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The Brimfield (?) and Paxton (?) Formations in Northeastern Connecticut

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Trip F-5

THE BRIMFIELD(?) AND PAXTON(?) FORMATIONS IN NORTHEASTERN CONNECTICUT 1/

by

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INTRODUCTION

The purpose of this field trip is to examine a sequence of rocks, principally in the Westford and Eastford quadrangles, Connecticut, that are contiguous with strata in Massachusetts mapped by Emerson (1917) as Brimfield Schist and Paxton Quartz Schist. Recent mapping has shown that contacts between the two formations mapped by Emerson are not strictly valid; the rocks exposed northwest of the Eastford fault (Pease, unpub. data) can be divided broadly into a Brimfield(?) Schist and a Paxton(?) Quartz Schist. It has been possible to subdivide the Brimfield(?) Schist; the broad outlines of these subdivisions are shown on the geologic map that accompanies this road log.

LITHOLOGY

In the following description, 11 subdivisions have been made by grouping mapped lithologic units:

The Paxton(?) Quartz Schist (Pease, unpub. data)

px Feldspar-quartz-biotite schist and gneiss-schist layers which are medium to dark gray, rich in black biotite, and locally contain accessory actinolite, diopside, or hornblende; gneiss layers, composed mostly of feldspar and quartz, are lighter gray and mostly coarse grained. Megacrysts of potassium feldspar are characteristic, particularly in the lower part. Garnet and muscovite are present locally, but, along with graphite sulfide layers, are rare.

The Brimfield(?) Schist (Pease, unpub. data)

b_1 Brownish-gray schist containing red-brown biotite, sillimanite (muscovite), and garnet is interlayered with lighter gray granular gneiss composed chiefly of feldspar and quartz. Graphite, pyrite, and pyrrhotite are present but are abundant only in a few mapped lenses of schist. Members and lenticular layers in which calc-silicate minerals are abundant (diopside, hornblende, actinolite, scapolite) have also been mapped; these beds are more common in subdivision b_1 than

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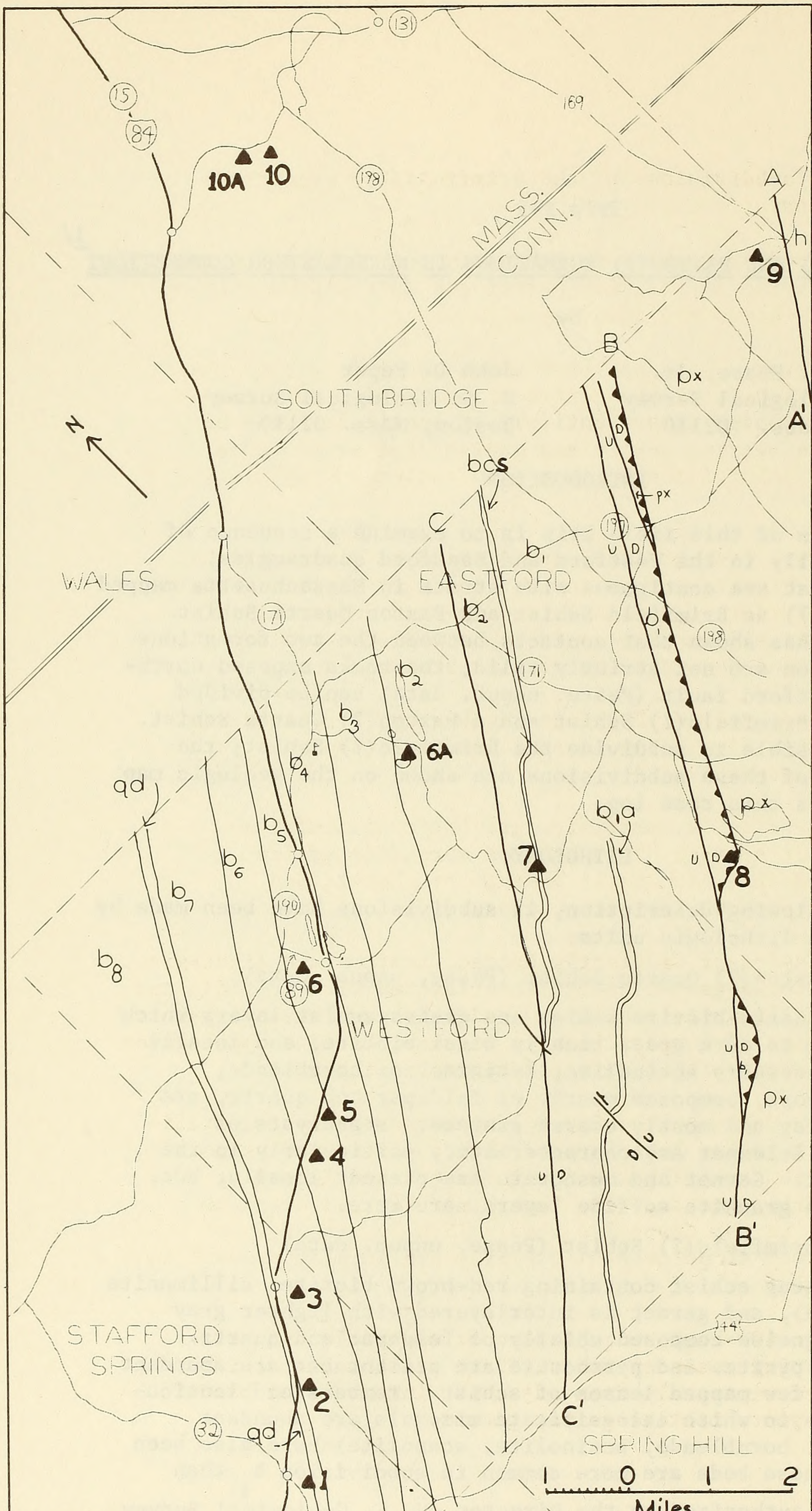

