Putnam Quadrangle Bedrock Geology w/ Explanation & Cross-Sections

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Putnam Conn

Prepared in Cooperation with the
State of Connecticut
Geological and Natural History Survey

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PUTNAM QUADRANGLE
CONNECTICUT—WINDHAM CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USC&GS, USGS, and Connecticut Geodetic Survey

Topography by planetable surveys 1943. Revised 1955

Polyconic projection. 1927 North American datum
10,000-foot grid based on Connecticut coordinate system

Red tint indicates areas in which only
landmark buildings are shown

1000-meter Universal Transverse Mercator grid ticks,
zone 19, shown in blue

Revisions shown in purple compiled in cooperation with
Connecticut Highway Department from aerial photographs
taken 1970. This information not field checked

West Thompson Lake is subject to controlled
inundation to 342 feet

the above information applies to
the topographic base map

UTM GRID AND 1970 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

CONNECTICUT
QUADRANGLE LOCATION

Preliminary Bedrock Geologic Map of the Putnam Quadrangle, Connecticut

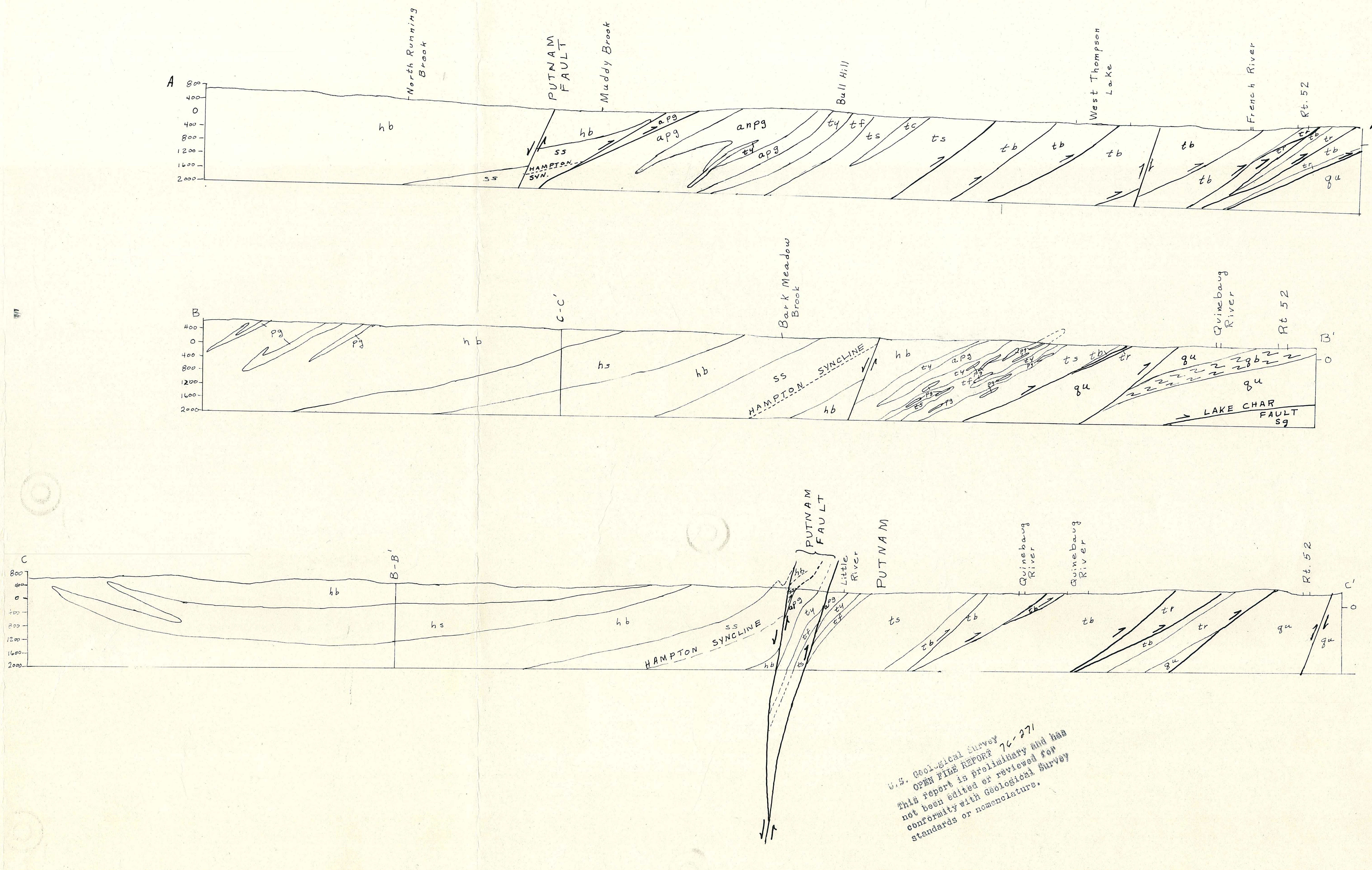
by H. R. Dixon

1976

U.S. Geological Survey
OPEN FILE REPORT 76-271
This report is preliminary and has
not been edited or reviewed for
conformity with Geological Survey
standards or nomenclature.

