1-1-1975

Fold-thrust tectonism in the southern Berkshire massif, Connecticut and Massachusetts

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by

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Introduction

The western front of the Berkshire massif consists of imbricate thrust slices of Precambrian and lower Paleozoic rocks transported westward over Cambrian and Ordovician rocks of the carbonate platform sequence. Thrusting was accompanied by large and small scale recumbent folding, attenuation and transposition along the overturned limbs of the recumbent folds, and the formation of cataclastic foliation, now recrystallized, in the thrust zones. The folding, thrusting, and cataclasis define a tectonic style for the Berkshire massif that closely resembles the tectonic style of the Reading Prong described by Drake (1970) and one that may be characteristic of most, if not all, of the Precambrian massifs along the backbone of the Appalachian orogen. It seems appropriate, therefore, to examine the rocks in some of the thrust zones to see the textures and structures that make up the fold-thrust fabric and the fold-thrust style of tectonism.

Although the fold-thrust style of deformation persists throughout the Berkshire massif, there are some significant variations in the structures and lithologic sequences along its length. North of the Massachusetts-Connecticut State line (fig. 1), the thrust slices are stacked up, shinglelike, to the north, so that successively higher tectonic levels and, perhaps consequently, more brittle structures are exposed northward. South of the State line, the thrust slices stack up to the south and are overlapped at the southe end of the massif by the parautochthonous Waramaug Formation of Gate (1952, 1965) which traces into the Hoosac Schist (Lower Cambrian or older) east of the massif. The Waramaug Formation rests structurall above a sequence of feldspathic granulites, volcanic rocks, and garn sillimanite schist, referred to collectively as the Canaan Mountain Schist by Rodgers and others (1959). Lithologically, the rocks of t Canaan Mountain Schist appear to be a transitional facies between th Dalton Formation, the basal clastic unit of the platform sequence to the west, and the Hoosac Schist and possibly the Rowe Schist, the lower units of the basin sequence east of the massif. This trip offers the opportunity to compare the rocks of the Dalton Formation with some of those of the Canaan Mountain Schist and to see the contact relationships between the platform sequence and the Canaan Mountain Schist.

Most of the stops are on private property; please respect it. Also, most of the geologic features, particularly the cataclastic features, show up best on the weathered surface. There is no need to quarry the outcrops which don't yield readily to the standard size geologic hammer anyway. The optimum cost-benefit ratio for hand-specimen collecting is associated with the talus blocks.

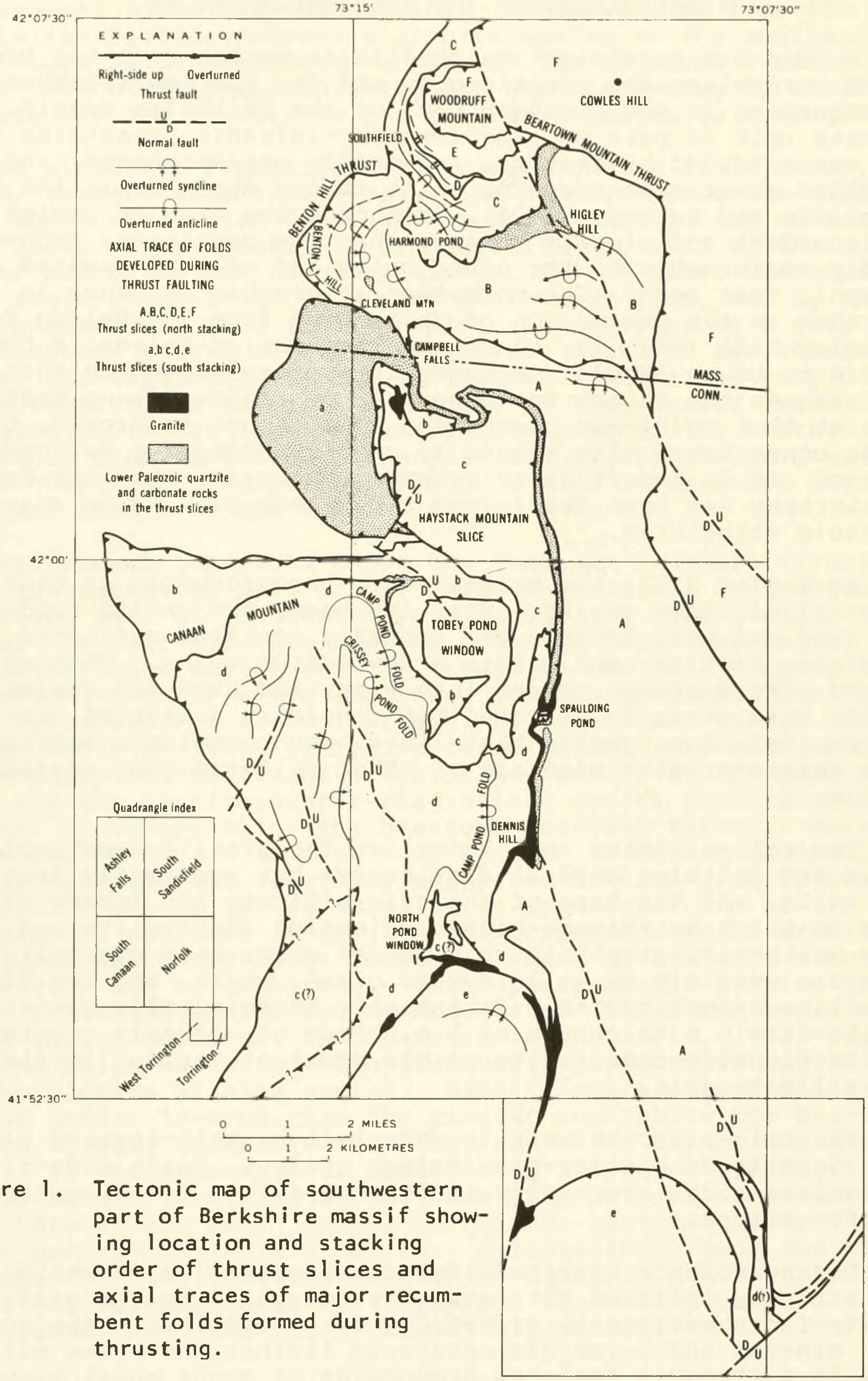


Figure 1. Tectonic map of southwestern part of Berkshire massif showing location and stacking order of thrust slices and axial traces of major recumbent folds formed during thrusting.

Stratigraphy of the Precambrian Rocks

A thin but persistent calc-silicate marker unit has been the key to unraveling the stratigraphy and the complex recumbent folding and thrusting in the southern part of the Berkshire massif. The calc-silicate unit is part of a sedimentary-volcanic paragneiss sequence that was intruded by granite, regionally metamorphosed, and complexly folded about east-trending axial traces about 1 billion years ago (Ratcliffe and Zartman, 1971). Although the granite gneiss is locally discordant and clearly younger than the paragneiss sequence, it is broadly conformable to the other units and will be treated as a stratigraphic unit here. The normal stratigraphic sequence is arbitrarily taken as the succession of units away from the Dalton Formation on Higley Hill (fig. 2), where the Precambrian-Paleozoic boundary appears to be an angular unconformity uncomplicated by thrust faulting. This assumes the Dalton was deposited on right-side-up Precambrian rocks at that point--an assumption that cannot be proved, but one of little consequence with regard to understanding the Paleozoic deformations. It is important to remember, however, that the Precambrian stratigraphy has been determined concurrent with an in respect to Paleozoic structures.