EXPLANATION

h - Hebron Formation

px - Paxton(?) Quartz Schist

b_1-b_8 - Subdivisions of Brimfield(?) Schist

qd - Quartz diorite

A-A′ - Eastford fault

B-B′ - Black Pond fault

C-C′ - Boston Hollow fault

— - Contact

▲▲▲ - Thrust fault; sawteeth on upper plate

Fault
U = upthrown block
D = downthrown block

Figure 1. -- Geologic map of the Eastford-Westford area, Connecticut. Thickness of thin units exaggerated. Field-trip localities indicated by triangles.

in any other subdivisions of the Brimfield(?), except the overlying subdivision bcs.

b_1a Distinctly banded, dark- and light-gray, -- amphibolite and amphibole-bearing gneiss with garnet ore interbedded with gray, garnetiferous sillimanite-poor schist and gneiss.

bcs This subdivision, which has been mapped as a member of the Brimfield(?) Schist in the Eastford quadrangle, overlies b_1. It is composed almost entirely of lenticular beds of calc-silicate-bearing schist and gneiss similar to those occurring in subdivision b_1, but also includes gray biotite schist.

b_2 Layers of gray, even-grained, crosslaminated biotite-garnet gneiss, gray biotite-garnet gneiss, and gray biotite-garnet sillimanite-corderite schist form mappeable units within biotite-garnet sillimanite-gneiss that characteristically weathers yellowish orange and reddish brown.

b_3 Coarse-grained, yellowish-orange-weathering, biotite-garnet gneiss contains distinctly less sillimanite than in b_2 and is highly feldspathic.

b_4 Fine-grained, fissile, sulfidic, graphitic sillimanite-biotite-garnet schist. Thin beds of very fine grained, quartz-rich gneiss with small amounts of biotite and diopside are present in some outcrops.

b_5 Lenses and layers of distinctly banded, medium- and light-gray, biotite-amphibole-garnet gneiss interlayered with sulfidic and graphitic, sillimanite schist and reddish-brown biotite-garnet gneiss. Layers of compositionally massive, biotite-hypersthene gneiss also occur within this stratigraphic interval.

b_6 Predominantly rusty-weathering feldspar-quartz-biotite-sillimanite garnet gneiss interlayered with sulfidic and graphitic sillimanite schist. Thick and thin layers and lenses of diopside-bearing gneiss, rare impure marble, and graphite schist occur in the lower 300 feet. Thin layers of even-grained biotite-diopside-garnet gneiss are locally present in the upper 500 feet.

b_7 Twelve 50- to 400-foot-thick layers of amphibole and calc-silicate-bearing gneisses and sulfidic sillimanite schist can be mapped separately from adjacent intervals of banded, sillimanite-poor, biotite-garnet gneiss.

b_8 Fine-grained, fissile graphitic and sulfidic sillimanite schist intertongues with and grades into feldspathic gneisses with biotite, garnet, and, rarely, sillimanite. Stratigraphic marker units within the subdivision have not as yet been recognized.

Lenses of gneissoid pegmatite are present. These are interlayered with and grade into fine-grained, foliated granite. The lenses are as much as 50 feet wide and 100 yards long. They intrude and are concordant with the layered gneiss and schist; they are more abundant in the Brimfield(?) than in the Paxton(?). Foliated biotite-quartz diorite also intrudes the country rock. Contacts are parallel or subparallel to the regional foliation. Most diorite bodies are small isolated lenses less than 100 feet thick, but one body (Stop 2) is as much as 650 feet thick and 15 miles long. The diorite bodies are locally cut by discordant, younger binary granite (Stop 4) and muscovite-bearing pegmatite (Stop 6A). The granite and pegmatite commonly are emplaced along tension joints and high-angle faults.