PUTNAM, CONN.
N4152.5—W7152.5/7.5

1955
PHOTOREVISED 1970
AMS 6667 IV NW—SERIES V816



Cross Sections to Accompany the

Preliminary Bedrock Geologic Map of the Putnam Quadrangle, Connecticut

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S. 126

PRELIMINARY BEDROCK GEOLOGIC MAP OF THE PUTNAM QUADRANGLE, CONNECTICUT

By

H.R. DIXON, 1976

The Putnam quadrangle is located in the northeast corner of Connecticut. The rocks of the area are probable lower to possibly middle Paleozoic sedimentary, volcanic, and intrusive igneous rocks that were regionally metamorphosed to a medium to high grade, and many of which were subsequently deformed cataclastically. Most of the area is in the upper plate of the Lake Char fault (Dixon and Lundgren, 1968), which cuts the extreme southeast corner of the Putnam quadrangle. Rocks of the lower plate of the fault are not exposed, but exposures south and east of the quadrangle indicate the Scituate Gneiss underlies that corner. Bedrock units in the upper plate of the Lake Char fault are the Quinebaug Formation, a heterogeneous group of metavolcanic rocks; the Tatnic Hill Formation, a sequence of pelitic gneisses with lesser amounts of calc-silicate gneiss; the Hebron Formation, a thinly layered, fine-grained calcic schist; the Scotland Schist, a pelitic schist; the Southbridge Formation, a pelitic gneiss here considered to be correlative with the upper part of the Tatnic Hill Formation; and the Ayer Granite of Emerson (1917), a heterogeneous granitic gneiss which may be intrusive in origin or may be a metamorphosed felsic volcanic rock. Granitic to pegmatitic gneisses cut all bedrock units within the quadrangle, but are most abundant in the upper part of the Tatnic Hill Formation and in parts of the Hebron. All rock units except the Ayer Granite have been mapped and described in the surrounding quadrangles (Dixon, 1968a; 1968b; 1974 and Pease, 1972) and only the Ayer will be further described here.

Ayer Granite:--The name Ayer Granite was used by Emerson (1917) for the belt of granitic gneiss that extends from the Putnam quadrangle north, almost to Worcester, Mass. This belt of gneiss is not continuous with the belt of type Ayer in Ayer, Mass., but is on strike with it, is associated with similar rocks, and has similar compositions and structures. Emerson (1917, p. 224-225) describes the type Ayer Granite as partly coarsely porphyritic, with feldspar megacrysts 2-8 cm (1-3 in.) long. The porphyritic rock occurs in broad bands which alternate with bands of fine-grained, nonporphyritic rock. The rocks typically contain both muscovite and biotite. Locally there are bands of a dark dioritic rock. This general description fits very well the Ayer rocks in the Putnam quadrangle and Emerson's name of Ayer is retained for the belt of rock.

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The Ayer Granite is probably genetically related to the Canterbury and Eastford Gneisses south and west of this area. (The Canterbury and Eastford Gneisses are considered to be equivalent rocks in opposite limbs of the Hampton syncline, and characteristics of the Canterbury given below would, for the most part, apply also to the Eastford). The two groups of rocks occur at a generally similar stratigraphic level and have similar compositions, but differ structurally and texturally. The Canterbury forms a sill mostly within the Hebron Formation although it cuts across it locally upward and downward. The Ayer is mostly between the Hebron and the Yantic Member of the Tatnic Hill Formation although in the southern part of the Putnam quadrangle it is within the Yantic. The rocks of both sills are mostly granodiorite to quartz monzonite in composition, although both may range from quartz diorite to granite; the dark dioritic lenses have not been observed in the Canterbury. Compositional differences between the two rocks are mostly reflected in the mica content. The Canterbury is a biotite gneiss and contains muscovite only as microscopic inclusions in plagioclase. The Ayer shows much greater variability both as to kind and amount of mica. The porphyritic variety is a biotite gneiss although it commonly contains secondary muscovite after plagioclase. The nonporphyritic gneiss is mainly a muscovite gneiss with or without accompanying biotite; locally it is a biotite gneiss and resembles the Canterbury. The most striking difference between the Canterbury and the Ayer is the heterogeneous, layered nature of the Ayer as opposed to the massive, uniform nature of the Canterbury. In the Ayer

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867-100

the porphyritic gneiss and the various varieties of nonporphyritic gneiss are interlayered with each other on all scales; where separated on the map it is on the basis of the most prevalent variety. The two rocks also differ texturally; the Canterbury is porphyritic, containing feldspar megacrysts that average 1 cm in diameter, and vary little from this average. The porphyritic gneiss of the Ayer contains variable sized feldspar megacrysts that are as much as 5 cm long, commonly showing a well-defined Carlsbad twin plane.

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The age of the Ayer Granite in the Putnam quadrangle can be established only within certain limits. Uranium-lead systematics from zircons in the porphyritic Ayer Granite along strike to the northeast in Massachusetts give an age of 435 m.y., indicating a late Ordovician or early Silurian age. Zircon and whole rock Rb/Sr analyses of the Canterbury and Eastford Gneisses give ages of 405 and 400 m.y. respectively, or a late Silurian or early Devonian age, assuming the Silurian-Devonian boundary to be approximately 410 m.y. (Bottino and Fullagar, 1966). (All radiometric analyses from R. Zartman, oral communication, 1974). As indicated above these two groups of rocks are thought to be genetically related, and it is not yet clear whether or not this 30 m.y. difference in age is real. For the most part the Ayer Granite in Massachusetts is in a lower grade metamorphic terrane than the Canterbury and Eastford Gneisses, and lacks the metamorphic foliation imposed on the Connecticut rocks, including the Ayer Granite of the Putnam quadrangle. Thus it is possible the Connecticut rocks are older than the analysed age, and the ages reflect a younger deformation. Until these discrepancies can be resolved, a general age of Silurian is assigned to the Ayer Granite in the Putnam quadrangle.

The layered nature of the Ayer body suggests the possibility that the rocks may be metamorphosed felsic volcanic rocks. The layers within the body are parallel to the foliation and, lamination in the rocks where present; discordant contacts between layers were not observed in the quadrangle. Some of the more massive units, such as the porphyritic gneiss, may represent shallow intrusives in a volcanic pile.

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Structure

Faults:--Four northeast-trending zones of thrust faults, several northwest-trending and one northeast-trending fault have been mapped in the Putnam quadrangle. Of these the thrust faults are the earlier and are offset by the northwest faults although the time separation cannot be determined and, at least for some, may not have been great; there also may have been some overlap in the two types of faults.

Numerous small faults, of no apparent regional significance, can be observed in outcrops, especially in the Tatnic Hill and Quinebaug Formations. Many of these were measured and a few plotted on the map (as in the roadcuts on Rt. 52 northeast of Mechanicsville, and west of the West Thompson Dam). The faults are widely divergent in attitude and in sense and style of movement. Where these faults cross unit contact, offsets are only a few feet. Also common, especially in the cataclastic rocks of the lower part of the Tatnic Hill Formation and the Quinebaug Formation are slickensided surfaces. These too are widely divergent in attitude and in orientation of the slicks. None of these features was useful in plotting the larger faults.

