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Stratigraphic and structural relationships along the east side of the Berkshire massif, Massachusetts

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TRIP B-4 (Sat.) and C-4 (Sun.)

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Introduction

The purpose of this trip is to examine the evidence for: (1) polyphase deformation and metamorphism of Precambrian and Lower Cambrian rocks at the north end of the Berkshire massif and southward for 30 miles along the east side; and (2) premetamorphic thrust faults which have produced an interlayering of Lower Cambrian schists and Precambrian gneisses and plutons.

Stratigraphy

Gneisses of the Berkshire massif are composed dominantly of quartz, plagioclase, and microcline[1] and accessory amounts of garnet, various amphiboles, biotite, or rare muscovite. Metapelites, quartzite, calc-silicate gneiss, and marble are subordinate regionally but locally are common. Openly to tightly folded thrust slices make regional correlation of less distinctive lithologies difficult. All these rocks are believed to be Precambrian in age. Whole-rock Rb/Sr ages on the gneisses (Brookins and Norton, 1975) suggest an age of about 1.1 b.y. These lithologies are intruded by igneous rocks of two separate ages, 0.9 and 0.6 b.y. (Brookins and Norton, 1975).

At the north end of and along the east side of the massif (Fig. 1), the Precambrian rocks are in contact with aluminous rocks of the Hoosac Formation of Early Cambrian or older age. The detailed stratigraphy has been discussed by Norton (in press). The rocks range from quartz-albite-muscovite-chlorite (or biotite at higher grade) to quartz-muscovite-garnet (+ staurolite, kyanite, and sillimanite) schist.

The foliation of the rocks of the massif and the Hoosac schists is nearly everywhere parallel at their mutual contact. This has led some workers to interpret the contact as depositional (Gates et al., 1973). Emerson (1898) interpreted part of the "Becket Granite Gneiss" at the base of the Hoosac as a conglomerate, the contact between the two formations being a profound unconformity. These rocks have been reinterpreted as pre- and synmetamorphic tectonic breccias and mylonites by Norton (1975). The contact between the Precambrian rocks (Brookins and Norton, 1975) and the Lower Cambrian or older Hoosac rocks along the entire eastern margin of the

[1]Minerals are listed in approximate order of decreasing abundance

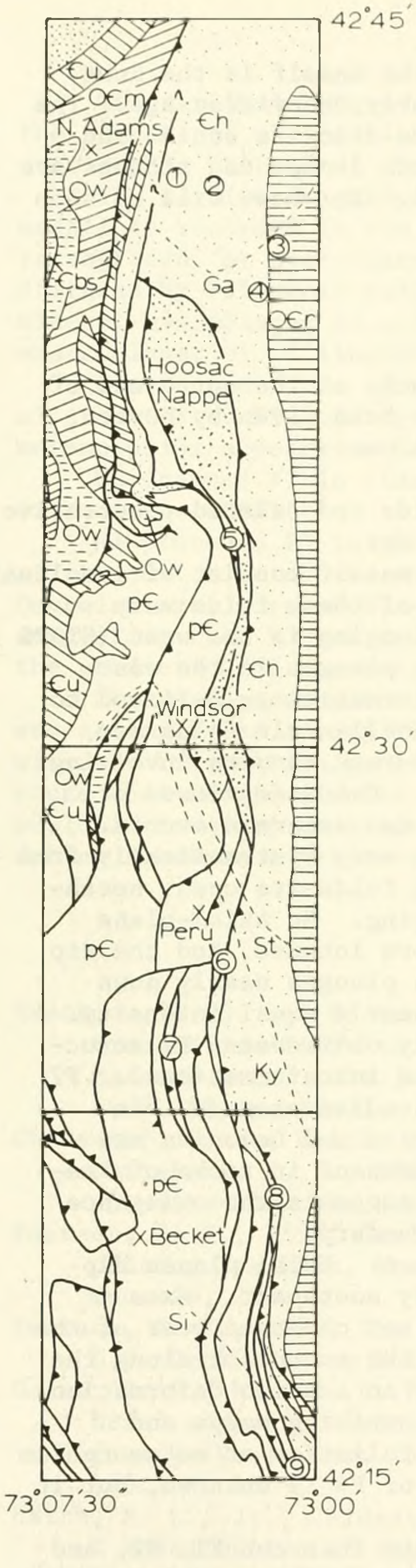

Figure 1: Geologic map of the east margin of the Berkshire massif, Massachusetts. (Geology of the North Adams quadrangle generalized from Herz, 1961.)

massif is interpreted to be a premetamorphic fault.

Directly overlying the Hoosac to the east of the massif is the Rowe Schist (Hatch et al., 1966) of Early Cambrian to Early Ordovician age. The Rowe consists primarily of unbedded quartz-muscovite-chlorite schist and accessory garnet, magnetite, and plagioclase. Quartz lenses and ribbons are common. The contact with the Hoosac is gradational. The Rowe will be seen only at STOP 3.

Structure

At least six deformations have affected the rocks at the north end of the Berkshire massif. Details of these events have been given by Norton (1975). Briefly, the different episodes are as follows:

F0: This deformation is evidenced by isoclinal folds and related penetrative foliation, found only in rocks of Precambrian age.

F1: The dominant structures west and north of the massif consist of isoclinal folds and axial-plane schistosity. Attitudes of these folds vary systematically from recumbent, gently north-plunging in the west (STOPS 1 and 2) to steeply east-dipping with variable plunges in the east (STOPS 3, 4, 6, 8 and 9). The age of this deformation is believed to be Ordovician. Concurrent with formation of small-scale folds are large-scale recumbent folds and soft- and hard-rock thrusts involving Paleozoic and Precambrian rocks, respectively. Evidence viewed at STOPS 1 and 2 suggests that F1 may consist of two separate events.

