

Quartz, plagioclase, and microcline are the dominant minerals with less abundant muscovite and biotite. Accessories are garnet, apatite, zircon, and chlorite. The average mode of 2 samples is shown in table 9 along with values for 12 samples from the same granite body in the West Torrington quadrangle taken from Gates and Christensen (1965). Microcline occurs both as small anhedral grains and coarse poikilitic grains, the latter with inclusions of quartz and plagioclase. Some of the coarse grains are perthitic. Anhedral plagioclase is also found in the matrix with granular guartz and microcline. Plagioclase included in microcline is typically more sericitized than that in the matrix and commonly has a clear rim zone in contact with the microcline. Twinning is present but not abundant. Plagioclase composition ranges from An 10 to 16 and averages An 13. Clear rim zones are more sodic than cores of grains. Mica flakes are mostly medium sized in the samples studied, and their parallelism generally defines the foliation of the rock.

Table 9.—Petrographic data,[1] Nonewaug and Tyler Lake granites

	Plagioclase[2]	Quartz	Microcline	Muscovite	Biotite	Others[3]
A[4] Average	37.8	35.1	15.6	10.8	0.5	0.2
Range	26–49	32–38	6–30	5–18	0–2	—
B[4] Average	34.9	29.4	20.1	9.2	5.8	0.6
C[4] Average	37.3	33.9	19.8	8.9	1.1	0.1
Range	17–54	27–40	0–43	3–15	0–2.3	—
D[4] Average	23	37	27	10	3	—

[1] Modal analyses in volume percent.

[2] Plagioclase data:

	Average composition	Number of determinations	Range
A	An 9.7	29	An 4–13
B	An 12.8	6	An 10–16
C	An 6–10	340	An 0–15
D	—	—	An 12–15

[3] Garnet, apatite, zircon, chlorite, magnetite.

[4] Composition and number of samples:

A. Nonewaug Granite in Torrington quadrangle (9 samples)
B. Tyler Lake Granite in Torrington quadrangle (2 samples)
C. Nonewaug Granite in Woodbury quadrangle (22 samples); data from Gates and Scheerer (1963)
D. Tyler Lake Granite in West Torrington quadrangle (12 samples); data from Gates and Christensen (1965)

The discordant relationships between the Tyler Lake Granite and adjacent metasediments; the presence of inclusions of the Hartland Formation in the granite, particularly near the contact of the two formations at the eastern edge of Hillside Cemetery; and the absence of any indication of gradational contacts all point to an intrusive origin for the Tyler Lake Granite. Similar features were noted by Gates and

Christensen (1965) in the adjacent West Torrington quadrangle. The presence of gneissic as well as massive granite indicates that the intrusion of the Tyler Lake Granite was in part syntectonic.

THE NONEWAUG GRANITE

General statement

Widely scattered outcrops of fine-grained to pegmatitic granite are present in the central and southeastern portions of the Torrington quadrangle. This granite displays nearly all the distinctive features of the Nonewaug Granite body in the Woodbury quadrangle (Gates, 1954; Gates and Scheerer, 1963). Within the area in the Torrington quadrangle mapped as Nonewaug Granite outcrops are not abundant, but with minor exceptions they are consistently the same type of granite. Glacial boulders of Nonewaug Granite, absent in other parts of the quadrangle, are abundant within this area, in many places to the almost complete exclusion of other rock types.

The Nonewaug Granite forms two large irregularly shaped bodies separated only by a narrow belt of unit II schist. In several areas pegmatitic tongues projecting away from the main granite bodies can be traced into the surrounding metasediments with apparently conformable relationships. Several inclusions of country rock are found in the granite, and all occur along the projected strike of the same rock type outside the granite, suggesting that the emplacement of the granite was not a disruptive event. Contacts between the Nonewaug Granite and adjacent rocks are poorly exposed. Except for locally abundant pegmatite, the granite appears to have had little effect upon the surrounding rocks.