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The thrust faults are all marked by cataclasis and mylonitization near the faults. The most intense and most widespread cataclasis is in the eastern part of the map near the Lake Char fault. Rocks adjacent to the Lake Char fault are not exposed in the Putnam quadrangle, but exposures to the south and east in the Danielson and Thompson quadrangles (Dixon, 1968a; 1974) indicate it must cut the southeast corner of Putnam. The Lake Char fault forms the contact between the Scituate Gneiss of the Sterling Plutonic Group in the lower plate and the Quinebaug Formation in the upper plate. Most of the exposed Quinebaug between the Lake Char fault and the Tatnic Hill Formation has a cataclastic fabric.

A second fault zone occurs at or near the contact of the Quinebaug and Tatnic Hill Formations, and in the lower part of the Tatnic Hill, where a series of thrusts are marked by cataclasis, locally intense, and repetitions of stratigraphic units within the Tatnic Hill. Also indicative of a fault near the Tatnic Hill-Quinebaug contact is an inversion of isograds. The lowermost Tatnic Hill is in the sillimanite-potassium feldspar metamorphic grade. The metamorphic grade of the Quinebaug cannot be determined in the Putnam quadrangle as no pelitic rocks were observed. The mineral assemblages of the Quinebaug are, however, the same as those in the Quinebaug south of this area where the rocks are associated with sillimanite-muscovite-bearing gneisses and it is assumed the metamorphic grade is the same as it is to the south. Thus, along this fault zone higher grade metamorphic rocks overlie lower grade rocks.

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A third zone of thrust faulting occurs along the western edge of the Ayer Granite north of the Putnam fault. The fault separates Ayer from the adjacent Scotland Schist and the Hebron Formation to the north. The fault cuts out the Scotland Schist to the north, the axial surface of the Hampton syncline (see section A-A'), and the staurolite-sillimanite isograd. Exposures near this fault are not abundant but where seen the rocks are strongly cataclastic and locally mylonites. Small ultramylonite dikelets, commonly less than 1 cm thick, occur in the cataclastic Hebron exposed east of Paine District Road, as well as in Hebron boulders in that vicinity. The cataclastic Ayer Granite exposed on Chandler Hill has been silicified. A branch of this fault has been drawn along the east side of the Hebron Schist exposed west of Paine District Road. The schist is strongly sheared and its low metamorphic grade is apparently the result of retrogressive downgrading of a previously staurolite grade rock; sericitic pseudomorphs after probable staurolite were observed locally.

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The fourth thrust fault is the Eastford fault cutting the extreme northwest corner of the quadrangle, and separating the Hebron Formation from the Southbridge Formation. This fault apparently cuts out the sillimanite-staurolite isograd. A narrow zone (a few metres in thickness) of cataclasis occurs along the fault contact. The cataclastic rocks dip northwestward about 20°, suggesting a 20° dip of the fault plane. Cataclastic Hebron rocks with ultramylonite occur in Gravelly Brook about 450 m southeast of the fault or 150 m stratigraphically below the 20° -dipping fault. These could indicate a local flattening in the plane of the fault as projected above the ground or a local offshoot of the fault.

Scotland Schist and Hebron Formation exposed west of Pomfret Center in Wappoquia Brook are strongly cataclastic and contain ultramylonite dikelets. These rocks are near the axial zone of the Hampton syncline, but are in the overturned limb and structurally above the axial surface, and thus indicate movement in the overturned limb. Exposures are not sufficient to define a fault, but the cataclasis may represent incipient movement that, north of the Putnam fault, resulted in the fault along the west margin of the Ayer Granite.

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Several high-angle northwest-trending faults break the rocks of the area, but for the most part offsets are simple and no more than a few hundred metres. Many of these northwest-trending faults are reflected on the aeromagnetic map of the quadrangle (U.S. Geol. Survey 1969a) by an offset of the northeast-trending aeromagnetic lineaments. The largest fault, both in length and in apparent offset, is the Putnam fault which extends from the Lake Char fault in the southeast corner of the quadrangle to the northwest corner. It apparently does not offset the Lake Char fault, as no evidence for it was found to the southeast in the East Killingly quadrangle (G. Moore, written commun., 1968). To the northwest the fault continues across the northeast corner of the Eastford quadrangle (Pease, 1972) with a simple offset of about 150 m. Near the community of Putnam the fault is complex, most likely as the result of interaction of differential stress from two other faults intersecting the Putnam fault in the vicinity of the village of Putnam. One is the west-trending fault on the northeast side of the Putnam fault and the other is the north-northeast fault on the southwest side. The effect has been to splinter the Putnam fault into two branches, with the horst between the two branches squeezed up relative to the two sides and rotated counterclockwise. Fairly strong counterclockwise rotational drag was also imposed on the rocks on either side of the branched fault. Southeast and northwest of the horst, away from the effects of the two intersecting faults, movement on the Putnam fault was simple with the northeast side moved up relative to the southwest side, without strong drag on either side.

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The northeast-trending fault is projected into the Putnam quadrangle from the Danielson quadrangle where it is exposed in two places (Dixon, 1968a). There is no strong evidence for it in the Putnam quadrangle, although the Scotland Schist exposed east of Gary School Road is strongly cataclastic. The fault apparently terminates against the Putnam fault; there is no evidence for a continuation of it north of the Putnam fault.

Hampton syncline:--The Hampton syncline is a part of a major recumbent fold that has been traced across much of eastern Connecticut (Dixon, 1968b; Dixon and Lundgren, 1968, in which the fold was referred to as the Hunts Brook-Chester syncline). The trace of the axial surface of the Hampton syncline is drawn through the middle of the Scotland Schist, the youngest metasedimentary rock unit of the area. North of the Putnam fault the axial trace is cut out by the thrust fault along the west side of the Ayer Granite (see section A-A'). On this basis only the belt of Hebron Formation east of the Scotland Schist in the south-central part of the quadrangle is in the normal limb of the fold; the rest of the Hebron is in the overturned limb. Also on this basis the Southbridge Formation, in the northwest corner of the quadrangle would be the overturned equivalent of the Yantic Member of the Tatnic Hill Formation.

