STATE GEOLOGICAL AND
NATURAL HISTORY SURVEY
OF CONNECTICUT

THE BEDROCK GEOLOGY of the ELLINGTON QUADRANGLE

With Map

Open Map

By

GLENDON E. COLLINS

QUADRANGLE REPORT NO. 4

1954

State Geological and Natural History Survey of Connecticut

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INTRODUCTION

Location and physiographic province. The Ellington quadrangle is located in northeast central Connecticut, its northern border extending to within 2.5 miles of the Connecticut-Massachusetts line (Figure 1). Physiographically, the area is situated within the New England Upland section of the New England Province which has been described as an "upraised peneplain bearing occasional monadnocks and dissected by narrow valleys" (Fenneman, 1938, p. 358)*. The area studied, however, can be further subdivided into the eastern crystalline highlands and the Triassic lowlands.

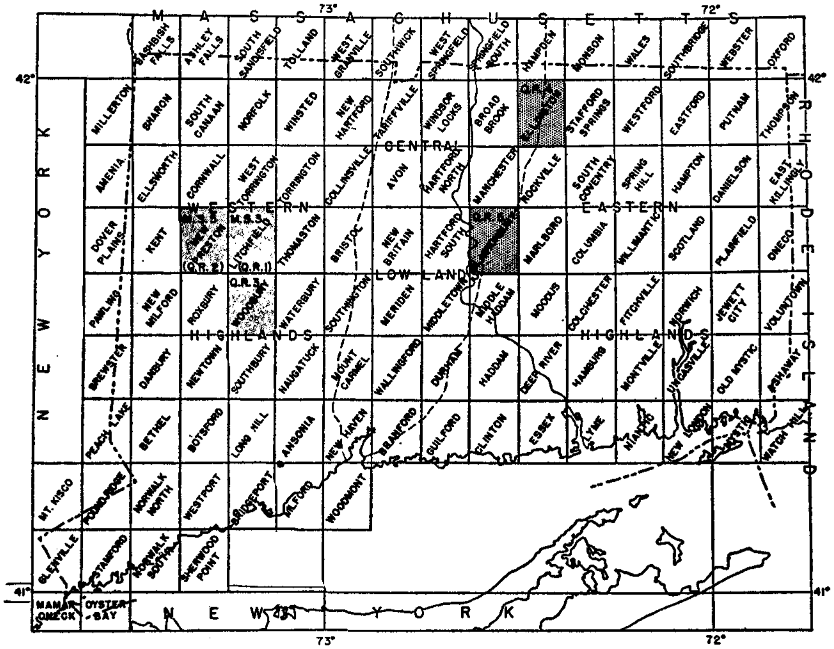

Figure 1: Index map of Connecticut, showing location of Ellington quadrangle

Geomorphology. The area mapped includes approximately 56 square miles of mature topography. The drainage system, while not complete, is well developed and reaches all but the remotest swampy depressions atop

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* References are listed at the end of this report.

some of the hills of the highlands. The most prominent topographic feature is the escarpment which marks the line of the great eastern border fault of the Triassic basin. This slope extends north-south through the center of the quadrangle and presents a sharp rise of from 30 to 50 feet between the Triassic lowlands and the eastern highlands. There is about 961 feet of relief within the area studied, the highest point being Bald Mountain with an elevation of 1121 feet. Much of this relief, however, is the result of the fault-line scarp; within either sector the differences in elevation amount to only 300 to 500 feet.

Pleistocene glaciation has played an important part in the molding of the present topography. Glacial ice moved southeast over the land surface; it piled drift against the northwest slopes of the rounded knobs of the uplands and the red rock ridges of the lowlands, and plucked away huge blocks of bedrock from the southeast slopes of the hills. The general direction of ice movements was from approximately 30° west of north, as measured from glacial striations on recently uncovered sandstone and soapstone, and as inferred from the direction of friction cracks on resistant pegmatite and Glastonbury gneiss and from the elongated shapes of hills in both sections of the area mapped.

The character of the drift varies from coarse boulder-filled till to well-sorted ice contact features, the till predominating in both physiographic sections. The thickness of cover varies, but at the center of Ellington and on the slope east of Shenipsit Lake wells have been drilled through 100 to 125 feet of unconsolidated material.

In the lowlands bordering the fault slope and along the valleys of Broad Brook and Scantic River, many flat-topped kame terraces, pock-marked by kettle holes, mark the positions where ice blocks became isolated and melted as the ice front retreated from southern New England. Ice contact deposits on a smaller scale are found in the depressions between Shenipsit and Crystal lakes, but the stratified drift is much less extensive in the upland section.

Outcrops of the crystalline rocks are abundant, but are usually restricted to the southeast slopes of the hills, illustrating the effect of glacial plucking. Glacial cover in the lowlands is much more complete and outcrops are at a minimum.

Method of mapping. The area was covered on foot by pace-and-compass methods. The 7½ minute topographic map of the United States Geological Survey was used as a base map. Outcrops were located and their position, rock type, and the dip and strike of schistosity or bedding were recorded on the field map. Contact lines were drawn in the field.

Previous investigations. No detailed work on the geology of the Ellington area has been done previously. Percival made a study of the entire state in the several years previous to 1842. His published report (1842) is noted for its exhaustive detail and lack of generalizations, but his state geologic map has yet to be surpassed in accuracy. Rice and Gregory in 1906 compiled a report of the geology of the state in which they named and described the formations, but did little to improve on the map by Percival. The glacial geology of the state by Flint was published in 1929 and records the general outline of the larger deposits of drift in the Ellington quadrangle. The most recent report is Foye's *Geology of Eastern Connecticut* which was compiled from the notes and maps of W. G. Foye and published by others in 1949, some years after the death of the author. Foye was more concerned with the southern portion of the state and incorporated unpublished work by Ford who mapped the area including the Ellington quadrangle. The resulting map, or at least the portion included within the Ellington quadrangle, is very general and is in part inaccurate.

Present work. The present investigation was begun as a Master's thesis study for Brown University, and the geology of the southern two-thirds of the quadrangle was mapped during the summer of 1952. Over 200 hand specimens were collected and studied. Mineral identification was made from crushed grains by refractive index liquids and from 33 thin sections of selected rocks. Volumetric analyses of these thin sections followed the point-counter method prescribed by Chayes (1949).

The field mapping of the northern third of the quadrangle was completed during June, 1953, in the employment of the Connecticut Geological and Natural History Survey.

Acknowledgements. The writer particularly wishes to acknowledge the aid and advice given him by Dr. Alonzo W. Quinn of Brown University during the field and laboratory studies and in the preparation of the manuscript.

To Dr. J. W. Peoples of Wesleyan University and Dr. Janet M. Aitken of the University of Connecticut the writer wishes to express thanks for their helpful suggestions and for supplying valuable information concerning the results of present and past work done in the general area.

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GEOLOGIC FORMATIONS

Eight rock units are described from the Ellington quadrangle; six are major formations and two, the pegmatites and the diabase, are minor intrusives. From oldest to youngest, the units are: The Monson gneiss, the Bolton garnet-muscovite schist, the Glastonbury gneiss, the amphibolites, the Amherst muscovite schist, the pegmatites, the Triassic sedimentary red beds, and the diabase dike.

THE MONSON GNEISS

The Monson gneiss outcrops in the southeast corner of the quadrangle and underlies only a small portion of the area mapped. It has been traced by previous workers as a narrow belt that extends southward into southern Connecticut and northward into Massachusetts. Foye considered this gneiss as equivalent to the Glastonbury gneiss, but Percival as early as 1842 had distinguished between the two formations on the basis of arrangement of mica seams. Percival states that the Granitic gneiss (Glastonbury gneiss) "generally presents more or less detached flakes or patches of dark mica . . .," while in the Monson, "the mica seams are generally uniform, and more or less marked by small, round sub-porphyritic points of feldspar" (1842, p. 222).

The Monson gneiss is a light gray, foliated rock composed predominantly of oligoclase, quartz, and biotite. Magnetite and garnet are the chief accessory minerals. Previous workers, Percival, and Rice and Gregory, have reported lenses of hornblende schist scattered throughout the gneiss; and at the western border of the Monson, at its contact with the hornblende schist, the dark mineral of the gneiss is chiefly hornblende. Epidote and chlorite, the latter being an alteration product of the hornblende and biotite, are also common in this border phase of the Monson.

No detailed petrographic study was made of the Monson gneiss and only a small area of this formation was covered in the field. However, the similarity between the Monson and the Glastonbury gneisses in mineralogy and contact relationships, and in the presence of lenses of hornblende schist, has led the writer to believe that both gneisses had similar origins. Both are assumed to have resulted from the metamorphism of predominantly arenaceous sediments. The lenses of hornblende schist probably represent the altered remains of interbeds of intermediate to basic volcanics. A more complete discussion of these processes is given after the Glastonbury gneiss and the hornblende schists have been discussed.

THE BOLTON GARNET-MUSCOVITE SCHIST

General relations and correlations. The Bolton garnet-muscovite schist occupies a belt averaging about a mile and a half in width and trending through the southeast corner of the quadrangle. This narrow belt of schist has been traced by Percival from East Hampton in south-central Connecticut northward to a point northwest of Monson, Massachusetts. Throughout its length, the Bolton is marked by a high ridge or series of ridges crossed by only a few major streams (Rice and Gregory, 1906, p. 120).

The Bolton is a muscovite schist containing abundant garnet and variable amounts of staurolite. It grades westward into the Glastonbury gneiss. The contact between the two formations is exposed only at Newell Hill, being covered elsewhere by the thick deposit of till piled up by the glacier as it overrode the Bolton ridges that must have lain almost directly across the direction of ice motion.

Quartzite layers of considerable extent form interbeds within the schist and along its eastern border. These quartzose beds range from a quartz schist to a quartz-mica gneiss, and are more resistant to erosion than is the garnet-muscovite schist. This is well illustrated by the line of hills southwest of Crystal Lake that are held up by a thick layer of quartzite. This bed pinches out southward and does not outcrop south of North Cemetery. It is composed predominantly of quartz with scattered seams of muscovite which give the rock a silvery appearance.

The contact of this quartzite with the schist is in some places sharp and in others gradational. Where sharp, the base of the quartzite is commonly slickensided, as a result of slipping between it and the schist that occurred during the tilting and metamorphism of the strata. The upper contact is drift-covered and its position can only be inferred. The quartzite layer, however, cannot be much thicker than 300 feet.

The eastern border of the Bolton in the Ellington quadrangle is characterized by the interlaying of two more quartzose layers of variable composition with the schist, and by the presence of dark amphibolitic schist. The extent of the border quartzites cannot be determined from the work done. They have been extended by Foye north and south for some distance. He separates them as a distinct formation and considers them as part of his Hebron or Paxton quartz schist. It seems to the writer, however, that because of the interbedded, gradational nature of the quartzite zone, it is best to consider it as a member of the Bolton schist.

The hornblende schist was first mapped by Percival as a north-south belt of "Hornblende rock" east of the Bolton formation. It probably represents the metamorphosed remains of basic volcanics that were extruded before the deposition of the Bolton sediments.

Petrography. In the Ellington quadrangle the Bolton schist is usually a silvery or lead-gray well-foliated schist consisting mainly of quartz and muscovite with variable amounts of biotite, garnet, staurolite, graphite, and magnetite. The average grain-size of the schist is 0.5 mm. for the matrix minerals and from 1 to 5 cm. for the larger garnet and staurolite crystals. Interbeds of quartzite are important variations of the schist, but are too numerous and thin to be considered as separate formations. Thin beds of impure marble several feet in thickness occur in the schist in the type locality of the Bolton several miles south in the Rockville quadrangle, but none was found in the Ellington quadrangle.

Quartz is the most abundant mineral, composing on the average 40-50 percent of the rock. Its presence is usually disguised in the outcrop because it occurs in layers of tiny grains between the muscovite seams. These seams usually coat the exposed surface and give a shiny appearance to the rock which seems at a glance to be composed almost entirely of muscovite. Vein quartz in large pods several feet across occurs in the schist and was probably emplaced during folding.

Muscovite composes about 25 percent of the schist, but for reasons stated above is the most distinctive mineral. Biotite is the minor mica, composing from 5 to 10 percent of the rock, and is scattered in thick flakes throughout the muscovite layers. Some of the biotite contains tiny grains of zircon with pleochroic halos. The micas usually wrap around the garnet, staurolite, and large quartz grains. Disseminated throughout the muscovite flakes are tiny specks of graphite which is the main opaque mineral of the schist. It also occurs in less numerous larger masses and makes up between 5 and 10 percent of the rock.

Garnet and staurolite are the two most obvious accessory minerals. Together they make up on the average 10 percent of the schist, the garnet being the more abundant. The garnets are manganese garnets with n ranging from 1.806 to 1.815 (± .002). They are rather large averaging 2 to 3 mm. in diameter, and vary in color from light pink to deep red. Many contain inclusions of quartz. The garnets are usually restricted to the schistose layers and are rare in the quartzites.

Staurolite is locally more abundant than garnet, but in some of the schist it is absent altogether. It occurs in large dark brown prisms that show yellowish-brown pleochroism and contain many quartz inclusions. Rudimentary staurolite crosses may be seen in the hand specimen. The larger grains of staurolite attain lengths of 5 cm. and commonly enclose garnets within them. The presence of staurolite in a rock has been considered proof that the rock is of sedimentary origin (Rogers and Kerr, 1942, p. 328).

