Petrochemistry and Bedrock Geology of the Fitchville Quadrangle Connecticut

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GEOLOGICAL SURVEY BULLETIN 1161-I

Prepared in cooperation with the Connecticut Geological and Natural History Survey

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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By GEORGE L. SNYDER

CONTRIBUTIONS TO GENERAL GEOLOGY

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PETROCHEMISTRY AND BEDROCK GEOLOGY OF THE FITCHVILLE QUADRANGLE, CONNECTICUT

By George L. Snyder

ABSTRACT

Pre-Pennsylvanian metasedimentary and metaigneous rocks underlie the entire Fitchville quadrangle. The rocks sustained regional dynamothermal metamorphism at least once, mostly under conditions representative of the almandine amphibolite facies. Four zones of progressive regional metamorphism (garnet, staurolite, sillimanite, and sillimanite and potassium feldspar) are mapped, and it is noted that the first appearance of sillimanite in the pelitic rocks is about coincident with the first appearance of diopside, scapolite, or garnet in the calc-silicate rocks. Probably early in this metamorphism, a major system of isoclinal folds having axial planes parallel to the trends of the present geologic units formed. Before the close of metamorphism, gabbro, pegmatite, and quartz monzonite were intruded, and their intrusion was followed by the formation of a system of folds having axial planes at a large angle to the trends of the present geologic units. As temperature dropped, dynamic metamorphism became dominant, locally culminating in movement along a fault, the Honey Hill fault, which is indicated by truncated isoclinally folded geologic units, a cataclastic zone half a mile wide, and a truncation of one of the older metamorphic zones. Eight new lead-alpha age determinations on zircon or monazite range from 280 to 530 million years old and probably record metamorphic recrystallization during this interval.

New chemical, modal, and semiquantitative spectrographic analyses for 49 rocks from the Norwich and Fitchville quadrangles are recorded. Similar suites of rocks have their analyses grouped together, and the average of these suites are available for comparison in a separate table. Pelitic rocks containing aluminum silicate minerals have been most susceptible to alteration, and a suite of these rocks shows a general variation in composition with amount of alteration that is probably mostly due to original compositional differences controlling the extent of alteration.

INTRODUCTION

The Fitchville quadrangle, in southeastern Connecticut northwest of the Thames River estuary, includes about 55 square miles, two-thirds of which is forest covered. Altitudes within the quadrangle range from less than 50 feet in Trading Cove Brook in the southeast corner of the map area to more than 580 feet in the southwest and northwest corners. Local relief is 50 to 300 feet.

Drainage and topography have been little affected by structure or differential erodibility of the rock units. The Yantic River drains eastward and appears to have been superimposed on the north-trending bedrock units across which it flows. However, Trading Cove Brook and part of Pease Brook do reflect the positions, respectively, of the Honey Hill fault and the unnamed fault which offsets the gabbro in the area. Two other faults which offset the gabbro in the northeastern part of the Colchester quadrangle are also indicated by north-south segments of stream valleys. Calc-silicate rocks, pelitic schists, and granitic gneisses have been about equally resistant to erosion. These rocks maintain equivalent summit levels and generally stand above the less common but more readily eroded calcite-biotite schist of the Hebron Formation, as in the McCarthy Brook area. The Lebanon Gabbro of Rodgers and others (1956) makes a prominent topographic bench, possibly because it overlies weak calcite containing schists. Joints are not conspicuous in the schists, and they are present in closely spaced sets only rarely in the granitic rocks. Possibly the valley in Canterbury Gneiss south of Fitchville Pond has been controlled by such a joint set.

The area has been glaciated at least once. Rock crops out in 6 percent of the quadrangle, and areas of outcrop are fairly uniformly distributed throughout the quadrangle. Float boulders are abundant in some areas that lack outcrops, as on Mason Hill and west of Bozrah Street.

The bedrock geology of the Fitchville area has been shown on small-scale geologic maps of eastern Connecticut by Mather (1834), Percival (1842), Gregory and Robinson (1907), Foye (1949), and Rodgers and others (1956), and it is mapped here (pl. 1) at a scale of 1:24,000. Gregory and Robinson show a belt of Pomfret Phyllite of Gregory (in Rice and Gregory, 1906) within the quadrangle that would cross the geologic contacts shown on this map. For this reason and because no true phyllites were found, the name Pomfret Phyllite is not used here.

Petrographic descriptions are based on the study of about 500 thin-section samples that were collected fairly evenly over the quadrangle, except that many more samples were collected in areas of tight structure. The most abundant mineral is always mentioned first in the text and is followed successively by minerals of lesser abundance. Mineral abundances in all rocks are also summarized in table 1.

I am grateful for the free access granted by Prof. Lawrence Lundgren, Lawrence Ashmead, and Prof. John Rosenfeld and

TABLE 1.—*Petrographic summary of rocks of Fitchville quadrangle, Connecticut*

[Key to mineral abundance: *A*, abundant in all rocks observed; A, abundant in most rocks observed; a, abundant in a few rocks, not observed in most; *C*, common in small amounts in all rocks observed; C, common in small amounts in most rocks observed; c, present in small amounts in a few rocks, not observed in most; --, not observed]

	Quartz	Plagioclase	Potassium feldspar	Muscovite	Sillimanite	Kyanite	Scapolite	Epidote-clinozoisite	Calcite	Staurolite	Chlorite	Biotite	Diopside-augite	Aegirinaugite	Hornblende	Tremolite-actinolite	Garnet	Magnetite-ilmenite	Pyrite	Galena	Pyrrhotite	Graphite	Tourmaline	Apatite	Rutile	Sphene	Zircon	Monazite	Allanite
Quartz monzonite gneiss	*A*	*A*	*A*	A–C	--	--	--	c	--	--	--	A–C	--	--	--	--	a	c	c	--	--	--	c?	c	--	c	c	c	c
Pegmatite	A	A	A	A–C	--	--	--	c	--	--	--	A–C	--	--	--	--	A–C	c	c	--	--	c	a	c	c	c	c	c	c
Lebanon Gabbro of Rodgers and others (1956)	*C*	*A*	--	--	--	--	c	a–c	--	--	c	A	c	--	*A*	c	--	A–C	c	--	--	--	c	A–C	c	a–c	c	c?	c
Aegirinaugite gneiss	*A*	*A*	*A*	--	--	--	--	--	--	--	c?	--	--	*A*	--	--	C	--	--	--	--	--	--	--	c	c	c	--	--
Alaskite gneiss	A	*A*	*A*	--	--	--	--	--	c	--	--	C	c	--	c	--	c	*C*	c	--	--	c	--	c	--	C	C	--	c
Canterbury Gneiss	*A*	*A*	*A*	C	--	--	--	C	--	--	--	*A*	--	--	c	--	c	c	c	--	--	c	c	c	--	C	c	c	c
Scotland Schist:																													
Scotland belt	*A*	A	c	*A*	a	a	--	--	--	A	--	A	--	--	--	--	A	c	c	--	a–c	c	C	c	c	c	c?	c	c
Pitchers Pond belt	*A*	*A*	--	A	c	a	--	--	--	a	--	*A*	--	--	--	--	C	c	c	--	c	c?	C	c	--	c	c	c	c
Quartzite at Franklin	*A*	a	a	C	--	--	--	--	a	--	--	C	--	--	--	--	c	c	c	--	--	--	c	c	--	--	c?	--	--
Hebron Formation:																													
Calc-silicate rock	*A*	*A*	a	--	--	--	--	A	c	--	--	A	a	--	*A*	a	a	c	c	--	c	c	c	c	--	*C*	c	c?	c
Biotite-calcite schist	*A*	*A*	a	c	--	--	a	C	*A–C*	--	C–c	*A*	a	--	A	A–a	c	c	c	--	c	--	c	c	--	C	c	c?	c
Biotite schist	*A*	*A*	a	--	--	--	--	--	--	--	a–c	*A*	--	--	--	--	c	c	c	--	c	c	c	c	--	C	c	c	c
Putnam Gneiss:																													
Amphibolite	C	A	--	--	--	--	--	a	--	--	--	C	--	--	*A*	--	--	c	C	--	--	--	--	--	c	C	--	--	--
Biotite-muscovite schist	*A*	*A*	a	A	c	--	--	c	c	c	--	*A*	--	--	--	--	a	c	c	--	--	c	c	c	c	c	c	c	c
Sillimanite-pinite schist	*A*	*A*	c	*C*	*C*	--	--	c	--	--	--	*A*	--	--	--	--	*C*	c	c	--	--	--	--	--	c	--	c	c	--
Fly Pond Member:																													
Calc-silicate rock	*A*	*A*	A–C	--	--	--	a	A–C	c	--	--	A–C	a	--	*A*	C	--	c	c	--	c?	c	--	c	--	*C*	c?	c?	c
Marble	c	A	a	--	--	--	A	a	A	--	--	C	A	--	a	c	a	c	c	c	C	C	--	--	c	C	c	--	c
Brimfield Schist	*A*	*A*	--	*A*	c	--	--	--	--	--	--	*A*	--	--	--	--	A	c	c	--	--	c	c	c	c	--	c?	c	--
Plagioclase gneiss south of Honey Hill fault	*C*	*A*	C	c	--	--	--	c	--	--	--	*C*	--	--	c	--	c	C	c	--	--	--	--	c	--	c	c	--	c
Amphibolite south of Honey Hill fault	A	*A*	c	--	--	--	a	c	--	--	--	A	--	--	*A*	--	--	C	--	--	--	--	--	c	--	C	--	--	--

Prof. Gordon Eaton to their unpublished maps of the Deep River and Hamburg, Moodus, and Middle Haddam quadrangles, respectively. Prof. Patrick Hurley kindly made his manuscript on radioactive ages in the Narragansett Basin, Rhode Island, available to me before its publication.

ROCK DESCRIPTIONS

Six metasedimentary formations and six metaigneous rocks have been mapped as a folded sequence that is cut by the Honey Hill fault at the south edge of the quadrangle. The metasedimentary rocks, in order of probable decreasing age, are (1) plagioclase gneiss and amphibolite, (2) Putnam Gneiss, (3) Brimfield Schist (possibly equivalent to Putnam Gneiss), (4) Hebron Formation, (5) quartzite, and (6) Scotland Schist. This order depends on structural considerations favored by modern workers in the area. Another sequence, depending on a less-favored structural model, might be 1 (lowest unit), 2, 4, 5, 6, and 3 (uppermost unit). The metaigneous rocks, which are mostly prekinematic or synkinematic, comprise Canterbury Gneiss, light-colored alaskite gneiss, aegirinaugite gneiss, Lebanon Gabbro of Rodgers and others (1956), pegmatite, and quartz monzonite gneiss.

METASEDIMENTARY ROCKS

PLAGIOCLASE GNEISS AND AMPHIBOLITE

Two types of compositionally layered probable metasedimentary rocks have been mapped south of the Honey Hill fault: a dull-gray medium-grained layered plagioclase gneiss, and local lenses of speckled dark-green medium-grained granular amphibolite. The plagioclase gneiss north of the main body of alaskite contains layers of alaskite as much as 10 feet thick locally; that south of the alaskite is well exposed in many places north of Stony Brook, as in the southern part of the Barrett quarry. Amphibolite is well exposed in the lens southwest of Heilwield Road. Most amphibolites contain about equal amounts of hornblende and feldspar.

Major minerals of the plagioclase gneiss are oligoclase, quartz, potassium feldspar, biotite, and magnetite-ilmenite; the rock also contains minor amounts of hornblende, muscovite, epidote, and sphene. Accessory minerals are apatite, zircon, allanite, garnet, and pyrite. Major minerals of the amphibolite are calcic oligoclase or andesine, blue-green hornblende, biotite, quartz, and sphene; minor minerals are magnetite-ilmenite, potassium feldspar, epidote, apatite, and scapolite.

PUTNAM GNEISS

The Putnam Gneiss comprises a variety of calcic and aluminous metasedimentary rocks. Two pelitic facies (lithofacies)—biotite-muscovite schist and sillimanite-pinite schist—and one calcic, amphibole-bearing member—the Fly Pond Member—are mapped. Amphibole-bearing rocks in the western part of the Putnam Gneiss were recognized by Percival (1842, p. 274) and were mapped and named by Snyder (1961).

BIOTITE-MUSCOVITE SCHIST

Biotite-muscovite schist is lustrous, gray and medium grained and can be distinguished from other schists by conspicuous porphyroblasts of muscovite and large augen of white plagioclase. Garnet is generally absent but is locally conspicuous; individual crystals are as large as 1 inch in diameter. Biotite is generally more abundant than muscovite, except on the west side of the western belt of schist where muscovite is more abundant. Within half a mile of the Honey Hill fault, most schists are partly crushed and are darker in color and more porphyritic than the usual schist. Porphyroclasts of plagioclase and muscovite are set in a fine-grained gray-green to black matrix. In the Honey Hill fault zone, quartz and biotite are very fine grained; muscovite and plagioclase porphyroclasts are rotated, bent, and broken; and cataclastic textures are abundant. Locally, extremely fine grained mylonites have the outward appearance of a layered black argillite. The best exposures of normal biotite-muscovite schist are in the new roadcuts near Yantic; recrystallized, darker mylonite gneisses are present in several exposures along South Road. The biotite-muscovite schist is in sharp contact with calc-silicate rocks of the Hebron Formation and the Fly Pond Member of the Putnam Gneiss.

Major minerals of the biotite-muscovite schist are quartz, oligoclase-andesine, biotite, and muscovite; garnet is a minor constituent. Accessory minerals are potassium feldspar, magnetite-ilmenite, pyrite, apatite, zircon, monazite, epidote, sphene, rutile, allanite, calcite, and very local graphite, staurolite, tourmaline, and sillimanite. Prismatic sillimanite occurs only in or around a few of the large garnet porphyroblasts.

Unmapped lenses of amphibolite or hornblendite as much as 5 feet thick are confined to biotite-muscovite schist within 50 yards of the contact with the Fly Pond Member. They consist of hornblende, zoned labradorite, and minor amounts of quartz, biotite, epidote, pyrite, sphene, magnetite-ilmenite, and rutile. These hornblendic rocks are slightly more calcic and less potassic than the amphibolites south of the Honey Hill fault.

SILLIMANITE-PINITE SCHIST

Sillimanite-pinite schist of the Putnam Gneiss is characterized by garnet and prismatic sillimanite or by pods of pinite pseudomorphous after sillimanite in a rock otherwise similar to the biotite-muscovite schist (table 1). Sillimanite-pinite schist is gradational with biotite-muscovite schist.

FLY POND MEMBER

The Fly Pond Member consists mostly of light- to dark-gray-green layered medium- to coarse-grained calc-silicate gneiss and granofels (a coarse-grained rock without significant megascopic mineral orientation; Goldsmith, 1959) and marble. The calc-silicate granofels, the most abundant rock, contains compositional layers from ¼ to 3 inches thick that weather differentially. Layers with biotite and potassium feldspar are recessed on the weathered surface with respect to layers without these minerals. The contact between the calc-silicate granofels and other rocks is sharp. Contorted marble is well exposed under the word "South" of "South Road" (pl. 1), and calc-silicate granofels is well exposed on the steep south-facing slope of the hill just north of this.

Major minerals of the calc-silicate granofels are calcic andesine or labradorite, quartz, hornblende, biotite, potassium feldspar, aluminous epidote, and lesser amounts of tremolite-actinolite, diopside, scapolite, and sphene. The marble, which is mapped separately, consists of highly variable proportions of calcite, diopside, and scapolite, and lesser amounts of calcic plagioclase, biotite, potassium feldspar, aluminous epidote, garnet, hornblende, and graphite. Interlayered with both the calc-silicate granofels and the marble are minor amounts of oligoclase-biotite-quartz-orthoclase schist containing small quantities of garnet and graphite. Locally, marble grades into very coarse grained mineral segregations consisting largely of scapolite, diopside, garnet, or hornblende, and lesser quantities of the other minerals. Accessory minerals in the Fly Pond Member are allanite, calcite, pyrite, pyrrhotite(?), monazite(?), zircon, apatite, galena, rutile, magnetite-ilmenite, and graphite.

BRIMFIELD SCHIST

Silvery- to rusty-weathering medium- to coarse-grained schist, mapped as Brimfield Schist, is poorly exposed in a narrow belt along the west-central edge of the quadrangle; good exposures are present in the Colchester quadrangle northwest of Deep River Reservoir. The rock is granular as well as schistose, and it forms steep ledges. Pods of coarse muscovite as much as several inches long are conspicuous in hand specimen, and quartz, plagioclase, biotite, and garnet are usually visible. Biotite and muscovite are about equally abundant. This schist is similar in composition and grain size to the biotite-muscovite schist of the Putnam Gneiss but differs from the Putnam in that it has a rusty-weathering color, contains muscovite pods, and does not contain plagioclase augen.

The name Brimfield Schist was introduced by Emerson (1898, p. 252; 1917, p. 68) for rusty graphitic biotite schist in the vicinity of Brimfield, Mass. Callaghan (1931, p. 29, 74) redefined the Brimfield Schist and restricted the name to the upper part of the old formation. Mapping by Lawrence Ashmead in the Moodus quadrangle and my reconnaissance work in the adjoining Colchester quadrangle indicate that the schist here mapped as Brimfield Schist is continuous with rusty graphitic sillimanite schist at East Hampton, Middle Haddam quadrangle, that is lithologically similar to, and on strike with, both Emerson's type Brimfield Schist and Callaghan's redefined Brimfield Schist. Brimfield Schist was not recognized in the Rockville quadrangle between East Hampton and the type area, however (Aitken, 1955); so this correlation should be considered a tentative one.

The Brimfield Schist in the Fitchville quadrangle is largely mica schist, but it also has a few thin lenses of calc-silicate rock that contain more poikilitic garnet than does any other rock in the quadrangle. Major minerals of the mica schist are quartz, oligoclase, biotite, muscovite, and smaller amounts of garnet, graphite, and fibrolitic sillimanite, the last usually in sheaves or clots in the centers of the pods of coarse muscovite. Accessory minerals are tourmaline, magnetite-ilmenite, pyrite, monazite, zircon(?), apatite, and rutile. Major minerals of the garnetiferous calc-silicate rock are quartz, extremely poikilitic garnet, hornblende, epidote, calcic plagioclase, diopside, pyrrhotite, and a carbonate, Accessory minerals are biotite, sphene, allanite, apatite, and magnetite-ilmenite.