STRUCTURE

There is no evidence that any part of this homoclinal sequence has been repeated by large-scale folding. None of the mapped units are exposed in reverse image, and most primary sedimentary structures observed (Stops 5 and 9) indicate that the units top westward. This top sense is locally reversed by folds with wavelengths of less than 500 feet, and larger folds appear to be absent. Small-scale folds, however, have thickened the stratigraphic sequence by unknown amounts. The amount of thickening apparently varies with the lithology folded; i.e., biotite-sillimanite schist commonly is tightly folded and most quartzo-feldspathic gneiss is not folded. Most of the small-scale folds observed in outcrop show a west over east sense of movement. Some have axial planes parallel to the regional foliation and plunges parallel to the regional mineral lineation; others, which exhibit a sillimanite lineation down the dip normal to the regional lineation, appear to be drag folds related to low-angle reverse faults that are parallel and subparallel to foliation and bedding.

The stratigraphic sequence is complicated by a system of northeast-trending faults and north-trending cross faults. Most northeast faults are subparallel to the regional foliation and bedding. Thin stratigraphic units are commonly cut out along these faults, and single stratigraphic units are rarely observed on opposite sides of the faults. Thus, direction of movement and amount of stratigraphic displacement are difficult to determine. Most cross faults transect blocks between northeast-trending faults. Displacement on these cross faults is shown by offset of stratigraphic units, generally on the order of a few hundred feet of apparent lateral dislocation.

High-angle faults of small displacement occur in many outcrops (Stops 1,3, and 4); strata are offset and dragged along the fault planes. Small-scale, northeast-trending, low-angle thrust faults can be seen in abundance at widely separate localities (Stops 3 and 4). These faults have cataclased sillimanite-orthoclase-grade rock and induced a muscovite foliation along fault traces. Minor drag folds are abundantly associated with the faults; they have west over east sense of movement, and their axes plunge north-northeast at low angles.

STRATIGRAPHIC CORRELATIONS

Emerson (1917) considered the Brimfield to be younger than the Paxton and assigned a Carboniferous age to both on the basis of a rather tenuous correlation with the Worcester Phyllite. The age of these formations is still uncertain, but it is now generally accepted that both were metamorphosed during the Acadian orogeny and consequently are older than Middle Devonian. Because of the absence of fossils and reliable radiometric ages, and because of structural separation from the stratigraphic sequence in southeastern Connecticut by the Eastford fault any correlation of the Brimfield(?) and Paxton(?) with other stratigraphic units can be suggested only on the basis of physical resemblance and long-range stratigraphic projection.

Subdivision b8 of the Brimfield(?) Schist is physically similar to and on strike with the type Brimfield Schist ½ mile east of the town of Brimfield. Subdivisions below b8 are physically distinct from the type Brimfield, although they contain minor amounts of type Brimfield lithology. The lowest two subdivisions of the Brimsfield(?) and much of the Paxton(?) are, in general, on strike with and bear a striking physical resemblance to the Berwick, Elliot, and Kittery Formations of Silurian-Devonian age of Billings (1956) exposed in southeastern New Hampshire and northeastern Massachusetts. A structurally complex stratigraphy between these two areas must be resolved, however, before such a correlation can be made with any degree of certainty.

On the basis of reconnaissance mapping in the western part of eastern Connecticut, Dixon (1968) has correlated rocks of the Brimfield(?) Schist with the Partridge Formation of Ordovician age and the Paxton(?) Quartz Schist with the Hebron Formation; she tentatively correlated the Hebron Formatiȯn with the Fitch Formation of Silurian age. According to her interpretation, all the rocks in the Eastford and Westford quadrangles lie on the inverted limb of a recumbent fold and are upside down.

Our recent geologic quadrangle mapping in the Eastford and Westford quadrangles does not support this contention. Instead, we have demonstrated that the Brimfield(?) Schist overlies the Paxton(?) Quartz Schist in a structurally complex but right-side-up homoclinal sequence northwest of the Eastford fault and that the Brimfield(?) rocks have been thrust southeastward over the Paxton(?) on the Black Pond fault (Pease, unpub. data).

The physical character of the rocks of subdivision b8 (equivalent to type Brimfield) does closely resemble the Partridge Formation of Ordovician Age exposed along the Bronson Hill anticline (Peper, 1967), but subdivision b8 is several times as thick as the Partridge and is separated from the Partridge by a large body of Monson gneiss. Perhaps the Partridge Formation exposed along the Bronson Hill anticline represents deposition on the western border of a deep sedimentary basin, and subdivision b8 is a greatly thickened equivalent of the Partridge deposited nearer the center of the basin. If so the Brimfield(?) and Paxton(?) are (1) equivalent to or older than the Partridge, or (2) subdivision b8 has been faulted into juxtaposition with younger rocks along one or more of the northeast-trending thrust faults common to the area. If (1) is true, the tentative correlation of the lower part of the Brimfield(?) and the Paxton(?) with the Berwick, Elliot, and Kittery sequence is invalid. If (2) is true, we have yet to recognize the fault or faults that separate older rocks from younger rocks.