Quartz makes up 85 to 90 percent of the quartzite layer within the central portion of the Bolton schist. The grains, which average 0.4 mm. in length, show strained extinction and an interlocking texture. The muscovite is well foliated and is present in amounts up to 11 percent. It occurs either as tiny flakes about 0.1 mm. in length scattered throughout the quartzite or as larger plates along slippage planes in the rock. The quartz along these slippage planes is fine-grained and has a minutely interlocking texture. Kyanite is a minor mineral along these zones of slippage and occurs in prisms about 0.5 cm. long. These prisms are fairly well oriented with the direction of movement.

The border quartzites vary in appearance from silvery quartz schist to gray, almost gneissic rocks. They contain variable amounts of quartz and muscovite and minor amounts of garnet, staurolite, kyanite, magnetite, chlorite and biotite. Southeast of Poehnarts Pond and atop hill 954 the quartzite is spotted with elongated masses of milky quartz which represent pebbles stretched during metamorphism. The ratio of length to width of the stretched pebbles is about 3:1, some being 3 or 4 inches long.

In thin section most of the quartz shows strained extinction and many grains have muscovite wrapped roughly around them. This shows up especially well in the stretched pebbles. These pebbles are composed of several fractured grains of quartz with the muscovite restricted to a coat around the edge. Foliation is fairly well developed in the muscovite and a little biotite is found, usually within masses of muscovite. Sheared masses of chlorite are common at the border of the quartzite, near the contact with the metadiorite.

Garnet and staurolite are present locally; both contain many quartz inclusions and the staurolite has a distinct yellowish-brown pleochroism.

Kyanite in tiny, light yellow needles is locally abundant in the quartzite near its contact with the hornblende schist at the eastern border of the quadrangle.

Origin. There is little doubt that the Bolton schist resulted from the metamorphism of stratified shale, sandstone, and conglomerate with a few thin lenses of limestone. The alternating aluminous and siliceous beds, and the presence of staurolite and stretched pebbles, are all good indications of sedimentary origin for this series.

There is no evidence to indicate any overturning of strata. The quartzose layers vary in composition, thickness, and extent and do not represent the repetition of a single bed by isoclinal folding. The Bolton schist dips under the Glastonbury gneiss and is the older formation.

THE GLASTONBURY GNEISS

General relations and correlations. The Glastonbury gneiss occupies a belt that runs through the eastern half of the quadrangle, trending in a general north-northeast direction. It is bounded on the east by the Bolton garnet-muscovite schist. Its western boundary is irregular and is characterized by the interfingering of the gneiss with an amphibolitic rock, and the occurrence of an amphibolitic variety of the gneiss. The gneiss has been traced southward as far as Middletown by previous workers (Percival, 1842; Rice and Gregory, 1906; Foye, 1949). Northward it widens to the extent that it underlies most of the crystalline half of the quadrangle. Emerson (1917) has extended this belt of gneiss northward into Massachusetts as far as Palmer.

The Glastonbury gneiss has also been named the Monson or Haddam orthogneiss by Foye and the Monson granodiorite by Emerson. However, Rice and Gregory separated this body from the belt of Monson gneiss east of the Bolton formation and their nomenclature is used in this paper.

The Glastonbury gneiss throughout the area is a foliated, light gray rock composed chiefly of quartz, plagioclase, and biotite. It varies so greatly in texture and composition, that previous writers (Percival, 1842; Rice and Gregory, 1906) split the formation into two main subdivisions, a western portion generally darker in color and containing high amounts of biotite and hornblende, and an eastern belt commonly narrower and more granitic in appearance. The western belt is also characterized by a fairly high epidote content. These two general rock types blend into each other and no clear-cut boundary between the two can be drawn.

The rock in all outcrops is foliated; the strike of the foliation trends from north to nearly east and dips at angles ranging from 17° to 52° west. However, the strikes and dips of the gneiss average near N 250° E and 30° NW.

In the area west of Shenipsit Lake, the rock is highly biotitic, well foliated, dark, and characterized by an augen-like structure of the quartz and feldspar. Northward to Soapstone Mountain the rock becomes less biotitic, is lighter in color, and is less well foliated. Along the western border, the dark mineral is commonly hornblende. Toward the eastern border the rock is more fine-grained, more banded, and contains more muscovite. Near the pegmatites chlorite and tourmaline are abundant.

The Glastonbury gneiss grades eastward into the Bolton garnet-muscovite schist. The contact is exposed only in the vicinity of Newell Hill where it is possible to trace the gradation between the two formations. The grain-size of the gneiss decreases toward the contact, and the rock takes on a shiny appearance resulting from the muscovite which takes the place of biotite as the main mica. The rock becomes more banded and interbeds of crinkled muscovite schist quite like the Bolton occur in the gneiss paralleling its foliation. These probably represent interbeds of the same shaly material that produced the true Bolton formation. Folding on a minor scale has occurred in this border zone of the Glastonbury.

Discontinuous interbeds of hornblende schist, varying in thickness but rarely exceeding 10 feet, trace the border of the Glastonbury. These interbedded amphibolites are tentatively correlated with Emerson's Erving hornblende schist (1917, p. 73) and are considered to be of volcanic origin.

No sharp break between the Glastonbury and the Bolton can be drawn, but the border gneisses rich in mica and quartz and low in feldspar are included within the Bolton formation.

The western contact of the Glastonbury gneiss with the hornblende schist is also gradational but it is a gradation that is traced along the strike of the foliation and not across it as is the case at the eastern border of the gneiss. The gneiss interfingers with the hornblende schist and the foliation of the schist can be traced across the contact and into the gneiss. The foliation of the gneiss is less well developed, but the many inclusions of hornblende schist within the gneiss line up with this foliation. Many of these inclusions extend as long tongues into the gneiss, which has partially digested them. Other fingers of the gneiss have invaded the schist and commonly cut across its foliation, but the foliation in these fingers of gneiss is everywhere aligned with that of the schist. This is especially well developed in the outcrops near the head of the north branch of Hydes Brook. It seems to be a case of the interfingering of rock types with the partial digestion of the hornblende schist by the gneiss.

This digestion on a larger scale has resulted in large areas of hornblende gneiss in which hornblende rather than biotite is the main dark mineral. This gneiss so resembles the rest of the Glastonbury in appearance and origin that it is mapped as a variation of the Glastonbury gneiss.

Petrography. The Glastonbury gneiss is composed chiefly of quartz, plagioclase, and biotite, with varying amounts of epidote, hornblende, garnet, magnetite, muscovite, and microcline. Pyrite, apatite, chlorite, tourmaline, ilmenite, leucoxene, zircon, and allanite are present as minor accessories. The grain size ranges from less than 0.1 mm. to 2-3 mm., the average being about 0.5 mm. Porphyroblasts of microcline 4.5 mm. by 6 mm. are present in one of the varieties of the gneiss.

No one volumetric analysis of the Glastonbury gneiss will give a true representation of its mineral composition because of the wide variability within the formation. Most of the great variation, however, occurs in the minor minerals and accessories, so the problem of combining the whole mass together as one formation is not as great as one might at first believe.

The following table gives the ranges of the main constituents of the gneiss as derived from volumetric analyses of five thin sections. An average content is given if the mineral was found in all the sections studied.

MINERAL	LOW	TO HIGH	AVERAGE
Plagioclase	12%	41%	31%
Microcline	0	16	..
Quartz	41	58	51
Biotite	4	23	9
Hornblende	0	10	..
Muscovite	0	4	..
Epidote	0	11	..

Accessory minerals rarely compose more than 2 percent of the rock and include magnetite, garnet, chlorite, tourmaline, pyrite, allanite, apatite, ilmenite, leucoxene, and zircon.

The gneiss, then, although superficially resembling granitic material in appearance, comes closer to having the composition of a quartz granodiorite or a quartz tonalite (Johannsen's classification, 1931).

The plagioclase throughout the gneiss is oligoclase, An 25-29. It usually occurs in fairly large, cream-colored or pinkish grains that commonly contain inclusions of quartz and biotite. A majority of the grains are untwinned, but many show fairly fine albite twinning and a few show pericline twinning. Faint signs of zoning were seen in a few thin sections. The plagioclase in all slides was the more abundant feldspar. Potash feldspar other than microcline and a few probable perthitic intergrowths was not identified. Minor amounts of microcline occur as small scattered grains in some varieties of the gneiss. In those rocks having greater quantities, the microcline occurs in large porphyroblasts or "pods." The microcline "pod" is usually one large twinned grain surrounded by tiny grains of quartz and quartz-feldspar intergrowths, giving an almost crushed or granulated border to the microcline mass. Biotite and muscovite commonly wrap around the porphyroblasts.

Quartz in all the thin sections studied was the most abundant mineral. It occurs as interlocking grains, as large masses of small, sutured grains, as isolated small grains, and as inclusions within feldspar, garnet, and tourmaline. It commonly is found in discontinuous layers or masses parallel to the foliation of the rock. These masses generally show greater strain than do many of the single quartz grains. Quartz and oligoclase are usually confined to the light layers between the darker, foliated biotite bands. These darker layers wrap around quartz-feldspar masses, producing an augen structure in some varieties of the gneiss. Some of the augen are large grains of quartz, but usually they are masses of small quartz and oligoclase grains. In some outcrops of the weathered rock, the quartz takes on a yellowish stain and is easily distinguished from the cream-colored feldspar.

Biotite shows the greatest variation in texture and abundance throughout the gneiss. In the southern portion of the area, the biotite is most abundant, being in large, platy, well-foliated flakes that wrap around the augen-like masses of quartz and feldspar. In some cases, however, the foliation extends into the augen with the biotite as inclusions within the lighter mass. Northward within the central portion of the gneiss the biotite is less abundant and less well foliated. The flakes become finer toward the eastern border of the gneiss, and muscovite becomes the dominant mica. Near the western border of the gneiss, a few allanite grains with pleochroic halos are included with the biotite. Throughout the gneiss the biotite is pleochroic from brown to light brown.

Epidote is a characteristic mineral of the western half of the gneiss. It occurs as small, rounded or elongated, greenish grains ($n=1.743 \pm .002$), and is found in both the dark and the light bands of the gneiss. In the southwestern portion of the formation it is an important constituent of the rock, but northward it is scarcer, occurring only in scattered grains and in several epidosite (quartz-epidote) veins that generally follow the foliation of the gneiss. Eastward along the strike the epidote gradually disappears, none being found east of Shenipsit Lake. No sharp line can be drawn, however, between the epidote facies and the non-epidote rock to the east.

Muscovite is present in only minor amounts scattered throughout the rock. Near the eastern border of the gneiss where it grades into the Bolton garnet-muscovite schist, it is the important mica. Usually in the gneiss it is less well foliated than the biotite and in many areas is lacking altogether.

Garnet and magnetite are ubiquitous accessory minerals. The reddish almandine-spessartite garnet ($n=1.785 \pm .002$) grains vary somewhat in size, but all are relatively small. Nearly all contain quartz inclusions. The magnetite occurs in tiny irregular grains and octahedrons and varies in abundance, some zones of the rock having more and larger grains than others.

Ilmenite and pyrite are minor opaque accessories that attain local abundance. Both are in small grains and some of the ilmenite has altered to leucoxene.

Apatite occurs in tiny prisms scattered throughout the gneiss and is more common in the western half of the formation. Chlorite and tourmaline are found in the gneiss near the borders of the intruded pegmatites and are of secondary origin. The chlorite occurs in large platy masses several inches across and probably resulted from the alteration of biotite by the hydrothermal activity of the pegmatites. This same activity also introduced the tourmaline.

In the hornblende gneiss, the western border variety of the Glastonbury, plagioclase is the most abundant mineral, averaging about 45 to 50 percent of the rock with quartz making up from 25 to 35 percent. Hornblende is the main dark mineral and composes from 15 to 20 percent of the gneiss. Epidote, rutile, magnetite, sphene, apatite, garnet, biotite, and chlorite are present as accessory minerals.

The plagioclase is slightly more calcic than that of the rest of the Glastonbury, ranging from oligoclase, An 29, to andesine, An 37. The quartz is in lenses or irregular grains that appear to have been introduced into the rock.

Hornblende occurs in dark green to black needles that are rather strongly pleochroic with colors of bluish green on Z, light brown on X, and dark brownish green on Y. The birefringence varies from 0.020 to 0.026 and the n ranges from 1.660 to 1.670 (± .002). The 2V falls between 60° and 70°. The hornblende prisms vary in length, but average 0.75 mm. long.

Amphibolitic interbeds occur along the eastern border of the gneiss. Hornblende and plagioclase in approximately equal proportions make up the bulk of these beds. Small green grains of epidote are disseminated through the rock and minor amounts of quartz are present. Locally nodules and patches of calcite are numerous. The plagioclase is calcic oligoclase in small untwinned and unzoned grains. Hornblende in small needles has a 2V of 60°, n=1.672 (± .002), and it has a bluish green color on Z. Calcite and epidote (n=1.745 ± .002) are associated in nodules. Some zones are rich in magnetite and spessartite garnet, and weathering of the latter has coated the rock with manganese oxide.