HEBRON FORMATION

The Hebron Formation includes a variety of granular and micaceous schists and gneisses that represent metamorphosed calcic sedimentary rocks (Snyder, 1961). Calcic rocks, dominantly calc-silicate types and calcite-biotite schist, occur in three parallel belts, described separately below, that are separated by the Lebanon Gabbro of Rodgers and others (1956) and the main belt of the Scotland Schist. The formation as here defined is similar to the Hebron Gneiss of Rodgers and others (1959, p. 49, 50) except that the Scotland Schist and the Brimfield Schist are excluded.

Calcic rocks of the Hebron Formation consist of (1) layered fine-grained greenish-gray calc-silicate rock composed of quartz, andesine-labradorite, hornblende, and lesser amounts of biotite, diopside, aluminous epidote, potassium feldspar, tremolite, and sphene; (2) purplish-brown nonresistant schist composed of quartz, andesine-labradorite, biotite, and calcite; and (3) brown schist composed of quartz, oligoclase-andesine, biotite, potassium feldspar, and sphene. All three rocks contain a peculiar purplish-brown biotite and are high in quartz and plagioclase. The different lithologies are mixed in repeated layers from one-fourth inch to several tens of feet thick. Calc-silicate rock and biotite schist generally weather in slabs from ½ to 3 inches thick; calcite-biotite schist weathers readily to a chocolate-brown punky sand and is generally exposed only in natural or artificial excavations. Calc-silicate rock and biotite schist are exceptionally well exposed in several new roadcuts on the north side of Bashon Hill. Calcareous biotite schist is exposed in a small roadside outcrop just southeast of BM 207.

The rocks of the different calcic belts differ mainly in the relative proportions of calc-silicate rock and calcite-biotite schist and in some aspects of their detailed mineralogy. In the belt west of the Lebanon Gabbro, the estimated volumetric proportions of calc-silicate rock, calcareous biotite shist, and noncalcareous biotite schist are 8, 0, and 2, respectively; in the belt between the Lebanon Gabbro and Scotland Schist they are 2, 7, and 1; and east of the Scotland Schist, 4, 5, and 1. All calcareous schist in the belt east of the Scotland Schist crops out north of the Yantic River. The westernmost calcic belt contains many concordant pegmatites. The calcic rocks of the Hebron Formation are similar in mineralogy and average composition to those of the Fly Pond Member of the Putnam Gneiss but differ from them in that they are finer grained, contain no marble or tourmaline, and contain more interlayered biotite schist.

Besides the minerals in the three kinds of calcic rocks listed above, other minerals are of local significance. Scapolite, garnet, and chlorite are abundant in a few layers. Plagioclase is locally as calcic as anorthite in layers that contain diopside, aluminous epidote, and tremolite. Biotite and diopside, usually in different layers (of different total composition), are together only in the presence of potassium feldspar. Potassium feldspar is especially conspicuous in those layers of the Hebron Formation that are interleaved with Canterbury Gneiss. Accessory minerals are pyrrhotite, allanite, pyrite, magnetite-ilmenite, apatite, zircon, monazite(?), tourmaline, graphite, calcite, and muscovite. The westernmost belt is the only one that contains graphite; the central belt is the only one that contains tremolite in the absence of diopside and hornblende; and the eastern belt is the only one that contains chlorite, which is either in calcite-biotite schist or in biotite schist.

QUARTZITE AT FRANKLIN

Dirty-white medium-grained uniform to layered quartzite is well exposed north of the village of Franklin in a roadcut along

State Route 32. Quartzite was noted near Franklin by Percival (1842, p. 269), but it has not been previously mapped. This rock forms a layer 3 inches to 30 feet thick in lenses as much as 1 mile long; all lenses 5 feet or more thick are mapped The quartzite lentils are exposed as far south as section *A–A′*. They grade by interlayering into both the Scotland Schist above and the calc-silicate rock or biotite schist of the Hebron Formation below. The zone of gradation is as much as 10 feet thick where the quartzite is thickest.

The quartzite at Franklin is lithologically distinct. From 85 to more than 95 percent of the rock is quartz, and muscovite is commonly the only other major constituent. Biotite, potassium feldspar, oligoclase-andesine, or calcite are relatively abundant locally. Rare accessory minerals are pyrite, garnet, ilmenite, zircon(?), tourmaline, and apatite.

SCOTLAND SCHIST

Silvery- to rusty-weathering muscovite schist was first named Scotland Schist by Gregory (in Rice and Gregory, 1906, p. 141). In the Fitchville area, Scotland Schist is typically exposed in a new roadcut northeast of Brush Hill. It typically forms shiny low rounded outcrops or moss-covered cliff faces that have prominent lenticles of quartz usually several inches long but as much as several feet long parallel to the foliation. Red garnet, brown staurolite, and light- to dark-gray muscovite (colored by tiny included particles of graphite) are visible in most outcrops. Muscovite is generally much more abundant than biotite, and micas are more abundant than feldspar, distinguishing the Scotland Schist from the biotite-muscovite schist of the Putnam Gneiss. Scotland Schist is generally in sharp contact with calcic rocks of the Hebron Formation; locally, muscovite schist and hornblende schist are interlayered near the contact.

Scotland Schist is composed of a highly micaceous schist, which forms more than three-fourths of the outcrops, and a granular schist. Both rocks are high in quartz, but the micaceous schist also contains much muscovite and biotite and is low in plagioclase; the granular schist is high in plagioclase and relatively low in muscovite. The granular schist is most conspicuous near the borders of the main belt or throughout the thinnest part of the belt west of Bozrah Street. The two types are interlayered on all scales and are gradational with each other near their contact both by minute interlayering and by gradual change in overall mineralogical composition.

Major minerals of the micaceous schists are quartz, muscovite, biotite, calcic oligoclase or sodic andesine, and lesser amounts of staurolite and garnet. Locally significant accessory minerals are graphite, tourmaline, pyrrhotite, magnetite-ilmenite, apatite, fibrolitic sillimanite, and kyanite. Other accessories are zircon, monazite, pyrite, allanite, microcline, sphene, and rutile. Major minerals of the granular schists are quartz, calcic oligoclase to sodic andesine, muscovite, and biotite; garnet and staurolite are in minor abundance. The muscovite-biotite ratio is close to unity in the granular schists and greater than unity in the micaceous schists. Accessory minerals in the granular schists are similar to those in the micaceous schists.

Medium-grained dull gray granular biotite schist that crops out in the northwest corner of the map area near Pitchers Pond may be correlative with Scotland Schist (H. R. Dixon, written communication, 1961). The identification of it is queried at that locality. The rock forms slabby gray ledges, and the glacial till south of the outcrop area contains numerous slabs of gray biotite schist. Plagioclase, quartz, and biotite are recognizable in every outcrop; muscovite, light-yellow staurolite, garnet, and kyanite are present locally.

The schist near Pitchers Pond is composed of granular biotite schist, which forms more than three-fourths of the outcrops, and micaceous schist. Both rocks are high in plagioclase, quartz, and biotite content. The granular schist contains mainly these minerals, but the micaceous schist also contains much muscovite and is higher in total amount of mica. In almost every place biotite is more abundant than muscovite. The schist near Pitchers Pond and the main belt of Scotland Schist contain reverse proportions of granular schist and micaceous schist. The schist near Pitchers Pond also differs from that to the east in that it has a much lower content of muscovite and garnet, and its staurolite is lighter colored.

Near Pitchers Pond, major minerals of the granular schist are andesine, quartz, and biotite; minor minerals are muscovite, garnet, and tourmaline. Major minerals of the micaceous schists are andesine, quartz, biotite, muscovite, garnet, and, locally, concentrations of kyanite and staurolite; tourmaline is nearly ubiquitous but minor. Accessory minerals are similar to those in the rest of the Scotland Schist.

METAIGNEOUS ROCKS

CANTERBURY GNEISS

Canterbury Gneiss is a generally uniform medium-grained gray micaceous orthogneiss that ranges in composition from granite to tonalite but most commonly is granodiorite or quartz monzonite. It is in sharp contact with Scotland Schist, pelitic rocks of the Putnam Gneiss, and calc-silicate rocks of the Hebron Formation and is gradational with the pegmatite west of Dark Swamp. The rock typically crops out in broad flat whalebacks on hilltops or in long bald ledges on hillsides. It is best exposed in a new roadcut on the hill east of

Fitchville. Purplish-tinted discordant quartz veins are locally conspicuous, as in the roadcut northwest of Yantic. The Canterbury Gneiss was named by Gregory (in Rice and Gregory, 1906, p. 142), though he did not map any in the Fitchville quadrangle except for one small body west of Smith Corner which is here mapped as pegmatite. The name Canterbury Gneiss is here applied provisionally to one complex and two simple bodies that are geographically separate. Two of these probably connect at depth (section *B–B′*); their relationship with the third body is not known. Each of these bodies consists of feldspar-quartz-biotite gneiss, but there are slight differences between them. The body underlying Fitchville is continuous with the main mass of Canterbury Gneiss. It is medium grained and uniformly foliated but lacks megascopic muscovite. The body north of Gardner Lake is less uniformly foliated and generally contains conspicuous megascopic muscovite and, locally, garnet and tourmaline. The body west of Tadma Pond is darker and more manifestly porphyroclastic than the other two bodies owing to its proximity to a branch of the Honey Hill fault. The rock commonly has a mortar texture, especially near its south contact, and contains porphyroclasts of feldspar set in a dark groundmass of fine-grained quartz and biotite.

Major minerals in all bodies of Canterbury Gneiss are oligoclase or sodic andesine, quartz, microcline, and green-black biotite; minor minerals are muscovite, ferruginous epidote, sphene, and garnet. Gneisses high in microcline and containing small amounts of garnet and brown biotite form part of the body that underlies Fitchville in a zone within 100 yards of the west contact, from State Route 163 to Stockhouse Road. Accessory minerals are nearly ubiquitous euhedral allanite grains that have epidote rims, zircon, magnetite-ilmenite, pyrite and apatite, and rare blue-green hornblende, tourmaline, and monazite.

LIGHT-COLORED ALASKITE GNEISS

Light-red-, buff-, or gray-weathering medium-grained mafic-poor alaskite gneiss crops out in abrupt high domical ledges or long low continuous ledges south of the Honey Hill fault; it is especially well exposed in the Barrett quarry. It ranges in composition from granodiorite to granite. Light-colored albite alaskite or quartz monzonite predominates. The rock characteristically displays a strong uniform gneissic foliation. Mafic minerals, which are identifiable only locally in hand specimen, average 3 percent of the rock. Alaskite gneiss is generally in sharp contact with amphibolite or plagioclase gneiss and encloses small areas of these rocks. This gneiss differs from Canterbury Gneiss in that it weathers red and has a low content of mafic minerals, a lower anorthite content of the plagioclase, and no muscovite or ferruginous epidote.

The light-colored alaskite gneiss is probably equivalent to, or to part of, the Sterling Granite Gneiss that was first mapped by Mather (1834) but first named by G. F. Loughlin in 1904. (See Rodgers and others, 1959, p. 57.) This name was first published by Gregory (in Rice and Gregory, 1906, p. 134). Between 1834 and the present, Sterling Granite Gneiss has been mapped and separated into several different units by many workers. (See summary, in Rodgers and others, 1959, p. 57.) The most recent mapping of rocks formerly mapped as Sterling Granite Gneiss was by Lundgren (1962, fig. 2) in the Deep River area, and correlative rocks are currently being mapped and subdivided by Richard Goldsmith in the adjoining Montville and Uncasville quadrangles.

Typical light-colored albite alaskite gneiss consists of about equal amounts of albite, microcline, and quartz, and minor amounts of magnetite-ilmenite, biotite, blue-green hornblende, and sphene. Sphene usually occurs as rims on magnetite-ilmenite; in one rock it was identified as keilhauite, which is the characteristic yttrium- or cerium-bearing sphene of the Sterling (Young, 1938). Clear green ferriferous augite is known from two localities—in a roadcut on Heilwield Road and in the Barrett quarry. Other accessory minerals are zircon, pyrite, allanite, apatite, garnet, calcite, and graphite.

A rock of unusual composition, here included with the alaskite, is a quartz-free light-colored albite syenite found in a sill-like layer 6 inches thick parallel to the foliation of normal alaskite in the Barrett quarry.

AEGIRINAUGITE GNEISS

Aegirinaugite has been identified in white gneiss on the south slope of the hill north-northwest of BM 473 at lat 41°30′15.7″ N. and long 72°12′16.7″ W. The aegirinaugite-bearing rock is exceptional in its overall composition, mineralogy, and texture. It is an albite granodiorite or granite, three-fourths of which is a compact granular aggregate of albite and minor amounts of microcline, melanite(?), sphene, zircon, and rutile. The remainder of the rock consists of vuglike aggregates of quartz containing radiating or parallel groups of rods of green aegirinaugite. Albite, in contact with quartz near the borders of the vuglike areas, is uniformly euhedral and locally contains rods or needles of aegirinaugite near the outer edges of the crystals. Perhaps this rock is derived from a contaminated magma that crystallized after deformation had ceased. Possibly the aegirinaugite gneiss is correlative with the aegirinaugite-containing marker bed of Goldsmith (1961, fig. 169.1) and Lundgren (1962, p. 8, 9).

LEBANON GABBRO OF RODGERS AND OTHERS (1956)

Spotted gray to black coarse-grained hornblende metagabbro crops out in a thin curving belt from Goshen Hill to Gardner Brook. This sill-like mass is believed to be continuous with a body of gabbro in the adjoining Willimantic quadrangle that was originally named the Lebanon Gabbro by Dow.[1] This name has been accepted by Rodgers and others (1956) and is used here. Percival (1842, p. 260–263) mapped a linear belt of rock equivalent to the Lebanon Gabbro west of Pease Brook. The rock forms low ledges or bald knobs, which in many places are littered with large frost-quarried blocks and one-half-inch grus granules that have weathered from both the outcrop surface and the blocks. It ranges in composition from diorite to metagabbro, but gabbro is predominant. West of Pease Brook, the Lebanon is coarse-grained to very coarse grained and nearly granoblastic and contains more light than dark minerals. South of Kahn Ponds it is gneissic and contains more dark than light minerals. The metagabbro differs from other amphibolites by its coarse texture and by having highly twinned plagioclase. Typical exposures of metagabbro are present near the road north-northeast of Avery Corner and in Parson Brook.

The texture of the metababbro ranges from subhedral granular to gneissic. Major minerals are plagioclase, dark-blue-green hornblende, and biotite; minor minerals are quartz, apatite, magnetite-ilmenite, ferruginous epidote, and sphene. Grains of plagioclase are subhedral and progressively zoned and show abundant twinning on both albite and Carlsbad laws. Plagioclase ranges in composition from calcic andesine to anorthite but commonly is labradorite or bytownite. Bytownite is more abundant in the more felsic rocks west of Pease Brook than in the more mafic rocks south of Kahn Ponds. Quartz is generally associated with hornblende either as aggregates of individual crystals or as tiny inclusions in hornblende poikiloblasts. Accessory minerals are pyrite, chlorite, rutile, monazite(?), allanite, augite (one locality), tremolite-actinolite, zircon, scapolite (one locality), and tourmaline. Rutile is scarce in felsic metagabbro west of Pease Brook but common in mafic metagabbro south of Kahn Ponds.

The subhedral habit, progressive zoning, and abundant twinning on both albite and Carlsbad laws mark the plagioclase as a former igneous plagioclase (Gorai, 1951, p. 886, 887). Association of minor quartz with hornblende, especially as swarms of inclusions in the center of hornblende crystals, suggests that at least part of the hornblende and all the quartz having this association are derived from augite. Six analyses of hornblende listed by Clarke (1924, p. 388) average more

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[1] Dow, D. W., 1942, The Lebanon Gabbro of Connecticut: Northwestern Univ. M.S. Thesis, 51 p.

than 7 percent lower in SiO_2 than the average of six analyses of augite (Clarke, 1924, p. 285). This difference suggests that an augite altering to hornblende would normally have quartz left over, which might then be trapped as inclusions in the hornblende. This alteration might have taken place deuterically prior to, but with later rearrangement during, metamorphism, or it might have been synkinematic. Dow[2] recognized small grains of quartz in hornblende and thought they crystallized simultaneously with magmatic hornblende under conditions of moderate pressure, low temperature, and presence of water.

Masses of black hornblendite as much as 6 inches long occur in the metagabbro northeast of Avery Corner. Hornblende makes up more than 95 percent of the inclusions, and quartz and sphene are minor constituents. Similar hornblendite masses of much larger size are recorded by Dow from the adjoining Willimantic quadrangle.

PEGMATITE

Most of the rock units contain very coarse grained dirty-white strongly foliated pegmatites having conspicuous white feldspar augen, but the pegmatities are most conspicuous in the rocks of the Putnam Gneiss and in the belt of the Hebron Formation west of the Lebanon Gabbro. Pegmatite is generally quartz monzonite or granite in composition, but it ranges from granodiorite to leucogranite. Single lenses are as much as three-fourths of a mile long; some of the larger bodies shown on the map (pl. 1) may consist of groups of pegmatites. The larger lenses form individual ledges or crop out in roches moutonnées. Contacts are generally sharp against calc-silicate rock or muscovite schist but are locally gradational with biotite schist or Canterbury Gneiss. Most pegmatite lenses appear to be nearly concordant, but a few are markedly discordant. In several places, metamorphic minerals characteristic of the wallrock, such as tourmaline, graphite, or diopside, occur within the pegmatite.

Pegmatite differs from the Canterbury Gneiss in that it is coarser grained, it has a more variable biotite-muscovite ratio, and it contains more abundant garnet. Pegmatite in the Hebron Formation also differs from the Canterbury Gneiss in that its plagioclase is more albitic, and, in half the rocks studied, pegmatite in the Hebron Formation contains black megascopic tourmaline and microscopic spherules of graphite. Pegmatites south of the Honey Hill fault contain bright-pink potassium feldspar and are exceptionally coarse grained, having an average crystal diameter locally as much as 6 inches.