The most compelling evidence for the existence of the Hampton syncline is southwest of the Putnam quadrangle. Substantiating evidence for a fold in this area is a repetition of lithologies of the Hebron Formation across the axial surface in the northern part of the Danielson and southern part of the Putnam quadrangles. In Day Brook in northern Danielson a distinctive, spotted actinolite-calcite-biotite-quartz-andesine schist, in which the spots are aggregates of actinolite and biotite is interlayered with normal Hebron calc-silicate rocks. These calcic schists are interfolded with but stratigraphically above a phyllitic schist shown on the Danielson map (Dixon, 1968a) as Scotland Schist, but which is more like the Hebron schist in the Putnam quadrangle than it is like typical Scotland, that is it is richer in sulfides and lacks the coarse muscovite plates of the Scotland Schist, and was probably misidentified. A similar, but reverse, sequence of similar lithologies occurs in Wappoquia Brook west of Pomfret Center. There the calc-silicate Hebron schists, with the interlayered spotted schist, is structurally overlain by the phyllitic schist. Thus the Day Brook exposures in northern Danielson would be in the normal limb of the Hampton syncline, and the Wappoquia Brook exposures in the Putnam quadrangle would be in the overturned limb.

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887-100

The Hebron Formation in the overturned limb of the Hampton syncline has a considerably greater apparent thickness than that in the normal limb. This is true not only in the Putnam quadrangle, but for the entire overturned part of the Chester-Hampton syncline southwest of this area. This could be in part a result of original thickening of the sediments to the west, but is almost certainly in part due to intense folding and low angle thrusting of the overturned limb. Both features can be observed in large exposures of Hebron Formation to the southwest, as for instance road cuts on Rt. 2 in the Fitchville quadrangle (Synder, 1964).

Geologists mapping west and north of the Putnam quadrangle do not accept this interpretation of the Chester-Hampton syncline as a regional structure in eastern Connecticut. They believe they have evidence indicating that the rocks in the overturned limb of the syncline are, in fact, not overturned, but lie in a normal stratigraphic sequence, interrupted by a series of thrust faults. (See Peper and others, 1975; Dixon, in press.) This difference in structural interpretation also implies a difference in stratigraphic interpretation, and they assign a younger age to units such as the Southbridge, Hebron and Scotland Formations than is assigned here. Resolution of this difference in interpretation will have to come with future work.

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Aeromagnetic map interpretation

The aeromagnetic map of the Putnam quadrangle (U.S.G.S., 1969a) shows two areas of contrasting magnetic character separated by a steep magnetic gradient. The western two-thirds of the quadrangle has a subdued magnetic character, with widely spaced magnetic contours showing a maximum difference of about 200 gammas. The rock types and formations that underlie this area include the granitic gneisses of the Ayer Granite, pelitic schists and gneisses of the Scotland Schist, Yantic Member of the Tatnic Hill Formation and the sillimanite gneiss at the top of the lower member of the Tatnic Hill, and the calc-silicate schists and gneisses of the Hebron Formation and the Fly Pond Member of the Tatnic Hill. The eastern third of the quadrangle shows a much more complex magnetic pattern with closely spaced magnetic contours and anomalies of 500-800 gammas. The rocks generating this complex pattern include the pelitic gneisses of the lower member of the Tatnic Hill Formation, except for the uppermost 250 m of the sillimanite gneiss, and the biotite and hornblende gneisses and amphibolites of the Quinebaug Formation. The steep gradient that separates the two areas follows very closely the contact between the mapped belt of calc-silicate gneiss in the lower member of the Tatnic Hill and the underlying sillimanite gneiss. Thus the sillimanite gneiss that overlies the calc-silicate gneiss is on the magnetically low side of the gradient, although it is megascopically indistinguishable from the stratigraphically lower sillimanite gneiss, and to the south, where the calc-silicate gneiss lenses out, is continuous with it. South of the Putnam fault the gradient flattens considerably. To the south of the Putnam quadrangle this gradient, separating areas of differing magnetic character persists at about the same stratigraphic level to the Honey Hill fault, and to the north, to the eastern side of the Webster quadrangle to the Lake Char fault, although throughout much of this distance it is rarely as steep as in the Putnam quadrangle.

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In the Putnam quadrangle there are a few places where there are good bedrock exposures across the magnetic gradient and it was possible to sample the rocks across it. The magnetic susceptibility of these samples was determined by L.A. Anderson of the Branch of Theoretical and Applied Geophysics of the U.S. Geological Survey, and the magnetic susceptibilities are given in table 1. One set of samples came from north of Duquette Street, west of North Grosvenor Dale, and a second set was collected about 400-500 m (one-quarter mile) south of Bull Hill Road. Sample measurements indicate that the magnetic levels shown on the aeromagnetic map are a function of the magnetic properties of the rocks exposed at the ground surface. The magnetic susceptibility of the calc-silicate gneiss (samples P4-58,P4-9) and the sillimanite gneiss (samples P4-57, P4-10) west of the gradient is significantly less than that of the sillimanite gneiss on the east side (samples P4-59, P4-7). The difference in magnetite content indicated by these numbers is not visible in hand sample (although it can be detected by a simple, magnetic stud finder, suspended by a wire) and the sillimanite gneisses on either side of the gradient are otherwise indistinguishable. The cause of this abrupt increase in magnetite content of the rocks is not clear. It does not represent a structural discontinuity; there is no evidence of faulting in the closely spaced bedrock exposures, nor is there evidence of truncation either of unit trends in the rocks or of magnetic trends on the aeromagnetic map. It could represent a metamorphic change in which magnetite was formed from one of the preexisting phases during progressive regional

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metamorphism. The gradient is close to the sillimanite-muscovite and sillimanite-potassium feldspar isograd, so the rocks were at or near a temperature where phase changes were taking place. Another possibility is that it represents a difference in iron content in the original sediments. Chemical analyses of similar rocks to the south (Snyder, 1964; Dixon, 1968b) suggest the rocks on the east side of the gradient have a higher total iron content than those on the west. Before either of these possibilities can be evaluated, systematic sampling across the gradient is needed for analyses of the rocks and the mineral phases involved.