Three distinctive features characterize the Nonewaug Granite in the Woodbury quadrangle (Gates, 1954; Gates and Scheerer, 1963). They are textural layering in which the variation is from fine-grained to pegmatitic granite, the presence of coarse graphic granite crystals, and the occurrence of plumose muscovite in association with the graphic granite crystals. The first two of these features are abundant in all parts of the Nonewaug Granite in the Torrington quadrangle. Plumose muscovite was not observed in the field, but microscopic study reveals the presence in a few thin sections of small feathery aggregates of muscovite flakes that resemble closely the larger plumes found in the Woodbury quadrangle. The textural variations in the Nonewaug Granite in the Woodbury quadrangle led Gates (1954) to divide the unit into four groups: 1) layered granite, 2) patchy granite and pegmatite, 3) "plum-pudding" type, and 4) massive granite. All four types are found throughout the Nonewaug Granite in the Torrington quadrangle, although scarcity of outcrops and intermixing of the types prevents delineation of areas characterized by any one type.

Layering in the Nonewaug Granite results primarily from differences in grain size from fine-grained to pegmatitic, the composition of the layers remaining constant. Most layers are between 2 in. and 1 ft in thickness, although the range is from less than 1 in. to several feet. Coarser layers tend to be thicker. In some outcrops, the distribution of coarse graphic granite crystals defines a rather indistinct layering which both accompanies other types of textural layering and occurs in otherwise unlayered rocks. Where metasediments are present in the layered granite, their foliation and the layering are typically parallel.

Patchy granite with pegmatite is probably the most abundant type of Nonewaug Granite exposed in the Torrington quadrangle. This is similar to the layered granite in that the variation is one of grain size, from fine-grained to pegmatitic. The difference is that the areas of textural similarity are of irregular size, shape, and distribution, rather than being planar as in the layered granite.

The "plum-pudding" type (fig. 10) is characterized by coarse graphic granite crystals in a finer-grained matrix. Commonly these crystals are clustered into groupings several feet across, although scattered individual crystals are not rare. Most graphic crystals are about 2 to 4 in. in diameter with the largest one seen measuring 5 ft across. In this type of granite both the single graphic crystals and the clusters of crystals are randomly distributed. Because they are more resistant than the finer grained matrix, they form rounded projections that stud the weathered surface.

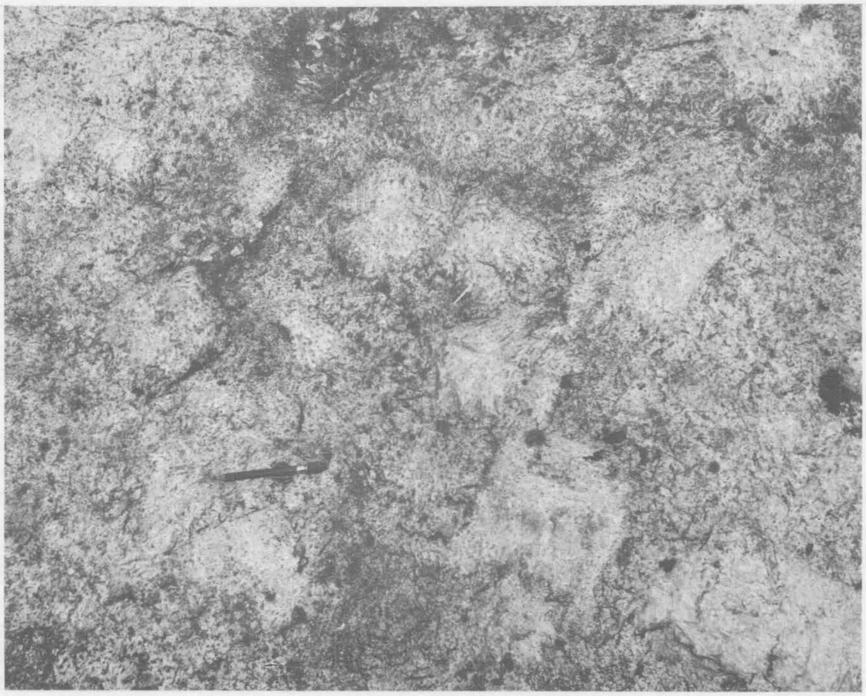

Fig. 10. "Plum-pudding" type of Nonewaug Granite with graphic feldspar crystals from Fairgrounds 1 mi. southeast of Harwinton. Scale given by 4.5-in. pencil.