Major minerals of the pegmatites are microcline-perthite, plagioclase, quartz, and lesser amounts of biotite, muscovite, garnet, and tourmaline. The biotite-muscovite ratio is highly variable. Plagio-

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[2] Thesis, 1942; see footnote 1, p. I 13.

clase is albite or sodic oligoclase in pegmatites within the Hebron Formation and the rocks south of the Honey Hill fault. Calcic oligoclase or andesine is characteristic of pegmatites within marble of the Fly Pond Member. In this quadrangle, tourmaline is restricted to pegmatites within the Brimfield Schist and Hebron Formation.

Accessory minerals of the pegmatites are graphite, apatite, sphene, pyrite, monazite, magnetite-ilmenite, allanite, epidote, rutile, and zircon. Graphite occurs not as flakes but as equidimensional spherules and is restricted to pegmatites within calcic rocks of the Hebron Formation west of the main belt of the Scotland Schist. In this quadrangle, zircon has been identified only in the pegmatites south of the Honey Hill fault.

QUARTZ MONZONITE GNEISS

Uniform white to gray medium-grained quartz monzonite gneiss forms several lenses as much as half a mile long, mostly within the Fly Pond Member. The lenses have sharp contacts with their country rocks and are generally parallel to the regional foliation. Rocks of the lenses have a less consistent biotite-muscovite ratio and less abundant epidote than do rocks of the Canterbury Gneiss. They are finer grained and contain less potassium feldspar than do the pegmatitic rocks, although probably all gradations in both texture and composition exist between these two units. They differ from the light-colored alaskite south of the Honey Hill fault in that their plagioclase has a higher anorthite content; they contain no hornblende but do contain muscovite.

Major minerals of the quartz monzonite gneiss lenses are microcline, oligoclase, quartz, and lesser amounts of muscovite and biotite. The muscovite-biotite ratio is variable; similar rocks in the Norwich quadrangle consistently contain predominant muscovite (Snyder, 1961). Accessory minerals are similar to those in Canterbury Gneiss. Garnet and tourmaline are restricted to quartz monzonite gneiss lenses within the Hebron Formation.

STRUCTURAL GEOLOGY

BEDDING-SCHISTOSITY RELATIONS

Crudely defined to well-defined compositional layering without certainly recognized primary structures is abundant in the Hebron Formation, Putnam Gneiss, Brimfield Schist, and the plagioclase gneiss south of the Honey Hill fault. The layering probably represents the sheared recrystallized remnants of bedding and suggests that there was no large-scale transfer of chemical constituents during regional metamorphism. Faint layering caused by alternate zones of coarse- and fine-grained quartz in the quartzite at Franklin may be remnants of crossbeds which would indicate that the beds in this area are right side up. Schistosity, as defined by the parallel orientation of micaceous minerals, is parallel to the compositional layering in most outcrops, and, therefore, both are shown with a single symbol on the map (pl. 1). Schistosity is sensibly parallel to major formational contacts, but, locally, as north of Fitchville, it is at an angle or even perpendicular to them. Schistosity lies at any angle to the lithofacial boundaries (Snyder, 1961) between the different pelitic facies of the Putnam Gneiss.

Igneous foliation, if present, was not distinguishable by the author from metamorphically induced gneissosity in the more massive rocks of the Fitchville quadrangle. No later regional cleavages were recognized.

The regional strike of schistosity is east-west, northeast, or northwest. The regional dip is west or north at about 15° to 35°, but locally it is shallower. Between State Route 163 and the southeast edge of the map, in a zone parallel to Trading Cove Brook, the schistosity is steep, vertical, or overturned with respect to the regional trend. One estimate of stratigraphic order can be made for the body of Canterbury Gneiss that underlies Fitchville. The potassium-rich zone near the west contact of this body, from Gardner Brook to Stockhouse Road, may have formed as a differentiate on the upper surface of a tabular body such as a sill or thick flow, which would indicate that the Canterbury Gneiss in this area is right side up. This determination agrees with that based on possible crossbeds in the quartzite at Franklin.

FOLDS

Five folds have been mapped, and at least the southern two were actively compressed during movement on the Honey Hill fault. The axial planes of all the folds strike approximately parallel to the trace of the Honey Hill fault and generally across the trend of the rock units. The folds vary progressively from open and gentle in the north to overturned and isoclinal in the south. The axes of all the folds plunge westward, as shown by both the map pattern of the large folds and the plunge of the axes of minor folds in their limbs. The folds may have begun to form during regional metamorphism and continued to be compressed when late movements were concentrated along the Honey Hill fault.

An earlier set of major isoclinal folds having axial planes parallel to the trend of the rock units may possibly be present in this area. The bipartite symmetry of the major belts of map units in the eastern half of the quadrangle permits the hypothesis that the Scotland Schist is the keel or crest of an isoclinal fold rather than a simple bed. The isolated mass of Scotland Schist on Misery Hill might be at the keel or crest of a subsidiary fold off the larger fold possibly represented by the main map belt. If so (section *A–A′*, pl. 1), the limbs are extremely attenuated, and the crestal areas have been rendered unrecognizable. There is no way to distinguish a structural connection due to isoclinal folds from a stratigraphic one due to complex interfingering of lenticular beds. If the main belt of Scotland Schist were an isoclinal fold, quartzite at Franklin could be expected on the west side as well as on the east side of the belt. Despite extensive search, the quartzite has not been found on the west side of the main belt of the Scotland Schist, but this contact is very poorly exposed. This evidence is more suggestive of stratigraphic variation than of structural repetition, but dominant regional considerations favor a complex structural interpretation. Lundgren (1962, p. 10) believed that the westernmost belt of calc-silicate rock of the Hebron Gneiss is probably, though not certainly, an isoclinal syncline—the Chester syncline—in the area to the southwest. This belt, when traced farther south and then east again to the Montville quadrangle, is the Hunts Brook syncline of Goldsmith (1961, fig. 169.1). The main belt of the Scotland Schist may be the trace of a syncline, as indicated by the emergence of the Putnam Gneiss west of the Hebron Formation in the Willimantic dome to the northwest and by the inward opposing dips on both east and west sides of the main belt of the Scotland Schist in the Scotland and Hampton quadrangles to the northeast (H. R. Dixon, written communication, 1960). If these synclinal interpretations are correct, Brimfield Schist may be equivalent to part of the Putnam Gneiss on the opposite limb of a major recumbent fold.

FAULTS

The Honey Hill fault in the southern part of the quadrangle is a major thrust fault that has been mapped for 25 miles eastward from Chester (Deep River quadrangle) to Lantern Hill (Old Mystic quadrangle) without apparent repetition of the stratigraphy on either side of the fault (Lundgren, Goldsmith, and Snyder, 1958; fig. 1). In the Fitchville quadrangle the Honey Hill fault is characterized by a zone of structural discontinuity, lenticularity of rock units, and cataclasis, especially in the hanging wall. In this area the mylonitic foliation, and hence the fault plane, dips 15° to 50° N. parallel to foliation in the underlying and immediately overlying rocks. The main fault plane truncates part of the Putnam Gneiss and the plagioclase gneiss south of the fault. The sillimanite and potassium feldspar isograd is truncated by the Honey Hill fault. A smaller parallel fault ¼ to ½ mile north of the main fault truncates the Canterbury Gneiss and Scotland Schist. A similar parallel fault (not shown on fig. 1) may exist along the contact of the Canterbury Gneiss and

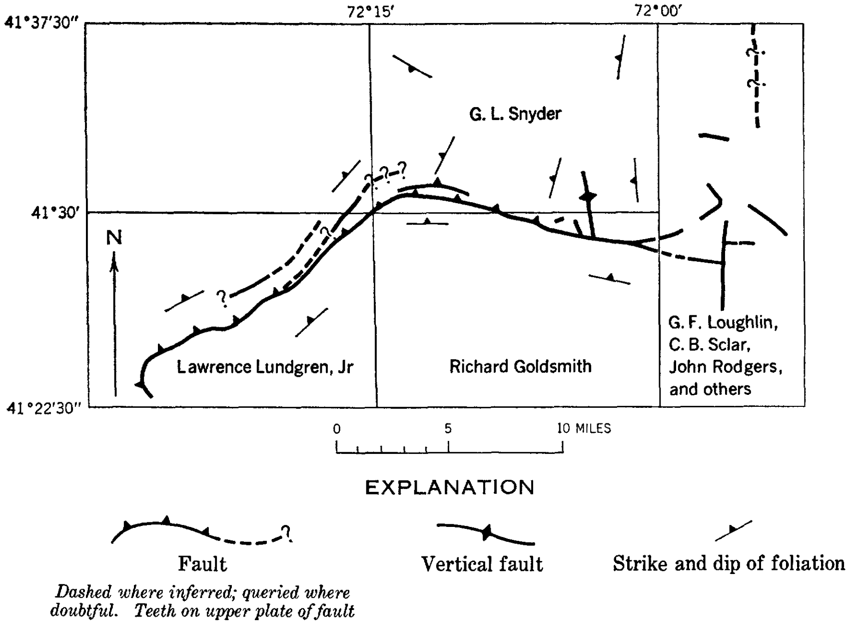

FIGURE 1.—The Honey Hill fault of southeastern Connecticut. Names indicate geologists responsible for mapping different areas. Possible, but unmapped, continuation of Honey Hill fault to northeast is indicated.

Hebron Formation north of Gardner Lake. Mylonite is exposed along this contact in the Colchester quadrangle, but outcrops are scarce in this zone in the Fitchville quadrangle. If a fault is present here, its continuation to the northeast may be represented by the zone in which the Lebanon Gabbro was intruded.

The hanging-wall rock of the main fault is some part of the Putnam Gneiss. Apparently the pelitic schists in this unit served as effective lubricants during fault movement. They are enormously thinned west of Bishop Road, however. From Bishop Road to Chester, 17 miles to the west, the layer of mylonitized biotite-muscovite schist is from $\frac{1}{8}$ to $\frac{1}{2}$ mile wide (Lawrence Lundgren, written communication, 1960). This is 20 to 80 times thinner than the Putnam Gneiss in the adjoining Norwich and Jewett City quadrangles (Snyder, 1961; Sclar, 1958), and much of the thinning takes place abruptly as the gneiss turns westward south of Tadma Pond.

All rocks within about half a mile of the Honey Hill fault in its hanging wall and within about 100 yards in its footwall have undergone some degree of cataclasis. Locally, especially near the fault, the deformation may be extreme. Most rocks are mylonite, mylonite gneiss, or blastomylonite, but ultramylonite is known from dikes as much as several feet long that usually are in footwall rocks.

All partially crushed rocks in the field are darker than the respective formations away from the fault zone. In hand specimen, Canterbury Gneiss and the biotite-muscovite schist of the Putnam Gneiss show the effects of partial or complete granulation most conspicuously. The average rock near the fault contains bent and broken augen or porphyroclasts of plagioclase and muscovite in a much finer grained recrystallized cataclastic matrix of quartz and biotite. Locally, all four of these main minerals are reduced in size to the limit of resolution of the microscope. Calc-silicate rocks of the Fly Pond Member near the fault also show cataclastic texture in thin section, but this is usually not visible in hand specimen. Blue-black concordant or discordant ultramylonite dikes can be found in the following places: (a) In the roadcut near where the Honey Hill fault intersects State Route 82; (b) half a mile east of Gardner Cemetery; and (c) below the steep cliff of Canterbury Gneiss half a mile southwest of Bishop Pond approximately at the line of section *B′–B′*.

A normal fault having more than 1,000 feet of displacement near its center is postulated on the basis of indirect evidence in the valley of Pease Brook west of Blue Hill. Two en echelon faults of similar displacement in the same direction are believed to underlie parallel valleys in the northeastern part of the Colchester quadrangle just west of Goshen Hill. Calcic rocks of the Hebron Formation and the Lebanon Gabbro are apparently offset, east side north, on each fault.

METAMORPHISM

At least three periods of metamorphism or three phases of a single metamorphism have affected the metasedimentary and metaigneous rocks in the Fitchville quadrangle. During the first period recognized—a regional dynamothermal metamorphism—most primary structures were recrystallized under conditions ranging from those that develop in the quartz-albite-epidote-almandine subfacies(?) of the greenschist facies to those that produce the sillimanite-almandine subfacies of the almandine amphibolite facies (Turner, in Fyfe, Turner, and Verhoogen, 1958, p. 217–232). After the thermal peak, dynamic metamorphism continued or was reinstituted at a later time and was localized along the Honey Hill fault zone; there the rocks were partly recrystallized in the quartz-albite-epidote-biotite subfacies of the greenschist facies (Turner, ibid). Following the dynamic metamorphism, and perhaps partly concomitant with it, a late alteration affected most rocks slightly, generally by hydration reactions. During this late alteration the rocks were partially recrystallized in the quartz-albite-muscovite-chlorite subfacies of the greenschist faces (Turner, ibid).

REGIONAL DYNAMOTHERMAL METAMORPHISM

Regional dynamothermal metamorphism increased in intensity downward and outward from hill 262 southwest of Misery Hill. Hill 262 apparently was near the center of a flat depression in the isotherms near the upper part of a regionally hot area. Four metamorphic zones are delineated on the map by isograds based on the first appearance of three critical metamorphic minerals in pelitic rocks. These isograds, from hill 262 to the southeast corner of the map area, mark the first appearance of staurolite, sillimanite, and sillimanite with potassium feldspar. There is no evidence in this area for a kyanite isograd between the staurolite and sillimanite isograds. The sillimanite and potassium feldspar isograd is based on detailed petrographic data from the rocks of the Norwich quadrangle (Snyder, 1961). Rocks south of the Honey Hill fault are probably all in the sillimanite zone (Richard Goldsmith, oral communication, 1960), although pelitic rocks containing key index minerals are not present south of the fault in this quadrangle.

The garnet zone is possibly represented on hill 262 by muscovite-garnet schist without staurolite. Staurolite is present but very scarce in the same pelitic unit on Misery Hill.

Critical rocks of the staurolite zone are muscovite-biotite-staurolite-garnet schist without sillimanite or kyanite. Critical calcic rocks of the staurolite zone are calc-silicate rocks lacking diopside, scapolite, or garnet; calcite-biotite-chlorite schist; and biotite-chlorite schist.

Critical pelitic rocks of the sillimanite zone are biotite-muscovite-sillimanite-garnet schist and muscovite-biotite-staurolite-garnet-sillimanite schist (locally with kyanite). Critical calcic rocks of the sillimanite zone are calcite-biotite schist without chlorite and calc-silicate rocks usually with diopside, scapolite, or garnet.

Critical pelitic rocks of the zone of sillimanite and potassium feldspar are biotite-muscovite-sillimanite-garnet schist containing scarce potassium feldspar.

METAMORPHIC MINERALS

The first appearance of sillimanite in pelitic rocks is about coincident with the first appearance of diopside, scapolite, or garnet in calc-silicate rocks of the Fitchville quadrangle. Sillimanite usually occurs as euhedral prismatic crystals in the Putnam Gneiss and as anhedral bundles of fibrolite in other rocks.

Kyanite occurs only in Scotland Schist either within 1½ miles of the north border of the map area or in a narrow zone southwest of Bishop Pond between road intersection 305 and the small swamp at the head of Mineral Spring Brook. Some kyanite apparently crystallized before staurolite, because one rock northwest of Pitchers Pond contains kyanite crystals that have thin rims of optically continuous staurolite. Most kyanite is in rocks that also contain sillimanite and staurolite, indicating that both staurolite and kyanite in these rocks persist into the sillimanite zone.

Accessory zircon and monazite in the rocks of the Scotland Schist increase in size with increasing grade in this unit. Zircon and monazite in rocks containing only staurolite or garnet are barely resolvable under a petrographic microscope. The same minerals in rocks of sillimanite grade are several times as large as those in the lower grade rocks.

Chlorites of two ages are distinguishable in the Fitchville quadrangle. One chlorite is a product of regional dynamothermal metamorphism of staurolite grade in biotite schist of the Hebron Formation in the northeastern part of the quadrangle. The other, which has color, pleochroism, and birefringence similar to the first, is a very common product of late alteration of biotite, locally in the same rock with regional metamorphic chlorite. Regional-metamorphic chlorite usually occurs in uniformly distributed clear grains, in sharp contact with, but larger than, associated grains of biotite, and with nonparallel internal structure in the two minerals. Most of the alteration chlorite has an irregular contact with biotite and parallel internal structure; in most places, it contains granules of sphene derived from altered biotite.

LATE DYNAMIC METAMORPHISM

Dynamic metamorphism, which continued after the thermal peak, produced the finer grained lower grade cataclasites including mylonite, mylonite gneiss, blastomylonite, and ultramylonite along the Honey Hill fault. All gradations between normal coarse-grained schist or gneiss and fine-grained mylonite gneiss exist locally. Cataclasites mapped as biotite-muscovite schist of the Putnam Gneiss within half a mile of the Honey Hill fault typically have a distinct mortar structure in which porphyroclastic augen of plagioclase and muscovite are set in a granulated but recrystallized matrix of quartz and biotite. Locally, all minerals within several hundred yards of the Honey Hill fault are granulated, and the resultant rock may resemble a layered unmetamorphosed siliceous argillite. Blastomylonites contain recrystallized biotite and muscovite, but the temperature was not as high as that which prevailed during the original dynamothermal metamorphism, for index minerals of higher grade are not present.

LATE ALTERATION

Late alteration took place mostly by low-temperature hydration reactions that affected some minerals of all rocks after the period of thrusting. Most rocks contain less than 1 percent late alteration minerals, and none in this quadrangle contain more than 15 percent˙ In the Norwich quadrangle, late alteration has affected some cataclasites that formed during late dynamic metamorphism (Snyder, 1961), but cataclasites along the Honey Hill fault in the Fitchville quadrangle have not been altered. It seems likely that at least some alteration is later in time than the cataclasis, however, because the minerals involved imply lower temperatures for the alteration or a greater supply of water. Brown biotite crystallized during both regional metamorphism and cataclasis but was later altered to chlorite.