There is also the possibility that none of the rusty-weathering sulfidic graphitic schists and gneisses of the Brimfield(?) are equivalent to the Partridge but that they represent a younger Silurian and Devonian sequence not present in the Bronson Hill anticline. A thick sulfide-bearing sequence of Silurian age has been mapped as the Smalls Falls Formation in the vicinity of Rangeley, Maine (Moench, unpub. data). Also, rocks, observed by road reconnaissance of the poorly exposed sequence above the Berwick in south-central New Hampshire, shown as Littleton Formation on the geologic map of New Hampshire (Billings, 1956), physically resembles the sulfide-bearing gneisses and schists of the Brimfield(?) in the Eastford and Westford quadrangles.

In summary, although the Brimfield(?) and Paxton(?) stratigraphic sequence is westward topping, it is not necessarily younger to the west throughout. Faults of unknown displacement may have caused repetitions or gaps in the stratigraphic section that have not yet been recognized. Rocks of Ordovician age on the west may have been thrust over younger Silurian and Devonian rocks on the east, and a full appreciation of the age relations must await more extensive mapping to the northeast and southwest. The sequence does not appear to be overturned, and correlation with the stratigraphic sequence of Dixon and others (Trip F-4) southeast of the Eastford fault is still uncertain.

REFERENCES

Billings, M. P., 1956, The geology of New Hampshire. Part II--Bedrock geology: Concord, New Hampshire State Planning and Development Commission, 203 p.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, 289 p.

Peper, J. D., 1967, Stratigraphy and structure of the Monson area, Massachusetts-Connecticut, in New England Intercollegiate Geol. Conf., 59th Annual Meeting, Oct. 13-15, 1967, Guidebook for field trips in the Connecticut Valley of Massachusetts: Amherst, Mass., p. 105-113.

ROAD LOG

0.0 Trip will assemble at the Intersection of Routes 32 and 15. People heading north on Route 15 should get off at exit 101. Proceed across Route 32 to access road to Route 15 north. Line cars up along east side of access road. See trip leaders for further instructions. (Walk north to the series of outcrops on the east side of Route 15).

Stop 1 (38.88 N - 72.60 E) High-angle fault in rocks of the Brimfield(?) Schist

The 40-foot-wide vegetated area dividing this outcrop marks the trace of a high-angle fault trending about N10 E, 80 W. The drag sense of bedding-foliation implies that this is a normal fault with the foot wall to the east. Rocks on both sides have been dragged against the fault from dips of less than 45° to nearly vertical. The granulated material within the fault zone is cataclased schist and clayey gouge material. The amount of displacement on this fault is not known, but the apparent vertical displacement is greater than the height of the outcrop.

There are at least two other faults in the outcrop west of the principal fault. Displacement on these faults is small and shows offset and drag of lithologic units. A dike of binary granite, about 6 inches wide, has been emplaced along one of these faults. The granite has been offset by later movement on the fault. Cross-bedding and graded bedding west of this fault show tops to the west.

Note the contrast in weathering characteristics on opposite sides of this fault. Rocks on the east side are quartz-feldspar-biotite-garnet schist and gneiss containing very little sulfide. Rocks on the west side are garnetiferous quartz-feldspar-biotite-sillimanite-gneiss containing laminae rich in finely disseminated sulfide and graphite. On weathering, sulfide-bearing layers slake badly and develop the sulfur-yellow and rusty-orange staining that is so prominent.

Return to cars; head north on Route 15.

1.2 Outcrop ahead on right, pull over onto grass.

Stop 2 (39.35 N - 73.08 E) Foliated biotite quartz diorite.

Exposures here and to the north form a nearly complete section of one of the most distinctive map units in this part of northeastern Connecticut. The diorite can be traced for at least 15 miles along strike through the South Coventry, Stafford Springs, and Wales quadrangles and maintains a nearly uniform thickness of about 650 feet. This strongly jointed, coarsely layered, compositionally homogeneous, dark-gray, foliated igneous rock is composed mostly of plagioclase and biotite with quartz and minor amounts of clinopyroxene, amphibole, and garnet. The few thin sections examined show a hypidiomorphic granular texture in which clinopyroxene is intersertal with intermediate plagioclase; the clinopyroxene is altered to blue-green hornblende. Superimposed on the igneous texture is a strong biotite foliation concordant with the regional foliation. The combination of igneous texture and strong biotite foliation indicates that this is an early syntectonic sill. It is probably correlative with the New Hampshire Plutonic Series of Billings (1956).

1.7 Ruby Road exit ahead; park in wide area adjacent to the extensive roadcut on right.

<u>Stop 3</u> (39.63 N - 73.26 E) Metavolcanic biotite schist and metapelitic rusty sillimanite schist.

In this west-facing dip-slope outcrop, an irregularly shaped body of gray, granular, fine-grained biotite-amphibole schist (metavolcanic rock) overlies quartz-feldspar-biotite-sillimanite-garnet schist and gneiss (metapelitic rock). The latter is characteristic of much of the Brimfield(?) Schist. The contact is extremely uneven, as clearly shown by exposures in the north-central part of the outcrop where the metavolcanic rock forms a bulge about 4 feet wide in the face of the outcrop and the contacts bend sharply into the face. Undulant surfaces in the metavolcanic schist are common. Contacts with the metapelitic schist locally are crenulated. The contacts show no distinct preferred orientation and plunge generally southward, contrary to tectonic trends. In many places, thin layers of metavolcanic schist, as much as 4 inches thick, extend for tens of feet into the metapelitic schist. Most of these layers occur along bedding-foliation planes, but some crosscut at a very low angle.