At Higley Hill, the Dalton rests unconformably on biotite-quartz-plagioclase gneiss. Near its base, the gneiss tends to be dark gray and well layered and commonly contains scattered lenses of hornblende-biotite amphibolite a few metres thick. This well-layered gneiss grades upward into wispy and streaked gneiss and finally into strongly foliated but generally unlayered gray biotite-quartz-plagioclase gneiss that lacks both hornblende and/or microcline characteristic minerals of other foliated gray gneisses in the section.

The calc-silicate unit underlies the biotite-quartz-plagioclase gneiss and contains several distinctive but apparently lenticular rock units. At the base of the calc-silicate are lenses of dark-green to black hornblende-biotite-diopside amphibolite and, locally, rusty weathering graphitic thin-bedded calcareous quartzite. These rocks are overlain by well-layered green, white, and red diopside-microcline-garnet gneiss. Essentially monomineralic garnet layers locally attain a thickness of 1 m. Pods of coarsely crystalline calcite-diopside-chondrodite marble occur at various levels in the calc-silicate unit.

The calc-silicate unit is underlain by well-layered black and white hornblende-biotite-plagioclase gneiss. Hornblende-rich and plagioclase-rich layers vary in thickness from a few centimetres to a few metres.

The hornblende-biotite-plagioclase gneiss is in sharp contact with strongly foliated but generally unlayered coarse grained biotite-ferrohastingsite granite gneiss. Biotite is the dominant mafic mineral and forms discontinuous laminations a few millimetres thick in a strongly foliated groundmass of about equal amounts of quartz, plagioclase, and microcline. Ferrohastingsite is present in minor amounts and distinguishes this granite gneiss from the otherwise similar biotite-muscovite granite gneiss in the southern part of the South Sandisfield quadrangle and the adjacent Norfolk quadrangle. The biotite-ferrohastingsite granite gneiss is similar in mineralogy and texture to the Tyringham Gneiss of Emerson (1899).

The biotite-ferrohastingsite granite gneiss is in sharp, locally chilled, contact with rusty-weathering biotite-muscovite-sillimanite schist and gneiss which forms an extensive unit in the eastern part of the area. These rocks are readily distinguished by their abundance of muscovite, an uncommon mineral in the other Precambrian rocks, their rusty-brown or orange weathering rind, and by the distinctive quartzite beds in the schist that weather to a gray vitreous lacework pitted surface. All these features are characteristic of the Washington Gneiss of Emerson (1899); the only difference between the two is the absence of blue quartz found in the Washington Gneiss at lower metamorphic grades to the north. Along the eastern side of the South Sandisfield quadrangle is a unit of biotite-quartz-plagioclase hornblende gneiss in or below the rusty schist and gneiss of the Washington.

The Precambrian rocks below the Beartown Mountain thrust (fig. 2) in the south-central part of the South Sandisfield quadrangle and the eastern part of the Norfolk quadrangle are very similar to those of the calc-silicate-bearing sequence described above, but the calc-silicate marker unit is missing. For this reason, the correlation of units above and below the Beartown Mountain thrust cannot be considered above reproach, but there are enough similarities to merit at least tentative correlation. The rusty-weathering biotite-muscovite-sillimanite schist and gneiss of the Washington Gneiss and the biotite-quartz-plagioclase gneiss associated with it appear unchanged below the Beartown Mountain thrust. Below the Washington Gneiss is a unit of medium- to coarse-grained, strongly foliated but generally unlayered biotite granite gneiss. This granite gneiss is very similar in appearance and at the same stratigraphic position as the biotite-ferrohastingsite granite gneiss, but there are large tracts in which it contains minor amounts of muscovite and no amphibole. Other parts of the granite gneiss contain ferrohastingsite and no muscovite. These two types of granite gneiss could not be separated in the field. Well-layered, black and white hornblende-biotite-quartz-plagioclase gneiss underlies the biotite granite gneiss. Biotite-quartz-plagioclase gneiss, somewhat better layered than the similar rock above the Beartown Mountain thrust, underlies the black and white hornblende-biotite gneiss. If the sequences of rocks above and below the Beartown Mountain thrust were exactly the same, the calc-silicate unit should appear between the well-layered hornblende-biotite gneiss and the biotite-quartz-plagioclase gneiss. Calc-silicate pods and patches of hornblende-biotite-diopside rock do occur in the hornblende-biotite gneiss, and these may represent the well-developed calcareous horizon above the Beartown Mountain thrust.