The most common reactions were the alteration of biotite to chlorite and minor sphene, potassium feldspar(?), and muscovite, and the alteration of staurolite to sericite, magnetite, chlorite, and sphene. Less common reactions altered garnet, plagioclase, sillimanite, or kyanite, pyrite, pyrrhotite, microcline, actinolite-hornblende, and sphene. In the Lebanon Gabbro, late prehnite(?) dilates biotite cleavages locally. Pickeringite and limonite are weathering products formed from sulfide-containing schists. Pickeringite is well exposed in a roadcut of the Scotland Schist at lat 41°31′18.9″ N. and long 72°12′2.7″ W.

CHEMISTRY OF ROCKS OF NORWICH AND FITCHVILLE QUADRANGLES

Chemical, modal, and semiquantitative spectrographic analyses of 49 rock samples from eastern Connecticut are presented in tables 3 through 7, and averages of certain groups of chemical analyses are summarized in table 8. The rocks for 26 of these analyses were collected in the Norwich quandrangle, 22 are from the Fitchville quadrangle, and 1 is from the Colchester quadrangle. All the geologic units from which the analyzed rocks were collected have been described previously, either in this report or in the report on the Norwich quadrangle (Snyder, 1961). Forty of the analyses are typical of geologic units which, though variable, are areally quite extensive. The other nine samples, from areally small geologic units are samples 11 (table 5); 5, 6, 7, 8, 10 (table 6); and 1, 3, 4 (table 7).

Analyses of sillimanite or kyanite schists of the Putnam Gneiss in varying stages of retrogressive alteration are presented in table 3. The sillimanite-pinite schist and the graphite schist of the Putnam Gneiss are similar to each other in their content of aluminum silicate minerals and differ only in their average weathering mode and in the presence or absence of a small quantity of graphite. Both rocks are commonly highly altered, mainly to white mica after sillimanite, plagioclase, biotite, and garnet. In table 3, the analyses are arranged within each unit in order of increasing percent of total alteration minerals, which ranges from 1.0 to 76.1 percent. In columns 1, 2, and

3 of table 8, the same analyses have been averaged in groups of low, medium, and high total alteration, respectively. One-third of the available analyses occurs in each group. The fact that K_2O increases and Na_2O decreases with increasing alteration—that is, increasing quantity of alteration mica—suggests that this alteration mica is a potassium mica (Snyder, 1961).

The first three columns of table 8 reveal that there is a systematic variation with alteration in the amount of all major constituents except Fe_2O_3. Whether this is due to selective addition or removal of certain constitutents during alteration of initially similar rocks or to selective alteration of a suite of rocks of variable composition is not a first apparent, but it seems possible that both of these mechanisms may have participated during alteration of these rocks. Several chemical and mineral parameters are plotted against the amount of total alteration in each of the specimens in figure 2. The rise in alumina content with total alteration is paralleled by a rise in the quantity of sillimanite that was available for alteration (shown by euhedral pseudomorphs of sillimanite in the more highly altered rocks). This indicates that the more sillimanitic rocks were originally more aluminous and that this difference in composition probably controlled the susceptibility to late alteration. On the other hand, the rise in content of combined water could not have been an original property of these rocks at the peak of metamorphism because they were all metamorphosed to high amphibolite or granulite facies, and probably none could have contained more than about 1 percent water under these conditions. Therefore, the larger amounts of water in the more highly altered rocks must have been selectively added during late alteration. With other chemical constituents it is not so easy to decide with certainty between selective addition or removal and selective alteration of rocks of originally different composition. Perhaps the rise or fall of other oxides with total alteration may be due partly to one factor and partly to the other. However, the fact that the sillimanitic schists of the Putnam Gneiss as a group are generally more highly altered than any other rock type (see profiles of alteration along cross sections shown by Snyder, 1961) suggests that the rocks containing aluminum silicate minerals were more susceptible to the alteration of all their minerals. If this is true, then one could surmise that the major part of the compositional differences is original and served as a selective control for the late alteration.

Chemical, modal, and spectrographic analyses of the other pelitic metasediments in this area of Connecticut are presented in table 4, and analyses of the calc-silicate rocks and one marble, in table 5. Averages of all these metasediments can be compared in table 8. In general, the metapelites are higher in Al_2O_3, total iron, and K_2O, and

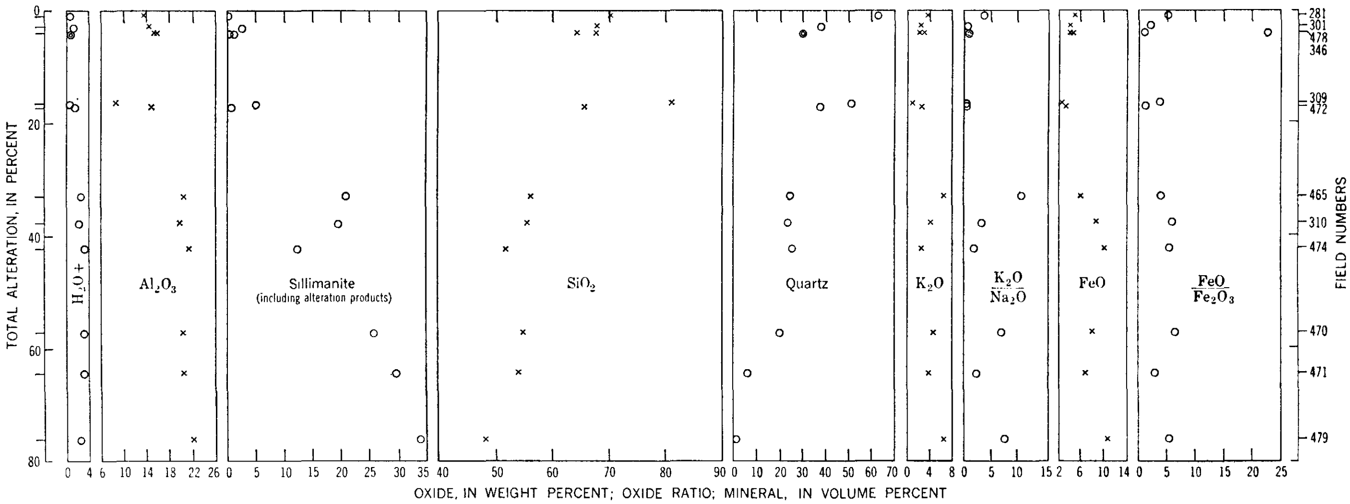

Figure 2.—Variation in some chemical and mineral parameters with respect to amount of alteration in sillimanite or kyanite schist of Putnam Gneiss, Norwich quadrangle, Connecticut.

the calc-silicate rocks are higher in CaO and MgO, probably reflecting an initially higher clay content in the pelitic metasediments and an initially higher carbonate content in the calc-silicate rocks. Only one chemical analysis of a metasediment from this area has appeared in previous literature. Moore (1935, p. 41) quoted an 1883 analysis of marble, probaly from the Fly Pond Member of the Putnam Gneiss on Wawecus Hill. The reliability of this old analysis is open to question, however, because all the constitutents in the analysis total only 80 percent.

Analyses of granitic rocks are compiled in table 6, and analyses of metasediments and metaigneous rocks of more unusual composition, in table 7. Canterbury Gneiss and the small bodies of pegmatite or quartz monzonite are very similar to each other in composition, as can be seen by comparing their averages in table 8, except that the pegmatitic rocks are generally significantly higher in K_2O. This similarity of composition could indicate either that the small pegmatites are derived from the Canterbury Gneiss or that they each owe their origin to a process which produces rocks of similar composition. Both these classes of rocks differ from the alaskite gneiss by their generally higher Al_2O_3 and CaO and lower Na_2O, reflecting the presence of oligoclase in the pegmatites and Canterbury (except sample 8, table 6) and albite in the alaskite gneiss. The aegirinaugite gneiss differs from all these by its much higher Na_2O content. With the more mafic rocks in table 7, the Lebanon Gabbro has the highest CaO and Al_2O_3 content, the amphibolite lens in the Putnam Gneiss has the highest MgO and total iron content, and the Bates Pond Lentil of the Putnam Gneiss has the highest SiO_2 and alkali content.

Several of the metaigneous rocks differ from each other significantly in mineralogical or compositional details. Sphene in the alaskite is higher in rare earths and iron than that in Canterbury Gneiss. Compare columns 2 and 3 in table 399.1 of Goldsmith, Snyder, and Conklin (1961, p. D–310), which give analyses of sphene from analyzed samples 9 and 2, respectively (table 6, this report). Zircons from these same two rocks are much different in shape; those from alaskite are stubby equidimensional prisms containing numerous dark inclusions, whereas those from Canterbury Gneiss are very elongate, needlelike prisms containing few inclusions. Potassium feldspar in the Bates Pond Lentil of the Putnam Gneiss is probably richer in barium than is any other feldspar in this part of Connecticut. A semiquantitative spectrographic analysis by John C. Hamilton on hand-picked potassium feldspar from sample 4 (table 7) shows the following weight percentages of elements: Si$>$10; Al, $>$10; Fe, 0.15; Mg, 0.0015; Ca, 0.015; Na, 1.5; K, 7; Ti, 0.007; Mn, 0.0015; Ba, 1.5; Cr, 0.0003; Cu, 0.0007; Ga, 0.0003; Pb, 0.007; and Sr, 0.3 (see tables

3–7 for an explanation of this notation); all other standard elements except cesium, fluorine and rubidium were looked for but not found.

It is significant to compare the metaigneous rocks on the basis of their normative minerals or other chemical parameters. The micaceous granitic rocks—for example, the Canterbury Gneiss—all contain normative corundum as compared to the alaskite gneiss which contains no unusual normative minerals. The aegirinaugite gneiss contains normative wollastonite; the Lebanon Gabbro, normative olivine; and the Bates Pond Lentil of Putnam Gneiss, normative olivine, corundum, and nepheline. The extrusive equivalent name for each of these rocks by the chemical classification of Rittmann (1952) is: Canterbury Gneiss quartz, latite or rhyodacite; pegmatite, quartz monzonite, and alaskite, rhyolite; aegirinaugite gneiss, sodatrachyte; Lebanon Gabbro, pigeonite labradorite andesite; and Bates Pond Lentil, nephelite tephrite. The amphibolite lens in the Putnam Gneiss (sample 3, table 7) has a composition conforming to that of a common mafic igneous rock, but, from its field relations, it is probably a metasediment. Some amphibolite lenses similar to this one may represent water-deposited volcanic ash, but others, particularly, those which occur in pelitic schist near the contact of the Fly Pond Member, might owe their origin to simultaneous contribution of some detrital pelitic constituents and some chemical calcareous constituents into a single localized basin of sedimentary deposition. Two analyses of compositionally similiar amphibolite from a nearby area of Connecticut as well as several others of gabbro or granitic rocks, were published by Loughlin (1912, p. 114, 123).

The compiled modal analyses in tables 3–7 are mostly self-explanatory, but a few details should be mentioned here. The determinations of the opaque minerals, magnetite-ilmenite, specular hematite, pyrite, pyrrhotite, and graphite were made mostly by observations in reflected light on normal thin sections, although a few polished sections of the same rocks were studied for calibration purposes. One occurrence of galena and several of pyrite and graphite were identified from mineral aggregates of crushed rock samples. Dolomite was checked for by staining several thin sections with Högberg solution but it was never found; however, most of the minerals listed as calcite in the tables have not been checked. Wherever it was considered necessary—that is, for most calc-silicate and granitic rocks—both potassium feldspar and plagioclase were stained before point counting. The plagioclase stain used, eosine "B" (Hayes and Klugman, 1958, 1959), was also found to stain calcite, cordierite, and scapolite, but no difficulty arose in distinguishing any of these from plagioclase.

Minor elements are variable in their distribution. Some, like zirconium and ytterbium, are present in nearly all rocks and seem to vary within narrow limits without appreciable concentration in any of the major rock types. Others like cobalt, chromium, copper, gallium, nickel, lead, scandium, and vanadium show slightly different averages between metasediments and granitic rocks but have similar averages and ranges for the various subgroups within these groups. Other elements like barium and strontium give promise of distinguishing between all the major rock groups, especially when plotted graphically against CaO. Several elements have been reported from only one or two rocks: silver is only in sample 4 (table 7), bismuth is only in samples 9 (table 4) and 3 (table 6), molybdenum is only in sample 8 (table 4), and tin is only in sample 8 (table 6).

Several crude cross checks are possible between the different methods of analysis. For those rocks where it was calculated, normative quartz agrees fairly well with modal quartz. There is a definite correlation, but also considerable scatter, between barium as reported in the semiquantitative spectrographic analyses and barium as calculated from BaO in the standard chemical analyses. The percentage of CO_2 reported in the chemical analyses agrees reasonably well with the quantities of calcite and scapolite actually observed in the rocks. The total percentage of rare earths is a crude gage of the quantity of allanite, keilhauite, or monazite in the rocks. Boron correlates with observations of tourmaline in five rocks, was reported in one where tourmaline was not observed (but is known to be characteristic), and was below threshold in three where small amounts of tourmaline were observed. There was no apparent correlation between the amount of TiO_2 reported and the quantities of minerals actually observed where TiO_2 is known to be stoichiometrically important, possibly because TiO_2 also occurs in too many other minerals in nonstoichiometric amounts.

Cummingtonite is a conspicuous constituent of a quartzitic biotitic garnet granofels in a glacial erratic at lat 41°31′15″ N., long 72°8′52″ W., west of Goldmine Brook in the southeastern part of the Fitchville quadrangle. There is no known or probable source for this erratic in the direction of its glacial source within the Fitchville quadrangle. E. J. Young reported the following optical properties for the cummingtonite: $\beta=1.679\pm0.002$, α and β=colorless, γ=pale yellow, (—)2V $=83°\pm3°$ (Universal stage), $Z\wedge C=13°$ (Universal stage). A semiquantitative spectrographic analysis by Nancy M. Conklin on hand-separated cummingtonite from this erratic boulder shows the following weight percentages of elements: Al, 0.3; Fe, >10; Mg, 7; Ca, 0.7; Ti, 0.07; Mn, 1.5; Ba, 0.003; Co, 0.007; Cr, 0.0007; Ga, trace; Ni, 0.007; Sc, 0.0015; V, 0.003; Zn, 0.07; and Zr, trace (see tables 3–7 for an explanation of this notation): all other standard elements except silica, cesium, fluorine, and rubidium were looked for but not found.

AGE

Eight new lead-alpha age determinations (table 2) from metasedimentary and metaigneous rocks of the Norwich and Fitchville quadrangles indicate that these rocks crystallized in pre-Pennsylvanian time and therefore were deposited in pre-Pennsylvanian time. Because the isograd pattern is a simple one, rock units without radioactive ages are assumed to have crystallized during the same metamorphism; the exceptions are noted below. However, there is no guarantee that these rocks have not gone through several major metamorphic periods, elements of which are reflected in some of the radioactive minerals. The 250-million-year spread in the age determinations may be due to long-continued or repeated periods of crystallization or diffusion or to inadequacies in the samples or the method of dating; it will not be evaluated further here. Fossils have not been found in eastern Connecticut, but uncertain correlation with fossiliferous rocks in distant areas suggests early to late Paleozoic ages for most metasedimentary rocks. Problems concerned with these distant correlations were discussed by Snyder (1961) and by Rodgers and Rosenfeld (in Rodgers, Gates, and Rosenfeld, 1959, p. 18–27). Previous age estimates of all metasedimentary rock units have ranged from Precambrian to Carboniferous.

Putnam Gneiss is probably in normal stratigraphic contact with the Hebron Formation. Many pelitic compositional variants are found within the Putnam Gneiss, but the rarest type and the one most

TABLE 2.—*Lead-alpha age determinations of zircon and monazite from some rocks of southeastern Connecticut*

Field No.	Unit	Locality	Age, in millions of years	Mineral
[1] 150	Pegmatite (in sillimanite-pinite schist of Putnam Gneiss).	Norwich quadrangle, across Shetucket River from Occum.	340±40	Monazite.
[2] 136	Pegmatite (in Fly Pond Member of Putnam Gneiss).	Norwich quadrangle, near intersection of Hanson and Bowen Hollow Roads.	530±60 380±45	Do. Zircon.
[2]1121	Light-colored alaskite gneiss	Fitchville quadrangle, State Route 163, roadcut 2,000 ft north of BM 473.	530±60	Do.
[2] 87	Putnam Gneiss (biotite gneiss)	Norwich quadrangle, ½ mile east of Bishop School.	335±40	Do.
[2] 255	Putnam Gneiss (sillimanite-pinite schist).	Norwich quadrangle, 1,000 ft north of north tip of Fairview Reservoir.	475±55	Monazite.
[2] 346	Putnam Gneiss (graphite schist)	Norwich quadrangle, 0.8 mile N. 12° E. of BM 68.	440±50	Do.
[2] 582	do	Norwich quadrangle, Connecticut turnpike roadcut east of State Route 93.	450±50	Do.
[2] 1149	Putnam Gneiss (Bates Pond Lentil).	Norwich quadrangle, 2,000 ft south of Bates Pond.	280±30	Zircon.

[1] See Snyder (1961) for detailed description of this sample.

[2] Ages determined by T. W. Stern (written communication, June 2, 1960); lead determinations by N. B. Sheffey.

like Scotland Schist is found nearest to Scotland Schist. Biotite-muscovite schist typical of the western Putnam Gneiss grades into muscovite-biotite schist along the western margin of the Putnam Gneiss, and this muscovite-biotite schist resembles that of the Scotland Schist. At the south end of Tadma Pond, muscovitic schist of the Putnam Gneiss is compositionally and mineralogically identical with the Scotland Schist. Furthermore, the calc-silicate rocks of the Hebron Formation are compositionally and mineralogically similar to those of the Fly Pond Member of the Putnam Gneiss. The Hebron Formation and Scotland Schist have gradational contacts, suggesting that no unconformity exists between these two units. The contact between Scotland Schist and calcic rocks of the Hebron Formation where quartzite like that at Franklin is absent, need not represent a time break of greater than diastemic rank.