Massive granite, which has a uniform texture throughout, is the least abundant type. It is found in only a few scattered outcrops and occurs in all grain sizes from fine to coarse.

Layered and "plum-pudding" types of Nonewaug Granite can be seen in scattered small outcrops in the Fairgrounds off Locust Street southeast of Harwinton. Patchy granite and pegmatite, and massive medium- to coarse-grained granite are present in several outcrops extending for about 800 ft north from the summit of Cotton Hill.

Petrography

It is beyond the scope of this report to discuss in detail all the petrographic and petrologic aspects of the Nonewaug Granite. Gates and Scheerer (1963) have described fully the petrology of the Nonewaug Granite in the Woodbury quadrangle. In this section, only those features that are characteristic of the granite and serve to distinguish it from other rock types will be discussed. All of these are treated more fully by Gates and Scheerer, and the reader wishing more details is referred to their paper.

The average of 9 modal analyses of the Nonewaug Granite is shown in table 9. Included for comparison is the modal composition of fine- to coarse-grained Nonewaug Granite in the Woodbury quadrangle (Gates and Scheerer, 1963). Plagioclase, microcline, quartz, and muscovite are the essential minerals, and biotite, garnet, apatite, zircon, and magnetite are present as accessories or in trace amounts. The texture is xenomorphic-granular.

Plagioclase occurs as twinned, anhedral grains of variable size, with twin lamellae bent in some samples. Twenty-nine determinations give a range of composition from An 4 to 13, with the average An 9. A few thin sections reveal the presence of two distinctly different kinds of plagioclase: small, clear grains with sharply defined multiple twinning; and coarse grains clouded with fine sericite and containing indistinct twin lamellae. The latter type, which also contains small microcline inclusions, all with common optical orientation, has been interpreted by Gates and Scheerer (1963) as being of replacement origin. The presence of plagioclase containing small microcline inclusions, many of which are optically continuous among themselves and with an adjacent microcline grain, is common even in rocks where it is not clear that there are two kinds of plagioclase. This type of texture has been interpreted in various ways, but Gates and Scheerer (1963) cite it as evidence indicating that microcline is replaced by plagioclase. Serrated borders between plagioclase and quartz can be found in most thin sections. Typically the serrations are controlled by alternate plagioclase twin lamellae in the same manner as described by Gates and Scheerer (1963), who attribute them to replacement of plagioclase by quartz. A very few serrated borders are also found between plagioclase and microcline. In most, the serration is related to plagioclase twinning, but in one instance microcline twinning appears to be the control.

Microcline occurs as irregular anhedral grains, quite variable in size within a single thin section. Its relationship with plagioclase is noted above. In a few places microcline-quartz borders are serrated, much like the plagioclase-quartz borders. Where not serrated, microcline borders tend to be straight or gently curving. In some thin sections coarse microcline grains are perthitic with plagioclase in irregular stringers or patches, many of which have twin lamellae parallel to those in the host microcline grain.

Quartz grains are typically rounded and strained, and like the other essential minerals, show a wide range of sizes within a single sample. Quartz also occurs in two types of intergrowths: 1) as myrmekitic patches in plagioclase which are restricted to contact zones between plagioclase and microcline; and 2) in vermicular intergrowths with muscovite where it is in contact with both microcline and plagioclase. The latter type has been interpreted by Gates and Scheerer (1963) as silica released in the replacement of feldspar by muscovite. Alternative explanations are possible for the myrmekitic intergrowths.