Along 15 feet near the base of the outcrop is a coarse-grained, foliated, hornblende-pyroxene gabbro exposed in irregularly shaped blobs as much as 3 feet in diameter. Undulant sheets and tongues of brown biotite schist with abundant 1-4-inch feldspar porphyroblasts separate the blobs of diorite on the surface, but they probably are interconnected in third dimension. Locally the gabbro has a thin, fine-grained selvage. Pyrrhotite is disseminated throughout much of the gabbro; pyrite occurs in fractures. The gabbro apparently is a local occurrence, lying stratigraphically between the metapelitic schist and the metavolcanic schist.

The bedrock outcrop further north on the west side of the exit road has a good exposure of the basal contact of the metavolcanic rock overlying the metapelitic rock. The contact, although irregular and displaced locally by small faults, appears to be conformable. The irregular, west surface of the outcrop shows a bulbous, pillowlike shape which is typical of the metavolcanic schist. Tongues and sheets of brown-biotite schist with feldspar porphyroblasts are prominent along this surface.

About 4 feet beneath the contact is a 2-inch-layer of gray, fine-grained granular schist. Its lithology is identical with the overlying metavolcanic schist. The coarse-grained gabbro is not present in this outcrop.

Cross Ruby Road onto access road onto Route 15, heading north again.

2.7 Outcrops ahead on the left expose layers of sulfidic schist. These occur in a mappable unit of metavolcanic rock extensively exposed in the vicinity of Pinney's Pond, about 4 miles to the northeast.

3.0 A road bridge crosses Route 15 on the horizon ahead. Pull off road into the wide area on the right, just before the bridge.

Stop 4 (40.30 N - 74.25 E) Thrust fault and high-angle faults of small displacement.

The coarse-grained, medium-gray foliated quartz diorite that is extensively exposed here on the east side of Route 15 is also exposed in the lower part of the roadcut on the west side of the highway under the bridge -- where it is overridden by sillimanite-biotite-garnet gneiss and schist along branching thrust faults that dip at low angles to the west. Abundant thin dikes of binary granite fill fractures in the quartz-diorite.

Four high-angle faults of small displacement complicate the schist and gneiss exposed on the west side of the highway, about 150 yards southwest of the bridge. These strike about north-south and dip steeply. A dike of crumbly-weathering granite intrudes the northernmost fault. Primary foliation in the dike and the dike-schist contact are dragged, suggesting that the dike was emplaced during faulting. Varied senses of movement on the other three faults can be inferred from the attitudes at which the schist is dragged into the fault zones. In the sharply defined gouge zones of the faults, the schist is cataclased and retrograded. Structural elements in the cataclased rock include: muscovite foliation parallel to the planes of faulting; induced platiness of quartz and feldspar grains parallel to this foliation and rodding of the grains parallel to transport direction; induced biotite streaking parallel to transport. In addition, a rotation-sense is shown by recrystallized garnets. (See trip leaders for oriented and slabbed samples of cataclased rock).

4.7 Series of outcrops on left near top of hill ahead. Pull onto shoulder at right across from outcrops.

Stop 5 (40.35 N - 74.30 E) Low-angle thrust faults; styles of drag folding; and late-syntectonic granite pegmatite dikes.

The three large bedrock exposures on the west side of Route 15 have the structural features and lithologies characteristic of the Brimfield(?) Schist in this stratigraphic position. These exposures are about 3/4 of a mile northwest along strike from the thrust-fault at Stop 4, but they are about 300 feet lower in stratigraphic position (trip leaders will explain the stratigraphic significance of the lithologies present).

In the northernmost outcrop, two low-angle thrust faults cut and retrograde the sillimanite-biotite-garnet-cordierite gneiss. The faults branch and splay along foliation planes but trend, in general, N50 E and dip at low angles to the west. Structural elements in the cataclased rock of these faults are similar to those described from the high-angle faults at Stop 4. The pronounced downdip lineations in the cataclased rock are approximately at right angles to the regional N15 E sillimanite lineations in gneiss away from the fault zones. Small purple grains of cordierite are abundant in, and adjacent to, the small and irregular lenses of white, coarse-grained, feldspar-quartz rock in the gneiss.

The second outcrop, about 100 yards to the southwest, exposes a 25-foot-thick lens of calc-silicate gneiss and impure marble. The thin beds outline abundant small drag folds which are characteristic of this lithology. These drag folds have the dominant regional west-over-east sense of movement and have curvilinear axes that plunge at low angles NNE and SSW. The axial planes of the folds dip at moderate angles to the west, parallel and subparallel to shearing, regional foliation, and bedding.