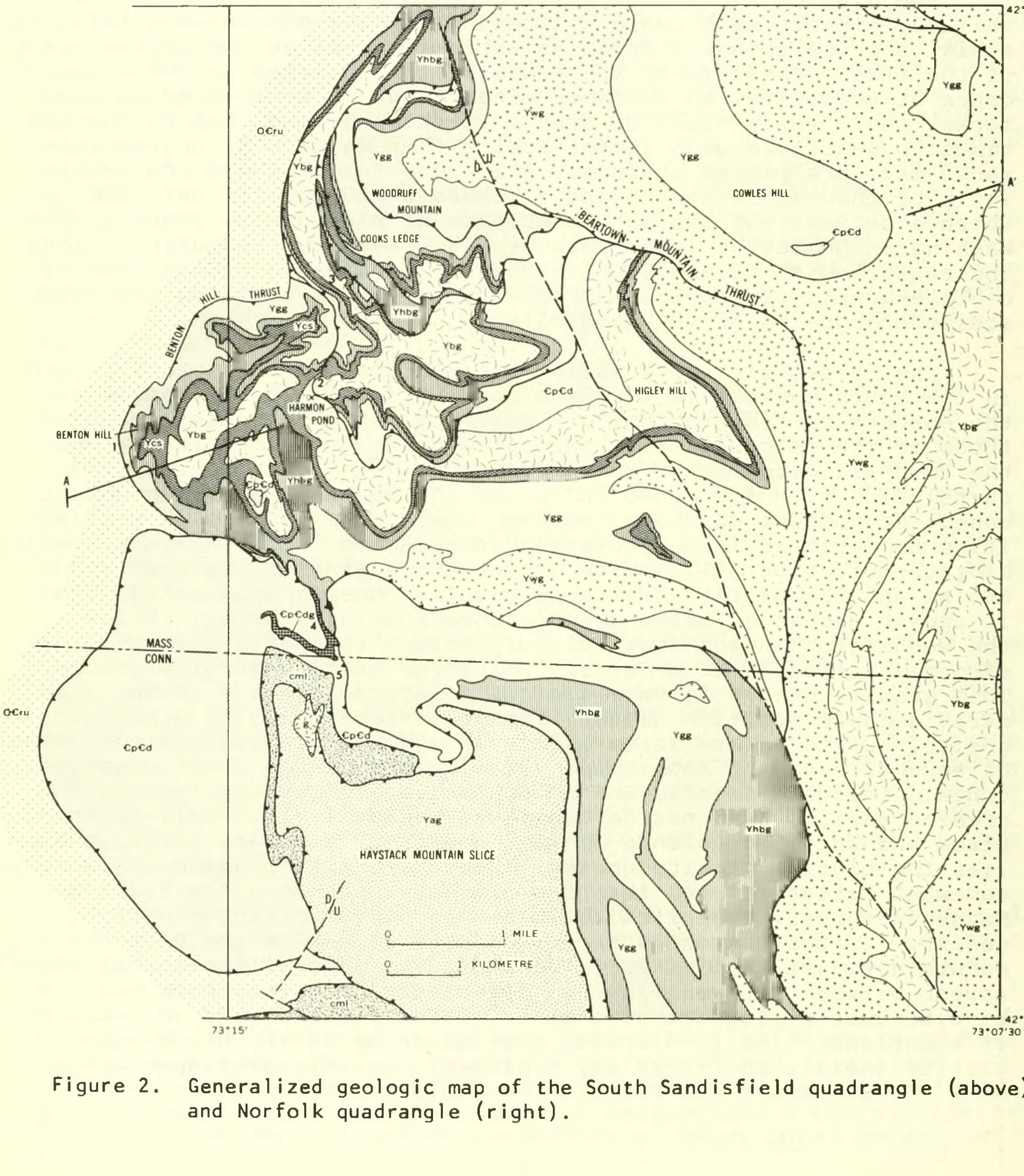
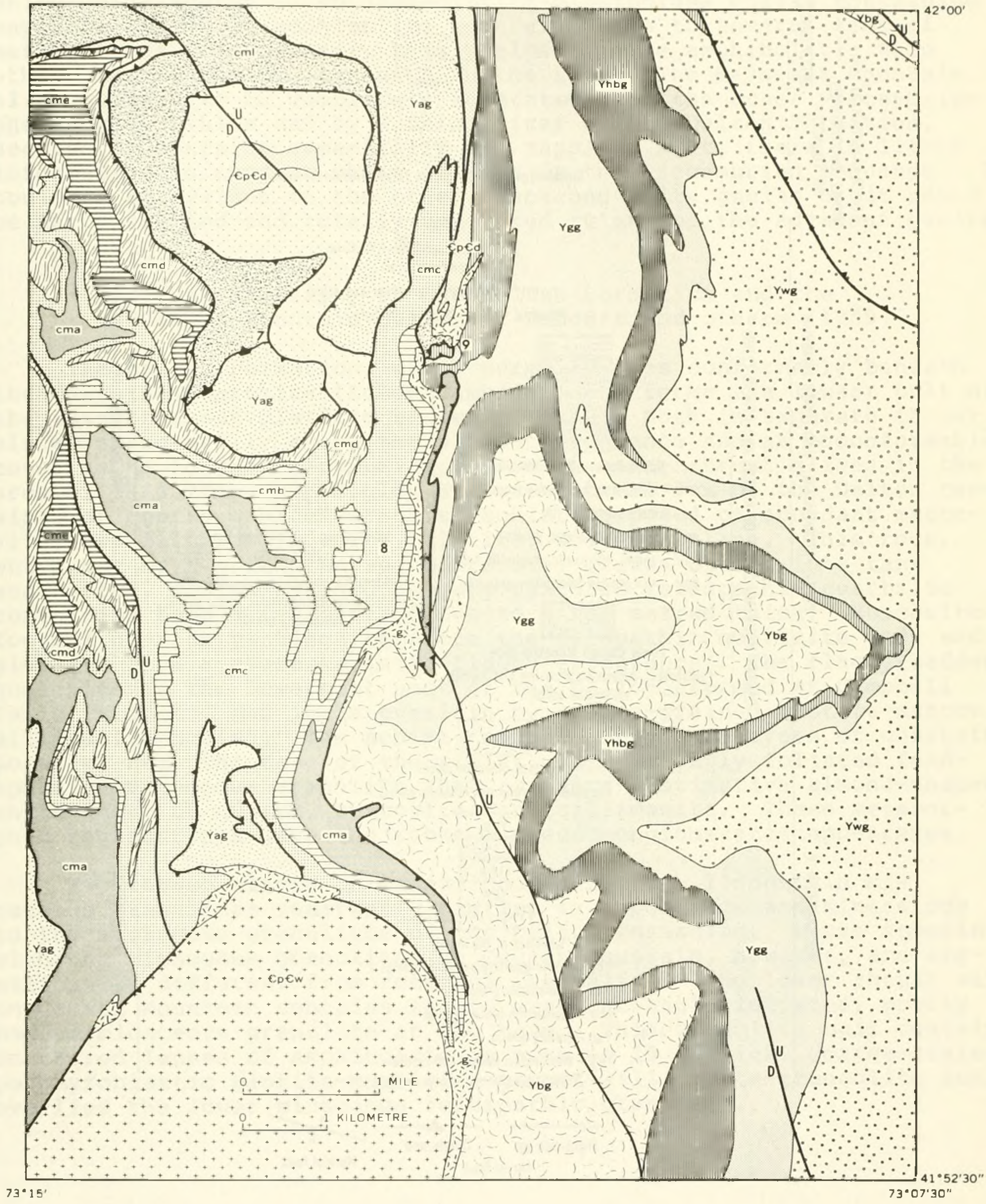


Figure 2. Generalized geologic map of the South Sandisfield quadrangle (above) and Norfolk quadrangle (right).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g
Ybg
41°52'30"
73°15'
73°07'30"

EXPLANATION

ORDOVICIAN (?)

g

Granite

LOWER CAMBRIAN TO MIDDLE ORDOVICIAN(?) OR YOUNGER

O€ru

Stockbridge and Walloomsac Formations, undivided

ORDOVICIAN

UPPER PRECAMBRIAN(?) AND LOWER CAMBRIAN

€p€d

€p€dg

Dalton Formation

€p€d - feldspathic granulite and schist

€p€dg - flaggy-bedded quartzite

CANAAN MOUNTAIN SCHIST OF ROGERS AND OTHERS (1959)

cme

cmd

cmc

cmb

cma

Upper Canaan Mountain slice

cma - feldspathic micaceous granulite

cmb - mafic volcanic rock

cmc - mucovite-spangled gneiss

cmd - garnet, sillimanite, magnetite schist

cme - well bedded feldspathic granulite

cml

Lower Canaan Mountain slice

Feldspathic, micaceous granulite and garnet, sillimanite schist

€p€w

Waramaug Formation of Gates (1952, 1965)

Feldspathic, micaceous granulite with abundant amphibolite lenses, minor garnet, sillimanite schist