Uniform unlayered Canterbury Gneiss is a pre-Pennsylvanian orthogneiss, probably a premetamorphic or synmetamorphic igneous body, in the Hebron Formation. The rock is strongly foliated parallel to the regional foliation, and there are no visible contact effects on adjacent calc-silicate rocks of the Hebron Formation. Both Gregory (in Rice and Gregory, 1906, p. 115) and Foye (1949, p. 55) recognized that the Canterbury Gneiss had been emplaced before or during the last major metamorphism.

Alaskite south of the Honey Hill fault was formerly mapped as part of the Sterling Granite Gneiss but may be of Precambrian or early Paleozoic age or possibly as young as early Carboniferous. If it is of Precambrian or early Paleozoic age, it was recrystallized one or more times from Precambrian to late Paleozoic(?). Most of the alaskite is either a syntectonic intrusive or part of a metamorphosed extrusive sequence (Richard Goldsmith, oral communication, 1960). The "Oneco granite" from Moosup, Conn., in the type area of the Sterling Granite Gneiss of Loughlin, contains zircons dated as 286 million years old by the lead-alpha method (Jaffe and others, 1959, p. 104). On the basis of regional evidence, the quartz monzonite (lead-alpha age of 530 million years) of the Fitchbille quadrangle may be correlative with this "Oneco granite" and with the older series of granites in Rhode Island that contain zircons dated by the same method as 289 to 337 million years old (Quinn and others, 1957, p. 556). However, all these lead-alpha ages should probably be redone (Stern and Rose 1961). The older granites of Rhode Island are unconformably overlain by sedimentary rocks of Pennsylvanian age (Quinn, 1951) but were apparently recrystallized during the metamorphism of the sediments 255 millions years ago (Hurley and others, 1960, p. 254).

The texture of the aegirinaugite rock at the contact of the alaskite unit indicates that this rock may have crystallized after metamorphism, and, if so, it must have been magmatic. It may be as young as late Paleozic.

Lebanon Gabbo was probably emplaced during regional metamorphism as a plagioclase-augite porphyry. The pronounced gneissic foliation of the metagabbro locally parallel to the regional foliation shows that it was present during at least part of the dynamic metamorphism. Dow [3] thought that the gabbro was intruded after the country rock had been metamorphosed to schist.

Pegmatites and lenses of quartz monzonite gneiss north of the Honey Hill fault are dated as pre-Pennsylvanian and probably were intruded over a long time span. Some pegmatites in this area are postgabbro; in the area of the Middle Haddam quadrangle, pegmatites are 260 million years old (Rodgers, 1952), or of post-Early Permian age (Faul, 1959). The maximum range of age for pegmatites is probably between the age of the geologic unit in which they occur and the age of the Honey Hill fault, because the Honey Hill fault is not known to be cut by any pegmatites, and pegmatites near it have a granulated mortar or blastomylonitic texture like the surrounding rocks.

GEOLOGIC HISTORY

Aluminous and calcic shales, marl, quartz sand, and possibly quartz latite extrusives were deposited in the mapped area in pre-Pennsylvanian time. Large bodies of rock, now quartz monzonite or alaskite, were either extruded onto the sediments during deposition or intruded into them before or during regional dynamothermal metamorphism, which seems to have occurred in this area between 530 and 280 million years ago. Early in the period of dynamothermal metamorphism, most primary structures were obliterated, the schistosity and most mineral lineations began to be formed, and possibly a major system of isoclinal folds was formed with axial planes parallel to the trends of the present geologic units. Before or after the thermal peak but before the close of metamorphism, gabbro, pegmatite, and small bodies of quartz monzonite were intruded; some pegmatite probably preceded the gabbro, but some certainly followed it. At about this time a system of folds having axial planes at a large angle to the trends of the present geologic units began to form, and, as the temperature dropped and dynamic metamorphism became dominant locally, this culminated in the Honey Hill fault movement which is possibly late Paleozoic in age, as suggested by Foye (1949, p. 88). Cataclastic foliation, some lineation, and some foliation in the metagabbro were formed at this time. (Compare Sclar, 1950, for a similar sequence.) Following

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[3] Thesis, 1942; see footnote 1, p. I 13.

this, dynamic metamorphism ceased, the temperature dropped still further, and some minerals of all rocks were slightly altered. This was succeeded by uplift, erosion during deposition of nearby sediments of Triassic age, and minor normal faulting. The rocks of the area have been cool and tectonically relatively inactive since Triassic time.

ECONOMIC GEOLOGY

Granitoid rocks containing conspicuous potassium feldspar, quartz, and sodic plagioclase have been used from time to time either as building stone or as crushed aggregate, and reserves of this type are practically unlimited. Light-colored albite alaskite has been quarried for building stone in the past from a small quarry northwest of the U-shaped bend of State Route 82. This area has recently been developed extensively, and many hundreds of tons of sized aggregate were produced principally for use in road construction.

The potassium-rich rocks near the west contact of the body of Canterbury Gneiss underlying Fitchville have been used for building stone from at least four quarries between Gardner Brook and Stockhouse Road. The quarry on the hill west of Fitchville Pond seems to seems to have provided the best material for this purpose. At least some of this quarrying was done before 1834 (Mather, 1834, p. 10).

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TABLE 3.—*Chemical, modal, and spectrographic analyses of sillimanite or kyanite schist of Putnam Gneiss, Norwich quadrangle, Connecticut*

	Putnam Gneiss—sillimanite-pinite schist					
Sample No.	1	2	3	4	5	6
Laboratory No.	C1000	C1001	C1022	C1004	C1016	C1010
Field No.	281	301	478	309	472	465
CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT						
[Arranged by variation in total alteration within each mapped unit. Samples 1, 2, 4, 7, and 11 were analyzed by F. H. Neuerberg in April 1957; the remaining samples were analyzed by Marguerite Seerveld in September 1957]						
SiO_2	70.44	67.85	64.52	81.45	64.87	56.59
Al_2O_3	13.73	14.35	15.80	8.66	15.06	20.79
Fe_2O_3	.97	2.05	3.27	.69	2.63	1.47
FeO	5.14	3.92	4.13	2.48	3.39	6.03
MgO	2.20	2.30	3.08	.92	2.76	2.83
CaO	.73	2.08	2.03	1.13	2.43	.27
Na_2O	.97	2.57	2.42	1.69	3.21	.63
K_2O	3.73	2.48	2.55	1.17	2.70	6.71
H_2O-	.07	.08	.10	.03	.02	.11
H_2O+	.48	1.10	.61	.36	1.39	2.58
TiO_2	1.01	.88	.98	.70	.86	1.29
CO_2	.01	.00	.11	.17	.27	.03
P_2O_5	.03	.05	.03	.04	.07	.03
Cl	.01	.03	.01	.01	.04	.13
F	.03	.05	.06	.01	.06	.09
S	.03	.02	.01	.03	.01	.01
MnO	.12	.07	.09	.09	.10	.12
BaO	.15	.04	.05	.06	.04	.08
C	.02	.03	.03	.00	.00	.00
	99.87	99.95	99.88	99.69	99.91	99.79
Less O	.03	.04	.04	.02	.04	.07
Total	99.84	99.91	99.84	99.67	99.87	99.72

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–59]

Number of points	1,328	1,455	2,338	2,350	1,457	1,177
Texture	Schistose, sutured, porphyroblastic.	Schistose, granular	Schistose, porphyroblastic.	Schistose, two *S*-planes.	Gneissic porphyroblastic.	Schistose porphyroblastic.
Quartz	64.4	38.7	31.2	51.7	37.7	26.1
Plagioclase	1.5 (calcic oligoclase); altered to sericite plus albite, 0.2; chlorite, <0.1; kaolin, <0.1.	29.5 (An_{30})	30.3 (An_{31}); altered to sericite, 2.3; calcite, 0.4.	20.3 (oligoclase); altered to sericite, 0.5; coarse muscovite, 4.7.	27.8 (calcic oligoclase); altered to sericite, 5.2; coarse muscovite, 0.4; calcite, 0.1; sodic plagioclase, 0.1; chlorite, <0.1.	8.0 (calcic oligoclase); altered to sericite, 0.3; limonite, 0.3.
Potassium feldspar	19.3 (microcline perthite); altered to sericite, 0.5.	Only in vein (volumetrically insignificant).	14.5 (microcline perthite).	0(?)	0(?)	0(?)
Muscovite	0.1	5.1	0	4.7(?)	<0.1	0.9(?)
Sillimanite	0.1 (altered to sericite, <0.1).	2.6 (all altered to sericite and coarse muscovite).	0.9 (altered to sericite, <0.1).	5.2 (altered to sericite, 4.2; coarse muscovite, 0.9).	0.6 (all altered to sericite).	21.1 (altered to coarse muscovite, 19.3; sericite, 1.7).
Kyanite	0	0	0	0	0	0
Cordierite	0	0	0.3 (altered to sericite, <0.1; isotropic substance, 0.1).	0	0	0
Epidote-clinozoisite	0	0	0	0	2.6	0
Calcite	0	0	0	0.5	0.1	0
Biotite	7.2 (brown); altered to muscovite, 0.2.	21.4 (green); altered to chlorite, 0.3.	18.0 (brown); altered to muscovite, 1.0; chlorite, 0.1; light-green biotite, <0.1; leucoxene, <0.1.	12.1 (green); altered to muscovite, 3.2; sphene, <0.1; chlorite, <0.1.	28.2 (green); altered to sericite, 5.5; sphene 1.6; chlorite, 2.1; coarse muscovite, 0.4.	39.6 (brown); altered to muscovite, 10.1; magnetite, 1.7.
Garnet	6.9 (altered to biotite, 0.1; sericite, <0.1; feldspar(?), <0.1).	0	3.1 (altered to sericite, 0.1).	4.5 (altered to muscovite, 2.1; biotite, 0.6).	1.0(?) (altered to biotite, 0.3; magnetite, 0.2; sericite, 0.5).	4.3 (altered to limonite-stained sericite, <0.1).
Spinel	0	0	<0.1 (in magnetite)	0	0	0
Magnetite-ilmenite	0.1	2.7	1.1 (magnetite)	0.7 (altered to leucoxene, 0.3).	1.9	0.1
Hematite	0	0	0.5	0	0	0
Pyrite	0.3 (altered to limonite, 0.2; hematite, 0.1).	0	0	0.1	0	<0.1 (partly altered to hematite).
Pyrrhotite	0	0	0	0	0	0
Graphite	0	<0.1(?)	0	0	0	0
Tourmaline	0	0	0	0	0	0
Apatite	0	0	<0.1	0	0	<0.1
Rutile	0.2 (altered to leucoxene, <0.1).	0	<0.1	0	0	0
Sphene	0	0	<0.1	0	0	0
Zircon	0.1	<0.1	<0.1	0.1	<0.1	0.1

TABLE 3.—*Chemical, modal, and spectrographic analyses of sillimanite or kyanite schist of Putnam Gneiss, Norwich quadrangle, Connecticut*—Continued

	Putnam Gneiss—sillimanite-pinite schist					
Sample No.	1	2	3	4	5	6
Laboratory No.	C1000	C1001	C1022	C1004	C1016	C1010
Field No.	281	301	478	309	472	465

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT—Continued

[All modes are based on study of a single thin section of the analyzed rock, G. L. Snyder, 1958-59]

Sample No.	1	2	3	4	5	6
Monazite	0	0	<0.1	0	0.2 (altered to leucoxene(?), 0.1).	0
Allanite	0	0	0	<0.1	<0.1	0
Total alteration	1.0	2.9	4.0	16.5	17.1	32.8

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, B, Bi, Cd, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W, Zn. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957]

Sample No.	1	2	3	4	5	6
Ba	0.15	0.03	0.07	0.03	0.03	0.15
Be			Trace			
Ce			.03			
Co	.003	.003	.003	.0015	.003	.003
Cr	.003	.007	.007	.003	.007	.007
Cu	.007	.003	.0007	.0015	.0007	.003
Ga	.0015	.0015	.0015	.0003	.0015	.003
La	.007	.007	.015	.007	.003	.003
Nb	.0015	.003	.0015	.0015	.0015	.003
Nd	Trace		.015	Trace		
Ni	.007	.007	.007	.0015	.007	.007
Pb	.003	.0015	.0015	.0015	.0015	Trace
Sc	.003	.003	.003	.0015	.003	.003
Sr	.015	.015	.03	.015	.015	.015
V	.007	.007	.015	.003	.007	.015
Y	.003	.0015	.003	.0015	.0015	.007
Yb	.0007	.0003	.0007	.0003	.0003	.0015
Zr	.03	.03	.03	.03	.03	.03

Norwich belt of the Norwich 7½-minute quadrangle:
1. East ninth.
2. West ninth.
3. South ninth.
4. Central ninth.
5. East ninth.
6. Southwest ninth.
7. Central ninth.
8. Central ninth.
9. North ninth.
10. South ninth.
11. Southeast ninth.
12. East ninth.

TABLE 3.—*Chemical, modal, and spectrographic analyses of sillimanite or kyanite schist of Putnam Gneiss, Norwich quadrangle, Connecticut*—Continued

	Putnam Gneiss—sillimanite-pinite schist				Putnam Gneiss—graphite schist	
Sample No	7	8	9	10	11	12
Laboratory No	C1005	C1014	C1015	C1023	C1006	C1018
Field No	310	470	471	479	346	474

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Arranged by variation in total alteration within each mapped unit. Samples 1, 2, 4, 7, and 11 were analyzed by F. H. Neuerburg in April 1957; the remaining samples were analyzed by Marguerite Seerveld in September 1957]

	7	8	9	10	11	12
SiO_2	56.01	55.44	54.54	48.72	67.83	52.15
Al_2O_3	19.85	20.63	20.78	22.40	15.46	21.82
F_2O_3	1.43	1.20	2.22	1.87	.19	1.80
FeO	8.47	7.95	6.62	10.52	4.31	9.80
MgO	3.66	3.58	3.46	3.63	2.03	3.81
CaO	.35	.25	1.41	.53	2.32	.47
Na_2O	1.28	.67	1.63	.87	2.83	1.29
K_2O	4.48	4.80	4.19	6.78	3.08	2.92
H_2O-	.14	.06	.07	.06	.05	.27
H_2O+	2.27	3.28	3.30	2.59	.47	3.32
TiO_2	1.34	1.36	1.16	1.36	.76	1.02
CO_2	.00	.03	.03	.02	.09	.03
P_2O_5	.05	.06	.05	.02	.06	.05
Cl	.12	.06	.02	.06	.02	.02
F	.08	.12	.11	.10	.05	.04
S	.00	.15	.01	.01	.04	.39
MnO	.15	.18	.15	.27	.11	.26
BaO	.11	.06	.06	.08	.07	.06
C	.00	.00	.00	.00	.07	.57
	99.79	99.88	99.81	99.89	99.84	100.09
Less O	.06	.10	.05	.06	.04	.12
Total	99.73	99.78	99.76	99.83	99.80	99.97

TABLE 3.—*Chemical, modal, and spectrographic analyses of sillimanite or kyanite schist of Putnam Gneiss, Norwich quadrangle, Connecticut*—Continued

	Putnam Gneiss—sillimanite-pinite schist				Putnam Gneiss—graphite schist	
Sample No.	7	8	9	10	11	12
Laboratory No.	C1005	C1014	C1015	C1023	C1006	C1018
Field No.	310	470	471	479	346	474
MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT [All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–59]						
Number of points	1,857	1,262	1,174	1,184	1,994	1,410
Texture	Schistose, porphyroblastic.	Gneissic, porphyroblastic.	Schistose, porphyroblastic.	Gneissic, porphyroblastic.	Schistose, porphyroblastic.	Schistose, porphyroblastic.
Quartz	24.5	21.1	7.2	1.3	31.1	27.1
Plagioclase	9.4 (oligoclase); altered to albite, 8.6.	5.4 (sodic oligoclase); altered to muscovite, 2.5.	18.7 (An_{33}); altered to sericite, 0.3.	1.0 (oligoclase-andesine)	32.9 (An_{28}); altered to sericite, 2.3; calcite, 0.1.	28.0 (andesine); altered to sericite, 9.4; chlorite, 0.6.
Potassium feldspar	0(?)	0(?)	0(?)	0(?)	6.6 (microcline); altered to sericite, 0.3.	0(?)
Muscovite	4.0(?)	0.6(?)	0	0.6(?)	0.6	0.2(?)
Sillimanite	19.5 (altered to coarse muscovite, 16.3; sericite, 1.9).	25.8 (altered to sericite, 23.9; coarse muscovite, 1.7; chlorite, 0.2).	29.8 (altered to sericite, 14.4; coarse muscovite, 15.4).	33.8 (altered to sericite and coarse muscovite, 32.5; chlorite, 0.4).	0	12.4 (altered to sericite, 11.1).
Kyanite	0	0	0	0	<0.1	0
Cordierite	0	0	0	0	0	0
Epidote-clinozoisite	0	0	0.6	0	0	0
Calcite	0	0	0	0	0	0
Biotite	27.7 (brown); altered to chlorite, 2.9; muscovite, 1.4; goethite(?), 0.1.	29.6 (brown); altered to muscovite, 10.9; chlorite, 5.7; magnetite, 2.0; leucoxene, <0.1.	42.2 (brown); altered to muscovite, 15.3; chlorite, 16.3; magnetite, 1.7; limonite, 0.1.	50.9 (brown); altered to muscovite, 25.8; chlorite, 8.6; magnetite, 1.9; sphene, 0.2; epidote, <0.1.	17.8 (red-brown); altered to sphene or leucoxene, 0.6; sericite, 0.4.	13.5 (red-brown); altered to muscovite, 4.8; chlorite, 4.8; magnetite, 1.0; sphene, 0.1.
Garnet	13.2 (altered to muscovite, 3.1; biotite 2.5; chlorite, 0.4; albite, 0.2).	17.0 (altered to chlorite, 5.9; sericite, 4.3; sphene, 0.1).	1.8 (altered to sericite, 0.5; green biotite, 0.3; chlorite, 0.1).	11.0 (altered to sericite, 4.9; chlorite, 0.8; green biotite, 1.0).	10.2 (altered to sericite, 0.3; calcite, 0.1; chlorite, <0.1).	16.5 (altered to sericite, 8.9; chlorite, 1.6).
Spinel	0	0	0	0	0	0
Magnetite-ilmenite	1.4	0.3	0	1.2	0.1 (altered to leucoxene, <0.1).	0
Hematite	0	0	0	0	0	0
Pyrite	0.2(?) (all altered to hematite).	0	0	0	<0.1	0