The third and largest roadcut, to the southwest, provides an additional exposure of sulfidic, sillimanite-biotite-garnet gneiss and schist interbedded with thin lenses of fine-grained, diopside-bearing granulite. At the southern end of the cut, a late-syntectonic combed dike has been emplaced along a high-angle fault. The walls of the dike consist of fine-grained biotite granite, foliated parallel to the schist-dike contact. Pegmatite in the dike core is quartz rich and contains muscovite. This pegmatite should be compared with older gneissoid pegmatites in the surrounding rocks. The older pegmatites are strongly foliated, concordant, and contain no muscovite. They typically contain small amounts of tiny, pink euhedral garnet. The older pegmatites are found throughout the Brimfield(?) section, regardless of local lithology, and they appear to have been forcefully injected along foliation and bedding. They also grade into fine-grained, foliated, concordant granite which contains biotite and garnet. In contrast, the irregular lenses of white, cordierite-bearing, quartz-feldspar rock, similar to those in the first exposure at this stop, are more sporadically distributed and apparently are restricted to certain pelitic lithologies. These may have been derived from the crystallization of a local melt fraction, developed during the peak of metamorphism, that remained more or less in place.

5.5 Outcrop of schist and gneiss on left is characteristic of a mappable unit extensively exposed on Snow Hill to the west.

6.3 Exit 104 ahead. Exit, turning left, and head west across Route 15 on Route 89.

6.9 Park in borrow pit just west of Route 15 on the north side of Route 89.

Stop 6 (41.10 N - 75.00 E) Interbedded metavolcanic and metasedimentary rocks.

The outcrops scattered along both sides of Route 89 expose the upper two-thirds of a mappable unit of interbedded metavolcanic rock and metashale. At the east end of the series of exposures, thin beds of amphibolite alternate with plagioclase-quartz-biotite-amphibole gneiss. These rocks are overlain by about 40 feet of rusty, red-orange-weathering, layered, plagioclase-quartz-biotite-garnet-sillimanite gneiss. About 100 yards west, on the north side of the road, another outcrop exposes 20 feet of compositionally layered, biotite- and amphibole-bearing gneisses. These are cross-laminated metavolcanic rocks which top west.

Another 10 yards west, on the south side of the road, a homogeneous thick layer of dark-greenish-gray, calcium plagioclase-biotite-hypersthene gneiss overlies platy and fissile, sulfidic, sillimanite-biotite-garnet schist. The compositionally homogeneous rock and physically similar rocks in this unit, are probably metamorphosed and foliated lava.

Continue west on Route 89.

7.4 Intersection with Route 190. Turn right and head northeast on Route 190.

7.6 Outcrops on both sides of road ahead are part of the metavolcanic unit exposed at Stop 5, southwest of Morey Pond.

8.5 Bridge ahead, Route 190 crosses Route 15.

8.8 The outcrop of sulfidic schist, on the right, lies in a thick belt of sulfidic schist, which is extensively exposed at Union School. The contact of this schist with the overlying metavolcanic unit follows the steep gully west of the road.

9.8 Bear right onto road ahead; continue up hill to northeast.

10.1 Union School building to right. Continue east across intersection(downhill). SLOW! ROAD CURVES.

The long east-facing slope we are traversing is covered with thick till. Along Gulf Brook to the north and the mid-reach of Scranton Brook to the south are sulfidic schist and gneiss, which are more quartzofeldspathic than the platy, fissile, sulfidic schist exposed at Union School.

10.8 Walker Mountain ahead, across Bigelow Hollow.

11.0 Unnamed pond on the left, Kinney Pond on right.

Stop 6A (41.84 N - 76.28 E) Northeast Faults.

Although not readily accessible to large groups, outcrops along the valley north of the road show many features of the faults and folds that control prominent topographic lineaments in this area.

About 1,200 feet north of the unnamed pond, the northeast-trending valley branches to either side of a small hill. West of this hill is a rusty-orange weathering, quartzo-feldspathic, sillimanite-garnet-biotite gneiss. Abundant folds are developed in the gneiss by kinking of primary foliation and bedding along later, steeply west-dipping planes. On the south end of the hill, the steeply west-dipping shear cleavages cut across and offset bedding and foliation in quartzo-feldspathic gneiss and layering in foliated pegmatite. Late-syntectonic, quartz-rich, muscovite-bearing pegmatites and quartz veins locally follow the shear cleavages.

The late foliation and cleavage strike consistently 5°-10° E of the strike of primary foliation and bedding and dip consistently 10°-20° steeper to the west. Most kink folds have a west-over-east sense of movement; a few have an opposite sense of movement or none at all.

11.1 Outcrops north of the road on the east side of the pond expose layers of gray-weathering, granular, plagioclase-quartz-biotite-garnet gneiss, interbedded with gray, cordierite-bearing, calcium plagioclase-potassium feldspar-quartz-biotite-garnet-sillimanite schist. These rocks make up a mappable unit exposed in the vicinity of Kinney Pond.