PRECAMBRIAN(?) AND CAMBRIAN

PRECAMBRIAN Y

Yag

Haystack Mountain slice

Hornblende-biotite amphibolitic gneiss

Ybg

Ycs

Yhbg

Ygg

Ywg

Ybg

Gneisses of the massif

Ybg - biotite-quartz-plagioclase gneiss

Ycs - calc-silicate gneiss

Yhbg - hornblende-biotite gneiss

Ygg - granite gneiss

Ywg - Washington Gneiss and biotite-quartz-plagioclase gneiss (Ybg)

PRECAMBRIAN

Right-side up

Overturned

Thrust fault

D

U

Normal fault

1

Stop locality

Rocks of the Haystack Mountain slice (fig. 1) are black and white well-layered hornblende-biotite-plagioclase gneiss containing mappable layers of amphibolite several metres to several tens of metres thick. In general, this gneiss is more amphibolitic than other black and white gneisses in the area. The Haystack Mountain slice appears to be completely separated from the other Precambrian gneisses by faults and by a thin sliver of the Dalton Formation. Because it contains essentially one mappable unit, there is little information to suggest where it fits in the Precambrian sequence. It could be equivalent to the other black and white gneiss or it could be far travelled and totally unrelated to any of the adjacent gneisses.

Stratigraphy of the Dalton Formation and the Canaan Mountain Schist of Rodgers and others (1959)

The Dalton Formation, which normally lies conformably beneath the Cheshire Quartzite (Lower Cambrian) and forms the lowest unit of the autochthonous platform sequence, occurs both in separate thrust slices structurally above the platform sequence and as unconformable cover rocks to the Precambrian gneiss in other thrust slices in the area of this trip. On Higley Hill, the basal 3 m of the Dalton consists of coarse-grained granular schist composed of abundant muscovite, two feldspars, quartz, biotite, and tourmaline. This rock, which may be a metamorphosed saprolite, grades upward into tan-weathering, medium-grained, sugary-textured feldspathic quartzite containing beds a few centimetres to a few metres thick. Muscovite-tourmaline-rich partings separate the felspathic quartzite beds and give the rock a characteristic flaggy appearance. The flaggy-bedded quartzite is the lowermost unit of the Dalton exposed at Campbell Falls (stop 4), and it is overlain by coarse-grained biotite-muscovite-sillimanite schist. The schist contains mappable layers of quartzite. Locally, near the base of the schist, is a strongly foliated feldspathic, micaceous granulite that contains distinctive almond-shaped white knots of quartz, muscovite, and sillimanite. These metamorphic segregations give the rocks a pseudoconglomeratic appearance.

Two thrust slices on Canaan Mountain (fig. 1) contain micaceous granulites remarkably similar in appearance and mineralogy to the micaceous granulites of the Dalton Formation. Rocks associated with the micaceous granulites on Canaan Mountain, however, are significantly different from rocks of the Dalton. The lower thrust slice on Canaan Mountain contains tan to gray, strongly foliated, poorly bedded micaceous granulite at the base. This granulite unit contains scattered lenses of amphibolite as much as 15 m thick. Coarse-grained, porphyroblastic biotite-muscovite-garnet-sillimanite-staurolite schist overlies the lower micaceous feldspathic granulite.

The upper thrust slice on Canaan Mountain contains a more varied stratigraphy than either the lower Canaan Mountain slice or the Dalton Formation. The lowermost unit is poorly bedded, strongly foliated, tan-weathering feldspathic and micaceous granulite that contains almond-shaped quartz-muscovite-sillimanite knots. This rock is virtually indistinguishable from parts of the Dalton, but it is overlain by black to dark-gray biotite-hornblende-quartz-plagioclase gneiss that contains white porphyroblasts of albite or sodic oligoclase. This unit also contains some massive amphibolite beds a few metres thick suggesting it originated as a mixture of mafic volcanic flows and pyroclastic deposits. Above the volcanic rocks is a distinctive steel-gray to black coarse-grained muscovite-biotite-quartz-microcline gneiss. This micaceous gneiss is strongly foliated and contains aggregates of coarse-grained muscovite that look like fish scales smeared out in the biotite-rich folia. Above the micaceous gneiss is medium- to coarse-grained garnet-sillimanite-staurolite schist that contains abundant quartz stringers and finely disseminated magnetite. The abundance of magnetite suggests that this gray to tan schist was once a red hematite-rich pelitic sediment. Red plates of hematite are, in fact, trapped in some of the garnets. Above the magnetite-rich schist is a unit of well-bedded tan feldspathic quartzite. This quartzite contains biotite, muscovite, quartz, microcline, and plagioclase much like the Dalton, but the bedding is less distinct, the slabby parting parallel to bedding is missing, and this rock contains considerably less quartz than does the typical feldspathic quartzite in the Dalton.

In general, the feldspathic micaceous granulite in the Canaan Mountain slices closely resembles the granulite in the Dalton, including the muscovite-quartz-sillimanite segregations common to both. In contrast to those of the Dalton, the schists in the Canaan Mountain slices are more aluminous, more iron-rich, and contain abundant thin stringers of quartz. The schist and granulite of the Dalton contain quartz and feldspar segregations, but these segregations tend to be contorted knots studded with black tourmaline. The relatively quartz-rich flaggy-bedded quartzites of the Dalton are missing from the Canaan Mountain sequence, which contains more massive, more feldspathic arenaceous rocks. The amphibolite lenses and pyroclastic rock are missing in the Dalton. The Dalton north of the trip area contains quartz pebble to cobble conglomerate beds, whereas the arenaceous rock in the Canaan Mountain slices are medium- to coarse-grained sand containing no pebble layers. Compared with those of the Dalton, therefore, the rocks of the Canaan Mountain sequence appear to be deeper water deposits laid down east of the carbonate platform within range of volcanic flows and pyroclastic deposits possibly originating from fissures and volcanoes in a marginal basin-island arc setting.

Fold-Thrust Structures in the Precambrian Rocks

In the northwestern part of the South Sandisfield quadrangle, the calc-silicate unit outlines some strongly overturned to recumbent folds which are broken and truncated by generally east-dipping thrust faults. The thrust faults cut the calc-silicate-bearing sequence into a series of imbricate thrust slices so that the lower slices are successively overlapped to the north and east by the next higher slices, much like shingles on a roof. Within each thrust slice, the relatively older rocks tend to be in contact with the thrust fault at the base of the slice and form the cores of westward- or southward-closing anticlines. The relatively younger rocks in the calc-silicate sequence either form the troughs of major overturned synclines or they appear as synclinal digitations on the overturned sheared-out limbs of the recumbent anticlines adjacent to the thrust faults. Within a few tens of metres of the thrust faults is a pronounced cataclastic foliation, described in detail by Ratcliffe and Harwood (1975), that lies parallel to both the axial surfaces of the overturned folds and to the thrust faults. This penetrative cataclastic foliation clearly relates the recumbent folding to the thrusting. The general fold-thrust style of deformation is shown by the composite cross section in figure 3.