Muscovite is uniformly distributed and randomly oriented and ranges from aggregates of fine flakes to coarse blocky or elongate flakes. The tips of many flakes are frayed-looking, and the vermicular intergrowths noted above are common. In a few thin sections microscopic clusters of radiating fine muscovite flakes resemble the much larger plumes of muscovite developed in the Nonewaug Granite in the Woodbury quadrangle. The evidence is clearly inconclusive, but these may represent incipient development of the same type of plumose muscovite as that which concluded crystallization of the Nonewaug Granite in the Woodbury quadrangle.

The similarity of features in the Nonewaug Granite in both this and the Woodbury quadrangle suggests that both originated in the same way. The formation and emplacement of the Nonewaug Granite in the Woodbury area is thoroughly discussed by Gates and Scheerer (1963), and their major conclusions, that the granite is posttectonic and was intruded as a liquid or in a crystal mush state that crystalized in place accompanied by slight movement, are believed to be valid in the Torrington quadrangle as well.

ULTRABASIC ROCKS

At 11 places in the Torrington quadrangle (indicated on the geologic map by a special symbol) altered ultrabasic rocks crop out. All these are restricted either to unit II or to Nonewaug Granite along the projected strike of unit II, and all appear to be discontinuous lens-shaped bodies. The fact that several of the ultrabasic rocks occur in a linear pattern parallel to the strike of the adjacent rocks suggests that they may once have been continuous bodies, the separation resulting from deformation. The outcrop width of these rocks is consistently about 50 ft. The body immediately south of Lake Harwinton is well exposed and easily accessible.

The ultrabasic rocks, although soft where talc is abundant, are massive and coherent. Fresh surfaces are gray to black, weathering to various shades of buff or gray. All are altered, and varying proportions of serpentine, talc, and tremolite are the most abundant minerals. Talc occurs as fine to coarse flakes, either randomly oriented or in clusters of radiating flakes. Tremolite forms elongate needles as well as prismatic grains and typically occurs as radiating clusters up to 3 in. in diameter. Serpentine, mostly antigorite, is commonly present, and constitutes nearly all of some rocks. In the locality west of Woodchuck

Lane, bifurcating veinlets of chrysotile up to 1 mm thick cross an antigorite matrix. Isolated remnants of olivine, mostly replaced by serpentine, are present in one thin section. Fine- to coarse-grained carbonate is present in several samples. Opaque minerals include rounded grains of both magnetite and pyrite, and very tiny, dustlike particles of an unidentified opaque.

The ultrabasic rocks are intrusives, which because of their extensive alteration are considered to predate at least most of the deformation and metamorphism. Their distribution indicates that they were preferentially intruded into unit II, presumably along bedding planes of the original shale or, if metamorphism had begun, along foliation surfaces.

STRUCTURE

General statement

The overall structure of the Torrington quadrangle is that of a major anticline in the Gneiss Complex of the Berkshire Highlands in the northwestern corner with successively younger rocks exposed toward the southeastern corner, where a synclinal axis is believed to exist in unit III of the Hartland Formation. Map patterns of units where outcrop is abundant (such as southwest of Lake Harwinton), local reversals of dip, and the presence of minor folds in several units all indicate that smaller scale folds are present, although difficult to delineate. Some faulting is undoubtedly present, and there is evidence of at least a small fault along old Route 8 southeast of Goodwin Pond, but conclusive evidence of major faulting, such as that between the Hartland and Waramaug formations in the West Torrington quadrangle (Gates and Christensen, 1965), is lacking.

The Gneiss Complex of the Berkshire Highlands

There is abundant evidence to indicate that the Gneiss Complex in the Torrington and adjacent parts of the West Torrington quadrangles is a symmetrical anticline plunging south under the overlying Waramaug Formation. Along the eastern side of the Gneiss Complex, foliation and layering consistently dip steeply to the east and southeast, whereas along the western edge of the quadrangle and in the adjacent eastern side of the West Torrington quadrangle, the dip is equally consistently and nearly as steep to the west. The distribution of lithologic units is consistent with an anticlinal interpretation. The map pattern indicates that the fold axis trends about N 25° E. If the plunges of abundant and rather consistently oriented small folds with amplitudes and wavelengths of several feet reflect that of the major structure, the anticline plunges about 20° to the southwest.