Origin. Previous writers (Rice and Gregory, 1906; Foye, 1949) have attributed the Glastonbury gneiss to an igneous or probable igneous origin. The writer, however, believes that metamorphism and probably the addition of material to original sedimentary beds and to bordering amphibolites better accounts for the origin of the portion of the Glastonbury gneiss here studied. Metamorphism and later metasomatism have played major roles in this transformation. A much more complete account of the origin of the Glastonbury is given after these processes and the amphibolites themselves have been discussed (pp. 37-40). However, the following evidence briefly summarized from the study of the gneiss itself strongly supports a metasomatic origin for the Glastonbury formation.

The high content of quartz (about 50 percent) points toward either a high original quartz content or the metasomatic introduction of the mineral. The extreme variability in content of such minerals as biotite, epidote, and hornblende, the greater abundance of magnetite and garnet in some broad zones of the gneiss, and the large areas of hornblende gneiss can be better explained by the metamorphism and later metasomatism of variable rock types than by the intrusion of a granodioritic magma. The interbeds of muscovite schist and amphibolite and the banded gneiss along the gradational eastern border of the Glastonbury probably represent an original sedimentary series. The regional shape of the gneiss in a long, relatively narrow belt that trends parallel to the Bolton, Hebron, and Amherst of known sedimentary origin further suggests its derivation from a sedimentary series of beds. Finally, the alignment of the inclusions of hornblende schist with the regional foliation along the western border of the gneiss strongly suggests that the acidic material did not invade as a liquid magma.

In light of the above evidence, the writer believes that the gneiss resulted from the invasion of metasediments and metagabbros by acidic solutions of magmatic origin. The resulting metasomatism converted both the original sedimentary beds and the borders of the adjacent basic intrusives into the highly variable Glastonbury gneiss.

AMPHIBOLITES

General statement. The amphibolites of the Ellington area have been divided into two groups for the purpose of this report. One, the hornblende schist, includes the almost completely recrystallized rocks along and within the western border of the Glastonbury gneiss and along the eastern border of the Bolton schist. The other, the metagabbro, includes the partially recrystallized smaller, scattered bodies that still retain an unaltered core. The first are assumed to have originated as intermediate to basic volcanics, the second, as basic magmas. The intermediate, zoned feldspars of the hornblende schist indicate that the original material must have been dioritic in composition. The more calcic feldspars of the intrusive bodies point towards a more gabbroic composition for the original magma.

HORNBLENDE SCHIST

General relations and correlations. A discontinuous belt of hornblendic rock occurs along the western border of the Glastonbury gneiss. Of the previous workers in Connecticut, only Percival attempted to set off this rock as a separate formation in published reports. His map shows this "micaceous and chloritic formation," as he called it, occurring as a series of discontinuous lenses or bands bordering the fault line. He also mapped a continuous band of hornblendic rock along the east border of the Bolton schist. The hornblende schist in the southeast corner of the quadrangle is probably part of this subdivision of the Bolton. Later writers, Rice and Gregory, included the hornblende schist within the Glastonbury gneiss as a darker portion of that formation. The two, however, are unrelated in origin and appearance and should be separated as distinct units. Foye's map, compiled by others after his death, shows a tongue of Brimfield (or Bolton) schist bordering the fault and extending into the area from the north. Foye, however, included the hornblende schist with what the writer has mapped as the Amherst schist, and considered these schists as equivalent to the Bolton (J. W. Peoples, personal communication).

The hornblende schist may best be correlated with Emerson's Dana diorite which he mapped as a selvage band bordering the gneiss further north of Massachusetts. His suggested origin of the mass, as being a dark mineral concentrate which separated by some process of magmatic differentiation from the gneiss, is not acceptable for the rock of the Ellington area, but the mineral content and general relationships of the Dana diorite and this hornblendic rock are much the same (Emerson, 1917, p. 244). The author, however, will use the term hornblende schist when discussing this formation.

The hornblendic rock is of two main types. It may occur as either 1) dark, well-foliated and lineated hornblende schist or 2) light-colored hornblende gneiss which in appearance and composition is more related to the Glastonbury gneiss than to the hornblende schist and has been already described as a variation of that formation.

The schist is composed mainly of hornblende and plagioclase with minor epidote, rutile, quartz, pyrite, magnetite, and staurolite. It consists of either alternating dark and light layers, or of a dark hornblende matrix with patches of white feldspar scattered through it. The grains vary in length from 0.1 mm. for some of the tiny accessory minerals to over 1 cm. for the larger hornblende needles, but the average cross section of the grains in thin section is about 0.3 to 0.4 mm. across. Within the hornblende schist there are areas of dark-green, non-foliated rock which still retains its igneous texture. These unrecrystallized portions of the schist resemble in appearance the central portions of the metagabbros and should perhaps be correlated with these intrusive bodies. This massive rock, however, grades outward into the black hornblende schist and no sharp contact between the two rock types can be drawn. A second variation of the schist occurs as interbeds of hornblende schist that are found within adjacent Glastonbury gneiss.

Most of the rock is well foliated; the foliation dips generally west from 30° to 85° with the steepest dips near the Triassic fault. The northeast strike of the foliation extends across the contact and into the Glastonbury gneiss to the east. No large-scale folding was observed within the formation, but there are many crinkles and folds whose axes strike on the average N 50° W and plunge 30° NW.

A few small veins and lenses of pegmatite intrude the hornblende schist, the largest masses outcropping in the vicinity of the Somers—Ellington town line. Quartz veins and epidote veins, the latter usually being thin but numerous, cross-cut the foliation of the schist near the fault and were probably introduced during the faulting. Near the border of the formation green layers and pods of epidote follow the foliation of the schist. These, however, probably represent material concentrated during metamorphism and are not of later intrusive origin.

Petrography. The hornblende schist is composed chiefly of hornblende and plagioclase. The hornblende content averages 50 percent. The plagioclase makes up about 40 percent of the rock, the remaining 10 percent including varying amounts of epidote and quartz with minor rutile, magnetite, pyrite, chlorite, ilmenite, and staurolite.

The hornblende occurs as dark green to black needles that average 3 to 4 mm. in length. The mineral is rather strongly pleochroic with colors of bluish green on Z, light brown on X, and dark brownish green on Y. The birefringence varies from 0.020 to 0.026, the n ranges from 1.670 ($\pm$ .002), $y=b$, $Z \wedge C = 24°$. The 2V falls between 60° and 70°. Small grains of quartz and magnetite occur as inclusions within the hornblende as do a few grains of allanite (?) with pleochroic haloes. Minor amounts of chlorite are associated with the hornblende and are probably alteration products.

The feldspar varies over the range of the intermediate plagioclase, in some specimens being as high as labradorite, An 60, and in others as low as andesine, An 46. The majority of the plagioclase grains are zoned, with a more calcic interior. Many grains are twinned, both coarse and fine albite twinning being the predominant type; a few grains showed pericline twinning. Epidote, quartz, and rutile are found as inclusions within the plagioclase. The size of the plagioclase grains varies, but averages 0.3 mm. in width.

Epidote is a characteristic accessory mineral. It occurs in small rounded or elongated grains rarely over 0.2 mm. in length. This light-green mineral, $n=1.743$ (± .002), has four types of occurrences in the hornblende schist. First, it is scattered throughout the rock, in many cases being included within the hornblende and plagioclase. Secondly, it commonly is concentrated in greenish layers or nodules which generally lie parallel to the foliation of the schist, but which in places cut across it. These epidote layers and nodules attain a thickness of several inches and are composed either of epidote alone or of epidote interlayered with quartz. Thirdly, it is in tiny veinlets that cut across the foliation in an irregular or rectangular pattern. The epidote of these veins is much later, probably having been introduced during the faulting of Triassic time. A fourth type of occurrence is found in the metadiorite that intrudes the quartzite at the eastern border of the Bolton schist. Here, the epidote is not so disseminated, but occurs in concentrations of highly epidotic rock. Some of the grains grew in cavities and exhibit good crystal form, the crystals being about 1 cm. in length.

Quartz is generally absent from the main mass of the schist, but along the contacts with the gneiss, along the fault zone, and in the hornblende-schist interbeds in the gneiss, the quartz is quite abundant. Most of it is probably due to the later introduction. It occurs in both large elongated lenses and in small scattered grains. The larger masses are composed of several grains of quartz having sutured, interlocking contacts with each other; all the quartz shows effects of strain. Quartz is also found as the matrix mineral in some of the epidote layers.

Rutile is present in the schist in variable amounts up to 1.5 percent. It occurs as tiny reddish-brown grains associated with the dark minerals, in many cases being included within the hornblende. Small elongated grains of ilmenite are associated with or included within the hornblende and epidote. Magnetite in large masses is found within the epidote layers. Pyrite is locally quite abundant; it is usually associated with lenses or pods of quartz and appears to have been introduced into the rock by later solutions.

Staurolite is found only in small amounts near some of the epidote layers. It occurs in irregular grains and prisms containing quartz inclusions and exhibiting a brownish pleochroism.

Origin. A number of facts point toward an igneous origin for the hornblende schist formation. Remnants having an original dioritic texture and the abundance of zoning of the feldspars are two of the strongest evidences. Northeast of the head of Hydes Brook, and southeast of Gillette Brook at the base of the west slope of Bald Mountain, massive greenish diorite grades outward into the typical hornblende schist. This, of course, does not necessarily prove the igneous origin of the remainder of the schist, but the marked similarity of mineral content throughout the schist, and the ubiquitous zoning of the intermediate plagioclase grains, strongly support their correlation. The widespread occurrence of rutile in minor amounts also suggests an igneous origin for the mass.

Negative evidence is supplied by the lack of calcite, diopside, original quartz, and garnet: all minerals that might be expected if the hornblende schist had resulted from the metamorphism of a limy deposit.

The writer believes that the bodies of hornblende schist along the western border of the Glastonbury gneiss resulted from the metamorphism and metasomatism of a series of tuffs and lava flows that were laid down upon the original sediments of the Glastonbury. At the contact of the two formations the interbedding of the volcanics and the land-derived sediments resulted in an alternation of rock types. Tough quartzose beds can be found within the schist near its border with the gneiss, and large lenses of hornblende schist occur in the uppermost portion of the Glastonbury. These contact relationships are best illustrated in the outcrops on the southern flanks of Bald Mountain.

Staurolite was found within the hornblende schist and not far above its lower contact. Rogers and Kerr (1942, p. 328) state that the presence of staurolite proves that the original rock was sedimentary, and it here probably resulted from the metamorphism of aluminous, sedimentary material included as an interbed within the volcanics.

The original rock must have had the composition of diorite. It was probably extruded as andesitic flows onto the sediments that were to become the Glastonbury gneiss. After the deposition of the overlying aluminous sediments of the Amherst schist, metamorphism converted the volcanics into hornblende schist.

The accompanying map will serve to illustrate the extreme irregularity of the contact between the hornblende schist and the Glastonbury gneiss. This interfingering contact of the two units is due in part to the interbedding of the two rock types, but it is also the result of processes that affected the two rock masses after their formation. It seems highly probable that the hornblende schist originally was a much wider body that underlay the ridge west of Shenipsit Lake and extended northward and westward in a broader, more continuous belt. The metasomatic introduction of quartz and feldspar that followed the metamorphism altered the hornblende along the borders to biotite and the andesine to oligoclase. Both changes released lime which combined with alumina to produce the epidote so characteristic of the western border of the Glastonbury. The incomplete change or digestion of the schist resulted in the irregular contact and many of the unaltered patches of schist in the gneiss. The parallelism of the fingers along the contact with the strike of the foliation probably reflects the greater ease with which the solutions moved along the strike than across it.

Portions of the schist which probably contained a greater proportion of non-volcanic and volcanic material were much more completely altered by the permeating solutions. These remain as the hornblende gneiss, which underlies relatively large areas within the amphibolitic belt, and which is also found as a transitional phase between the hornblende schist and the Glastonbury gneiss.

The belt of hornblende schist found east of the Bolton formation resembles in appearance and mineralogy the masses of hornblende schist described above. The writer believes that the eastern portion of this schist also resulted from the metamorphism of volcanics that were interbedded with the arenaceous sediments at the base of the Bolton. The western half of this body of hornblendic rock, however, retains a very coarse igneous texture and is dioritic in composition. This portion was intruded as a magma into the quartzite that overlies the metavolcanics. The time of intrusion is unknown, but this body may well be correlated with the Soapstone Mountain metagabbros.

METAGABBRO

General relations and correlations. Several of the highest hills of the Ellington quadrangle are underlain by dark greenish-black hornblendic rock. The borders of these masses are now hornblende schist, but the centers retain the massive texture characteristic of a gabbroic rock. Soapstone Mountain and the smaller hills to the north and west of the mountain are underlain by this rock, and smaller sill-like bodies southwest of Soapstone Mountain have been mapped. Another basic, intrusive mass underlies the hills at the head of Polk Hill Brook in the southeast corner of the quadrangle. The rock is more resistant to erosion than are the gneisses and schists that it intrudes. This fact is well illustrated by the Soapstone Mountain mass where the topographic outline of the mountain follows the lithologic boundaries.