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887-100

A third set of samples was collected from around a large positive magnetic anomaly in the northeast corner of the quadrangle, and the measured magnetic susceptibilities are given in table 1. This anomaly, which peaks about 230 m east of Pompeo Road and is expressed by a 900-gamma difference from trough to peak, is also produced by rocks exposed at the surface. Sample P4-101 was collected near the intersection of Pasay Road and Buckley Hill Road, on the southeast flank of the anomaly. The other three samples were collected on Buckley Hill Road and Pompeo Road, southwest of the peak value of the anomaly, and these have a significantly higher magnetic susceptibility than P4-101. Another prominent magnetic anomaly in the southeast corner of the map, 600-700 gammas in amplitude, cannot be explained by surface bedrock, as it is over a large till hill with no bedrock exposures. However, the magnetic gradients strongly suggest that the source rock lies very close to the surface. The anomaly, plus its northeastward continuation in the Thompson quadrangle (U.S.G.S. 1969b) are in an area underlain by the Quinebaug Formation which is typically quite variable in magnetic character.

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_____1969b, Aeromagnetic map of the Thompson quadrangle and part of the East Killingly quadrangle, Conn. and Rhode Island: U.S. Geol. Survey Geophys. Inv. Map GP-653.

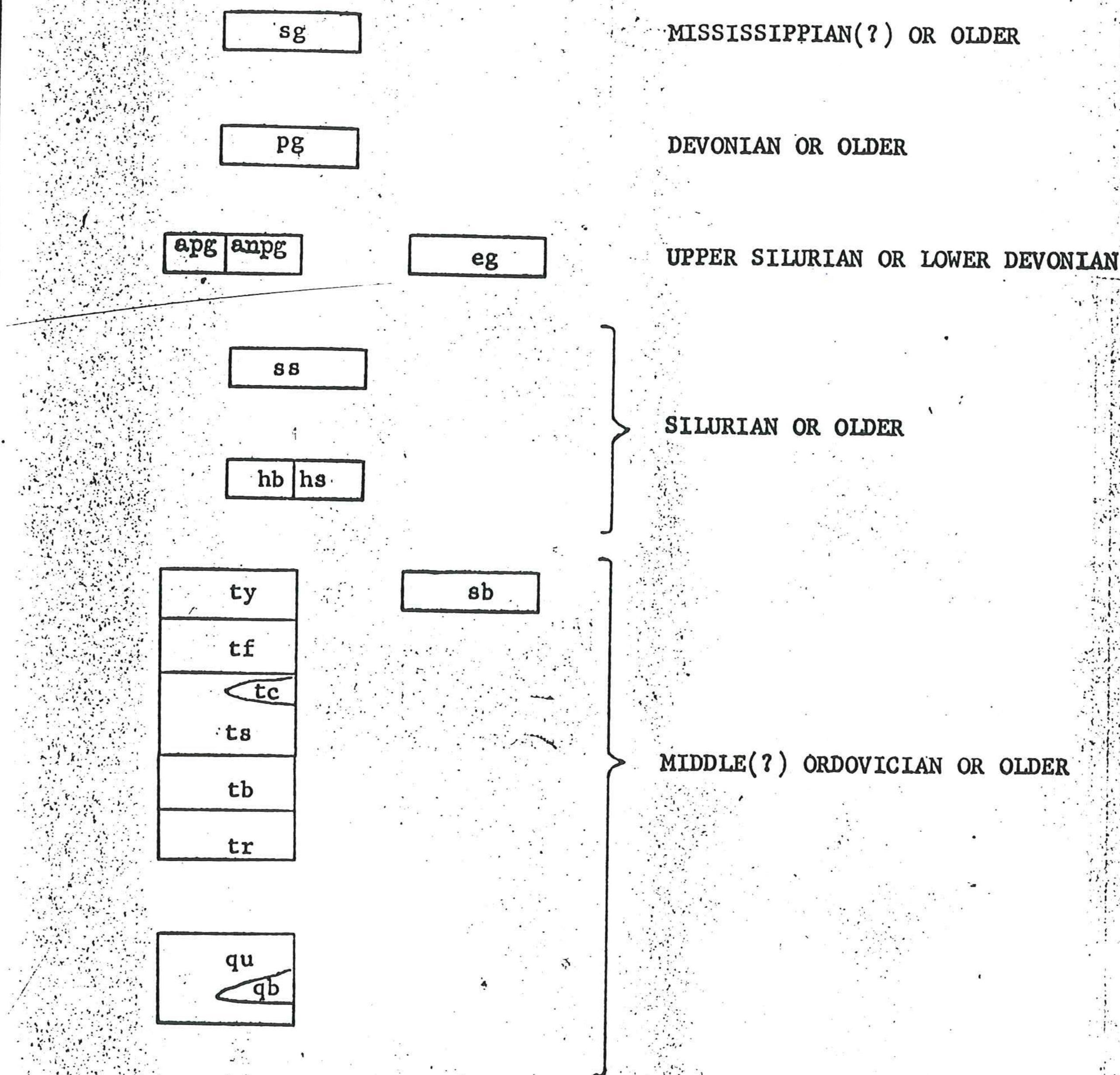
Table 1.--Magnetic susceptibilities of selected samples of the Tatnic Hill Formation

Sample no. and location	Member of Tatnic Hill Formation (map unit)	Magnetic susceptibility ($K \times 10^{-4}$ emv/cc)	Sample description
North of Duquette Road			
P4-57	ts	.38	sillimanite-garnet-muscovite-biotite-quartz-feldspar gneiss
P4-58	tc	.41	sphene-diopside-hornblende-actinolite-epidote-quartz-plagioclase gneiss
P4-59	ts	32.6	garnet-muscovite-biotite-quartz-feldspar gneiss
South of Bull Hill Road			
P4-10	ts	.38	garnet-muscovite-biotite-quartz-feldspar gneiss
P4-9	tc	.64	biotite-epidote-actinolite-quartz-plagioclase gneiss
P4-8	ts	30.0	garnet-muscovite-biotite-quartz-feldspar gneiss
P4-7	ts	17.1	sillimanite-muscovite-biotite-quartz-feldspar gneiss
Buckley Hill Road and Pompeo Road (Northeast Corner)			
P4-101	tb	.86	sillimanite-garnet-biotite-quartz-feldspar gneiss
P4-103	ts	21.1	garnet-sillimanite-biotite-quartz-feldspar gneiss
P4-102	ts	56.0	sillimanite-garnet-biotite-quartz-feldspar gneiss
P4-100	ts	10.3	garnet-biotite-quartz-feldspar gneiss