The two small, isolated patches of the Gneiss Complex in the Torrington quadrangle (pl. 1) are brought to the surface along anticlinal crests. In the body at the eastern side of Torrington, excellent roadcuts along new Route 8 reveal an undulating, folded contact between the Gneiss Complex and the Waramaug Formation that is responsible for the unusual map pattern. The folds are of differing magnitudes with wavelengths from a few feet up to 75 ft, and all are overturned to the southeast. The overturned limbs of a few of these folds may be faulted. The Gneiss Complex exposed in the anticline west of West Hill Pond at the northern edge of the quadrangle can be traced northward into the Winsted quadrangle, but knowledge of its relationship to the main body of gneiss must await further mapping. Reconnaissance work suggests that the two bodies may merge to the north.

The Waramaug Formation

The absence of recognizable stratigraphic units in the Waramaug Formation prevents recognition of major structures. In many outcrops small folds a few feet in wavelength can be seen, suggesting the presence of larger folds. If the base of the Waramaug Formation is at least structurally conformable with the Gneiss Complex, as seems likely, a small syncline is present between the West Hill Pond tongue and the main mass of the Highlands Gneiss Complex. Local variations in the direction of dip, commonly found within the Waramaug Formation, further suggest the presence of folds of larger than a single outcrop magnitude.

The Hartland Formation

Structural information is more abundant in the Hartland Formation than in either the Highlands Gneiss Complex or the Waramaug Formation, for several reasons: 1) structures can be seen clearly in the interlayered sequences comprising units I and III; 2) the unit II schist is both well exposed and easily recognized where in contact with units I and III; 3) the formation is probably less complexly deformed than the Waramaug Formation (Gates and Bradley, 1952) and therefore also less deformed than the still older Gneiss Complex. The major structure in the Hartland Formation is a synclinal axis in unit III, but where exposure is good there is abundant evidence of several magnitudes of smaller scale folding.

The correlation of unit II and The Straits Schist, discussed above, requires the presence of a major syncline in unit III. The attitudes of units II, III, and The Straits Schist indicate it to be isoclinal and overturned to the southeast with the axial plane striking about N 40° E and dipping about 60° northwest.

Small folds with wavelength and amplitude ranging from a few inches to several feet are abundant throughout units I and III. Typically these minor folds have about the same orientation as that postulated for the major syncline. Minor folds are not obvious in the more homogeneous schist of unit II but are presumed to be present. Most of these folds are isoclinal and have a high amplitude/wavelength ratio. Their limbs and axial planes typically parallel the foliation and the axes plunge either to the southwest or northeast. In unit I on the slopes on either side of the Naugatuck River just north of East Litchfield, broad open folds with lower amplitude/wavelength ratios are commonly found. These give many outcrops a spindled appearance. In a few places, the open folds can be seen to have warped earlier isoclinal folds, indicating at least two stages of folding. A similar situation was found in unit I in the Waterbury quadrangle (Dewees, 1966; Gates and Martin, 1967).

Plunging folds of somewhat greater magnitude are indicated by local dip reversals and by the distribution of recognizable units. The evidence for these is particularly good southwest of Lake Harwinton, where units I and II have been folded into an anticline and syncline 1,000 to 2,000 ft across. The two anticlinal structures in the southwestern corner of the Thomaston quadrangle boundary are postulated on the basis of work by Cassie (1965, and oral communication) and reconnaissance by the writer in the Thomaston quadrangle, where the two anticlines can be traced in abundant outcrop northward to the Torrington quadrangle boundary. As the geologic map (pl. 1) shows, outcrops are lacking in the Torrington quadrangle.