Only Percival (1842, pp. 222-226), of earlier workers in Connecticut, made any specific mention of these masses of basic rock. He made no attempt to map the Soapstone Mountain and related masses in detail, but mentioned the occurrence of this type of rock in a north-south line of summits.

This rock, like the hornblende schist previously described, can probably best be correlated with Emerson's Dana diorite, named for similar rock further north at Dana, Massachusetts. Emerson in his report on the Geology of Massachusetts and Rhode Island mapped a belt of Dana diorite extending south to the north border of the Ellington quadrangle. This belt, while by no means continuous, can be extended further south to include Soapstone Mountain, the nearby smaller masses, and probably the hornblende-schist formation that borders the Triassic fault.

The rock of these basic bodies is of two main types, dark green non-foliated gabbro and greenish-black hornblende schist quite similar in appearance and mineral composition to the hornblende-schist formation.

The igneous texture is commonly found near the center of the mass and it grades outward into the schist. The different bodies vary in the completeness of this conversion, but the metamorphic texture is commonly the predominant one. The schist is well foliated and lineated, and conforms with the regional trend of foliation produced by metamorphism. This foliation can be traced from the schist across the contact and into the country rock and is not a foliation that was developed by flow parallel to the contact at the time of intrusion.

Where the contacts are exposed, the effects of metasomatism on the metagabbros can be observed. Stringers of gneissic material have invaded the basic rock, but, as at the border of the hornblende schist formation, the hornblende patches that remain within the gneiss are aligned with the regional foliation. This "digestion" of the metagabbro at the border, however, is much less extensive than that at the contact of the Glastonbury gneiss and the hornblende-schist formation.

The grain-size of the schist of the intermediate and border zones is much finer than the texture of the central gabbro, the grains averaging 0.5 mm. as compared with 1.5 mm. for the gabbro. This does not appear to represent an original chill zone; the width of the fine-grained zone is too great for that. Instead it probably resulted from the metamorphic recrystallization of the original gabbroic material during the regional metamorphism that came after the intrusion of the gabbro.

Mineralogically the outer hornblende schist and the inner gabbro are much alike. Both are composed of hornblende, calcic plagioclase, chlorite, clinozoisite, and epidote with minor amounts of magnetite, pyrite, garnet, and rutile. The proportions vary, however, with plagioclase, in some places being more concentrated near the borders of the masses. Pyrite and quartz occur in variable amounts and appear to have been introduced at a later time.

The rock is intersected by both pegmatite and quartz veins. The pegmatite occurs in only a few small lenses, but the quartz veins are more widespread. Some occur as tiny stringers of quartz cutting across the foliation and must have originated later than the metamorphism. Other larger veins are shattered and pinched and must have been deposited before or during metamorphism.

On the east slope of Soapstone Mountain several bands of layers of a light quartzose rock are interbedded with the hornblende schist. These contain chlorite, kyanite, and muscovite, as well as abundant quartz, and were probably introduced later than the metamorphism. They undoubtedly helped produce the small deposits of soapstone for which the mountain is named.

Two old soapstone quarries have been worked on the east slope of the mountain. Percival as early as 1842 referred to a large bed of "light greenish grey Talcose Slate accompanied with a light greenish grey Actynolite Slate more or less filled with hornblendic asbestose . . ." as occurring on the east slope of Durfee's Mountain (now Soapstone Mountain). But even at that time the "Talcose Slate," which had been worked as soapstone, was considered of inferior quality because of "its too schistose structure and from the presence of hornblendic asbestose" (p. 226).

The soapstone is exposed in two small bodies of light greenish-gray, non-foliated rock. It is composed mainly of anthophyllite, chlorite, talc, calcite, and magnetite. The quarry on the northeast slope of the mountain followed a vein or bed of soapstone about two feet thick that dipped into the hill conformably with the foliation of the schist at an angle of about 33° NW. The soapstone overlies the quartzose layer mentioned above and was probably formed by the introduction of the hydrothermal siliceous solutions that produced the quartz vein. At the top of the southeast slope, a larger, irregular mass of soapstone some 50 feet across is enclosed in the hornblende schist. This has been extensively quarried, the last attempt having been made in the 1890's. The small size and poor quality of the deposit make any future venture unlikely.

There have been a number of reports of traces of gold in the quartz veins on the mountain. This, however, is probably more the result of local legend than of geologic fact, and it possibly stems from the pyrite which is rather abundant in both the schist and the gabbro, and which is commonly associated with minor quartz veins.

Petrography. The metagabbro is composed chiefly of hornblende and plagioclase in variable amounts. The gabbro centers usually have a more uniform composition, but metamorphic recrystallization and later alteration have resulted in the extremely variable mineral content of the hornblende schists. The gabbro contains, on the average, 55 to 60 percent hornblende and about 30 percent plagioclase. Chlorite makes up 10 to 15 percent of the rock and the remaining 5 percent is made up of epidote, magnetite, and pyrite. These minor minerals with the addition of rutile, garnet, and quartz are present in about the same proportions in the hornblende schist. The hornblende-plagioclase ratio varies considerably, however, ranging from 85 to 30 percent hornblende and from 65 to less than 5 percent plagioclase. These extremes seem to result from local concentrations of these minerals and the average composition of the schist would probably not differ much from that of the gabbro.

The hornblende occurs in dark-green to black prisms that average over 1 cm. in length. The mineral is generally rather strongly pleochroic, although there is some variaton in intensity of color. Colors of bluish green on Z, light brown on X, and dark brownish green on Y are common. The birefringence ranges from 0.021 to 0.026, and the n varies from 1.647 to 1.666 (± .002). The 2V falls between 80° and 85°, $b=y$, $Z \wedge C=12°$. Magnetite, pyrite, clinozoisite, and plagioclase occur as inclusions in the hornblende of both the gabbro and the schist. Small grains of rutile and quartz are also found in the hornblende of the schist. Ten to fifteen percent of the hornblende has altered to fibrous chlorite.

The plagioclase ranges from labradorite, An 60, to bytownite, An 80 to 85. Most of the grains are twinned; albite twinning is predominant, but a few grains show the pericline variety. Zoning, while not as well developed as in the plagioclase of the hornblende schist, is present in many of the feldspar grains, the outside being less calcic than the interior. Many of the grains contain inclusions of hornblende and clinozoisite.

Clinozoisite and epidote are common minerals of the Soapstone Mountain and related masses. While rarely present in amounts exceeding 2 percent, they occur as elongated, light-green grains scattered throughout both the gabbro and the hornblende-schist border, the clinozoisite being found more in the unaltered gabbro. The grains average 1 mm. in length, but in the chloritic rock near the soapstone the epidote grains attain lengths of over 1 cm. The n of the epidote ranges from 1.735 to 1.745 (± .002).

Magnetite, pyrite, and some ilmenite are present in amounts up to 1 percent. The magnetite and ilmenite are associated with the hornblende and in many cases are included within its cleavage planes. Pyrite and magnetite form intergrown clusters, the pyrite apparently having partially replaced the magnetite. Further evidence favoring a secondary origin for the pyrite is the fact that pyrite cubes extend unbroken through some of the tiny veinlets of quartz. These veinlets filled fractures crosscutting the foliation of the schist and presumably developed after metamorphism. In many of the specimens, pyrite was found to be the most abundant opaque mineral and, in general, was much more common in the metagabbro than in the hornblende-schist formation. Rutile in tiny reddish-brown grains occurs in some varieties of the hornblende schist. Tourmaline "suns" associated with the quartz veins were found developed on joint faces in the metagabbro northwest of Soapstone Mountain. Garnet, while not ubiquitous, is locally abundant. Large red garnets averaging 0.6 mm. in diameter spot the weathered surface of the schist of Soapstone Mountain. These contain numerous inclusions of plagioclase, hornblende, magnetite, and pyrite. The n of the garnet ranges from 1.785 to 1.796 (± .002).

A rather unusual assemblage of minerals is found at Soapstone Mountain where a white quartzose layer is associated with the soapstone deposit. The quartzose zone is composed of from 70 to 75 percent quartz with 20 to 25 percent muscovite, 5 to 10 percent kyanite, and minor amounts of chlorite. The kyanite has altered to muscovite, some grains of kyanite being in the center of frayed masses of mica. The quartz band is bordered by a green chloritic rock containing some actinolite and by the light-gray soapstone. A volumetric analysis of the soapstone showed it to be composed of anthophyllite 60 percent, chlorite 15 percent, talc 15 percent, calcite 6 percent, and magnetite and pyrite 1 to 4 percent. The soapstone is nonfoliated and the light-green, fibrous needles of anthophyllite are partially altered to frayed masses of chlorite. The 2V of the anthophyllite falls between 70° and 80°, $n=1.640$ (± .002), and the birefringence is 0.025. Calcite in large chunky grains and block-like masses of talc are scattered throughout the rock, the latter giving the soapstone a greasy feel. Magnetite in large clumps is abundant, being more concentrated in some portions of the mass. Pyrite is a minor mineral occurring with the magnetite.

Origin. These bodies of basic rock are almost certainly of igneous origin. The mineral composition, the type and zoning of the plagioclase, the texture of the central portions of the masses, the shape of the bodies, and the relation to the country rock are all highly suggestive of an intrusive origin. The presence of hornblende and calcic plagioclase, along with the igneous texture of the core of the bodies, are the strongest evidences. Minor amounts of rutile further support this conclusion. The irregular rounded or elongated outlines of the bodies and their sharp contacts are typical of intrusives.

It is highly probable that these masses are offshoots from the same source magma that produced the hornblende-schist formation west of the Glastonbury gneiss. The compositions of all the hornblendic rocks are very similar, the only exception being the more calcic plagioclases of the metagabbros. However, the more sodic plagioclases of the large body of hornblende schist are nearly all zoned with a much more calcic interior. All the basic igneous rocks probably had the same source, but local differences in the rate of reaction between the crystals and the melt resulted in the coating of the growing plagioclase crystals in some parts of the magma chamber with a more sodic outer zone. Magma that moved out of this portion of the magma chamber was extruded as andesitic volcanics, while magma whose plagioclase was still the predominantly unzoned calcic variety was intruded as a hornblende gabbro.

THE AMHERST MUSCOVITE SCHIST

General relations and correlations. A narrow tongue of Amherst muscovite schist borders the fault in the northwest corner of the crystallines. This schist was first mapped by Percival as the Micaceous and Chloritic Formation which he found in several lenses bordering the fault in central Connecticut, and which he extended in a narrow belt along the fault from the middle of the Ellington quadrangle northward into Massachusetts. This schist has been traced by Emerson into northern Massachusetts.

The Amherst is a silvery quartz-muscovite schist which resembles the Bolton in appearance and mineralogy. Foye included the adjacent hornblende schist with the Amherst and considered these schists as equivalent to the Bolton formation. This correlation was based on Foye's belief that the Glastonbury gneiss was intruded as a magma into the Bolton schist, separating the formation into two bodies. The writer's belief that the Glastonbury gneiss is an altered sedimentary body makes this correlation of the Amherst and the Bolton schist untenable.

Most of the area in the Ellington quadrangle underlain by the Amherst schist is drift-covered, and only a few good outcrops of this formation can be found. All these exposures are along the eastern border of the Amherst near its contact with the hornblende schist. This contact is gradational, layers and lenses of hornblende schist being interbedded with garnetiferous muscovite schist. This alternation of rock types has resulted in a transition zone at least several hundred feet thick, and no sharp contact line can be drawn between the two formations. Lenses of biotite gneiss, similar in appearance to the Glastonbury gneiss, and a few small bodies of pegmatite also occur within this gradational zone.

Westward the Amherst is truncated by the Triassic fault. The schist along the fault is a tough, greenish, chloritic rock, cut by quartz and epidote veins and broken by minor faults and shear zones. Faulting has obliterated the original outline of the formation, but, judging from the remnants of schist along the fault in central Connecticut and the widening of the body northward in Massachusetts, the Amherst schist must have been both thick and extensive.

Petrography. The Amherst schist in the Ellington quadrangle is a silvery muscovite schist that becomes rust-colored on exposure. It is a well-foliated rock composed mainly of quartz, muscovite, chlorite, and biotite with minor amounts of staurolite, garnet, kyanite, oligoclase, graphite, and magnetite. The average grain-size of the schist is 0.6 mm. for the matrix minerals and up to 1 cm. for some of the larger garnet crystals.

Quartz and muscovite are the two most abundant minerals of the schist. In one thin section of a typical sample of the schist each composed 35 percent of the rock. The quartz occurs as small, sutured grains in layers and in pods between the seams of muscovite. The muscovite is found in large, well-foliated plates and in smaller, shreddy aggregates. In places it appears to be an alteration product of kyanite, the kyanite being found in the center of a mass of muscovite.

Biotite and chlorite are minor micas, each making up about 10 percent of the schist. The biotite commonly occurs within the muscovite seams and some has altered to chlorite. Chlorite in shreddy aggregates resulting from the alteration of biotite is found in most of the schist. Near the Triassic fault it becomes one of the main constituents of the rock and gives the schist a distinct greenish color.

Garnet and staurolite are the main accessory minerals and make up 3 and 4 percent respectively of the thin section studied. Both the light-pink garnets and the staurolite, which exhibits a yellowish-brown pleochroism, occur in large fractured grains, and each contains rounded inclusions of quartz. The foliation of the muscovite usually wraps around the garnets.