PRELIMINARY BEDROCK GEOLOGIC MAP OF THE PUTNAM QUADRANGLE, CONNECTICUT

by H.R. Dixon 1976

CORRELATION OF MAP UNITS



PRELIMINARY BEDROCK GEOLOGIC MAP OF THE PUTNAM QUADRANGLE, CONNECTICUT

By H.R. Dixon 1976

DESCRIPTION OF MAP UNITS

Mineral modifiers in rock names are given in order of increasing abundance, with the least abundant mineral listed first. Minerals in parentheses are not present in all rocks. All colors cited are the closest match to colors of the Rock Color Chart, by E.N. Goddard and others, G.S.A., 1948.

sg SCITUATE GRANITE GNEISS-- Not exposed in the quadrangle but must underlie the extreme southeast corner in the lower plate of the Lake Char fault. Where exposed just east of the quadrangle border is a blastomylonite gneiss containing feldspar porphyroclasts as much as 1 cm long in a very fine grained matrix of quartz, feldspar, and chloritized biotite.

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pg PEGMATITIC AND GRANITIC SILLS AND DIKES--Light-colored, coarse- to fine-grained rock varying in composition from granite to quartz diorite. Rocks are composed of varying proportions of quartz, microcline and oligoclase, secondary amounts of either or both biotite and muscovite and accessory sphene, opaque minerals, apatite, zircon, epidote-allanite and locally garnet. The rock is commonly well foliated, and locally faintly laminated, although some of the coarse-grained rocks are nonfoliated. Forms sills and dikes a few centimetres to a few metres (few inches to tens of feet) thick; only those greater than 3 m in thickness are shown on the map. The large bodies in the Hebron Formation south and east of Wappaquosset Pond are probably not solid granite, but are thick sills between thin layers of unexposed Hebron. In some areas, as in the large mass east of Wappaquosset Pond, two stages of intrusion are indicated where fine- to medium-grained, foliated granitic gneiss is cut by coarse-grained, unfoliated pegmatite. Concordant to slightly discordant sills are abundant in the upper part of the Tatnic Hill Formation and in places occupy more than half of the volume of the Fly Pond Member. Thin, concordant sheets of foliated felsic gneiss in the lower part of the Tatnic Hill Formation and the Quinebaug Formation are numerous and similar in composition to

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867-100

the above, but are not thick enough to map separately. Those in the garnet-biotite gneiss unit of the Tatnic Hill commonly contain abundant garnet.

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887-100

eg

EASTFORD GNEISS--Medium-light-gray, weathers grayish-orange, medium-grained muscovite-biotite-microcline-quartz-oligoclase gneiss. Accessory minerals are sphene, apatitie, and zircon. Although commonly well foliated and strongly lineated to the west and south, in this area both foliation and lineation are indistinct. Is exposed only on the extreme western edge of the quadrangle.

AYER GRANITE OF EMERSON, 1917--Heterogeneous, commonly well-layered gneissic complex ranging in composition from quartz diorite to granite but predominantly quartz monzonite. Two types, a porphyritic and nonporphyritic gneiss, have been separated on the map; both types are interlayered with each other, expecially near the boundary between them, and separation is based on the most abundant type. Contacts between the two types are sharp and are commonly concordant to the foliation and to the layering in the nonporphyritic gneiss where present. Most of the rocks show some cataclasis and along the western margin of the body it is intense.

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887-100

apg

Porphyritic gneiss--A dark-gray gneiss containing megacrysts of orthoclase and oligoclase as much as 5 cm long in a fine- to small-grained matrix of biotite, quartz, and approximately equal amounts of the two feldspars. Muscovite is commonly present in minor amounts (less than 5 percent) and most is secondary after feldspar. Accessory minerals are sphene, epidote, zircon, and opaque minerals. Most rock has a cataclastic fabric in which 20-50 percent of the matrix is granulated to very fine grained; locally, and especially along the western margin, the matrix is completely granulated. Although biotite makes up only about 10 percent of most of the rock, the finely granulated nature of much of the biotite gives the rock a darker color than it normally would have. The porphyritic gneiss is difficult to distinguish from the Yantic Member of the Tatnic Hill Formation, with which it is in contact along the eastern side, and the separation was not made in the Danielson quadrangle to the south. It can be distinguished from the Yantic by the lack or scarcity of megascopic muscovite and garnet and presence of orthoclase megacrysts; megacrysts in the Yantic are oligoclase only. South of the Putnam fault the Ayer is porphyritic gneiss only, with thin layers, commonly less than 100 cm thick of nonporphyritic gneiss. It probably lenses out about 1 km south of the quadrangle border.

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887-100

anpg Nonporphyritic gneiss--Very light gray to medium-dark-gray, fine- to medium-grained gneiss commonly composed of roughly equal amounts of quartz, oligoclase, and microcline and either or both biotite and muscovite. The most common rocks is a quartz monzonite with 5-10 percent muscovite and 2-5 percent biotite but rocks containing only one mica are present. Also present locally is a fine-grained, medium-gray biotite quartz diorite in lenses 1 or 2 m thick and traceable for a few metres along strike. These are not shown separately on the map. Although the nonporphyritic gneisses are generally consistent in composition they vary considerably in appearance depending on the ratio of the micas, grain size, and type of foliation. Some rocks are poorly foliated but well lineated, most have a good gneissic foliation with coarse feldspar or quartz feldspar lenses separated by mica folia, and a few are laminated with layers as much as a centimetre in thickness. Most rocks show some cataclastic fabric; the least intense has streaks of granulated minerals between zones of ungranulated minerals. The most intense cataclasis is on Chandler Hill near the west edge of the Ayer body where the rock is thoroughly granulated and locally silicified.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
807-100

Ss

SCOTLAND SCHIST--Medium- to dark-gray, fine- to medium-grained garnet-biotite-oligoclase-muscovite-quartz schist. Staurolite and locally kyanite are present in minor amounts in many rocks south of the Putnam fault, and sillimanite in the lens of Scotland schist north of the Putnam fault; in the exposures east of Gary School road staurolite, kyanite, and fibrolitic sillimanite are present. Accessory minerals are tourmaline, zircon, apatite, and opaque minerals. Most of the rock exposed in this area is cataclastic, with streaks of granulated quartz, feldspar, and biotite separating zones of ungranulated minerals; coarse muscovite flakes are commonly kinked. In Wappoquia Brook, southwest of Pomfret School, cataclasis is intense, and accompanied by dikelets of ultramylonite.