METAMORPHISM

General Statement

The presence in all the metasedimentary formations of pelitic and basic rocks, both sensitive to their metamorphic environment, provides distinctive mineral assemblages that can readily be assigned to metamorphic facies. All the rocks in the Torrington quadrangle, with the exception of the scattered ultrabasic intrusives, are in the almandine-amphibolite facies of Turner and Verhoogen (1960) or, as more recently designated by Turner (1968), the amphibolite facies. In the Waramaug and Hartland formations assemblages typical of both the kyanite-almandine-muscovite and sillimanite-almandine-muscovite subfacies are found. The altered ultrabasic rocks consist primarily of talc, tremolite, and serpentine, and are assigned to the greenschist facies of Turner and Verhoogen (1960). Mild undulatory extinction in quartz is common in both the Gneiss Complex and the Waramaug Formation, but there is no other evidence of postmetamorphic deformation in any rocks. Thus at least the most recent peaks of metamorphism and deformation appear to have been about synchronous. There are no noticeable contact metamorphic effects that can be attributed to the intrusion of either the Tyler Lake or Nonewaug granites.

Biotite is present throughout the quadrangle, and staurolite, kyanite, and sillimanite, although widely distributed, are apparently largely controlled by the bulk chemical composition of the rocks. This, combined with the absence of any other pattern to their distribution, prevents drawing any major isograds. Retrograde metamorphism is indicated by ubiquitous chlorite formed at the expense of biotite and garnet and by widespread sericitization of plagioclase and, more locally, of kyanite.

The Gneiss Complex of the Berkshire Highlands

The most common assemblage in both the gray and pink granitic gneisses is *quartz-microcline-plagioclase-biotite-muscovite(-epidote),* an assemblage stable in both the greenschist and amphibolite facies. The fact that the plagioclase is oligoclase indicates that this assemblage belongs in the amphibolite facies rather than the greenschist facies, which is characterized by albite (Turner and Verhoogen, 1960).

The biotitic, quartz-feldspar gneiss contains the assemblage *quartz-plagioclase-microcline-biotite-muscovite-kyanite-sillimanite(-garnet),* indicative of the amphibolite facies. The coexistence of kyanite and sillimanite represents a metastable assemblage that is found not only in this rock but also in the Waramaug Formation and unit I of the Hartland Formation. Even where the two minerals are in contact there is no good evidence of reaction. An abnormal assemblage found in this rock is the association of microcline and kyanite. These minerals are generally not in contact, the microcline occurring in felsic streaks and the kyanite as small grains in biotitic layers.

The most common assemblage in the mafic gneiss, *hornblende-plagioclase-epidote-quartz-biotite(-garnet),* is characteristic of the amphibolite facies.

The Waramaug Formation

The Waramaug Formation consists essentially of quartz, plagioclase, mica, and garnet, with staurolite, kyanite, and sillimanite present where bulk composition permits. The most common assemblages are *quartz-muscovite-biotite-garnet-plagioclase-sillimanite(-kyanite)* in the pelitic rocks and *quartz-garnet-biotite-plagioclase(-muscovite)* in quartzo-feldspathic rocks. The widespread occurrence of sillimanite most properly places these rocks in the sillimanite-almandine-muscovite subfacies of the amphibolite facies, although a few samples studied lack sillimanite and contain assemblages typical of the kyanite-almandine-muscovite subfacies. Anomalous assemblages present are kyanite-sillimanite and staurolite-kyanite-sillimanite. The abundance of kyanite in the Waramaug Formation of the Torrington quadrangle is distinctly different from areas to the west, where kyanite is either absent or only locally present. It forms small, fresh-looking anhedral grains that show no evidence of reaction even where in contact with sillimanite needles. Staurolite was found in only one thin section, where it forms small subhedral grains associated with biotitic streaks, although it was noted at several localities in the field. Winkler (1965) suggests that under conditions of moderately high pressure (about 7 kilobars) staurolite is stable over a wider temperature range, perhaps accounting for its coexistence with sillimanite.