Pyrrhotite	0	0	0	0	0	<0.1
Graphite	0	0	0	0	0.1	2.2.
Tourmaline	0	0	0	0	0	<0.1
Apatite	<0.1	0	0	0	0	0
Rutile	<0.1	<0.1	0	0	0.3	0.3
Sphene	0.1	<0.1 (partly altered to leucoxene).	0	<0.1	0	0
Zircon	0.2	<0.1	0.1	0.1	0.1	<0.1
Monazite	0	0	0	0	<0.1	0
Allanite	0	0.1 (metamict)	0	0	0	0
Total alteration	37.6	57.2	64.4	76.1	4.1	42.3

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, B, Bi, Cd, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W, Zn. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957]

Ba	0.07	0.07	0.07	0.07	0.07	0.03
Be	0	0	0	0	0	0
Ce	0	0	0	0	0.03	0
Co	.003	.003	.003	.003	.0015	.0015
Cr	.007	.007	.007	.015	.003	.007
Cu	.003	.015	.0015	.0007	.0015	.015
Ga	.003	.003	.003	.003	.0015	.003
La	.007	.003	.007	.007	.015	.007
Nb	.0015	.003	.0015	.0015	.0015	.0015
Nd	Trace	0	Trace	Trace	.015	Trace
Ni	.007	.015	.015	.007	.003	.003
Pb	Trace	0	.0015	Trace	.003	.0015
Sc	.007	.003	.007	.007	.0015	.007
Sr	.015	.007	.015	.015	.015	.015
V	.015	.015	.015	.015	.007	.015
Y	.003	.003	.003	.003	.0015	.007
Yb	.0007	.0007	.0007	.0007	.0003	.0015
Zr	.03	.03	.03	.03	.03	.015

TABLE 4.—*Chemical, modal, and spectrographic analyses of selected pelitic metasediments in eastern Connecticut*

	Putnam Gneiss—biotite-muscovite schist				Putnam Gneiss—biotite gneiss	
Sample No.	1	2	3	4	5	6
Laboratory No.	C1011	D1678	C999	D1661	C1009	C1007
Field No.	466	1129	228	1109	460	392

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Marguerite Seerveld was the analyst for sample 1 in September 1957, and for samples 2, 4, 8, 9, 10, and 11 in April 1958 (except carbon); carbon for samples 2, 4, 8, 9, 10, and 11 by F. H. Neuerburg, February 1959; F. H. Neuerburg was the analyst for samples 3, 5, and 6 in April 1957; and P. M. Buschman was the analyst for sample 7 in March 1961]

	1	2	3	4	5	6
SiO_2	64.50	65.65	67.54	67.67	58.74	66.25
Al_2O_3	15.71	14.79	14.77	15.52	18.16	14.92
Fe_2O_3	2.83	1.76	.79	1.91	.61	1.64
FeO	3.32	4.41	4.23	2.65	5.81	4.25
MgO	2.65	2.79	2.43	1.88	2.93	2.46
CaO	1.86	2.03	2.21	1.45	4.87	2.57
Na_2O	2.79	2.78	3.20	2.62	2.93	2.42
K_2O	3.34	3.24	2.72	3.56	2.87	3.12
H_2O-	.11	.03	.05	.07	.07	.01
H_2O+	1.32	1.07	.78	1.38	.85	.95
TiO_2	.78	.94	.78	.61	1.10	.80
CO_2	.02	.04	.00	.01	.24	.04
P_2O_5	.18	.06	.08	.24	.37	.06
Cl	.03	.04	.03	.02	.06	.04
F	.07	.08	.05	.06	.11	.10
S	.00	.01	.03	.03	.15	.03
MnO	.11	.07	.08	.08	.11	.10
BaO	.03	.01	.08	.06	.09	.03
C	.00	.00	.00	.02	.04	.02
	99.65	99.80	99.85	99.84	100.11	99.81
Less O	.04	.05	.05	.05	.12	.07
Total	99.61	99.75	99.80	99.79	99.99	99.74

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958-61]

Number of points	1,008	1,472	1,387	1,747	1,509	1,749
Texture	Schistose, porphyroblastic.	Schistose, porphyroclastic, blastomylonitic.	Schistose, porphyroblastic.	Schistose, porphyroblastic.	Schistose, porphyroblastic.	Schistose, porphyroclastic, blastomylonitic.
Quartz	36.6	40.5	38.2	35.7	19.9	38.3
Plagioclase	37.4 (oligoclase); altered to kaolin, <0.1; sericite, <0.1.	30.5 (An_{28}); altered to sericite, 0.1.	32.2 (An_{26}) antiperthite; altered to calcite, <0.1; kaolin, <0.1.	29.6 (oligoclase); altered to sericite, 0.1.	48.6 (An_{41})	19.1 (An_{33})
Potassium feldspar	0	0	0	0	0.1 (orthoclase)	0
Muscovite	6.4	2.9	2.8	20.7	1.6	13.8(?)
Sillimanite	0	0	0	0	0	0
Epidote-clinozoisite	0.2	0.3	0	0.5	0.1	0.7
Calcite	0	0.1	0	0	0.7	0.5
Staurolite	0	0	0	0	0	0
Biotite	17.7 (green-brown); altered to chlorite, 1.1.	25.1 (green); altered to muscovite, 0.8; leucoxene, 0.3; chlorite, 0.1; epidote, 0.1.	26.3 (brown); altered to chlorite, <0.1; sphene, <0.1; hematite, <0.1.	11.4 (green); altered to chlorite, 0.1.	21.8 (brown)	26.4 (green to brown); altered to chlorite, <0.1.
Garnet	0	0	0	0	6.0 (altered to muscovite, 1.9; plagioclase, 1.6; green biotite, 0.5).	<0.1
Magnetite-ilmenite	1.7	0.3 (magnetite)	0.3	1.6	0.2	1.1
Hematite	<0.1	0	0	0	0	0
Pyrite	<0.1(?) (all altered to hematite).	0	0.1(?) (all altered to hematite).	<0.1(?) (all altered to hematite).	0.2 (altered to hematite, <0.1).	<0.1 (partly altered to hematite).
Pyrrhotite	0	0	0	0	0	0
Graphite	0	0	0	0	0	0
Tourmaline	0	0	0	0	0	0
Apatite	<0.1	0	0.2	0.4	0.5	<0.1
Rutile	0	0.1	0	0	0.1	0.
Sphene	0	0	0	0	0.1 (altered to leucoxene, <0.1).	0.1
Zircon	<0.1	<0.1	0.1	<0.1	<0.1	0.1
Monazite	0	0.1 (altered to clinozoisite, <0.1).	0	0.1	0.1 (altered to clinozoisite, <0.1).	0
Allanite	<0.1	<0.1	0	<0.1	0	0
Total alteration	1.1	1.4	~0.1	0.2	4.0	<0.1

TABLE 4.—*Chemical, modal, and spectrographic analyses of selected pelitic metasediments in eastern Connecticut*—Continued

	Putnam Gneiss—biotite-muscovite schist				Putnam Gneiss—biotite gneiss	
Sample No.	1	2	3	4	5	6
Laboratory No.	C1011	D1678	C999	D1661	C1009	C1007
Field No.	466	1129	228	1109	460	392

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Cd, Ge, Hf, Hg, In, Ir, Li, Os, Pd, Pt, Re, Rh, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 1, 3, 5, 6, and 7, and also Ho, Lu, Pr, Tb, and Tm, in sample 7; Dy, Er, Gd, Ho, Lu, Pr, Sm, Tb, and Tm were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957, January 1958, and December 1960]

B	0	0	0	0	0	0
Ba	.03	.07	.03	.07	.15	.07
Be	0	0	.00015	0	.00015	.0003
Bi	0	0	0	0	0	0
Ce	0	.03	0	0	.03	0
Co	.003	.003	.003	.0015	.003	.003
Cr	.007	.015	.007	.003	.003	.007
Cu	.003	.015	.003	.0007	.003	.007
Ga	.0015	.0015	.0015	.0015	.0015	.0015
La	.007	.015	.007	.003	.015	.007
Mo	0	0	0	0	0	0
Nb	.0015	.0015	.003	.0015	.0015	.0015
Nd	0	.015	Trace	0	.015	Trace
Ni	.007	.007	.007	.003	.003	.007
Pb	.0015	.0015	.003	.0007	.0015	.0015
Sc	.003	.003	.003	.0015	.003	.003
Sr	.015	.015	.015	.015	.03	.015
V	.007	.015	.007	.007	.015	.007
Y	.003	.0015	.0015	.003	.0015	.003
Yb	.0007	.00015	.0003	.0007	.0003	.0007
Zr	.03	.03	.03	.03	.03	.03

1. Yantic belt, west ninth, Norwich 7½-minute quadrangle.
2. Yantic belt, southeast ninth, Fitchville 7½-minute quadrangle.
3. Yantic belt, northwest ninth, Norwich 7½-minute quadrangle.
4. Yantic belt, east ninth, Fitchville 7½-minute quadrangle.
5. Norwich belt, northeast ninth, Norwich 7½-minute quadrangle.
6. Norwich belt, southwest ninth, Norwich 7½-minute quadrangle.

TABLE 4.—*Chemical, modal, and spectrographic analyses of selected pelitic metasediments in eastern Connecticut*—Continued

	Brimfield Schist	Scotland Schist			
Sample No.	7	8	9	10	11
Laboratory No.	G3130	D1663	D1667	D1680	D1675
Field No.	1474	1111	1115	1140	1124

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Marguerite Seerveld was the analyst for sample 1 in September 1957, and for samples 2, 4, 8, 9, 10, and 11 in April 1958 (except carbon); carbon for samples 2, 4, 8, 9, 10, and 11 by F. H. Neuerburg, February 1959; F. H. Neuerburg was the analyst for samples 3, 5, and 6 in April 1957; and P. M. Buschman was the analyst for sample 7 in March 1961]

	7	8	9	10	11
SiO_2	63.97	57.78	59.58	68.83	77.84
Al_2O_3	18.29	23.31	21.15	13.98	10.89
Fe_2O_3	.88	2.27	1.67	.36	.66
FeO	4.79	5.26	6.13	4.49	3.01
MgO	1.46	1.92	1.95	2.45	.96
CaO	0.14	.44	.55	2.76	1.14
Na_2O	.40	1.16	.82	2.15	2.84
K_2O	5.86	3.72	4.02	2.54	1.05
H_2O-	.13	.10	.10	.05	.00
H_2O+	2.37	2.26	2.18	.92	.65
TiO_2	.94	1.16	1.16	.80	.61
CO_2	.02	.02	.05	.02	.01
P_2O_5	.09	.10	.16	.18	.06
Cl	.03	.01	.01	.00	.01
F	.08	.07	.08	.05	.02
S	.01	.02	.24	.00	.02
MnO	.07	.11	.09	.09	.06
BaO	.07	.08	.07	.01	.01
C	.23	.20	.02	.02	.07
	99.83	99.99	100.03	99.70	99.91
Less O	.04	.04	.15	.02	.02
Total	99.79	99.95	99.88	99.68	99.89

TABLE 4.—*Chemical, modal, and spectrographic analyses of selected pelitic metasediments in eastern Connecticut*—Continued

	Brimfield Schist	Scotland Schist			
Sample No	7	8	9	10	11
Laboratory No	G3130	D1663	D1667	D1680	D1675
Field No	1474	1111	1115	1140	1124
MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT [All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–61]					
Number of points	1,367	1,736	2,007	1,819	3,174
Texture	Schistose, granular	Schistose, granular, porphyroblastic.	Schistose, granular, porphyroblastic, helycitic.	Schistose, granular	Schistose, granular.
Quartz	47.5	48.0	41.6	42.3	48.9
Plagioclase	3.6 (oligoclase)	10.0 (oligoclase)	4.2 (An_{28}); altered to sericite, 0.1.	28.8 (sodic andesine)	33.5 (An_{17}); altered to sericite, <0.1.
Potassium feldspar	0	0	0	0	0
Muscovite	30.7	19.6	28.5	1.8	4.2
Sillimanite	0	0	<0.1(?)	0	0.7(?) (altered to sericite, 0.6).
Epidote-clinozoisite	0	0	0	0.1	0
Calcite	0	0	0	0	0
Staurolite	0	8.2 (altered to sericite, <0.1).	5.7 (altered to sericite, <0.1; chlorite, 0.1.	0	0.7
Biotite	16.2 (brown); altered to chlorite, <0.1.	9.8 (light-brown)	12.9 (light-brown)	26.6 (brown); altered to chlorite, 0.9.	8.8 (brown); altered to chlorite, 0.7.
Garnet	0.4	3.3 (altered to sericite, 0.1).	4.4	0.1	2.2
Magnetite-ilmenite	0.4	0	1.6(?)	0	<0.1 (all altered to leucoxene).
Hematite	0	0	0	0	0
Pyrite	0	0	0.1	0.1(?) (all altered to hematite).	0
Pyrrhotite	0.1(?)	<0.1	0.4	0	<0.1 (partly altered to hematite).
Graphite	0.9	1.0	0	0.3	0.9
Tourmaline	0	0.1	0	0.1	0
Apatite	<0.1	0.1	0.4	0.4	0.1
Rutile	<0.1	0	0	0.1	0
Sphene	0	0	0	0.1	0
Zircon	0.1	<0.1	0.1	<0.1	<0.1
Monazite	0.1 (altered to isotropic mineral, <0.1).	0	0	0	0
Allanite	0	0	<0.1	0	0
Total alteration	<0.1	0.1	0.2	0.9	1.3

TABLE 4.—*Chemical, modal, and spectrographic analyses of selected pelitic metasediments in eastern Connecticut*—Continued

	Brimfield Schist	Scotland Schist			
Sample No	7	8	9	10	11
Laboratory No.	G3130	D1663	D1667	D1680	D1675
Field No	1474	1111	1115	1140	1124

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Cd, Ge, Hf, Hg, In, Ir, Li, Os, Pd, Pt, Re, Rh, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 1, 3, 5, 6, and 7, and also Ho, Lu, Pr, Tb, and Tm, in sample 7; Dy, Er, Gd, Ho, Lu, Pr, Sm, Tb, and Tm were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957, January 1958, and December 1960]

	7	8	9	10	11
B	0.0015	0.015	0	0.007	0
Ba	.07	.07	.07	.07	.03
Be	.00015	.00015	.0003	.00015	0
Bi	0	0	.003	0	0
Ce	.0015	.015	.015	.015	0
Co	.0015	.003	.003	.0015	.0015
Cr	.007	.015	.007	.015	.003
Cu	.0007	.003	.015	.0015	.0007
Ga	.0015	.003	.003	.0007	.0003
La	.007	.007	.007	.003	.003
Mo	0	.0003	0	0	0
Nb	.0015	.0015	.003	.0015	.0015
Nd	0	.007	.007	.007	0
Ni	.003	.007	.007	.007	.003
Pb	.0015	.003	.0015	.0015	.0015
Sc	.003	.007	.003	.0015	.0015
Sr	.003	.015	.015	.015	.03
V	.015	.03	.015	.007	.007
Y	.0015	.003	.003	.003	.003
Yb	.00015	.0007	.0007	.0003	.0003
Zr	.03	.03	.03	.03	.03

7. Colchester nappe, east ninth, Colchester 7½-minute quadrangle.
8. Micaceous schist, Scotland belt, northeast ninth, Fitchville 7½-minute quadrangle.
9. Micaceous schist Scotland belt, northeast ninth, Fitchville 7½-minute quadrangle.
10. Granular schist, Pitchers Pond belt, northwest ninth, Fitchville 7½-minute quadrangle.
11. Granular schist, Scotland belt, south ninth, Fitchville 7½-minute quadrangle.