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867-100

HEBRON FORMATION

hb

Dark-gray, greenish-gray, and purplish-gray, fine- to medium-grained, thinly layered biotite-quartz-andesine schist, epidote-actinolite-biotite-quartz-andesine schist and lesser amounts of muscovite-biotite-andesine-quartz schist. Calcite, microcline or diopside may be present locally. Accessory minerals include opaque minerals, apatite, zircon, tourmaline, sphene, and rarely garnet. In general the Hebron is well layered in layers 0.5-5 cm in thickness. In large exposures the rocks can be seen to be strongly folded; the majority of exposures are small and the folding is not apparent. The rock is non-resistant to erosion and is poorly exposed except where cut by the more resistant pegmatites. The Hebron is strongly cataclastic along Wappaquia Brook in the southern part of the quadrangle, along Gravelly Brook and in North Woodstock in the north-west corner, and east of Paine District Road in the north-central part of the quadrangle. In the cataclastic rocks the grain size of the constituent minerals is variable with streaks of ungranulated minerals (average size about 0.3 mm) separated by streaks of granulated minerals (less than 0.1 mm size). In the most strongly cataclastic rocks all minerals are granulated to a very fine grain such that quartz and feldspar cannot be distinguished. Some of the most strongly cataclastic rock is well neomineralized to blastomylonite in which biotite is chloritized and plagioclase is altered to sericite and calcite. Dikelets of ultramylonite occur in the most strongly cataclastic rocks.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

hs

Medium- to dark-gray, medium- to fine-grained oligoclase-biotite-muscovite-quartz schist. Minor amounts of garnet are common and locally the rock contains staurolite, or pseudomorphs of sercite and opaque material after staurolite. Accessory minerals include tourmaline, zircon, apatite, and opaque minerals. Thin layers of the granular biotite schist or biotite-actinolite schist typical of the bulk of the Hebron are interlayered with the muscovite schist, but in the mapped lenses the muscovite schist is the dominant lithology. It resembles some of the rocks of the Scotland Schist, in particular those near the base of the Scotland. Differences between this rock and the Scotland include (a) more abundant interlayers of normal Hebron-type rocks, (b) scarcity of the coarse muscovite schist that is typical of Scotland, and where present the muscovite flakes are less coarse, (c) more prominent rusty weathering, presumably indicating a higher amount of sulfide minerals. The rusty weathering is particularly strong in the lens north of the Putnam fault but is also evident in many of the rocks in the southern lens. The lens south of the Putnam fault is the original Pomfret Phyllite of Gregory (in Rice and Gregory,1906) but the rock is of much more limited extent than indicated by Gregory and a separate name is not justified. The

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887-100

lens north of the Putnam fault is strongly sheared and retrogressed. The rocks are mainly a very fine grained mosaic of quartz, muscovite, chlorite, limonite, and opaque minerals, although some rocks contain no quartz. Minor unaltered or partially altered plagioclase and biotite are seen in some rocks. The chlorite is in part altered biotite and in part was probably introduced during retrogression and shearing.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
887-100

TATNIC HILL FORMATION--Metasedimentary gneisses mixed with possible metavolcanic gneisses in the lower part. The bulk of the rock is pelitic gneiss composed of mica, quartz, and feldspar and in part containing garnet and sillimanite. Two mappable layers of calc-silicate gneiss occur in the upper part as well as small, unmappable lenses in the lower part. Small lenses of amphibolite are common in the lower part; none of these was large enough to show separately on the map. Metamorphic grade of the formation ranges from staurolite to sillimanite-potassium feldspar, although only the upper part of the Yantic Member in the southern part of the quadrangle is in staurolite grade. Many of the rocks show a cataclastic fabric superimposed on the regional metamorphic fabric. Cataclasis is most pervasive and intense in the lowermost part of the formation, but is present, and locally intense, throughout.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
887-100

ty

Yantic Member--Medium- to dark-gray, fine- to medium-grained muscovite-biotite-oligoclase-quartz schist with minor amounts of garnet (locally abundant); accessory minerals are zircon, apatite, opaque minerals and tourmaline. Minor lenses of schist contain staurolite or sillimanite and kyanite. In the northern part of the quadrangle, muscovite increases in abundance, and in some rocks makes up as much as 40 percent of the rock. Lenses of quartzite as much as 0.5 m thick were observed in cliff exposures west of Wheaton's Brook. Megacrysts of plagioclase averaging 1 cm in diameter are common. Where cataclastic, the feldspars are drawn out into partially granulated lenses.

tf

Fly Pond Member--Light- to medium-gray, medium-grained, thinly layered epidote-(diopside)-hornblende-biotite-quartz-andesine gneiss. In the northern part of the quadrangle the unit is more commonly cataclastic and altered than elsewhere and much of the hornblende and pyroxene is converted to epidote. The rocks are non-resistant to erosion and, except where intruded by the more resistant pegmatite, are poorly exposed.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

ts

SILLIMANITE GNEISS--Medium-grained, medium- to dark-greenish-gray sillimanite-garnet-(muscovite)-biotite-andesine-quartz gneiss interlayered with fine-grained, dark-gray (garnet)- biotite-sodic andesine-quartz gneiss. Accessory minerals include zircon, apatite, opaque minerals, epidote, and locally kyanite. Sillimanite is commonly altered to sericite, and the rock is characterized by dark-green, resistant sericite pods on the weathered surface. Potassium feldspar may be present in minor amounts and locally is abundant.