Minor amounts of kyanite and oligoclase are scattered through the schist, the kyanite associated with muscovite, and the oligoclase, An 18-20, found in small grains that show fine albite twinning. Large, blocky grains of magnetite and tiny, elongated grains of graphite are found disseminated throughout the rock, the graphite commonly being enclosed within the cleavage planes of the muscovite. Together they make up about 3 percent of the rock.

Origin. The Amherst schist has resulted from the metamorphism of aluminous sediments which overlay the volcanics of the hornblende schist. The alternation of muscovite and hornblende schists at the lower contact of the Amherst reflects the interbedding of volcanics and shaly material that resulted as volcanism gradually ceased and the deposition of land-derived sediments was resumed. Unlike sedimentation in Bolton time no thick arenaceous beds were deposited, and no quartzite beds are included within the Amherst muscovite schist in the Ellington quadrangle.

PEGMATITES

General relations and correlations. Many masses of coarse-grained white pegmatite have intruded the crystalline rocks of the Ellington quadrangle. These pegmatites and the quartz veins so commonly found associated with them occur as small veins and irregular bodies in the hornblende-schist formation and in the metagabbros, but it is in the Glastonbury gneiss that they reach their greatest development. Huge masses of this white rock several hundred feet across underlie the hills west and northwest of Crystal Lake. Similar bodies are found on the hills around the north end of Shenipsit Lake and on the slope east of the fault at the Ellington-Somers town line. Concordant and discordant lenses and veins of pegmatite may be found in both the amphibolites and the Glastonbury gneiss. However, the majority of the bodies in the gneiss tend to be larger and discordant, while those in the amphibolites are smaller and generally conform to the regional foliation.

Foye states that the pegmatites accompanied the Monson (Glastonbury) "orthogneiss batholith" and that they are usually found in the Bolton or other schists around its periphery (1949, p. 62). Quartz veins are common elsewhere in the Bolton schist, but oddly enough no pegmatite was found in the Bolton of the Ellington area.

The pegmatite is exceptionally resistant to erosion, and is largely responsible for the relief of the hills on which it is found. This is well illustrated by Newell Hill and the neighboring hills west of Crystal Lake, which are "held up" by a core of pegmatite. Pre-glacial erosion and the later southeast movement of glacial ice cut back their southern slopes and left an east-west scarp, separating the resistant pegmatite masses from the more easily eroded Bolton schist to the south. North of these hills nearly every outcrop of the Glastonbury gneiss is cut by at least one vein of quartz or pegmatite. This may be attributed to the abundance of these late silicic intrusions and to the fact that where the gneiss contained these resistant veins, its own chances of surviving erosion and of outcropping were greater. The preservation of glacial polish and "friction cracks" on the surface of the pegmatite at Newell Hill is further evidence of its resistance.

Petrography. The pegmatite has a rather simple composition, being composed mainly of microcline, sodic plagioclase, quartz, and muscovite with minor amounts of magnetite, garnet, and tourmaline. Its texture is coarse and consists either of large, but fairly uniform grains of microcline perthite, or of large phenocrysts of microcline in a groundmass of albite.

Microcline is usually most abundant, but in some bodies the albite, An 0-2, is the dominant feldspar. The pegmatites of the Crystal Lake area contain large cream-colored phenocrysts of microcline in a matrix of white albite. The phenocrysts are more resistant than the albite and stand out as knobs as much as an inch above the surface of the outcrop. These knobs retain glacial polish and give an indication of the amount of post-glacial weathering of the pegmatites.

Quartz occurs both in the phenocrysts and in the groundmass of the pegmatite, but is more important as the main constituent of the associated quartz veins. Northeast of Shenipsit Lake it is intergrown with the feldspar in a graphic granite texture. Muscovite is present in all outcrops in plates up to several inches in width. On the west slope of Newell Hill, books of the mica are aligned in parallel rows across the face of the outcrop. This foliation is probably the result of replacement or alteration and is not a foliation superimposed by metamorphism.

Black tourmaline in well-developed prisms is locally abundant. The pegmatites around Crystal Lake abound with the mineral and in a few places, for example, the east slope of Newell Hill, black crystals several inches long with well-formed triangular cross-sections weather out of the pegmatite and are scattered like pebbles throughout the overlying soil. Tourmaline is also abundant in some of the quartz veins and is found as clusters in the adjacent gneiss.

Small red garnets, $n = 1.795$ (± .002), and grains of magnetite occur as minor accessory minerals. Many of the pegmatite veins and masses also contain inclusions of the gneissic country rock that they intrude.

The pegmatites themselves have been cut by quartz veins that were either a late phase of the pegmatite intrusion or belong to a second, still later, period of pegmatization. Along the Triassic fault the pegmatites have been silicified by many tiny quartz veins, but this occurred during the crustal movements of Triassic time, long after pegmatite intrusion had ceased.

Origin. The intrusion of the pegmatite was effected by the introduction of highly siliceous aqueous solutions into the gneisses and schists. These solutions were probably a late stage of the process of metasomatism that produced the Glastonbury gneiss. These last liquids invaded the recrystallized country rock and cooled to form the veins and masses of pegmatites. Some of the crystallization of the feldspars occurred before or during introduction and resulted in the large phenocrysts of microcline in the finer-grained matrix.

Later more siliceous liquids followed the pegmatites and resulted in the quartz veins that intruded both the country rock and the pegmatite. These were accompanied by boron metasomatism which tourmalinized the pegmatite, the quartz veins, and the country rock.

The effect of this pegmatization on the country rock is evidenced by the abundant clusters of chlorite in the gneiss near the pegmatite. These, along with the chlorite-garnet zone in the roadcut west of Crystal Lake, are the result of retrogressive metamorphism of the biotite and hornblende and were caused by the invasion of the rocks by the siliceous pegmatite solutions and vapors.

AGE RELATIONSHIPS OF THE CRYSTALLINE ROCKS

Most of the pegmatites crosscut the well-developed foliation of the Glastonbury gneiss and show no signs of having been affected by metamorphism. In some outcrops, however, the gneiss or schist wraps around lenses of pegmatite, and small veinlets of pegmatite are found following the minor folds of the country rock. These intrusions must have occurred before or, more probably, during the folding and metamorphism of the strata. Two generations of pegmatites are known in the Middletown area, one being sheared and in part foliated, and the other being younger and unaffected by the regional foliation (Herz, 1954).

The most reliable estimate of age for the later pegmatites was derived from chemical and isotope analyses of the lead, uranium, and thorium of samarskite, a radioactive mineral, found in the Spinelli pegmatite quarry in Glastonbury, Connecticut. These pegmatites intrude the Glastonbury gneiss, cross-cutting its foliation, and are presumably related in time to the Ellington pegmatites. Rodgers has compiled the results of analyses of this samarskite and other radioactive minerals of the Appalachian region and states that 260 million years may be taken as an approximate age of the samarskite (1952, p. 414). This places the intrusion of the pegmatite at some time during the middle or late Paleozoic, probably near the beginning of the Mississippian.

Since these samarskite-bearing pegmatites have been unaffected by the regional metamorphism, the metamorphosed formations: the Monson gneiss, the Bolton schist, the Glastonbury gneiss, the hornblende schist, and the Amherst schist, must all be older than 260 million years. The writer believes that these schists and gneisses represent a sedimentary series of shales, sandstones, and volcanics that have been altered by metamorphism and metasomatism and tilted to the northwest. No evidence of overturning or isoclinal folding on a regional scale was observed in the field. The Monson gneiss is presumably the oldest formation. The rocks become successively younger to the northwest, the Amherst schist being the youngest formation studied.

No good evidence has been uncovered definitely to date any of these formations. Foye (1949, p. 80) believed the Bolton (Brimfield) schist to be Pre-Cambrian or early Paleozoic in age. John Rodgers (personal communication), however, has suggested that the Bolton may be equivalent to the Littleton formation of New Hampshire, which is probably Devonian. In view of the uncertainties, it is probably best to conclude that the gneisses and schists in the Ellington quadrangle are pre-Mississippian in age, and that the original sediments were probably deposited at some time during the early half of the Paleozoic era.

TRIASSIC SEDIMENTARY ROCKS

The origin, the lithology, and the structure of the Triassic sedimentary rocks that underlie the western half of the quadrangle are the result of the movements during Triassic time along the great fault that runs north-south through the center of the area studied. For this reason the eastern border fault and its effects on the crystalline and sedimentary rocks will be considered before the treatment of the sedimentary rocks themselves.

Eastern border fault. A brief review of Barrell's classic description of the formation of the Triassic depositional basin will perhaps help in an understanding of the structure of the Triassic strata. According to Barrell (1915), arching of the crust in western Connecticut in Triassic time resulted in the collapse of the flanks of the arch. The eastern border fault occurred in central Connecticut and the pivotal downsinking of the rock on the western side of the fault produced a wedge-shaped trough that filled with sediment as it subsided. Recurrent movements along the fault provided a continuous highland source of the sediment which poured into the great valley. The detritus was carried by the many small streams that must have coursed down the fault scarp from the eastern highlands which provided the bulk of the sediment. The minimum estimated throw of the fault is 16,000 feet (Krynine, 1950, p. 117). At least three lava flows poured out on the valley floor to form the trap sheets now included within the sedimentary series. Later crustal movements at the close of Triassic time broke the wedge of sedimentary rocks into separate blocks and tilted the strata eastward to their present position.

The exact position and nature of the Triassic fault that runs north-south through the center of the Ellington quadrangle cannot be precisely determined, but by the mapping of the silicified and brecciated outcrops and the collection of water-well data, a good estimation of the location of this fault can be made. The fault was a normal fault with the downdropped block on the west. The intense silicification and brecciation that occurred along the fault zone resulted in a resistant gouge that outcrops in the brooks crossing the fault and on a few of the hillsides along the scarp. A fairly straight fault line can be constructed connecting these outcrops and represents what must have been the zone of faulting.

There are, however, several indications that the fault may have been more complex. Silicified zones on hill 602 west of Shenipsit Lake and hill 663 north of Kimball's Brook indicate that the fracturing may have occurred along a set of overlapping splinter breaks. Further evidence inconsistent with the downdrop of a fault block along a single fault line is that a well at the house just northeast of BM 310 on route 83 east of Ellington center is said to have penetrated over 400 feet into "gray rock"; the house just to the south has a well that was driven over 400 feet into "red rock." For these data the author is relying on the memories of well drillers and owners, but, if correct, they imply that a block or mass of crystalline rock has slid down between the main body of hornblende schist and the Triassic. This dislocated mass is probably separated from the main body of the crystallines by one or more smaller faults that extend into the crystallines as splinter fractures now silicified. This compound faulting can only be inferred from scant data, but it is advanced as a possible explanation of the inconsistencies of the evidence.

The movement along the fault was recurrent and waters circulating along the fault plane intensely silicified this zone and the associated fractures in the crystallines. Earlier quartz veins are cut by later ones; tiny veins of epidote have intricately crosscut the rock, and together with the quartz have produced a very tough, silicified zone that in places is over 1000 feet wide. The hornblende schist has been partially altered to greenish chloritic rock; much magnetite and some pyrite has been introduced by the rising solutions. Much of the rock is stained reddish purple by iron weathering products. Some of the last movements along the fault must have been of the horizontal shear type, because on the knob directly east of Ellington center slickensided surfaces have their lineations dipping southward at a very gentle angle. Well-developed quartz crystals in a cavity on this surface also indicate that the siliceous waters were active after the movement had ceased.

Well records show that the fault contact between the sedimentary rocks and the crystallines is marked by a considerable difference in depth to bedrock. A steep scarp 40 to 60 feet high, hidden by a cover of glacial till, forms the surface contact between the two rock types. A zone of fault breccia composed of angular fragments of the crystallines in a fine-grained mylonitic matrix is transitional between the two formations. This breccia outcrops in the bed of Hydes brook where it crosses the fault zone in the center of the quadrangle.

The sedimentary rocks. The main emphasis of this work was on the crystalline rocks of the quadrangle, but the western portion of the area underlain by the sedimentary red beds of Triassic age was also covered. Only about a dozen outcrops of the Triassic were found, and all of these had been exposed by land-clearing, quarrying, or stream action. The paucity of outcrops can best be explained by the gentle dip of the beds to the east, with the resulting west-facing erosional scarps. Glacial ice moving southeastward piled its till to great depths up against these scarps, and the later retreat of the ice left thick outwash deposits in the lowlands.

All the outcrops are of the characteristic interbedded red sandstone and conglomerate. The average strike of the beds is about N 10° E; the dips are gentle and average 15° to 20° to the east. By plotting the various depths to bedrock as collected from water-well records it is possible to reconstruct in a very general way the bedrock topography. Several north-south lines of discontinuous hills or ridges extend roughly parallel to the eastern border fault at a distance of approximately two miles. The first more prominent "ledge" extends from the southwest corner of the quadrangle northward west of hill 455 near the center of the quadrangle. Similar rises further west generally parallel the first. These ridges have a gentle dip slope to the east and drop off sharply on the west side. The depth to bedrock at Ellington center is about 125 feet and a rather deep "valley" must extend along the border of the fault.