Near Higley Hill (fig. 2), the calc-silicate unit outlines the hinge of a major recumbent syncline that contains the Dalton Formation in its trough. The normal limb of this syncline follows the trace of the calc-silicate unit westward to Benton Hill (fig. 2), where successively lower units in the sequence are exposed. On the west slope of Benton Hill (stop 1), biotite-ferrohastingsite granitic gneiss rests on schist and marble of the Walloomsac Formation (Middle Ordovician or younger). The granitic gneiss is in the core of a recumbent anticline in which the lower limb is sheared out along the Benton Hill thrust.

The next higher thrust slice (slice C, fig. 1) truncates the Dalton Formation in the core of the recumbent syncline northwest of Higley Hill and also truncates the Benton Hill thrust west of the town of Southfield. A tectonic sliver of Walloomsac marble is caught between rocks of the Benton Hill thrust slice and intensely sheared biotite-ferrohastingsite at the base of the Harmon Pond slice (slice C, fig. 1) about a kilometre south of the town of Southfield. Within the Harmon Pond slice, the Precambrian rocks are in normal stratigraphic succession; and west of Southfield, the biotite-quartz-plagioclase gneiss forms the trough of a tightly appressed recumbent syncline that flairs out to the southeast into a series of strongly overturned folds. The map pattern east of Harmon Pond (fig. 2) is complex because northwest-trending, westward-overturned folds that formed during the thrusting are superposed on an earlier, probably Precambrian, fold that trends eastward from Harmon Pond.

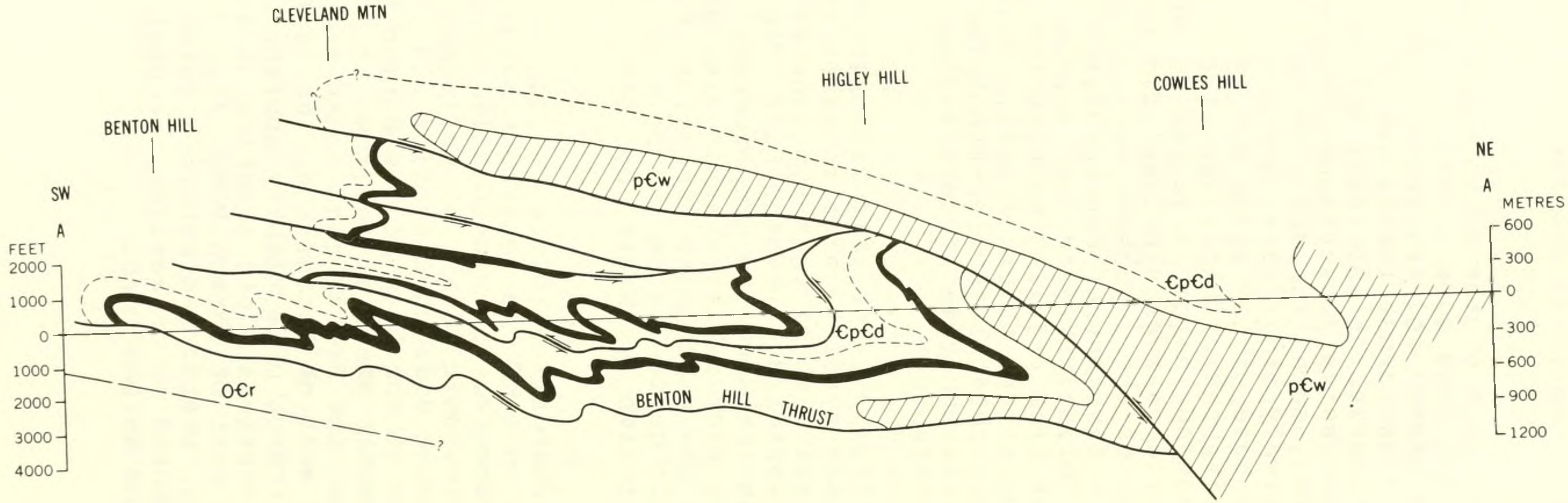

Figure 3. Composite cross section along A-A' (fig. 2) showing fold-thrust structures in the South Sandisfield quadrangle; calc-silicate unit (black); Washington Gneiss (p€w, ruled); dotted line is unconformity below Dalton Formation (€p€d); undivided carbonate platform rocks (O€r).

Between Cook's Ledge and Woodruff Mountain (fig. 2), the calc-silicate unit in thrust slices D and E outlines partial or complete synclinal digitations on the overturned limb of a major recumbent anticline cored by the Washington Gneiss. The form of these synclinal digitations and their relationship to the thrust faults are best shown in the composite cross section (fig. 3).

The total amount of shortening involved in the thrusting and recumbent folding is difficult to determine accurately. An order-of-magnitude estimate of the minimum shortening, however, can be obtained if we assume that the patches of Dalton Formation on Cleveland Mountain, Higley Hill, and Cowles Hill were once part of a continuous blanket of cover rocks resting unconformably above the Precambrian gneisses. The present horizontal distance between the patches of Dalton on Cleveland Mountain and Cowles Hill is about 8 km. The original distance between these two patches of Dalton, measured around the dotted line on figure 3, is about 28 km or a shortening of about 20 km. This amount of shortening does not include the movement on the fault at the base of the Benton Hill slice (slice B) because the eastward extent of carbonate platform rocks beneath that slice is not known. A minimum shortening of 20 km, however, compares very well with the minimum transport distance of about 21 km on the Beartown Mountain slice to the north (Ratcliffe and Harwood, 1975).

Fold-thrust Structures in the Canaan Mountain Rocks

There is not enough lithologic variation in the lower Canaan Mountain thrust slice to determine the geometry of any large-scale fold-thrust structures, if any exist. The repetition and attitude of distinctive lithologic units in the upper slice, however, indicates the presence of large-scale recumbent folds subsequently refolded about northwest- and northeast-trending axial surfaces. A pronounced schistosity lies parallel to the axial surfaces of the recumbent folds and deforms an earlier, less distinct foliation produced by fine-grained muscovite and biotite. Garnet appears to have formed initially during the metamorphism that produced the early foliation and subsequently grew inclusion-free rims during sillimanite-grade metamorphism following the thrusting. Sillimanite and staurolite lie in the fold-thrust fabric and formed by the breakdown of biotite and, to a lesser extent, muscovite. The dominant schistosity becomes a blastomylonitic foliation in the thrust zones.