11.4 Road turns right and heads south, following Bigelow Hollow, which is a major topographic lineament.

11.5 Scattered outcrops of gray schist and gneiss are on slope to right.

11.7 Outcrop of foliated quartz diorite on right. Additional exposures to northeast display the sill-like nature of the intrusive body.

12.7 You will pass an outcrop of gray gneiss on your right before the road surface changes to dirt. The gneiss is cross laminated and tops to the west.

12.7+ Wood bridge.

12.9 Dirt road enters on right. Bear left across wood bridge.

13.3 Wood bridge crossing Bigelow Brook. Scattered outcrops of gray gneiss and schist north of road east of bridge. The positions of a 10-foot thick layer of gneiss on either side of Bigelow Brook to the south, suggest displacement of 30-feet on a small fault following the bed of the brook.

13.4 Road turns right and crosses another wood bridge.

13.9 Prominent steep-sided valley to southwest is occupied by a fault along Boston Hollow.

14.1 Intersection Boston Hollow Road. Bear left (east) on North Ashford Road. Continue across wood bridge onto paved surface. Pull off to right and park on grass across from first roadcut.

<u>Stop 7</u> (40.50 N - 76.46 E) Calc-silicate-bearing schist and gneiss.

The two roadcuts along the north side of the road expose calc-silicate-mineral-bearing schist and gneiss characteristic of an important marker unit in this part of the stratigraphic section. The unit is traceable northeastward through the Eastford quadrangle and southwestward across the east slope of Turkey Hill. It separates gray-weathering, garnetiferous, sillimanite-poor schist below, from rusty-weathering, feldspar-quartz-sillimanite-biotite-garnet gneiss and schist above.

Continue east on North Ashford Road.

14.9 Walker Drive enters on right.

15.5 Kozy Road enters on right.

16.7 Note outcrop of foliated, garnet-bearing granite in back yard of the house north of the road, about 200 yards along strike to the southeast. This garnet-bearing granite intertongues and grades into coarser grained, layered, and foliated garnet-bearing pegmatite.

16.8 Intersection Route 171: Turn right and go south on Route 171.

17.7 Turn right on Crystal Pond Road (Floeting Road on topographic map) and continue south.

18.6 French Road enters on right.

18.9 Lake Drive enters on left; bear right through intersection.

19.0 Road forks; bear right.

19.5 Turn right on Buell Road to farmhouse. Park in front of first barn across the road from the house.

<u>Stop 8</u> (39.65 N - 77.32 E) Black Pond fault.

The Black Pond fault separates the Brimfield(?) Schist from the Paxton(?) Quartz Schist in the Eastford quadrangle. The fault trends in an easterly direction approximately through the chicken coop and barn north of Buell Road, where the fault appears to be a low-angle thrust fault. A few hundred yards further northeast, along the ridge north of the road, the fault steepens and turns abruptly northward, becoming not quite parallel to the foliation. The fault continues north-northeast beyond the northern border of the quadrangle.

Rocks of the upper plate on the north side of the fault are best exposed behind the chicken coop and barn. These are brownish-gray, rusty-weathering, garnetiferous, quartz-feldspar-biotite-sillimanite schist with abundant deformed quartzo-feldspathic lenses and stringers. The rocks are tightly compressed by shears and drag folds. The low-angle shear surfaces dip gently northwest and cross-cut the contorted axial surfaces of the drag folds. Retrograde muscovite is common on the shear surfaces. A strong downdip lineation is formed by the intersection of quartz and feldspar layers with these shear surfaces.

The exposures that crop out directly east of the barn are assigned to the Paxton(?) Quartz Schist and are in the footwall of the fault. Approximately 6,000 feet of section is cut out along the unexposed fault surface which passes north of these exposures. The dark-gray, biotite-amphibole schists and gneisses of the footwall also show the effect of west-over-east movement by tightly compressed, contorted folds. Shearing is less evident in the rocks of the lower plate.

At the eastern end of the series of outcrops exposed west of Crystal Pond Road, the position of the fault trace can be pinpointed locally to within a foot. It is here that the fault surface appears to have warped abruptly from low angle east trending to nearly vertical northeast trending. Tightly, complexly folded, steeply dipping footwall rocks are best exposed here The rusty brown schist of the upper plate is present only in a few small outcrops.

Return to Crystal Pond Road (Floeting Road).

19.5 Crystal Pond Road. Turn left and return to the town of North Ashford via Route 171.

21.3 Intersection Route 171: Turn left and head north on Route 171.

22.2 North Ashford. Bear right on Center Pike Road.

23.4 Intersection Union Road, Cross Union Road and continue northeast on Old Turnpike Road.

24.0 Intersection Route 198. Continue northeast across 198 onto dirt road.

24.9 Red and White School Road (Route 197) joins from left. Continue east on Route 197.

26.5 Brickyard Road crosses Route 197.

27.9 Lyon Hill Road crosses Route 197.

29.5 Intersection Route 169. Turn left and head north on Route 169.

29.6 Turn left and head northwest on English Neighborhood Road.

29.8 Pull over to left in branch of driveway.

<u>Stop 9</u> (42.40 N - 80.35 E) Representative exposure of the Paxton(?) Quartz Schist of the Kenyonville area, the oldest stratigraphic unit exposed in the Eastford quadrangle.