The Triassic bedrock is a deep red, micaceous, arkosic sandstone with interbedded conglomeratic layers. The sandstone is composed of poorly sorted, fine to coarse fragments and contains many flakes of muscovite and a relatively high percentage of feldspar. The conglomerate occurs in discontinuous lenses or interbedded layers generally not more than several feet thick. Pebbles as large as 3 to 4 inches in diameter were found in the conglomerate and represent the following rock types: gneiss (Glastonbury), pegmatite, tourmaline-bearing pegmatite, Bolton mica schist, and vein quartz, all of which were probably derived from sources within 5 miles of the fault scarp. Some of the fine-grained sandstone layers contain mudcracks. These along with the red color of the beds indicate an exposed mudflat type of environment of deposition.

The exposures are too few and the area studied too limited to draw any detailed conclusions from the Triassic sedimentary rocks. The results, however, do fit in well with other more complete studies of the Triassic rocks elsewhere in the Connecticut valley.

The "red beds" of the Ellington quadrangle may be best correlated with Krynine's Portland arkose formation which includes the uppermost conglomerates, arkoses, siltstones, and shales of the Triassic series. This whole Triassic series reaches an estimated thickness of 16,000 feet in the vicinity of the Eastern border fault (Krynine, 1950, p. 5).

The arkosic nature of the rock indicates that they were dumped rapidly out onto the floor of the basin. Their exposure to subaerial weathering resulted in the oxidized iron-stained coating around the grains that gives the rock its characteristic deep red color. Krynine (1950, p. 180) believes that this deposition took place in a warm and humid climate with a "pronounced but seasonally distributed rainfall."

During a dry period the finer-grained material would be distributed over the alluvial fans to be oxidized and mudcracked by the sun. When the rains came these sandy layers would be buried by a deluge of coarse conglomeratic material that was flooded out onto the valley, being concentrated in the stream beds; hence the discontinuous, lens-like deposits. Emerson (1917, p. 110) reports the finding of vertebrate remains in the Triassic red beds of the Ellington area and reptiles must have thrived in the subtropical climate.

THE DIABASE DIKE

General relations and correlations. A diabase dike has intruded the gneisses and schists of the Ellington quadrangle and is the youngest crystalline rock in the area. The dike is not a continuous body, but is made up of several slightly offset segments that have been mapped for a distance of more than eight miles. These bodies strike northeast and are part of a larger series of offset intrusions that were traced by Percival from Manchester northward into Massachusetts. Percival also mapped a second belt of diabase dikes extending from Branford on the south shore of Connecticut northeast to Union, a distance of nearly 70 miles. These dikes intrude along lines of weakness in the crystalline rocks and, as Foye so aptly put it, they "occur in overlapping fractures similar to the cracks in a wooden beam when bent by a heavy load" (1949, p. 65). They all dip west at a very steep angle.

The dike in the Ellington quadrangle varies in width from 60 to 200 feet, but it averages 100 to 120 feet wide throughout most of its length. Glacial cover generally conceals the contacts, but where exposed, the gneiss adjacent to the diabase is a tough siliceous rock. Small dikelets of diabase 0.5 to 2 inches wide fill fractures in the gneiss, most of these offshoots paralleling the main dike. The dike itself has a fine-grained border zone, indicating rapid chilling upon intrusion.

The diabase is a resistant rock and commonly forms a ridge or line of small knolls through the area of metamorphic rocks. In several places it underlies swamps, but these depressions were produced by the glacier as it overrode the resistant ridge of diabase and quarried out huge blocks of the well-jointed rock. The numerous diabase erratics strewn over the countryside southeast of the dike give some idea of the extent of this glacial plucking.

The fresh diabase is a dark-gray to black rock composed mainly of augite and lath-like grains of labradorite. Magnetite and minor amounts of biotite, muscovite, chlorite, and olivine are present as accessories. Post-glacial weathering has extended fairly uniformly into the diabase, altering much of the feldspar to muscovite and producing a reddish-brown skin 0.1 cm. thick over the surface of the outcrops.

Petrography. The diabase is composed chiefly of block-like grains of augite and laths of labradorite. The following composition is the average of three volumetric analyses made on samples taken from widely spaced outcrops along the dike:

Augite	**42.7%**
Labradorite An 60-63	**54.4**
Magnetite	**2.0**
Biotite	**.5**

Minor constituents include chlorite, muscovite, pyrite, and olivine.

The composition of the rock is remarkably uniform, the individual results varying only a small percent from the above average. The grain-size varies; in the interior the grains average 0.4 to 0.5 mm. across, but at the chill border zone the texture is much finer, averaging less than 0.2 mm.

The augite occurs in clusters of dark-brown grains intergrown with the plagioclase. Many are twinned and some contain inclusions of magnetite. The 2V of the augite is approximately 45° to 50°, the n is 1.705 (± .002) and its birefringence is about 0.025. Some of the pyroxene has altered to small patches of biotite.

The plagioclase is labradorite, An 60 to 63. It occurs in laths that range from 0.1 mm. to 0.8 mm. in length. Most of the grains show albite twinning parallel to the length of the lath; a few grains have pericline twinning. In some specimens most of the labradorite has altered to masses of muscovite. Clusters of yellowish feldspar 0.5 inches or so in diameter are scattered through the diabase, and many of these masses have been altered almost completely to an unidentifiable aggregation of minerals. This weathering has also resulted in limonite stains on the augite and the formation of small amounts of chlorite.

Magnetite in small chunky grains is associated with the augite and is in many cases included within it. Several small, irregular masses of pyrite were found in one section, and some samples of the diabase contain a minor amount of olivine in oval grains about 0.3 mm. in length.

At the contact of the diabase dike and the Glastonbury gneiss, the gneiss is a very tough, siliceous rock. Where the dike cross-cuts the foliation of the gneiss, this foliation has been disrupted; but where the dike parallels the trend of the foliation, the foliation is better developed along the contact than in the unaffected gneiss. There must have been some recrystallization and alteration of the country rock; the quartz and feldspar are separated into distinct layers, the biotite is bleached and full of tiny inclusions of magnetite, some quartz may have been introduced, and the feldspars are partially altered to muscovite. All these effects, however, are confined to a narrow zone about 0.5 inches wide at the contact. This plus the fact that the dike itself has a fine-grained chilled border zone indicates that the country rock was never heated to any great degree by the intrusion of the diabase.

Origin and age. The diabase dike has been unaffected by the regional metamorphism and metasomatism that altered the country rock into gneisses and schists. It must, therefore, have intruded after these processes had ceased completely. On the basis of similarity of composition, most previous writers have correlated these dikes with the diabase lavas that flowed out as the sheets now enclosed in the sedimentary strata of the Connecticut valley. These "red beds" with their included "trap" sheets are of known Triassic age. These diabase dikes within the crystallines were probably intruded during Triassic time into fractures caused by the same tensional stresses that resulted in the great fault along the eastern border of the depositional basin. The fault may well have been one of the splinter variety with a series of offset breaks along a general fault zone. Most of the diabase lava welled up along fractures in the Triassic strata and flowed out over the sediments of the basin, but some forced its way up along the splintered zones in the crystalline rocks and cooled to form the offset segments of the trap dike.

STRUCTURE

Definition of terms. In this discussion of the structure of the metamorphic rocks of the quadrangle, the terms schistosity, foliation, and lineation will be used to denote the megascopically conspicuous parallelism of the fabric elements. The term fabric is used to mean the total of all structural and textural features of a rock. Schistosity and foliation are essentially synonymous when applied to metamorphic rocks and refer to the parallel arrangement of the non-linear features which tend to give the rock a fissility. Lineation is applied to the alignment of the linear elements in the fabric such as hornblende prisms (Turner and Verhoogen, 1951, p. 559).

Schistosity. Schistosity (foliation) is a conspicuous element in the fabric of the recrystallized rocks of the Ellington area. Over 1000 readings of the schistosity were taken and a number of the more representative ones have been plotted on the accompanying map. The regional trend of the schistosity is northeast at about 30° and the dips are northwest at angles which average 40°.

A number of theories have been advanced to explain the origin of schistosity. Most have been based on sound evidence, but confusion has resulted when their proponents attempted to apply them universally. Turner and Verhoogen (1951, pp. 561-564) recognize that schistosity may be produced either by movement along shear planes in the rock or by alignment of platy minerals normal to a compressive force acting on the rock. The first may be correlated with slip planes and the second with the AB plane of the strain ellipsoid. Compression usually results in the development of foliation normal to the direction of pressure and essentially parallel with axial planes of the folds. All the schistosity in the rocks studied follows the folds, so compression alone could not have caused the schistosity.

A third cause of schistosity that must be considered is mimetic schistosity caused by the growth of platy minerals during recrystallization with their long dimensions parallel to the bedding. This results in a schistosity which follows the bedding and wraps around the noses of the folds (Billings, 1942, p. 218).

Compressive forces acting in a northwest-southeast direction caused the tilting of this series of sediments and volcanics to the northwest. Mimetic recrystallization during metamorphism tended to line up the mica in the direction of the bedding planes of the rock. The tilting at the same time set up shearing stresses that facilitated the foliation process and produced a lineation of the elongated minerals which lined up with the direction of shear. During the later stages of metamorphism the rock was invaded by solutions which metasomatized the beds that became the Glastonbury gneiss. This metasomatism tended to destroy the foliation produced by the mimetic recrystallization and shearing.

The several quartzites within the Bolton schist provide an opportunity for observing the relation of schistosity to bedding. These quartzites can be traced throughout the formation and the schistosity both within the quartzites and in the schist is generally conformable with the contacts. There are few indicators of bedding planes in the Glastonbury gneiss, but the foliation wraps around the noses of the folds in the banded gneiss at the gradational contact between the gneiss and the Bolton schist. In view of these facts, it can be said with reasonable certainty that the foliation is essentially parallel to the bedding throughout most of the area.

Lineation. Lineation is represented by the well-developed alignment of hornblende needles in the amphibolites, biotite streaks in the Glastonbury gneiss, stretched pebbles in the quartzite, and minor corrugations on the surface of the Bolton schist. The first two extend approximately down the dip. The stretched pebbles of the quartzite of the Bolton have their *a* axes or axes of greatest elongation parallel with the fold axis, and their *b* axes or intermediate axes in the plane of the bedding. This indicates a stretching of the beds parallel to the fold axis (Billings, 1950, p. 49), a hypothesis further substantiated by the minor corrugations and grooves on quartzose layers of the schist that strike and plunge in approximately the same direction as do the pebbles.

Folds. Minor folds are common in the amphibolites, in the Bolton and Amherst schists, and along the Bolton-Glastonbury contact. The Glastonbury gneiss in the area studied has been little affected by the folding although Aitken reports complex structures in this formation farther south in the Rockville quadrangle (personal communication).

Petrographic studies have shown that some of the larger quartz masses have wavy extinction and some of the microcline porphyroblasts have crushed or granulated borders. Both minerals were probably introduced during the metasomatic process that produced the Glastonbury gneiss. Their deformation indicates that the gneiss was under stress during metasomatism and after the early deformed pegmatites had been intruded. The gneiss was competent to resist deformation by folding, but the amphibolitic layers within the Glastonbury were exceptionally sensitive to shearing and much of the stress appears to have been relieved by the folding and crumpling of these layers.

Folding is more common in the rocks along the eastern margin of the quadrangle. The less resistant schists and border gneisses have been thrown into a number of minor folds, the axes of which strike slightly west of north and plunge about 25° to the north. Several sets of minor crinkles can be observed on the Bolton schist, indicating that compression came first from one direction and later from another.

Keppel (1941) thought that the Glastonbury gneiss was the center of an overturned anticline with the Bolton schist connected across the top. It might be argued that the Amherst schist is just a second body of Bolton separated from the first by the erosion of the crest of the anticline. There is, however, no evidence of doming and no important reversal of dip within the Glastonbury gneiss of the Ellington quadrangle. The majority of the outcrops show little or no evidence of having been affected by any folding force other than the original tilting. Furthermore, the hornblende schists of probable volcanic origin that are associated with both the Bolton and Amherst formations lie, in each case, to the east or beneath the muscovite schists. If anticlinal folding were the answer, the amphibolites should either appear on each border on the Glastonbury gneiss, or lie on the outside of the structure, above the Amherst and below the Bolton. Finally, there are no arenaceous beds within the Amherst schist that may be correlated with the quartzites found associated with the Bolton formation. For these reasons, the writer believes that all the folding was on a relatively minor scale.

Faults. The eastern border fault of the Triassic fault basin is the dominant structural feature in the area. Recurrent movement along this fault downdropped the crystalline rocks of the western block at least 16,000 feet and caused the depositional filling of the basin with the Triassic red beds. The structural events of Triassic time and their effects on the rocks of the quadrangle have already been discussed in some detail (pp. 26-29). There are minor slickensided surfaces in the gneiss bordering the fault, but these are undoubtedly also related to the crustal movements of Triassic time.

Shearing surfaces have been found at the lower contact of the competent quartzite bed within the Bolton and the weaker mica schist beneath, but these resulted from slippage during the tilting and are not true fault surfaces.

Joints. All the formations are cut by several systems of cross joints. This jointing is especially well developed in the more basic rocks, such as the amphibolites and the diabase dike. Little emphasis was placed on the jointing during the field study of the area and no attempt has been made to plot the joint patterns.