There are two major recumbent folds in the upper Canaan Mountain thrust slice. The upper fold, shown as the Crissey Pond fold on figure 1, is a northwest-closing anticline with feldspathic, micaceous granulite containing quartz-sillimanite knots much like those in part of the Dalton Formation in its core. The lower fold, the Camp Pond fold on figure 1, is a southeast-closing syncline containing well-bedded, feldspathic and micaceous quartzite in its trough. These major folds are domed upward around the Tobey Pond window (fig. 1), deformed by north-trending folds related to the upthrusting of Precambrian rocks east of Dennis Hill and Spaulding Pond, and are clearly truncated by the

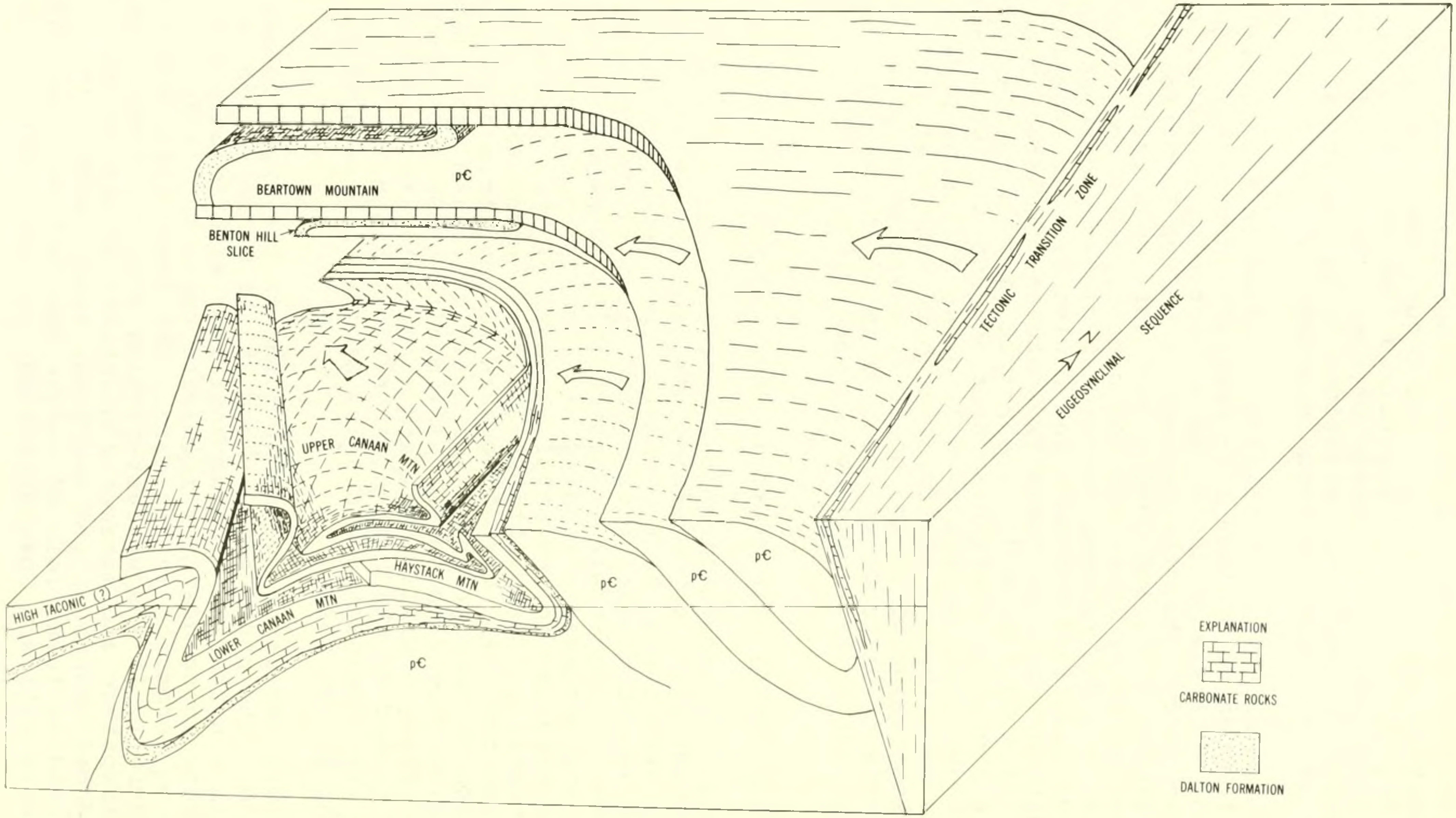

Figure 4. Block diagram showing stacking order of thrust slices and major folds formed during thrusting of Canaan Mountain rocks and Precambrian rocks of the Berkshire massif. Dashed line on front face of diagram approximately locates present erosion level; large arrows show possible directions of tectonic transport.

parautochthonous Waramaug Formation of Gates (1952, 1965) south of the North Pond windows (fig. 1). The period of fold-thrust tectonism, therefore, appears to have progressed through a series of deformational events, all preceding the late northwest- and northeast trending folds that warped the thrust slices.

Speculations on the fold-thrust tectonic events

The structural relations at Stop 9 and those to the west on Canaan Mountain indicate that the Canaan Mountain Schist is in fault contact with the carbonate sequence. Major fold-thrust structures in the upper Canaan Mountain thrust slice are truncated to the south by the Waramaug Formation. The lithologic similarity between units in the Canaan Mountain Schist and parts of the Dalton, Waramaug, Hoosac, and possibly the Everett and Rowe suggest that the Canaan Mountain rocks were originally part of the eugeosynclinal sequence deposited east of the Berkshire massif. I conclude that the Canaan Mountain rocks are allochthonous and probably part of the Taconic allochthon.

On Canaan Mountain, the recumbent folds related to the fold-thrust deformation are overturned to the northwest, whereas similar recumbent folds outlined by the calc-silicate unit in the Precambrian rocks are overturned to the west and southwest. Although no slip line directions have been determined for any of these folds, the direction of overturning and the significantly different stacking directions to the north and south suggest that the Canaan Mountain slices were transported from the southeast and that the Precambrian slices moved from the east.

The eastern part of the Canaan Mountain fold-thrust structures are refolded into a north-trending, westward-overturned synform against the upthrust Precambrian block to the east. The Canaan Mountain slices and the Haystack Mountain slice had to be emplaced before upthrusting of the Precambrian rocks. The geometry of the refolded Canaan Mountain slices and their relationship to the Precambrian rocks are shown in figure 4.

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Road Log for Trip B2 (Sat.) and C2 (Sun.)

Mileage

0 Trip starts in the parking lot of the Monument Mountain Regional High School and proceeds south through the Great Barrington, Ashley Falls, South Sandisfield, and Norfolk quadrangles.

Leave the parking lot and turn left on route 7.