The Hartland Formation

UNIT I

The dominant assemblage in this unit is *quartz-garnet-muscovite-biotite-plagioclase.* In the more pelitic layers kyanite, or sillimanite, or both, are found and identify the rocks as belonging to the amphibolite facies. The tough, kyanitic variety of unit I mapped as a narrow discontinuous belt along the southeastern side of the unit contains the assemblage *quartz-garnet-muscovite-biotite-plagioclase-staurolite-kyanite-sillimanite.* The anomalous assemblages of kyanite-sillimanite and staurolite-kyanite-sillimanite are similar in microscopic appearance to those described above. Kyanite forms small grains generally in clusters, many of which also contain small euhedral staurolite crystals. Sillimanite is fibrolitic and in a few thin sections is associated with bleached biotite, which it appears to replace. Amphibolites in all units of the Hartland Formation have the assemblage *hornblende-plagioclase-quartz-(-biotite).* Clearly the rocks of unit I belong in the amphibolite facies, but assignment of subfacies is difficult. The kyanite-garnet association is characteristic of the kyanite-almandine-muscovite subfacies; sillimanite-garnet is characteristic of the sillimanite-almandine-muscovite subfacies. The assemblage garnet-staurolite-kyanite-sillimanite is anomalous. It may be that these rocks represent a transitional stage between the two subfacies. A more precise designation is not possible at this time.

UNIT II

The common assemblages in unit II are 1) *quartz-staurolite-garnet-muscovite-biotite-plagioclase,* and 2) *quartz-kyanite-staurolite-garnet-muscovite-biotite-plagioclase,* both assignable to the staurolite-almandine subfacies. Less abundant is the assemblage *quartz-kyanite-muscovite-biotite-garnet-plagioclase,* typical of the kyanite-almandine-muscovite subfacies. In most thin sections the origin of staurolite and kyanite is obscure; in a few they appear to have formed at the expense of mica.

UNIT III

The assemblages of unit III are very similar to those of unit II. Most common is *quartz-garnet-muscovite-biotite-plagioclase,* stable throughout the amphibolite facies. In pelitic rocks the assemblages are 1) *quartz-kyanite-staurolite-garnet-muscovite-biotite-plagioclase,* and 2) *quartz-kyanite-muscovite-biotite-garnet-plagioclase.* These rocks are thus placed in the staurolite-kyanite zone, although again subfacies designation is difficult.

ECONOMIC GEOLOGY

The only deposits presently being worked in the quadrangle are sand and gravel. The largest pits are located in the Naugatuck River valley south of Torrington, the Still River valley near Travis Pond, and along North Nepaug Brook just north of the swamp at Maple Hollow. Small abandoned quarries in the Highlands Gneiss about 400 ft south of bench mark 730 south of the Sons of Jacob Cemetery, and in the amphibolite lens 400 ft west of the right-angle bend of West Pearl Road, attest to the former limited use of these rocks for construction purposes. Kyanite, although locally reaching several inches in length, is not sufficiently concentrated to be of economic value. The pegmatites and altered ultrabasic bodies are too small to be of commercial use, although the latter may have been used by Indians. Local residents have shown the writer what appear to be bowl fragments, found in the Torrington quadrangle, which consist of soapstone similar to that in the altered ultrabasics.

APPLIED GEOLOGY

The only bedrock units in the Torrington quadrangle that directly affect the topography are the Gneiss Complex and unit II of the Hartland Formation. Not only does the Gneiss Complex underlie the highest portion of the quadrangle, but also the trend of most hills in the northwestern corner approximates the attitude of the Gneiss Complex. The strike of unit II is responsible for the northeastern elongation of hills in both the area between Yellow Mountain and Townline Road and in the extreme southwestern corner of the quadrangle. Throughout most of the rest of the map area the topographic grain shows a strong northwest-southeast orientation which is nearly perpendicular to the trend of the rock units but parallel to the direction of glacial ice movement. The Naugatuck River cuts directly across the rock units in the southern half of the quadrangle and was apparently superposed.