to

CALC-SILICATE GNEISS--Similar to the Fly Pond Member

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

tb

GARNET-BIOTITE GNEISS--Dark-gray to black, medium-grained (garnet)-biotite-(potassium feldspar)-andesine-quartz gneiss, interlayered with sillimanite or kyanite gneiss, minor amphibolite, and small lenses of calc-silicate gneiss. Garnet averages about 5 percent of most rock but maybe as much as 20 percent and locally occurs in megacrysts as much as 8 cm in diameter; some rock contains no garnet. Megacrysts of plagioclase and a clear, pink potassium feldspar (orthoclase(?)) 1-2 cm in diameter are common. Sillimanite-bearing rocks are not as common as in ts,but where present sillimanite is abundant in coarse, prismatic grains. Magnetite is an important accessory mineral and in some rocks may constitute as much as 5 percent of the rock. Other accessory minerals are similar to those in the sillimanite gneiss. The unit is gradational into ts above with an increase in sericitic pods of altered sillimanite, and into tr below with an increase in interlayered rusty weathering gneiss.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
887-100

tr

RUSTY-WEATHERING GNEISS--Fine- to medium-grained, red- to yellow-weathering (medium- to dark-gray on fresh surface although weathering is deep and fresh rock is rarely seen) biotite-(garnet)-microcline-sodic andesine-quartz gneiss commonly with abundant fibrolitic sillimanite, although in some rocks neither garnet nor sillimanite is present. Kyanite occurs locally in coarse grains. Garnet is a distinctive pale red. Graphite and sulfides are abundant accessory minerals; other accessories include rutile, zircon, and apatite. Most rocks of this unit are strongly cataclastic and altered. Biotite is commonly chloritized and the feldspars sericitized. Ultramylonite dikelets occur locally.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
887-100

sb

SOUTHBRIDGE FORMATION--Medium-gray to light-brownish-gray, medium-grained biotite-quartz-andesine gneiss. Minor microcline may be present and is associated with myrmekitic plagioclase. A few lenses are actinolite-epidote bearing and sillimanite-muscovite bearing. The rock commonly contains feldspar megacrysts as much as 1 cm in diameter and averaging about 3 mm in diameter. Within the Putnam quadrangle the rocks are mostly massive to poorly layered. In the extreme northwest corner and in the areas west and north of the quadrangle boundary the rocks are more commonly well layered in layers a few centimetres thick and are strongly folded. Abundant pegmatitic gneisses are common in the unit.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
887-100

qu

QUINEBAUG FORMATION--Heterogeneous Group of gneisses of probable volcanic origin. The most abundant rocks are medium- to dark-greenish-gray, fine- to medium-grained biotite-quartz-andesine gneiss, and biotite-hornblende-quartz-andesine gneiss. Interlayered with these is less abundant amphibolite, calc-silicate gneiss and light-gray quartz-feldspar gneiss. Epidote is present in minor amounts in most rock and abundant in some. Garnet is also a minor constituent of some rocks. Accessory minerals include sphene, rutile, zircon, apatite, allanite, and opaque minerals. The rocks are typically well layered, with layers a few centimetres in thickness. Megacrysts of plagioclase as much as 2 cm in diameter are common in many rocks, and in the hornblende gneisses megacrysts of hornblende are as much as 1 cm in diameter. Only the uppermost part of the unit, near the contact with the Tatnic Hill Formation, is well exposed in the quadrangle. These rocks are probably in the sillimanite-muscovite grade of metamorphism, although there is no direct evidence within the area for metamorphic grade. Mineral assemblages in the rocks are, however, similar to those in the rocks south of this area that are associated with sillimanite-muscovite-bearing rocks. Much of the unit exposed within this area is cataclastic and most rocks

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
667-100

are mylonite gneiss in which 10-20 percent of the rock consists of small- to medium-grained clasts of plagioclase, hornblende, and less commonly quartz, in a very fine grained matrix of granulated quartz, feldspar, and biotite. The cataclastic rocks show varying degrees of alteration, but it is rarely strong; mafic minerals are partially chloritized, and plagioclase is partially altered to sericite-muscovite, epidote, calcite, or scapolite.

qb

Black Hill Member--Nonresistant, light- to dark-gray, fine-grained (calcite)-biotite-(hornblende)-quartz-oligoclase schist. Epidote is a common accessory mineral and may be abundant in some rock; other accessory minerals are sphene, apatite, and opaque minerals. Rock is thinly layered in layers a few centimetres in thickness and commonly shows intense, small-scale folding. The unit apparently lenses out north of the Putnam fault.

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887-100

SYMBOLS

CONTACT--Approximately located; dashed where indefinite

THRUST FAULT--Dashed where approximately located; short dashed where indefinite. Sawteeth on upper plate. Faults are mapped on the basis of cataclasis of the rocks, which increases in intensity toward the fault contacts, and on the repetition of units and lithologies.

HIGH ANGLE FAULT--Dashed where approximately located; short dashed where indefinite. U, upthrown side; D, downthrown side

OVERTURNED SYNFORM--Showing trace of axial surface

AXIAL PLANE OF MINOR FOLDS--Showing bearing and plunge of fold axis. Map sense of folds shown where determined

PLANAR FEATURES

Intersection of two symbols is at point of observation

STRIKE AND DIP OF FOLIATION--Includes planar arrangement of minerals and compositional layering. Relation of foliation to bedding of the metasedimentary rocks not determined, but in most of the noncataclastic rocks is probably parallel

Inclined

Vertical

STRIKE AND DIP OF CATACLASTIC LAMINATION

Inclined

Vertical

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867-100

LINEAR FEATURES

BEARING AND PLUNGE OF LINEATION--May be combined with foliation symbols at point of observation

← Plunging mineral lineation

↔ Horizontal mineral lineation

← Fold axis and crinkle lineation

X BOULDER CONCENTRATION LOCALITY--Boulder concentration of a given rock type used in determination of a map unit

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887-100

Reference cited in Explanation

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887-100