TABLE 5.—*Chemical, modal, and spectrographic analyses of calc-silicate rocks of Norwich and Fitchville quadrangles, Connecticut*

	Hebron Formation—calcareous schist to calc-silicate gneiss					
Sample No. Laboratory No. Field No.	1 D1662 1110	2 D1665 1113	3 D1666 1114	4 D1668 1116	5 D1679 1130	6 D1669 1118
CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT						
[Samples 1-8 (except carbon) were analyzed by Marguerite Seerveld, April 1958; carbon for samples 1-8 was analyzed by F. H. Neuerburg, February 1959; samples 9 and 11 were analyzed by F. H. Neuerburg, April 1957; sample 10 was analyzed by Marguerite Seerveld, September 1957]						
SiO_2	65.54	67.92	68.41	63.33	67.57	66.19
Al_2O_3	11.74	11.60	11.78	14.33	12.22	12.05
Fe_2O_3	.37	.45	.45	.65	.76	.30
FeO	3.72	3.69	3.56	4.95	3.79	4.01
MgO	2.82	2.75	2.74	3.82	3.10	3.83
CaO	6.53	5.92	6.01	6.07	7.61	6.57
Na_2O	2.15	2.10	2.15	1.94	1.81	1.10
K_2O	1.75	1.64	1.17	2.35	1.32	2.49
H_2O-	.05	.10	.09	.05	.07	.12
H_2O+	.94	.82	1.09	.98	.49	.97
TiO_2	.64	.68	.68	.82	.76	.65
CO_2	3.28	1.96	1.43	.22	.03	1.23
P_2O_5	.12	.16	.14	.15	.18	.16
Cl	.01	.01	.01	.01	.01	.02
F	.05	.04	.04	.06	.05	.05
S	.06	.00	.00	.02	.00	.04
MnO	.09	.07	.07	.08	.09	.09
BaO	.03	.01	.03	.03	.00	.01
C	.02	.01	.01	.02	.01	.00
	99.91	99.93	99.86	99.88	99.87	99.88
Less O	.05	.02	.02	.04	.02	.04
Total	99.86	99.91	99.84	99.84	99.85	99.84

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock by G. L. Snyder, 1958–59]

Number of points	1,836	1,902	1,862	4,794	2,935	2,547
Texture	Schistose, granular	Schistose, granular	Schistose, granular	Schistose, granular, poikiloblastic.	Gneissic, granular	Schistose, granular.
Quartz	38.1	41.0	31.0	19.7	20.4	39.9
Plagioclase	23.4 (calcic andesine)	22.5 (sodic andesine)	33.0 (An_{36}) altered to sericite, <0.1.	29.0 (An_{48})	35.9 (An_{49})	17.0 (calcic andesine).
Potassium feldspar	0	0	5.0 (orthoclase)	2.0 (orthoclase); altered to calcite, <0.1.	2.7 (orthoclase)	4.7 (orthoclase).
Scapolite	0	0	0	0	0	4.7
Epidote-clinozoisite	0	0.2	0.3	4.7	7.3	4.0
Calcite	7.1	3.2	3.1	0.6	0	2.4
Chlorite	0.9	0.5(?)	0	0	0	0
Biotite	30.1 (brown)	24.6 (brown); altered to chlorite, 0.4.	9.3 (brown); altered to chlorite, 8.0; sphene, 0.2.	12.7 (brown)	0	16.9 (brown).
Diopside	0	0	0	1.0	5.5	0
Dark-green to light-green actinolite-hornblende.	0	5.7 (altered to chlorite, <0.1).	15.4	23.6 (altered to biotite, <0.1).	22.2	0
Light-green to colorless tremolite-actinolite.	0	0	0	4.1	3.9	9.2
Magnetite-ilmenite	0	0	0	0	0	<0.1
Pyrite	0	0	<0.1 (all altered to hematite).	0.1	<0.1 (partly altered to hematite).	0
Galena	0	0	0	0	0	0
Pyrrhotite	0.3	<0.1(?) (partly altered to hematite).	<0.1	0.1	0	0.2
Graphite	0.2	0	<0.1(?)	0	0	
Tourmaline	0.1	0	0	<0.1	0	0.1
Apatite	0.5	0.3	0.4	0.1	0.2	0.1
Sphene	0.1	2.0 (altered to leucoxene, <0.1).	2.5	2.1	1.9	0.6
Zircon	0.1	<0.1	0	<0.1	0	0.1
Allanite	<0.1	0	0.1	0.1	0.1	0
Total alteration	0.9	0.4	8.2	<0.1	<0.1	0

TABLE 5.—*Chemical, modal, and spectrographic analyses of calc-silicate rocks of Norwich and Fitchville quadrangles, Connecticut*—Con.

	Hebron Formation—calcareous schist to calc-silicate gneiss					
Sample No	1	2	3	4	5	6
Laboratory No	D1662	D1665	D1666	D1668	D1679	D1669
Field No	1110	1113	1114	1116	1130	1118

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Bi, Cd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 9, 10, and 11; Dy, Er, Gd, and Sm were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957 and January 1958]

	1	2	3	4	5	6
B	0	0	0	0	0	0.003
Ba	.03	.03	.03	.03	.07	.03
Be	0	0	0	.00015	.00015	0
Ce	0	0	0	0	0	0
Co	.0015	.0015	.0007	.003	.0015	.0015
Cr	.007	.015	.007	.015	.015	.015
Cu	.003	.0015	.0015	.0015	.003	.003
Ga	.0007	.0007	.0007	.0015	.0007	.0007
La	.003	.003	0	.003	.007	.003
Nb	.0015	.0015	0	0	.0015	.0015
Nd	0	0	0	0	.007	0
Ni	.007	.007	.003	.007	.007	.015
Pb	.003	.0007	.0007	.0015	.0015	.0015
Sc	.0007	.003	.0015	.003	.003	.0015
Sr	.03	.03	.03	.03	.03	.03
V	.007	.015	.007	.007	.007	.007
Y	.003	.003	.0015	.003	.003	.003
Yb	.0003	.0003	.0003	.0003	.0003	.0003
Zr	.03	.03	.015	.015	.03	.03

TABLE 5.—*Chemical, modal, and spectrographic analyses of calc-silicate rocks of Norwich and Fitchville quadrangles, Connecticut*—Con.

	Hebron Formation—calcareous schist to calc-silicate gneiss	Fly Pond Member of Putman Gneiss, calc-silicate rock			Fly Pond Member of Putman Gneiss, marble
Sample No.	7	8	9	10	11
Laboratory No.	D1671	D1677	C1002	C1019	C1008
Field No.	1120	1128	302	475	431

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Samples 1-8 (except carbon) were analyzed by Marguerite Seerveld, April 1958; carbon for samples 1-8 was analyzed by F. H. Neuerburg, February 1959; samples 9 and 11 were analyzed by F. H. Neuerburg, April 1957; sample 10 was analyzed by Marguerite Seerveld, September 1957]

	7	8	9	10	11
SiO_2	64.19	66.00	59.45	66.32	22.57
Al_2O_3	11.87	12.71	15.37	12.27	6.64
Fe_2O_3	.76	.70	.95	1.07	.22
FeO	4.28	3.87	4.24	3.90	3.54
MgO	3.42	3.32	3.88	3.38	3.96
CaO	10.03	7.93	11.74	8.25	36.26
Na_2O	1.66	2.10	.98	1.84	.55
K_2O	1.22	1.14	.59	.80	1.31
H_2O^-	.03	.14	.04	.11	.04
H_2O^+	.50	.63	.77	.50	.39
TiO_2	.92	.72	1.03	.89	.30
CO_2	.63	.25	.35	.02	22.93
P_2O_5	.21	.20	.28	.17	.09
Cl	.00	.05	.03	.01	.03
F	.04	.06	.13	.06	.08
S	.01	.01	.00	.01	.51
MnO	.13	.10	.11	.10	.21
BaO	.00	.02	.03	.03	.03
C	.01	.01	.00	.00	.12
	99.91	99.96	99.97	99.73	99.78
Less O	.02	.05	.06	.03	.17
Total	99.89	99.91	99.91	99.70	99.61

TABLE 5.—*Chemical, modal, and spectrographic analyses of calc-silicate rocks of Norwich and Fitchville quadrangles, Connecticut*—Con.

	Hebron Formation—calcareous schist to calc-silicate gneiss	Fly Pond Member of Putman Gneiss, calc-silicate rock			Fly Pond Member of Putman Gneiss, marble
Sample No.	7	8	9	10	11
Laboratory No.	D1671	D1677	C1002	C1019	C1008
Field No.	1120	1128	302	475	431

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock by G. L. Snyder, 1958–59]

Number of points	2,510	2,257	1,769	1,172	1,751
Texture	Gneissic, granular	Gneissic, granular	Gneissic, granular	Gneissic, granular	Schistose, granular.
Quartz	30.4	25.0	30.0	32.3	0
Plagioclase	24.9 (An_{45})	31.1 (An_{47}) altered to calcite, 0.2; kaolin, 0.2; sericite, <0.1.	20.4 (An_{82}) altered to sericite, 0.2; sodic plagioclase, <0.1.	34.6 (zoned from An_{53} in core to An_{37} on rim) altered to sodic plagioclase, 0.3; epidote, 0.2; kaolin, 0.1.	0.6
Potassium feldspar	4.4 (orthoclase)	8.6 (microcline)	0	1.5 (microcline)	3.1 (microcline).
Scapolite	0	1.4 (altered to calcite, <0.1; kaolin, <0.1).	0	0	17.2
Epidote-clinozoisite	9.0	2.4	13.7	7.9	1.3
Calcite	3.6	0.6	0.1	0	54.0
Chlorite	0	0	0	0	0
Biotite	0.4 (brown)	2.7 (brown); altered to chlorite, 0.1; leucoxene, <0.1.	1.4 (light-brown)	<0.1 (brown)	8.8 (light-brown).
Diopside	7.9	0.6	0.7	2.4 (altered to actinolite, 0.6; tremoline, 0.4; biotite, 0.1).	12.6
Dark-green to light-green actinolite-hornblende	13.7	24.6	29.1	18.9	0
Light-green to colorless tremolite-actinolite	3.6	0.9	3.1	0.5	0
Magnetite-ilmenite	0.1	0	0	<0.1	0
Pyrite	0.1 (altered to hematite, <0.1).	0	0	0	0
Galena	0	0	0	0	<0.1
Pyrrhotite	0	0.1	0	0	1.1
Graphite	0	0	0	0	<0.1
Tourmaline	0.1	0	0	0	0.1
Apatite	0.1	0.4	0.1	0.4	0.1
Sphene	1.8	1.4	1.1 (altered to leucoxene, <0.1).	1.1	0.8
Zircon	<0.1	<0.1	0.1	0.1	<0.1
Allanite	0.1	0.1	0.3	<0.1	0
Total alteration	<0.1	0.5	0.2	1.7	0

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Bi, Cd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sn Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 9, 10, and 11; Dy, Er, Gd, and Sm were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957 and January 1958]

B	0.003	0	0	0	0
Ba	.03	.03	.015	.03	.03
Be	0	0	.00015	.00015	0
Ce	.015	0	0	.03	Not looked for.
Co	.0015	.0015	.0015	.0015	.0015
Cr	.015	.015	.007	.015	.003
Cu	.007	.0015	.0007	.0015	.003
Ga	.0007	.0007	.0015	.0007	.0003
La	.007	.003	.003	.015	0
Nb	.0015	.0015	.0015	.0015	0
Nd	.007	0	0	.015	Not looked for.
Ni	.007	.007	.007	.007	.003
Pb	.0015	0	.0015	.0015	Trace
Sc	.003	.0015	.003	.003	.0015
Sr	.03	.03	.015	.03	.07
V	.015	.015	.007	.007	.003
Y	.003	.003	.003	.003	.0015
Yb	.0007	.0003	.0007	.0007	.00015
Zr	.03	.03	.015	.03	.0007

1-4. McCarthy Brook belt, northeast ninth, Fitchville 7½-minute quadrangle.
5. Juncture of Bellows Brook belt and McCarthy Brook belt, south ninth, Fitchville 7½-minute quadrangle.
6. Mason Hill belt, north ninth, Fitchville 7½-minute quadrangle.
7. Standish Hill belt, west ninth, Fitchville 7½-minute quadrangle.
8. Fly Pond Member, south ninth, Fitchville 7½-minute quadrangle.
9. Fly Pond Member, west ninth, Norwich 7½-minute quadrangle.
10. Fly Pond Member, north ninth, Norwich 7½-minute quadrangle.
11. Fly Pond Member, southwest ninth, Norwich 7½-minute quadrangle.

TABLE 6.—*Chemical, modal, and spectrographic analyses of granitic rocks of Norwich and Fitchville qudarangles, Connecticut*

	Canterbury Gneiss				Quartz monzonite gneiss
Sample No.	1	2	3	4	5
Laboratory No.	C1012	C1013	D1674	D1676	C1003
Field No.	467	469	1123	1126	303

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Analyses for samples 1, 2, 6, by Marguerite Seerveld, September 1957; analyses (except carbon) for samples 3, 4, 8, 9 by Marguerite Seerveld, April 1958; carbon analyses for samples 3, 4, 8, 9 by F. H. Neuerburg, February 1959; samples 5 and 7 by F. H. Neuerburg, April 1957; sample 10 by P. M. Buschman, March 1961]

	1	2	3	4	5
SiO_2	67.25	71.89	71.89	73.48	69.12
Al_2O_3	16.10	14.43	14.55	14.14	14.72
Fe_2O_3	1.02	.60	.40	.35	.28
FeO	2.69	1.80	1.95	1.52	2.37
MgO	1.36	.77	.79	.47	.76
CaO	3.72	2.34	2.49	1.52	1.64
Na_2O	3.64	3.46	3.81	4.01	2.58
K_2O	2.64	3.60	3.07	3.45	6.30
H_2O-	.05	.01	.03	.03	.00
H_2O+	.60	.41	.30	.31	.58
TiO_2	.56	.36	.35	.26	.70
CO_2	.02	.03	.02	.02	.35
P_2O_5	.14	.10	.12	.09	.23
Cl	.00	.01	.00	.02	.02
F	.05	.04	.05	.06	.11
S	.01	.00	.00	.00	.00
MnO	.07	.06	.08	.05	.02
BaO	.02	.02	.03	.01	.10
C	.00	.00	.01	.00	.00
	99.94	99.93	99.94	99.79	99.88
Less O	.03	.02	0.02	.03	.05
Total	99.91	99.91	99.92	99.76	99.83

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–61]

Numbers of points	1,495	1,584	1,546	1,853	2,059
Texture	Gneissic, granular	Gneissic, granular, myrmekitic.	Gneissic, granular, myrmekitic.	Mortar	Gneissic, granular.
Quartz	30.5	33.8	31.2	34.2	27.0
Plagioclase	42.2 (An$_{29}$); contains crystallographically oriented flakes of sericite, 0.1.	41.4 (An$_{24}$) (antiperthite); altered to kaolin, <0.1; clinozoisite(?), 0.1; sericite(?), 0.6.	40.5 (sodic oligoclase antiperthite).	36.2 (median oligoclase); altered to sericite, 0.1.	24.1 (sodic oligoclase); altered to coarse muscovite, 2.7; sericite, 0.1.
Potassium feldspar	7.1 (microcline)	14.7 (microcline)	20.8 (microcline)	20.1 (microcline)	32.9 (microcline); altered to coarse muscovite, 0.5; sericite <0.1.
Muscovite	1.2	0.2	0	2.7	3.5
Epidote-clinozoisite	2.1	0.4	0.3	<0.1	0
Calcite	0	0	0	0	1.2
Celadonite(??)	0	0	0	0	0
Biotite	16.4 (dark-gray-green); altered to muscovite, 0.1; chlorite, <0.1.	9.5 (deep green); altered to chlorite, 0.3.	6.8 (deep green); altered to chlorite, 0.1; muscovite, <0.1.	6.5 (dark-gray-green); altered to chlorite, <0.1.	9.0 (brown); altered to muscovite, 0.4; chlorite, <0.1.
Aegirinaugite	0	0	0	0	0
Dark- to light-green actinolite-hornblende	0	0	0	0	0
Garnet	0	0	0	0	0
Magnetite-ilmenite	0	0	0	0.1(?)	0.5
Pyrite	<0.1(?) (all altered to hematite).	<0.1 (mostly altered to hematite).	<0.1(?) (all altered to hematite).	0	0
Pyrrhotite	0	0	0	0	0
Graphite	0	<0.1	0	0	0
Tourmaline	0	0	0	0	0
Apatite	0.2	<0.1(?)	0.2	0.1	0.3
Rutile	0	0	0	0	0
Sphene	0.1 (altered to leucoxene, <0.1).	0.2	0.3 (altered to leucoxene, <0.1).	0	0.6 (altered to leucoxene, 0.1).
Zircon	<0.1	<0.1	<0.1	<0.1	0.1
Monazite	0	0	0	<0.1(?)	0
Allanite	0.3 (metamict)	0	0	0	0.2
Total alteration	0.1	1.0	0.1	0.1	3.8

TABLE 6.—*Chemical, modal, and spectrographic analyses of granitic rocks of Norwich and Fitchville quadrangles, Connecticut*—Continued

	Canterbury Gneiss				Quartz monzonite gneiss
Sample No.	1	2	3	4	5
Laboratory No.	C1012	C1013	D1674	D1676	C1003
Field No.	467	469	1123	1126	303

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Cd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 1, 2, 5, 6, 7, and 10, and also Ho, Lu, Pr, Tb, and Tm, in sample 10; Dy, Er, Gd, Ho, Lu, Pr, Sm, Tb, and Tm, were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957, January 1958, and December 1960]

B	0	0	0	0	0
Ba	.07	.07	.03	.03	.07
Be	.00015	.00015	.0003	.00015	0
Bi	0	0	.0015	0	0
Ce	0	0	.015	.015	.07
Co	.0015	.0003	.0003	0	.0007
Cr	.0007	.0003	.0003	.0003	.0007
Cu	.0015	.003	.0003	.0003	.0007
Ga	.0015	.0007	.0007	.0015	.0015
La	.003	0	.003	.003	.03
Nb	.0015	.0015	.0015	.0015	.0015
Nd	0	0	0	0	.03
Ni	.0015	.0007	.0003	0	0
Pb	.0015	.003	.0015	.0015	.007
Sc	.0015	.0015	.0015	.0007	.0007
Sn	0	0	0	0	0
Sr	.015	.015	.015	.015	.015
V	.007	.003	.003	.0015	.003
Y	.003	.0015	.003	.003	.0015
Yb	.0003	.0003	.0007	.0007	.00015
Zr	.015	.015	.015	.015	.03

TABLE 6.—*Chemical, modal, and spectrographic analyses of granitic rocks of Norwich and Fitchville qudarangles, Connecticut*—Continued

	Pegmatite			Alaskite gneiss	Aegirinaugite gneiss
Sample No	6	7	8	9	10
Laboratory No	C1020	C998	D1673	D1672	G3125
Field No	476	136	1122	1121	441

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[Analyses for samples 1, 2, 6, by Marguerite Seerveld, September 1957; analyses (except carbon) for samples 3, 4, 8, 9 by Marguerite Seerveld, April 1958; carbon analyses for samples 3, 4, 8, 9 by F. H. Neuerburg, February 1959; samples 5 and 7 by F. H. Neuerburg, April 1957; sample 10 by P. M. Buschman, March 1961]

SiO_2	71.51	73.32	75.36	75.71	68.41
Al_2O_3	14.78	13.75	14.35	12.15	17.42
Fe_2O_3	.10	.19	.10	1.04	.85
FeO	.56	1.22	.59	1.01	.36
MgO	.45	.65	.11	.17	.30
CaO	.27	1.63	.74	.57	.79
Na_2O	1.92	2.43	4.46	4.28	9.09
K_2O	9.25	5.55	3.38	4.35	2.12
H_2O-	.06	.10	.02	.02	.04
H_2O+	.27	.38	.37	.07	.08
TiO_2	.27	.30	.04	.17	.29
CO_2	.11	.01	.01	.22	.01
P_2O_5	.07	.06	.20	.03	.02
Cl	.01	.01	.00	.00	.01
F	.01	.05	.02	.03	.01
S	.01	.01	.00	.02	.00
MnO	.01	.02	.07	.07	.06
BaO	.22	.07	.00	.03	.12
C	.00	.00	.01	.01	.00
	99.88	99.75	99.83	99.95	99.98
Less O	.01	.03	.01	.01	0
Total	99.87	99.72	99.82	99.94	99.98