0.2 Turn left on Monument Valley Road.

4.9 Cross route 23 - continue south on Lake Buel Road.

7.5 Turn right on Great Barrington Road.

9.3 Junction Mill River - Sheffield Road on right - continue south on Great Barrington Road to Mill River.

11.0 Town of Mill River. Turn left and follow Mill River Road uphill.

11.8 Four-way junction. Keep to the right and follow Hadsell Street.

12.6 Bridge-road junction. Cross bridge and turn right on Canaan-Southfield Road.

14.1 Turn left on Cross Road (dirt) and proceed uphill.

14.7 STOP 1. West slope of Benton Hill (Ashley Falls quad.). These outcrops have been graciously loaned to me by N. M. Ratcliffe and H. R. Burger who mapped the Ashley Falls quadrangle. Outcrops beside the road are tan-weathering micaceous marble, the lowermost unit of the Walloomsac Formation. Follow trail uphill to ledges and blocky talus of black biotite-splotched schist containing abundant quartz stringers, a few calcareous feldspathic quartzite beds, and scattered quartz-feldspar pods. This is the black slate member of the Walloomsac at sillimanite grade. Note the early asymmetrical folds overturned to the west; pronounced axial-plane schistosity strikes north and dips gently east. Later crenulation cleavage strikes about N.15°E. and is nearly vertical. Carefully continue uphill over scattered outcrops of the pelitic unit of the Walloomsac across a small swale to the ledge of biotite-ferrohastingsite granite gneiss. The granite gneiss is very similar to and probably akin to the Tyringham Gneiss dated at 1.06 b.y. (Ratcliffe and Zartman, 1971). The rock is normally a strongly foliated, pinkish-gray, coarse-grained, porphyritic granite gneiss. Here, a few metres above the Benton Hill thrust, the granite gneiss is strongly crushed and crossed by gently east-dipping dark gray to black zones of blastomylonite and an anastomosing cataclastic foliation described in detail by Ratcliffe and Harwood (1975). Remnants of the Precambrian foliation are preserved in the blastomylonite zones. Proceed north along the base of the granite gneiss ledges to the point where the contact between the Walloomsac marble and the granitic gneiss is exposed in a tight isoclinal upright fold. Note the idocrase at the contact and the fine grain size of the granitic gneiss. There is a strongly overturned fold outlined by pegmatic material in the granite gneiss in the ledges above the contact.

Retrace the route back to the cars. Turn the cars around and proceed west on Cross Road.

15.4 Turn right on Canaan-Southfield Road.

16.8 Junction of milestone 12.6 - continue east on Canaan-Southfield Road. DO NOT CROSS BRIDGE.

17.7 Four-way intersection--red house as landmark in the northwest quadrant. Continue east on Canaan-Southfield Road.

18.0 Turn right on Foley Hill Road. Sign to Xmas Tree Farm. Proceed uphill on dirt road.

19.2 Gate to YMCA camp on left; enter and park. There is a short hike to STOP 2.

There are scattered pavement outcrops of calc-silicate rock where the cars are parked; better exposures follow. Walk east (downhill) to the north end of Harmon Pond; cross the outlet stream and walk north about 100 m to outcrops of hornblende-biotite gneiss. The thrust fault is in the brook. Note gently east-dipping cataclastic foliation and the small scale westward-overturned folds sheared out along their overturned limbs. Within the cataclastic foliation are several detached fishhook-shaped folds outlined by the Precambrian foliation. Retrace the path to Harmon Pond and continue walking east along the water's edge. A variety of calc-silicate rocks are well exposed on the low hills east of the pond. They include white microcline gneiss spotted with coarse diopside and sphene, massive layers of garnet, diopside-garnet-quartz-microcline gneiss, and diopside-calcite-quartz marble pods.

Retrace the trail back to the cars. Turn the cars around and proceed down Foley Hill Road to the junction with Canaan-Southfield Road.

20.4 Turn right (east) on Canaan-Southfield Road.

21.0 Dirt road spurs off to the right - continue on paved road.

21.3 Junction with route 272 in the town of Southfield. Turn right and park the cars on the side of the road.

STOP 3 - CAUTION - The talus blocks are treacherous and parts of the overhanging ledges are metastable at best. Outcrops on the east side of the road are black and white hornblende-biotite gneiss in fault contact with the calc-silicate rock, which is exposed in a few places along the base of the ledge. Prominent features to note here are the recumbent folds in the black and white gneiss, the thin zones of cataclasis and granulation, minor fault surfaces with quartz stringers and slickensides and the late north-trending upright folds that deform the fold-thrust structures. At the eastern end of the ledge, layering in the gneiss outlines the hinge of a major recumbent fold that has been sheared out along the thrust fault.

Return to the cars and continue south on route 272.

24.9 Turn right (west) on dirt road to Campbell Falls. Massachusetts-Connecticut State line is landmark.

25.4 STOP 4 - LUNCH - Campbell Falls. Thin-bedded feldspathic quartzite containing muscovite-rich partings holds up the falls and is flanked to the west by coarse biotite-muscovite-sillimanite schist. Both rock types are in the Dalton Formation. The feldspathic quartzite beds outline the hinge of a late postthrusting anticline in which the axial surface dips steeply east and the axis plunges about 20°S. At the base of the falls the river has exposed a bedding surface on the hinge of the fold that contains abundant tourmaline needles. These tourmaline needles define an early lineation, possibly formed during thrusting, that was refolded into a helical pattern by the late anticline. It is left as an exercise for the interested student to gather and plot the tourmaline lineation data. Also at the base of the falls is an exposure of micaceous granulite which contains almond-shaped white quartz-sillimanite-muscovite knots; the pseudo-pebbles discussed by Emerson (1899, p. 67).

Return to the cars and continue west on Campbell Falls Road.

26.8 Junction with Canaan Valley Road - cross bridge.

26.9 Turn left (south) on Canaan Valley Road.

27.4 Junction Cross Road - continue south.

27.6 Turn left (east) on Toby Hill Road.

27.7 Junction - take left fork - uphill.

28.7 Pass Yale Farm on the right.

29.3 STOP 5. We are about a quarter of a mile south of Campbell Falls, still in the Dalton Formation and very close to the contact with the underlying Precambrian gneiss. The contact is not exposed here, but it is inferred to be a thrust fault from regional relationships. Micaceous granulite with abundant quartz-sillimanite knots contains a thin sill of two-mica granite that is essentially parallel to the early foliation in the Dalton. The granite sill and the early foliation are folded into a westward-overturned syncline that has the fold-thrust fabric as its axial surface. The quartz-sillimanite knots are parallel to the early foliation on the limbs of the syncline and become progressively deformed into sigmoids and are eventually flattened in the plane of the fold-thrust fabric near the axial surface of the syncline. Microscopically, the knots are aggregates of strained quartz surrounded by wisps of sillimanite replacing biotite. Large muscovite flakes at the edges of the knots are deformed and crossed by streaks of sillimanite. The groundmass is largel microcline, quartz, and biotite. The textures indicate that the knots, the sill, and the early foliation were present in the rock before the fold-thrust event. The age of the sillimanite with respect to the thrusting is not clearcut; the sillimanite appears to have formed from the breakdown of biotite either during or after thrusting.

Return to the cars and continue east on Toby Hill Road.

29.7 Turn right (south) on route 272.

33.9 Junction of routes 272 and 44 in Norfolk, Connecticut - continue south.

34.2 Junction of routes 44 and 72 - proceed south on route 72.

34.4 Turn right (west) on Mountain Road in Norfolk village.

34.5 Turn right onto grounds of Yale Music School and park by the large concert hall.

STOP 6 - Tan to gray strongly foliated feldspathic, micaceous granulite at the base of the lower thrust slice on Canaan Mountain. The granulite grades upward into garnet-sillimanite schist. The purpose of this stop is to compare the arenaceous and pelitic rocks of the Canaan Mountain sequence with those of the Dalton Formation seen at stops 4 and 5.