The rock type distinctive of the unit is gray, quartz-feldspar-biotite schist with numerous subhedral megacrysts of potassium feldspar. Interlayered with the biotite schist are light-gray, medium to coarse-grained layers composed almost entirely of feldspar and quartz and grayish-black, fine-grained layers rich in hornblende. The potassium feldspar megacrysts, which commonly show evidence of secondary growth, appear to be relic sedimentary clasts recrystallized during metamorphism.

Low-angle crossbedding showing tops up is well expressed in this outcrop. Note in one crossbed set the biotite schist layers thin upward and quartz-feldspar septa are cut out against an overlying set of coarser grained beds which show no crossbedding. At the south end of this outcrop small-scale folds are clearly exposed. The sense of these folds is left handed. This sense of folding has been observed in the Westford quadrangle only along very early faults that show a reverse sense to the regional west-over-east sense of movement.

Turn around and return to Route 169.

30.0 Turn left, north, on Route 169.

30.1 Large outcrop just visible on right below the yellow house is also in the Paxton(?) Quartz Schist. A binary granite dike less than a foot in maximum thickness trends at right angles to the foliation and is offset along bedding-plane shears.

Continue on Route 169 for 6 miles to the outskirts of Southbridge.

35.9 Intersection with Route 131. Proceed north on Route 131.

36.5 Bear left around rotary, under railroad bridge, and follow Route 131 through the center of Southbridge.

37.1 West of the center of town, bear left on South Street leaving the main thorough fare. Proceed along South Street through the outskirts of town and continue west along a relatively new macadam highway.

39.2 Sturbridge town line - park the cars wherever possible along the right side of the road.

Stop 10 (44.15 E - 39.20 N) Section of Brimfield(?) Schist - lower part in Massachusetts.

Exposures along this road beginning at Sturbridge town line and continuing to the outcrops just west of the entrance to the large automobile graveyard represent the thickest known well-exposed section of any part of the Brimfield(?) Schist. According to Emerson's map (1917), a tongue of Paxton Quartz Schist is infolded in the Brimfield in these outcrops, but the exposed rock types all are characteristic of the Brimfield(?) Schist, and the contact with the Paxton(?) Quartz Schist should be about 2 miles farther east. Accordingly, this section is tentatively assigned to the lower middle part of the Brimfield(?) Schist. The section quite possibly is interrupted by faults as yet unmapped.

Most of the rock types characteristic of the Brimfield(?) Schist are present in those exposures. The easternmost exposures consist chiefly of dark-gray, diopsidic, biotite schist and gneiss which characteristically contain greenish-gray lenses of granular schist containing abundant diopside and other calc-silicate minerals. These calc-silicate-rich pods commonly are zoned with light-pinkish-gray garnet and carbonate-rich cores grading outward into greenish-gray, diopside-rich rock. Borders are brown biotite schist. A zone about 50 feet thick contains thin layers rich in sulfide and graphite. Only slight weathering of trace amounts of sulfide causes pervasive staining on the outcrop face.

In the second series of exposures, sulfide- and graphite-bearing layers are more common. Most of the rock is biotite schist and gneiss with few calc-silicate layers. Garnet is appreciably more common in these exposures. The highly fractured, platy pegmatite exposed at the east end of these exposures is rich in sillimanite, but sillimanite is not abundant in the country rock.

The rather small exposures to the west on the south side of the road are divisible into two parts. Rust-stained sulfidic schist and gneiss overlie a zone in which greenish-gray, granular schist layers containing diopside and other calc-silicate minerals are abundant. Such calc-silicate-rich zones, where sufficiently thick and laterally extensive, have been mapped in the Eastford quadrangle. Note the cordierite-bearing pegmatite at the extreme west end of those exposures.

Return to cars and proceed west on highway.

40.0 Park on dirt road opposite entrance to the automobile graveyard.

Stop 10A (44.10 E - 39.21 N) Quartz diorite.

The outcrops are mostly foliated, garnetiferous, biotite quartz diorite similar to the larger mass of foliated quartz diorite at Stop 2. The quartz diorite concordantly intrudes calc-silicate-rich Brimfield(?) rocks. Further west around the corner exposures on the north side of the road consist of garnet-rich, biotite schist alternating with zones in which sillimanite-rich layers are abundant and commonly interleaved with sulfide-and graphite-rich layers. Sillimanite is notably more conspicuous in these rocks than it is lower in the section.

Most pegmatites in exposures at Stops 10 and 10A are concordant, gneissoid, and composed of potassium feldspar and oligoclase with less than 20 percent quartz and minor garnet and biotite. Blue cordierite is prominent in some pegmatites, sillimanite in others.

End of field trip.