TABLE 6.—*Chemical, modal, and spectrographic analyses of granitic rocks of Norwich and Fitchville quadrangles, Connecticut*—Continued

	Pegmatite			Alaskite gneiss	Aegirinaugite gneiss
Sample No.	6	7	8	9	10
Laboratory No.	C1020	C998	D1673	D1672	G3125
Field No.	476	136	1122	1121	441

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes, except for sample 6, are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–61. Two modes on two thin sections are listed for sample 6]

	6	7	8	9	10
Number of points	1,508 and 1,402	1,292	2,013	2,000	1.999
Texture	Porphyroblastic	Schistose, prophyroblastic, rapakivi.	Gneissic, granular, porphyroblastic.	Gneissic, granular	Filled miarolitic.
Quartz	30.6, 23.2	25.2	28.8	32.5	11.3
Plagioclase	5.3, 3.0 (oligoclase); altered to sericite, 2.1, 1.7.	22.9 (oligoclase); altered to sericite, 0.7; zoisite, 0.5.	41.3 (An_6)	32.9 (An_2)	68.9 (An_3); altered to kaolin, 0.1.
Potassium feldspar	57.8, 68.6 (microcline perthite, 5 percent of this is blebs of plagioclase) altered to kaolin <0.1, <0.1, and muscovite, 0, 0.3.	45.4 (microcline perthite, 10 percent of this is blebs and irregular areas of plagioclase).	17.5 (microcline)	29.6 (zoned microcline perthite).	11.4 (microcline); altered to kaolin, <0.1.
Muscovite	0.1, 0.4	0.7	10.4	0	0
Epidote-clinozoisite	0, 0	0	0	0	0
Calcite	0.6, 0.9	0	0	0.6 (altered to limonite(?), 0.1).	0
Celadonite(??)	0, 0	0	0	0	0.1 (vugs?)
Biotite	5.7, 3.7 (brown); altered to muscovite, 1.3, 0.1; chlorite, 0.1, <0.1; leucoxene, 0.1, <0.1.	5.0 (brown); altered to chlorite, 0.5; muscovite, 0.2.	<0.1 (brown); partly altered to chlorite.	1.9 (deep brown-green); altered to chlorite, <0.1.	0
Aegirinaugite	0, 0	0	0	0	8.6 (7.7 in quartz, 0.9 in feldspar).
Dark- to light-green actinolite-hornblende	0, 0	0	0	1.7	0
Garnet	0, 0	0	1.4 (altered to biotite, <0.1; chlorite, <0.1).	0	0.2 (melanite?)
Magnetite-ilmenite	0, 0	0.1	0	0.7	0
Pyrite	<0.1(?), <0.1(?) (all altered to hematite).	0	<0.1(?) (all altered to hematite).	<0.1	<0.1(?)
Pyrrhotite	0, 0	0	0	0	0

Graphite	0, 0	0	<0.1	0.1	0
Tourmaline	0, 0	0	0.4	0	0
Apatite	0, 0	<0.1	0.1	<0.1	0
Rutile	0.1, 0.1	<0.1	<0.1	0	<0.1
Sphene	0, 0	0.2 (altered to leucoxene, <0.1).	<0.1 (partly altered to leucoxene).	0.2 (keilhauite)	0.3 (altered to leucoxene, 0.1).
Zircon	0, 0	<0.1	0	<0.1	0.2
Monazite	0, 0	0.3 (altered to unknown isotropic material, 0.2).	0	0	0
Allanite	0, 0	0.3	0	<0.1	0
Total alteration	3.6, 2.1	2.1	<0.1	0.1	0.2

TABLE 6.—*Chemical, modal, and spectrographic analyses of granitic rocks of Norwich and Fitchville quadrangles, Connecticut*—Continued

	Pegmatite			Alaskite gneiss	Aegirinaugite gneiss
Sample No.	6	7	8	9	10
Laboratory No.	C1020	C998	D1673	D1672	G3125
Field No.	476	136	1122	1121	441

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: Ag, As, Au, Cd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Ta, Te, Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 1, 2, 5, 6, 7, and 10, and also Ho, Lu, Pr, Tb, and Tm, in sample 10; Dy, Er, Gd, Ho, Lu, Pr, Sm, Tb, and Tm, were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957, January 1958, and December 1960]

	6	7	8	9	10
B	0	0	.0015	0	0
Ba	.15	.03	.0015	.03	.15
Be	0	.00015	.0003	0	.0003
Bi	0	0	0	0	0
Ce	0	.07	0	.015	0
Co	.0003	.0003	0	0	0
Cr	.0003	.00015	0	.00015	.0003
Cu	.00015	.003	0	.0007	.0003
Ga	.0015	.0007	.0015	.0015	.0015
La	0	.03	0	.007	.007
Nb	0	.0015	.0015	0	.0015
Nd	0	.03	0	.007	0
Ni	.0007	0	0	0	0
Pb	.007	.007	.003	.0007	.0015
Sc	0	.0007	.0007	.0007	.0007
Sn	0	0	.0003	0	0
Sr	.03	.015	.0015	.003	.015
V	.003	.0015	0	0	0
Y	0	.0015	.0007	.003	.003
Yb	0	.00015	.00015	.0007	.0003
Zr	.003	.03	.007	.07	.015

1, 2. Uniform medium-grained biotite gneiss, northwest ninth, Norwich 7½-minute quadrangle.
3. Uniform medium-grained biotite gneiss, central ninth, Fitchville 7½-minute quadrangle.
4. Uniform medium-grained biotite-muscovite gneiss, south ninth, Fitchville 7½-minute quadrangle.
5. Medium-grained lens in Fly Pond Member of Putnam Gneiss, west ninth, Norwich 7½-minute quadrangle.
6. Pegmatitic lens in Norwich belt of Putnam Gneiss, southeast ninth, Norwich 7½-minute quadrangle.
7. Pegmatitic lens in Fly Pond Member of Putnam Gneiss, north ninth, Norwich 7½-minute quadrangle.
8. Pegmatitic lens in Mason Hill belt, Hebron Gneiss, central ninth, Fitchville 7½-minute quadrangle.
9. Synkinematic intrusive(?), south ninth, Fitchville 7½-minute quadrangle.
10. Lens near alaskite contact, south ninth, Fitchville 7½-minute quadrangle.

TABLE 7.—*Chemical, modal, and spectrographic analyses of miscellaneous rocks of Norwich and Fitchville quadrangles, Connecticut*

	Quartzite at Franklin	Lebanon Gabbro of Rodgers and others (1956)	Amphibolite lens in Putnam Gneiss	Bates Pond Lentil of Putnam Gneiss	Plagioclase gneiss
Sample No.	1	2	3	4	5
Laboratory No.	D1664	D1670	C1017	C1021	G2838
Field No.	1112	1119	473	477	1030

CHEMICAL ANALYSES FOR MAJOR CONSTITUENTS, IN WEIGHT PERCENT

[n.d., not determined. Analyses for samples 1-4 by Marguerite Seerveld, September 1957 and April 1958 (except carbon analyses for samples 1 and 2, which were by F. H. Neuerburg, February 1959); sample 5 by J. W. Goldsmith, August 1960]

	1	2	3	4	5
SiO_2	97.04	46.24	49.02	51.76	74.33
Al_2O_3	1.51	22.09	15.91	21.23	13.68
Fe_2O_3	.10	3.02	3.60	2.41	1.66
FeO	.14	5.85	6.92	4.40	.30
MgO	.11	3.50	8.00	2.56	.44
CaO	.00	11.31	10.75	7.02	.37
Na_2O	.05	2.51	1.79	3.53	5.66
K_2O	.40	1.65	.63	4.12	2.89
H_2O-	.05	.12	.14	.08	.01
H_2O+	.12	.83	1.62	.65	.14
TiO_2	.03	1.78	1.17	.83	.17
CO_2	.01	.01	.20	.02	.02
P_2O_5	.01	.86	.01	.51	.01
Cl	.00	.05	.04	.03	n.d.
F	.01	.07	.07	.09	n.d.
S	.01	.02	.02	.02	n.d.
MnO	.01	.12	.18	.14	.05
BaO	.00	.06	.01	.57	n.d.
C	.00	.00	.00	.00	n.d.
	99.60	100.09	100.08	99.97	99.73
Less O	.00	.04	.04	.05	.00
Total	99.60	100.05	100.04	99.92	99.73

MODAL (POINT-COUNT) ANALYSES OF MINERAL CONSTITUENTS, IN VOLUME PERCENT

[All modes are based on study of a single thin section of the analyzed rock, by G. L. Snyder, 1958–61]

Number of points	2,059	2,203	1,359	1,616	1,636
Texture	Schistose, granular	Hypidomorphic granular.	Granoblastic poikiloblastic.	Gneissic porphyroblastic.	Gneissic granular.
Quartz	93.9	1.7	6.4	0.2	1.8
Plagioclase	0	51.8 (zoned from An_{85} in core to An_{58} on rim); altered to sericite, 0.1.	31.1 (An_{79}); altered to kaolin, 0.1; sericite, <0.1; albite veins, 0.3.	56.5 (An_{41}); slightly zoned.	78.8 (An_6)
Potassium feldspar	0.5 (orthoclase); altered to serpentine(?), <0.1; muscovite, <0.1.	0	0	13.2 (soda-orthoclase, $Or_{70}Ab_{25}Cn_5$) (as determined from semiquantitative spectrographic analysis by J. C. Hamilton).	15.3 (microcline).
Muscovite	5.5	0	0	0	0
Scapolite	0	0.6 (altered to kaolin, <0.1).	1.5 (veins)	0	0
Epidote-clinozoisite	0	1.4	0.8	0	<0.1
Chlorite	0	0	0(?)	0	0.1 (vug?)
Biotite	0.1 (brown); altered to muscovite, <0.1; leucoxene, <0.1; chlorite, <0.1.	18.2 (brown)	0	14.2 (deep brown); altered to muscovite, <0.1.	2.9 (brown); altered to chlorite, <0.1.
Augite	0	0.2(?)	0	0	0
Dark-green to light-green actinolite-hornblende	0	20.4 (altered to serpentine(?) <0.1.	59.6 (altered to chlorite, 0.8; light-brown biotite, 0.2; olive-brown biotite, <0.1; calcite, 0.6; pyrite, <0.1).	12.6	0
Light-green to colorless tremolite-actinolite	0	0.6	0	0	0
Magnetite-ilmenite	0	2.4	0.7 (altered to leucoxene, <0.1).	1.2	0.9
Hematite	0	0	<0.1(?)	0	0
Pyrite	<0.1	0.1 (altered to hematite, <0.1).	0	0.4(?) (all altered to hematite).	0
Apatite	0	1.6	<0.1	1.2	0
Rutile	0	0	<0.1	0	0
Sphene	0	0.7	<0.1 (partly altered to leucoxene).	0	0.1
Zircon	0	0	<0.1	0.4	<0.1
Monazite	0	0	0	0	0.1
Allanite	0	0	0	<0.1	0.1
Total alteration	<0.1	0.1	2.0	0.4	<0.1

TABLE 7.—*Chemical, modal, and spectrographic analyses of miscellaneous rocks of Norwich and Fitchville quadrangles, Connecticut*—Con.

	Quartzite at Franklin	Lebanon Gabbro of Rodgers and others (1956)	Amphibolite lens in Putnam Gneiss	Bates Pond Lentil of Putnam Gneiss	Plagioclase gneiss
Sample No.	1	2	3	4	5
Laboratory No.	D1664	D1670	C1017	C1021	G2838
Field No.	1112	1119	473	477	1030

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES FOR MINOR CONSTITUENTS, IN WEIGHT PERCENT

[Besides the results tabulated below, the following elements were looked for but not detected: As, Au, B, Bi. Cd, Ge, Hf, Hg, In, Ir, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sn, Ta, Te Th, Tl, U, W, Zn. In addition Dy, Er, Gd, and Sm were looked for but not detected in samples 3 and 4; Dy, Er, Gd, and Sm were not looked for in the rest of the rocks. The figures below are reported to the nearest number in the percentage series: 7, 3, 1.5, 0.7, 0.3, 0.15, etc. Sixty percent of the reported results may be expected to agree with the results of quantitative methods. Analyst: P. R. Barnett, July 1957, January 1958, and August 1960]

	1	2	3	4	5
Ag	0	0	0	0.00015	0
Ba	.003	.07	.003	.7	.07
Be	0	0	0	.00015	.0007
Ce	0	0	0	.03	.015
Co	0	.003	.003	.0015	0
Cr	.00015	.0007	.015	.0007	0
Cu	.00015	.015	.003	.0015	.0003
Ga	0	.0015	.0015	.0015	.0015
La	0	.003	0	.015	.007
Nb	0	.0015	0	0	.0015
Nd	0	0	0	.015	.007
Ni	0	.015	.007	.0007	0
Pb	0	.0015	0	.003	0
Sc	0	.0015	.007	.003	.0007
Sr	0	.03	.015	.15	.003
V	0	.007	.015	.015	0
Y	0	.003	.0015	.003	.003
Yb	0	.0003	.0003	.0003	.0003
Zr	0	.03	.007	.07	.03

1. Marker bed locally present between Hebron Gneiss and Scotland Schist, northeast ninth, Fitchville 7½-minute quadrangle.
2. Discordant intrusive, northwest ninth, Fitchville 7½-minute quadrangle.
3. Metasedimentary(?) lens, southeast ninth, Norwich 7½-minute quadrangle.
4. Lentil in Putnam Gneiss, Norwich belt, southeast ninth, Norwich 7½-minute quadrangle.
5. Near alaskite contact, south ninth, Fitchville 7½-minute quadrangle.

TABLE 8.—*Average composition of selected rocks of Fitchville and Norwich quadrangles, Connecticut*

MAP UNIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Pelitic schists and gneisses									Calc-silicate schists and gneisses				Granitic gneisses	
	Putnam Gneiss						Scotland Schist	Overall average including Brimfield Schist	Average of columns 4, 5, 6, and 7, and Brimfield Schist	Hebron Formation	Fly Pond Member of Putnam Gneiss	Overall average	Average of columns 10 and 11	Canterbury Gneiss	Pegmatite and quartz monzonite gneiss
	Sillimanite-pinite and graphite schist				Biotite-muscovite schist	Biotite gneiss									
	Total alteration <10 percent	Total alteration 10–40 percent	Total alteration >40 percent	Overall average											
NUMBER OF ANALYSES	4	4	4	12	4	2	4	23		7	3	10		4	4
SiO_2	67.66	64.73	52.71	61.70	66.34	62.50	66.01	63.42	64.10	66.16	63.92	65.49	65.04	71.13	72.24
Al_2O_3	14.84	16.09	21.41	17.44	15.20	16.54	17.33	16.99	16.96	12.23	13.45	12.59	12.84	14.81	14.40
Fe_2O_3	1.62	1.56	1.77	1.65	1.82	1.13	1.24	1.53	1.34	.53	.91	.65	.72	.59	.17
FeO	4.38	5.09	8.72	6.06	3.65	5.03	4.72	5.27	4.85	4.00	4.00	4.00	4.00	1.99	1.19
MgO	2.40	2.54	3.62	2.86	2.44	2.70	1.82	2.53	2.26	3.21	3.53	3.31	3.37	.85	.49
CaO	1.79	1.05	.67	1.17	1.89	3.72	1.22	1.48	1.63	6.96	9.31	7.67	8.14	2.52	1.07
Na_2O	2.20	1.70	1.12	1.67	2.85	2.68	1.74	1.92	1.87	1.84	1.64	1.78	1.72	3.73	2.85
K_2O	2.96	3.77	4.67	3.80	3.22	3.00	2.83	3.55	3.74	1.71	.84	1.45	1.28	3.19	6.12
H_2O-	.08	.08	.12	.09	.07	.04	.06	.08	.08	.07	.10	.08	.09	.03	.05
H_2O+	.67	1.65	3.12	1.81	1.14	.90	1.50	1.59	1.54	.83	.63	.77	.73	.41	.40
TiO_2	.91	1.05	1.23	1.06	.78	.95	.93	.97	.93	.74	.88	.78	.81	.38	.33
CO_2	.05	.12	.03	.07	.02	.14	.03	.05	.06	1.25	.21	.94	.73	.02	.12
P_2O_5	.04	.05	.05	.05	.14	.22	.13	.09	.13	.16	.22	.18	.19	.11	.14
Cl	.02	.08	.04	.05	.03	.05	.01	.04	.03	.01	.03	.02	.02	.01	.01
F	.05	.06	.09	.07	.07	.11	.06	.07	.08	.05	.08	.06	.07	.05	.05
S	.03	.01	.14	06	.02	.09	.07	.05	.05	.02	.01	.02	.02	.00	.01
MnO	.10	.12	.22	.14	.09	.11	.09	.12	.10	.09	.10	.09	.10	.07	.03
BaO	.08	.07	.07	.07	.05	.06	.04	.06	.06	.02	.03	.02	.03	.02	.10
C	.04	.00	.14	.06	.01	.03	.08	.06	.08	.01	.00	.01	.01	.00	.00
Total	99.92	99.82	99.94	99.88	99.83	100.00	99.91	99.87	99.89	99.89	99.89	99.91	99.91	99.91	99.77

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Bibliography: p. 31–33.

(Continued on next card)

Snyder, George Leonard, 1927– Petrochemistry and bedrock geology of the Fitchville quadrangle, Connecticut. 1964. (Card 2)

1. Rocks—Analysis. 2. Geochemistry. 3. Geology—Connecticut—Fitchville quadrangle. I. Connecticut. Geological and Natural History Survey. II. Title. III. Title: Fitchville quadrangle, Connecticut. (Series)

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March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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[The letters in parentheses designate separately published chapters]