Outcrop is most abundant in the resistant Gneiss Complex and unit II and least abundant in areas underlain by the Waramaug Formation and the Nonewaug Granite. Land uses that require relative absence of bedrock, such as future landfill sites, would seem more feasible in areas underlain by the latter two units. It should be noted that even in areas of abundant glacial till, outcrops are commonly present at the summit of drumloidal hills, indicating that many are rock-cored. Therefore, it should be assumed that excavations in such areas might encounter bedrock at shallow depths unless drilling proves otherwise.

Although no studies of rock strength have been made, the physical characteristics of units II and III of the Hartland Formation suggest that problems could occur in excavations in these units. In several roadcuts in unit II, large slabs of rock have slid along the well-developed schistosity. The fissile, crumbly nature of unit III indicates that deep excavations or tunnels in this unit would probably need to be lined.

GEOLOGIC HISTORY

The main elements of geologic history as revealed by the rocks of the Torrington quadrangle consist of deposition, deformation, and metamorphism of a eugeosynclinal sequence of sedimentary and volcanic rocks and the intrusion of two large granitic bodies. A Precambrian age seems likely for the Berkshire Highlands Gneiss Complex because of its lithologic, structural, and stratigraphic similarity with the Housatonic Highlands Gneiss Complex, to which a Precambrian age can be assigned with some confidence (Gates, 1961). The interlayered acid and basic volcanics and subordinate shales that were originally deposited are typical of a eugeosynclinal environment. Impure sandstone and shale presumably were the original materials of the gneiss that now constitutes the Waramaug Formation. Scanty exposure of the contact in the Torrington quadrangle indicates that over a thickness of about 200 ft typical Waramaug Formation rock types are interlayered with rock types characteristic of the Gneiss Complex. Such apparent conformity could be explained not only as a continuous depositional sequence but also as either an unusual basal Waramaug section or as recrystallized, conformable fault slabs. The evidence available in the Torrington quadrangle is not sufficient to warrant a firm conclusion, but mapping presently in progress in the adjacent Winsted and Norfolk quadrangles may solve this problem. In neighboring areas, the Waramaug Formation has most recently been assigned a questionable Lower Paleozoic age (Gates, 1961; Gates and Christensen, 1965). The contact between the Waramaug Formation and the overlying Hartland Formation is marked in other areas by a pronounced structural break (Gates and Christensen, 1965). In the Torrington quadrangle this contact is not exposed, but the contrast in structural styles and textural features of the two formations seemingly indicates that the Waramaug Formation has been subjected to more periods of deformation than the Hartland Formation, substantiating the interpretation of a break between them. Although evidence from other quadrangles suggests that a fault contact might be more likely, the possibility of an unconformity must be considered an alternative because, unlike the situation in quadrangles to the west, the lowermost Hartland, unit I, directly overlies the Waramaug Formation in the Torrington quadrangle. The Hartland Formation is Lower Paleozoic and was deposited as an assemblage of clastic sediments, with subgraywacke and shale predominating. The abundance of graphite in the upper part suggests substantial organic activity.

All the sedimentary and volcanic rocks in the quadrangle were deformed during the Devonian Acadian Orogeny, which probably produced the isoclinal folding in the Hartland Formation. As indicated previously, the Waramaug Formation (and the underlying Gneiss Complex) bears evidence of prior deformation which could reasonably be assigned to the Taconic Orogeny. Accompanying the deformation was metamorphism, which produced mineral assemblages characteristic of the amphibolite facies. The intrusion of ultrabasic igneous rocks probably occurred in the early stages of deformation. The presence of foliation in the Tyler Lake Granite shows it to be at least partly synchronous with the deformation, and its cross-cutting relationship with the Hartland Formation dates it as post-unit I. The Nonewaug Granite is posttectonic.

From the Acadian Orogeny until the Pleistocene the rocks of the Torrington quadrangle were eroded. During the Pleistocene the area was buried under glacial ice and the drumloidal hills and polished outcrop surfaces were formed. With retreat of the ice, stratified sand and gravel was deposited along several major valleys.

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