Return to Mountain Road and turn right (west).

34.9 Turn right on Westside Road.

36.7 STOP 7 - Tan, feldspathic, and micaceous granulite in the lower Canaan Mountain thrust slice. Compare this pseudoconglomeratic granulite with that of the Dalton seen at stop 5.

37.8 Turn right (south) on route 72.

38.1 Enter Dennis Hill State Park and proceed to the pavilion on top of Dennis Hill.

STOP 8 - Steel-gray, muscovite-rich, biotite-quartz-microcline gneiss that forms a widespread unit in the upper Canaan Mountain thrust slice. In the service road east of the pavilion, the gneiss is intruded by a mafic dike, one of several in this zone of faulting near the contact with the Precambrian rocks, composed of diopside-garnet-hornblende-biotite-sodic plagioclase-quartz-magnetite and possibly ilmenite. Garnet is completely rimmed by quartz and plagioclase, and diopside and plagioclase are intergrown in a symplectite texture. The present mineralogy is peculiar for a mafic intrusive; the textures suggest the rock was originally composed largely of garnet and omphacite and thus was an eclogite. The jadeitic component of the omphacite is now present as sodic plagioclase intergrown with the diopside component.

Return to route 72 and proceed north toward Norfolk.

38.7 Turn right toward Lake Winchester and Winsted.

39.2 STOP 9 - Park on the side of the road and hike about 0.5 mile north to the steep hills at the south end of Spaulding Pond. The cars are parked on a narrow body of granite which intrudes rocks of the upper Canaan Mountain thrust slice. On the hike to stop 9, we will cross over hornblende-plagioclase gneiss also intruded by several small dikes of granite and see the Dalton Formation, about 1 m of relatively clean quartzite that may represent the Cheshire Quartzite, and about 1.5 m of coarse-grained white dolostone that is part of unit a of the Stockbridge Formation. These rocks of the carbonate platform sequence are intensely folded about north-trending axes and plunge northward beneath black and white hornblende-biotite gneiss. The Stockbridge is in obvious fault contact with strongly foliated feldspathic, micaceous granulite like that in the lower Canaan Mountain thrust slice seen at stop 6. Fine- to medium-grained two-mica granite forms north-trending dikes in the fault zones. The map pattern indicates that the carbonate platform sequence is caught in the heel of a north-trending, north-plunging, westward-overturned syncline capped by the trailing edge of the lower Canaan Mountain thrust slice. Vertical faulting cut the heel of

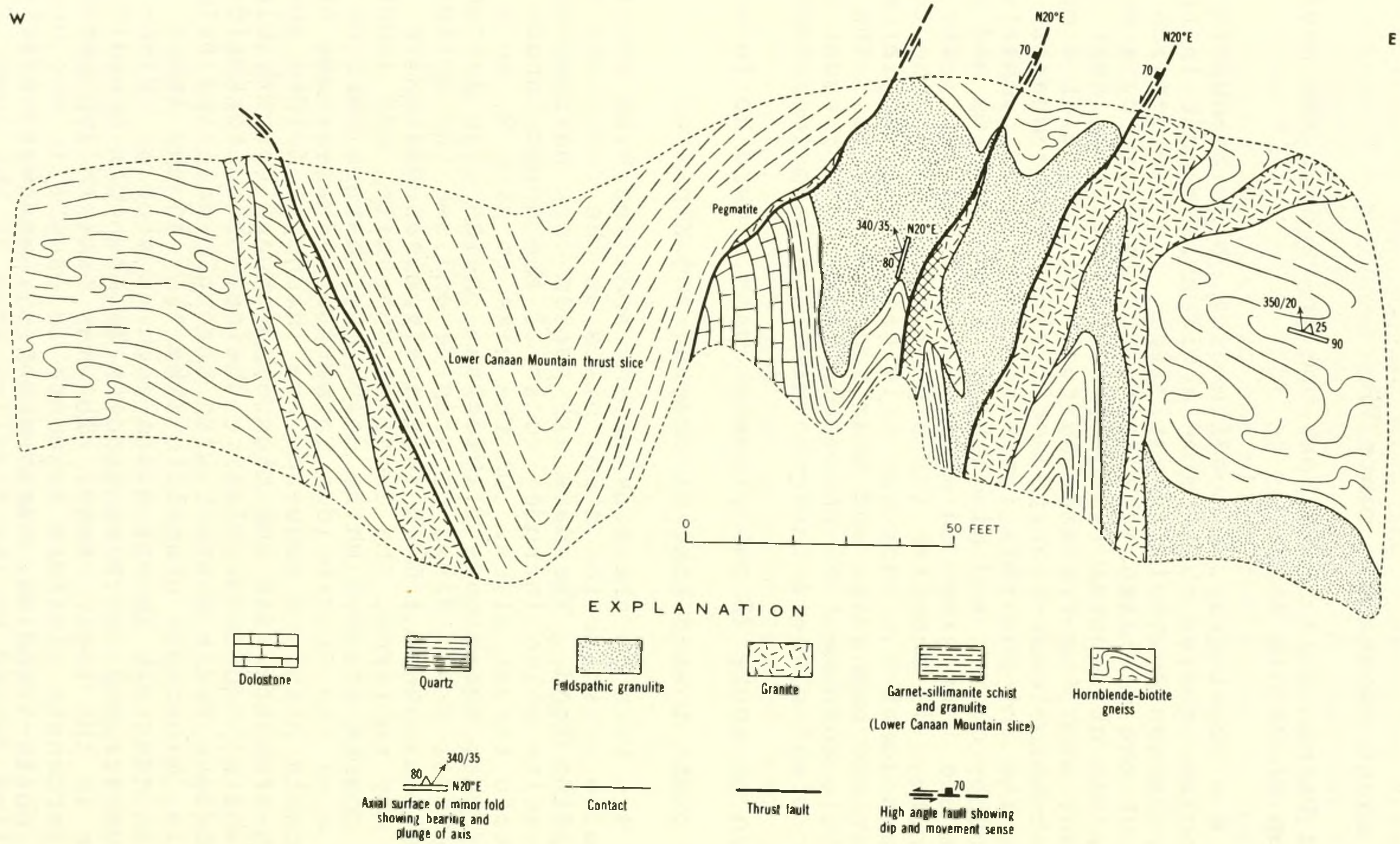

Figure 5. Sketch of near vertical ledge at stop 9 (south of Spaulding Pond; Norfolk quadrangle) showing fault contact between lower Canaan Mountain thrust slice and dolostone of the Stockbridge Formation. "Quartz" in the explanation should read quartzite.

the syncline after the thrusting and granite intruded along the vertical faults. The pattern of map units is shown in figure 5.

Return to the cars - retrace the route to highway 72 - turn north (right) to Norfolk.

The best way to get to Great Barrington is route 44 from Norfolk to Canaan and then north on route 7