Interpretation of structure. The geologic reports of Percival (1842), Rice and Gregory (1906), and Foye (1949) have established a general northeast trend of the lithologic units that can be traced from Middletown northward through the Ellington quadrangle and into Massachusetts. Throughout their extent these beds dip to the west or northwest.

The previous reports are sorely lacking in information on the regional structure, but it appears that the formations in this area are bordered on the east by an area of essentially flat-lying metamorphic rocks. These eastern rocks are older than the Bolton schist and presumably are folded down and dip beneath the rocks of the Ellington quadrangle.

The resulting structure in the Ellington quadrangle is relatively simple and involves three major lithologic units, the Bolton schist, the Glastonbury gneiss, and the hornblende schist, striking northeast and dipping about 40° to the northwest. The schistosity generally parallels the bedding planes of the metasediments. No major folding other than the original tilting has affected the rocks. The minor folds in the Bolton schist and along the Glastonbury-Bolton contact indicate that buckling on a relatively small scale did occur between the two formations. The alignment of stretched pebbles in the Bolton border quartzite with the axes of folding can be explained by stretching of the beds in the direction of the plunge of these minor folds.

The period of deformation began with the tilting and metamorphism of the gneisses and schists and continued through the intrusion of the early pegmatites and the metasomatism. The schistosity follows the folds and indicates that the recrystallization was accompanied by simultaneous mimetic alignment of the platy minerals in the bedding planes. Compression from an east-west direction during metasomatism caused minor folding in the rocks at the Glastonbury-Bolton border as the more competent gneiss "rode up" over the weaker schist beneath. Some of the early pegmatite lenses are broken and contorted by this folding, and their intrusion probably facilitated the folding of these border rocks. Later large-scale intrusions of pegmatite had little effect on the structure of the rock intruded.

In Triassic time the foliation of the metamorphic rocks was truncated by the eastern border fault that downdropped the western block of the crystalline rocks an estimated 16,000 feet (Krynine, 1950, p. 5). The sedimentation in the basin and subsequent block faulting resulted in the east-dipping sedimentary strata that underlie the western half of the quadrangle. A nearly vertical diabase dike intruded the crystallines, presumably along a fracture created by the crustal movements of Triassic time.

METAMORPHISM

The recrystallization that constitutes metamorphism can take place under a wide range of temperature and pressure conditions. This recrystallization is caused by rising temperature and pressures, usually accompanied by a wave of active fluids that accelerate the metamorphic reactions. The trend of the metamorphic reconstitution of rocks is toward the formation of an association of minerals that will be in equilibrium with the metamorphic conditions. The term facies has been used to include all rocks of varying chemical and mineralogical compositions which have reached chemical equilibrium during metamorphism under a particular set of physical conditions (Turner, 1948, p. 54). A well-defined facies serves a dual purpose. It enables one to correlate rocks of widely different lithologic character as having been subjected to the same metamorphic conditions, and, further, it gives some idea as to intensity of these conditions. A number of facies classifications have been devised, but the one suggested by Turner and Verhoogen (1951, pp. 443-480) will be used in this discussion.

The great majority of the rocks of the area studied may be fitted into the staurolite-kyanite subfacies of the amphibolite facies. A few representatives of the greenschist facies can also be distinguished.

THE AMPHIBOLITE FACIES

The amphibolite facies includes the range of temperature and pressure within which the combination of hornblende and plagioclase is stable. At higher temperatures hornblende is replaced by diopside and hypersthene and at lower temperatures albite-epidote takes the place of oligoclase or more calcic plagioclase. The amphibolite facies corresponds to medium- and high-grade regional metamorphism, but includes a wide enough range of conditions to permit a division into several subfacies (Turner and Verhoogen, 1951, p. 446). These subfacies are named after their characteristic assemblages and one, the staurolite-kyanite subfacies, is represented in the rocks of the Ellington area. Conditions of metamorphism indicated by the critical mineral assemblage of this subfacies are medium- to high-grade metamorphism that involved strong deformation under pressure and stress.

The Bolton schist, the Glastonbury gneiss, the amphibolites, and the Amherst schist have been subjected to the same degree of metamorphism. The critical minerals staurolite and kyanite have developed only in the Bolton and Amherst schists and in the quartzose interbeds, but equivalent mineral assemblages have resulted in the gneiss and the amphibolites.

Bolton and Amherst schists. The recrystallization of the original argillaceous material under moderate to high temperatures and intense stress resulted in the growth of idiomorphic crystals of spessartite-almandine garnet and the separation of quartz and muscovite, with the mica aligning to produce schistosity. Graphite formed from the carbon of the original sediments and is included as tiny specks within the muscovite.

Staurolite appeared first as small grains, then as large crystals, some of which are interpenetrations twins. The staurolite is crowded with quartz and contains some large garnets, all presumably included during the building of the large crystal of staurolite from the many small grains (Harker, 1939, p. 225). The deficiency of potash accounts for the paucity of feldspar in these schists.

The arenaceous interbeds in the Bolton recrystallized to quartzite and quartz schist. Kyanite appeared along shear zones within the quartz schists, supporting the belief of some that it may be a true stress mineral (Turner and Verhoogen, 1951, p. 392). The shearing also resulted in the stretching of the pebbles of the quartzites.

The end product of this metamorphism of shale and sandstone was garnet-muscovite schist, with interbedded quartzite, having a distinctly different mineral composition and a marked increase in grain-size as compared with the original rock.

Amphibolites. The mineral assemblage of the amphibolites, while quite different from that of the Bolton schist, conforms with the assemblage expected when the metamorphic conditions implied by the staurolite-kyanite subfacies are imposed on bodies of intermediate and basic igneous rock. Both intrusive gabbro and the extrusive volcanics must have been composed mainly of hornblende and plagioclase. The increased temperature and shearing stress that promoted the metamorphism caused a recrystallization of the hornblende and the almost complete conversion of these masses into well-lineated hornblende schist. No pyroxene was discovered in the unaltered parts of the metagabbro, and it seems probable that if the hornblende had been altered from original pyroxene, the recrystallization would have resulted in the complete formation of a schistose structure and no central gabbroic texture would remain. The change in composition of the plagioclases was toward the more sodic varieties, but in the isolated bodies of metagabbro, much of the plagioclase is still of a more calcic type. The epidote mineral clinozoisite occurs both as disseminations throughout the rock and in the local quartz-epidote veins in the amphibolites. Almandine and rutile are products of the recrystallization, the formation of the latter reflecting the relatively high pressures that must have existed during the metamorphism. Pyrite is secondary and its introduction was probably associated with the metasomatic activity that affected the Glastonbury gneiss.

Two apparent inconsistencies in the transformation of these igneous rocks to hornblende schist should be noted. First, the metamorphism of the gabbro resulted in a decrease in grain-size, a trend just opposite to the usual course of development of metamorphic textures. This phenomenon, however, has been observed by others (Poldervaart, 1953, p. 261).

Secondly, there is a marked variation in the completeness of conversion of the volcanics and the gabbro to hornblende schist. The completeness of this transformation does not seem to be governed by the size of the body; the large mass of the hornblende schist formation has been almost completely recrystallized, whereas the relatively small gabbroic bodies like that of Soapstone Mountain still retain an unaffected core. Yet both have had the regional schistosity superimposed upon them and have presumably been subjected to the same degree of metamorphism. This condition, too, has been observed elsewhere, and it seems best to conclude, as does Poldervaart, "that metabasaltic rocks throughout the world have been tardy in responding to plutonic conditions, though both in rate and manner of response they show puzzling differences among themselves, even in the same terrain and within short distances" (1953, p. 262).

The Greenschist Facies

The greenschist facies includes rocks formed at the lowest metamorphic temperatures. They are characterized by the assemblage of hydrous minerals like the micas and chlorite, and by absence of garnets (except spessartite), pyroxenes, and aluminous amphiboles (Turner and Verhoogen, 1951, p. 465). The low temperatures involved usually require the accelerating influences of hydrothermal action. The greenschist facies as represented in the rocks of the Ellington area is of extremely local extent, being associated with the borders of the pegmatites, the steatite deposit, and the Triassic fault zone.

In the Ellington area the late-stage pegmatization of portions of the Glastonbury resulted in the incomplete retrogressive metamorphism of the gneiss near the large pegmatite bodies. The permeation of the gneiss by solutions and vapors from the pegmatites developed clots or clusters of chlorite as an alteration of biotite, and leucoxene as an alteration of ilmenite, within the gneiss of the Newell Hill area. At least one of the amphibolite interbeds along the eastern border of the gneiss was converted into a mass of chlorite and large spessartite garnets. The retrogression here was facilitated by intense deformation of this bed by the crustal movements that accompanied the pegmatization. The abundant tourmaline associated with the chloritized rocks suggests that volatile constituents may have played an important part in the development of the greenschist facies. Spessartite garnet is present in abundance and substantiates the belief that garnets rich in manganese have a wide range of stability and can exist under low-grade metamorphic conditions (Poldervaart, 1953, p. 268).

Late-stage retrogressive metamorphism also led to the development of the steatite on Soapstone Mountain. Solutions, probably under considerable pressure, moved along a fracture or shear zone in the metagabbro. The reaction of these solutions with the hornblende of the metagabbro resulted in the removal of lime as a carbonate which formed calcite. This left the lime-poor amphibole, anthophyllite. At these lower temperatures of the greenschist facies, chlorite formed as an alteration product of the amphibole and, by the removal of Al_2O_3 and some MgO by the circulating solutions, it was partially replaced by talc. The result was an anthophyllite-chlorite-calcite-talc rock. The solutions that caused these alterations were probably connected with a late stage of the metasomatic fluids that invaded the Glastonbury gneiss.

Hydrothermal solutions moving along the fault line during Triassic time caused the retrogressive alteration of the hornblende schist to masses of chlorite, and the local development of the greenschist facies along the fault zone.

METASOMATISM

Glastonbury gneiss. The Glastonbury gneiss is partly the result of the isochemical metamorphism of sedimentary rocks and partly due to the metasomatic introduction of quartz and perhaps feldspar that followed. The mineral assemblage of the metasediment must have consisted of oligoclase, quartz and biotite which would have been in equilibrium under metamorphic conditions of the staurolite-kyanite subfacies. However, the effects of the later metasomatism have so blended with the effect of the earlier metamorphism that little can be positively deduced about the pre-metasomatic conditions. It is probable, however, that the original sedimentary beds contained a high amount of feldspar, some mica, and an unknown amount of quartz. The contrast in texture and composition of the banded gneiss with its shaly interbeds along the eastern border of the gneiss indicates that the original sediments of the Glastonbury formation were coarser and less micaceous than the original shales of the Bolton schist. These original sediments graded vertically into the underlying shales that were to become the Bolton formation. Near the gradational contact between the two main rock units, a number of discontinuous beds of basic volcanic material were interbedded with the sandy layers of the Glastonbury.

These original sediments were first intruded by gabbroic magmas. Metamorphism followed and superimposed a regional schistosity on all rocks. Within the sedimentary beds there must have been a recrystallization of the quartz, feldspar, and mica. Crystals of garnet and magnetite were developed throughout the metasediment, probably from material in the original detritus. In the tuffs and flows along the eastern border of the formation, the recrystallization of hornblende and the conversion of calcic plagioclase to the more sodic oligoclase released lime, some of which combined with iron, alumina, and silica to form epidote. The rest went into the formation of the calcite associated with the epidote in light patches found in some of the amphibolitic interbeds. Spessartite garnet crystallized in abundance where manganese was available, and oligoclase and quartz appeared to complete the equilibrium assemblage.

The heating and recrystallization of the rocks culminated in the invasion of these metasediments by fluids which caused the metasomatic introduction of quartz and feldspar. This introduction of material tended to destroy the foliation developed by the metamorphism. The central portion of the gneiss north of the Ellington-Crystal Lake road has only a poorly developed foliation, due to the alignment of discontinuous streaks of small biotite plates. South and westward, along the contact between the metasediments and the metavolcanics, the solutions invaded the more basic rocks. They converted the hornblende along the border into biotite and the andesine into less calcic oligoclase. Both changes released lime which combined with iron, alumina, and silica to produce the epidote so abundant in both the light and dark layers of this western border gneiss. Some of the lime reacted with rutile to produce the sphene in the hornblende gneiss. This sphene in certain cases forms a coat around the rutile grains.

This metasomatism of the hornblende schist is most strikingly evident on the hills west of Shenipsit Lake where the hornblende schist has been converted into a highly biotitic augen gneiss rich in epidote. The augen are composed of masses of small grains of quartz and oligoclase which have been added to the rock. In many places this transformation has been incomplete and patches of the original schist remain within the altered augen gneiss; in all cases the schistosity of these inclusions is aligned with that of the gneiss, indicating that the invading gneissic material was not in the form of a magma. A gradation in this rock can be traced southwestward into the hornblende-schist formation and northeastward into the poorly foliated, metasomatized sediments. Northward along the now irregular, gradational western border of the Glastonbury gneiss, epidote is abundant in scattered patches. In places it has separated by metamorphic differentiation into thin veins of epidosite that parallel the foliation of the gneiss. Portions of the hornblende schist have been so thoroughly permeated by the solutions that hornblende gneiss has resulted. This hornblende gneiss is so similar in composition and appearance to the Glastonbury that, in mapping, it was considered as a variation within the Glastonbury formation. Some of the interbeds of hornblende schist within the metasediments were converted to a highly biotitic schist; others remain relatively unaffected except for the introduction of some quartz.

It is not possible to say just what material has been introduced into the Glastonbury gneiss. However, judging from the quartz in the augen gneiss that is assumed to have been converted from the quartz-poor hornblende schist, there must have been some quartz added to both the metasediments and the borders of the adjacent basic intrusive. Oligoclase may also have been introduced, but the equilibrium assemblage of the metasediment must have consisted mainly of quartz and oligoclase, and no attempt was made in petrographic study to distinguish between original and secondary constituents. Both pyrite and apatite were introduced in minor amounts, the latter indicating that gaseous emanations may have played a part in the metasomatism.

The eastern border of the metasediments was less affected by metasomatism. Here finer-grained banded gneisses with interbedded amphibolites and muscovite schists give a truer indication of what the original metasediments must have been like. Foliation is better preserved and it follows the folds that were imprinted on the border gneiss during metasomatism.

The source of these fluids that accomplished the metasomatic conversion of the metasediments and portion of the hornblende schist is unknown. Previous workers, particularly Foye (1949, p. 74) and Aitken (1951, p. 52), have turned to the Monson magma, which Foye considered as equivalent to the Glastonbury, as a source of pore solutions that granitized gneissic bodies further east. However, in review, the following evidence strongly suggests that the Glastonbury gneiss was not intruded as a magma.

All the gneiss in the quadrangle was foliated by regional metamorphism and the original material, whether sediments or intruded mass, must have been in place before this metamorphism. There is good evidence, cited above, for believing that the western border of the present gneiss is the metasomatized border of the hornblende schist. The metasomatism tended to destroy the foliation and it must have occurred after the metamorphism had imprinted the foliation on the rocks, after any acidic magma would have cooled and ceased to furnish metasomatic emanations. It may be argued that this does not eliminate the possibility of an earlier intrusion which was more or less unrelated to the later metasomatism. However, when one considers the banded gneisses along the eastern border of the gneiss, with their shaly and volcanic derivatives, the zones within the gneiss rich in garnet and magnetite, and the long, narrow regional shape of the formation, the idea of an original sedimentary mass is hard to put aside. Further, the abnormally high quartz content (50 percent) must be attributed either to original sedimentary composition or to secondary addition. The writer believes that at least part of the quartz has been added by metasomatism, but in either case no magmatic intrusion need be involved.

It should be noted that any attempt to solve all the problems presented by the rocks of the Ellington quadrangle will be handicapped by the fact that half of the crystalline rocks underlying the area have been downfaulted and covered by Triassic strata. Portions of the Glastonbury gneiss and the hornblende gneiss border the fault. These may be minor extensions of the irregular Glastonbury formation or they may have been connected to another, perhaps igneous, body further west, but the answer to this and perhaps to the question of the source of the metasomatizing solutions now lies buried beneath many thousands of feet of sedimentary rocks.

SUMMARY

The whole cycle of metamorphism and later metasomatism can be related to a broad pattern of events. The tilting of the series of interbedded sediments and volcanics during early deformation could well have depressed the strata to depths where fusion of the sediments would begin to take place under the increased temperatures. Fluids, expelled from the initial fusion of the lower portions of the strata, would, upon rising, enter the upper rocks that were being subjected to medium-to-high temperatures and high stresses. These fluids probably acted as catalysts that accelerated the metamorphic reactions and produced mineral assemblages characteristic of the staurolite-kyanite subfacies of the amphibolite facies, and the metamorphism imposed a regional schistosity on the rocks.

Further fusion at depth resulted in more expulsion of fluids that channeled up through the more permeable metasediments and metasomatized these beds and the neighboring metavolcanics, producing the Glastonbury gneiss. Toward the close of the metasomatism, highly siliceous expulsions moved upward and were emplaced within the gneiss as pegmatites. These pegmatitic intrusions were at a lower temperature and caused retrogressive metamorphism, with the local development of the greenschist facies in the gneiss. This was accompanied by a pneumatolytic stage represented by the tourmalinization of the pegmatites, the quartz veins, and the adjacent gneiss.

ECONOMIC RESOURCES

The economic resources of the Ellington area may be divided into two main groups; bedrock and surficial deposits, the surficial being the more important at present.

Bedrock. Small quarries pockmark the hill in the southwest corner of the quadrangle where sandstone was quarried for building stone around the turn of the century. Paving and curbing stone have been quarried on a small scale from the Glastonbury gneiss on the hill west of Shenipsit Lake, but the dark color and lack of toughness make the crystalline rocks undesirable for use as building stone. Soapstone, as has been mentioned, has been worked on Soapstone Mountain, and trap rock has been taken from the diabase dike east of the mountain, presumably for use as road metal. Paving material has also been taken from two old quarries in the tough, silicified rock of the Triassic fault zone. One quarry is located on the west slope of the hill directly east of Ellington, and the second pit is found about one mile southeast of Somers. The quartzite interbeds of the Bolton are being quarried to the northeast and south in adjoining quadrangles for facing stone, but have never been worked in the Ellington area.

Surficial deposits. Sand and gravel pits in the stratified glacial deposits along Broad and Abbey brooks, northeast of Shenipsit Lake, and on the southwest slope of Bald Mountain provide the bulk of the mineral resources of the Ellington quadrangle. A small but profitable supply of humus for landscaping purposes comes from the bog at the head of Abbey Brook, and minor amounts are dug by the Lake Bonair Peat Company from the "shores" of the misnamed Lake Bonair.

GEOLOGIC HISTORY

The sequence of geologic events that resulted in the varied lithology of the Ellington quadrangle probably began during the early half of the Paleozoic era with the deposition of aluminous and arenaceous sediments accompanied by interbedded andesitic and basaltic volcanics. The sediments were probably deposited in a shallow marine environment. After lithification these beds were intruded by basic igneous magma which probably caused slight contact metamorphism of the adjacent country rock.

Compressive forces, perhaps occurring simultaneously with the basic intrusions, caused a tilting of the beds with a resulting average dip of 35° NW. Medium- to high-grade metamorphism involving strong deformation under high pressure and stress accompanied this tilting and converted the sedimentary beds to schists and quartzites, and the basic intrusives and extrusives to metagabbro and hornblende schist.

Metasomatism followed metamorphism and transformed a belt of the metasediments and portions of the adjacent hornblende schist into the Glastonbury gneiss. This metasomatism was accompanied by the early pegmatites and the minor folding that affected the eastern border of the Glastonbury gneiss. Large-scale pegmatite intrusion followed this deformation; radioactive minerals from these later pegmatites have furnished the only definite age determination for the crystalline rocks. The age of these pegmatites is estimated to be 260 million years (Rodgers, 1952, p. 414), and this places their intrusion near the beginning of the Mississippian period. The intrusion of these pegmatites was accompanied by the retrogressive metamorphism and the tourmalinization of the adjacent gneiss.

Triassic events included normal faulting with the downdropping of the western block of the crystalline rock. Recurrent movement along this fault line created the depositional basin, which filled with at least 16,000 feet of sandstone, shale, and conglomerate deposited under non-marine oxidizing conditions. Diabase lava filled a set of fractures in the crystalline rocks and cooled to form the en echelon trap dikes.

Later history included stream erosion throughout much of the Mesozoic era and the Tertiary period. Pleistocene glaciation and later stream erosion have molded the present topography.

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MODES

Percentage by Volume by Point Counter Method
Thin Sections

Minerals	E1	E2	E3	E8	E9	E10	E11	E12	E14	E16	E19	E20	E21	E23	E26	E29	E30	E33	E34
Quartz	..	..	..	46	58	55	41	55	..	6	26	48	60	88	..	tr	..	..	35
Oligoclase	..	..	..	41	33	12	30	37	..	..	..	..	8	..	..	..	..	..	tr
Andesine	..	..	..	..	..	..	..	..	40	32	57	..	..	..	..	..	..	..	..
Labradorite	52	54	55	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Bytownite	..	..	..	..	..	..	..	..	..	..	..	..	..	..	29	37	24	..	..
Microcline	..	..	..	..	..	tr	16	3	..	..	..	..	..	..	..	..	..	..	..
Biotite	tr	1	tr	..	7	23	7	4	..	..	..	8	12	..	..	..	..	..	9
Muscovite	tr	..	tr	..	..	..	4	..	..	..	..	25	19	11	..	..	..	..	35
Chlorite	..	tr	tr	..	..	..	tr	..	..	..	..	tr	tr	..	9	..	tr	15	10
Epidote	..	..	..	2	tr	10	2	..	6	..	2	..	..	..	..	..	tr	..	..
Clinozoisite	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	6	..	..	..
Garnet	..	..	..	..	tr	..	..	tr	..	..	..	3	tr	..	..	..		..	3
Staurolite	..	..	..	..	..	..	..	..	..	..	..	8	..	..	..	..		..	4
Kyanite	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	tr
Hornblende	..	..	..	10	..	..	..	..	52	61	14	..	..	..	60	57	75	..	..
Augite	46	41	42	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Magnetite	1	3	2	1	1	..	tr	tr	tr	tr	..	..	..	..	tr	..	tr	1	1
Pyrite	tr	..	..	..	..	..	..	tr	..	..	..	..	..	..	tr	tr	tr	1	..
Ilmenite	..	..	..	..	..	..	..	tr	..	..	..	..	..	..	tr	..	..	..	..
Leucoxene	..	..	..	..	..	..	..	tr	..	..	..	..	..	..	..	..	..	..	..
Graphite	..	..	..	..	..	..	..	..	..	..	..	7	..	..	..	..	..	..	2
Tourmaline	..	..	..	..	..	..	..	..	..	..	..	tr	..	..	..	..	..	..	..
Allanite	..	..	..	..	tr	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Apatite	..	..	..	tr	tr	..	tr	..	..	..	tr	..	..	..	..	..	..	..	..
Zircon	..	..	..	..	..	..	..	tr	..	..	..	..	..	..	..	..	..	..	..
Rutile	..	..	..	..	..	..	..	..	2	tr	tr	..	..	..	..	..	tr	..	..
Sphene	..	..	..	..	..	tr	..	..	..	..	tr	..	..	..	..	..	..	..	..
Olivene	..	tr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Anthophyllite	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	62	..
Calcite	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..
Talc	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	15	..

All figures given in percent.
tr—trace, mineral composes less than 1% of the rock.

Identification and Location of Analyzed Specimens

Diabase dike

E1 South end of the southernmost segment of the dike.
E2 Top of hill just north of Kimballs brook.
E3 Southeast slope of Soapstone Mountain.

Glastonbury gneiss

E8 Hornblende gneiss, at roadside 0.8 miles east of route 83 along the Ellington-Crystal Lake road.
E9 At roadside just north of the west lobe of Lake Bonair.
E10 Augen gneiss, just north of house on top of hill west of Shenipsit Lake. Due to the difficulty in distinguishing between quartz and oligoclase in thin section, the quartz-oligoclase ratio is probably too high. The analysis is included to show the relatively high amounts of biotite and epidote.
E11 Near the head of the small stream west of Shenipsit school.
E12 Top of hill southwest of pond at head of Martin brook.

Hornblende schist

E14 Top of hill 701 at south border of quadrangle, west of Shenipsit Lake.
E16 Hornblende schist interbed at roadside north of west lobe of Lake Bonair.
E19 Hornblende gneiss layer, just east of fault line 0.25 miles south of Ellington-Somers town line.

Bolton schist

E20 South slope of hill west of head of Brown's brook.
E21 Glastonbury-Bolton border zone, southeast slope of Newell hill.
E23 Quartzite interbed, east slope of hill northeast of head of Grant's brook.

Metagabbro

E26 Gabbro, south slope of hill west of Soapstone Mountain.
E29 Gabbro, north slope of Soapstone Mountain.
E30 Hornblende schist, southeast slope of Soapstone Mountain.
E33 Soapstone, from large quarry at top of southeast slope of Soapstone Mountain.

Amherst schist

E34 Just north of route 20 near contact with hornblende schist.

QUADRANGLE REPORTS

For location, see fig. 1, p. 3.

1. Bedrock geology of the Litchfield quadrangle, with map: by Robert M. Gates, Ph.D.; 13 pp. index map, and quadrangle map in color, 1951; published as Miscellaneous Series No. 3. (Quadrangle map alone, .25) .75

2. The geology of the New Preston quadrangle: Part I, The bedrock geology: by Robert M. Gates, Ph.D.; Part II, The glacial geology: by William C. Bradley; 46 pp., 14 pls., with charts, index map, and quadrangle map in color, 1952; published as Miscellaneous Series No. 5. (Quadrangle map alone, .25) 1.00

3. The bedrock geology of the Woodbury quadrangle, with map: by Robert M. Gates, Ph.D.; 23 pp., 8 pls., index map, and quadrangle map in color, 1954. (Quadrangle map alone .25) 1.00

4. The bedrock geology of the Ellington quadrangle, with map: by Glendon E. Collins; 44 pp., index map, and quadrangle map in color, 1954. (Quadrangle map alone, .25) 1.00

5. The bedrock geology of the Glastonbury quadrangle, with map: by Norman Herz, Ph.D.; in press.