F2: The intensity and orientation of F2 structures vary systematically from west to east. On the west (STOPS 1 and 2), F2 folds are open, north-striking, 45° east-dipping and shallowly plunging. No axial-plane foliation has formed. Eastward, F2 becomes more intense, and the dip of foliation steepens to nearly vertical, with plunges nearly down the dip. At STOPS 3 and 4, F1 and F2 are of nearly equal intensity. Southward, F2 is more intense than and commonly obliterates F1 structures. However, all F2 structures appear to be intraformational. F2 deformation is believed to be related to the Acadian orogeny. An episode of recumbent folding in rocks of Silurian and Devonian age (Osberg, 1975) which is older than F2 is not present in rocks of Precambrian, Cambrian, and Ordovician age. This suggests the existence of a décollement at the Ordovician-Silurian boundary.

F3: F3 folds are open to closed and strike northeast. Axial planes dip steeply northwest, are vertical, or dip steeply southeast. Axes plunge generally northeast. These folds are not observed west of the axis of the massif and become more intense to the southeast along the east side of the massif. F3 is believed to be an Acadian deformation.

F4: F4 is characterized by the formation of north-striking warps and crinkles on F1 and F2 foliation surfaces. No foliation or metamorphism is associated with this deformation. The age of F4 is unknown, but it probably is Devonian to Triassic in age.

F5: Rarely one observes small postmetamorphic faults that cut F1, F2, and F3 structures. F5 probably postdates F4 and may be Triassic in age.

Metamorphism

The regional isograds are shown on Fig. 1. These isograds integrate the effects of at least three Paleozoic events (M1, M2, M3). Details of the metamorphic history of the area are given by Norton (1975).

The earliest recorded metamorphic event (M0) at the north end of the massif is recorded in the Precambrian rocks, which have not been severely retrograded, or overprinted with a high-grade Paleozoic event, or reconstituted by Paleozoic folding and premetamorphic faulting. Textures and mineral assemblages in calcareous gneisses and metapelites suggest that M0 was at least of sillimanite grade.

M1 spanned F1 in time. The thermal peak (garnet grade) occurred slightly after F1 folding and faulting. The locus of the most intense M1 metamorphism appears to be west of the axis of the massif.

M2 spanned F2 in time, with a thermal peak at garnet grade east of the axis of the massif.

M3 preceded F3 in the area nearest to the Precambrian-Cambrian contact at the east side of the massif. Further east, in rocks of Silurian and Devonian age, porphyroblasts of kyanite and staurolite crosscut F3 foliation suggesting that M3 was time transgressive to the east. Within the Hoosac, the production of staurolite and kyanite appears to be an M3 event.

The retrograde metamorphism of the Precambrian gneisses most probably was accomplished during M1. No Silurian and Devonian rocks are in contact with the Precambrian gneisses. Consequently, the Cambrian and Ordovician rocks that provided water for the retrogression of the gneisses during M1 would in turn act as a sink for infiltration of water from younger rocks during subsequent metamorphisms.

References Cited

Brookins, D. G. and Norton, S. A., 1975, Rb/Sr whole rock ages along the Precambrian-Cambrian contact, east side of the Berkshire massif, Massachusetts [abs.]: Geol. Soc. America, Abstracts with Programs, v. 7, #1, p. 30-31.

Chidester, A. H., Hatch, N. L., Jr., Osberg, P. H., Norton, S. A., and Hartshorn, J. H., 1967, Geologic map of the Rowe quadrangle, Massachusetts-Vermont: U.S. Geol. Survey Geol. Quad. Map GQ-642.

Emerson, B. K., 1898, Geology of Old Hampshire County, Massachusetts, comprising Franklin, Hampshire, and Hampden Counties: U.S. Geol. Survey Mon. 29, 790 p.

Emerson, B. K., 1899, The geology of Eastern Berkshire County, Massachusetts: U.S. Geol. Survey Bull. 159, 139 p.

Gates, R. M., Martin, C. W., and Schnabel, R. W., 1973, The Cambrian-Precambrian contact in northwestern Connecticut and west-central Massachusetts [abs.]: Geol. Soc. America, Abstracts with Programs, v. 5, no. 3, p. 165.

Hatch, N. L., Jr., Chidester, A. H., Osberg, P. H., and Norton, S. A., 1966, A redefinition of the Rowe Schist in northwestern Massachusetts: U.S. Geol. Survey Bull. 1244-A, p. A23-A35.

Herz, Norman, 1961, Bedrock geology of the North Adams quadrangle, Massachusetts-Vermont: U.S. Geol. Survey Geol. Quad, Map GQ-139.

Norton, S. A., 1975a, Chronology of Paleozoic tectonic and thermal metamorphic events in Precambrian, Cambrian, and Ordovician rocks at the north end of the Berkshire massif, Massachusetts: U.S. Geol. Survey Prof. Paper 888-B, p. 20-31, in press.

Norton, S. A., 1975b, The Hoosac Formation (Lower Cambrian or older) on the east limb of the Berkshire massif, western Massachusetts: U.S. Geol. Survey Prof. Paper 888.

Osberg, P. H., 1975, Recumbent folding of the Goshen and Waits River Formations, western Massachusetts: U.S. Geol. Survey Prof. Paper 888 , p. .

Pumpelly, Raphael, Wolff, J. E., and Dale, T. N., 1894, Geology of the Green Mountains in Massachusetts: U.S. Geol. Survey Mon. 23, 192 p.

Raybould, J. G., 1975, Tectonic control on the formation of some fibrous quartz veins, mid-Wales: Geol. Mag., v. 112, p. 81-90.

Road Log

Outcrops will be visited in the North Adams (Herz, 1961), Windsor, Peru, and Becket quadrangles, Massachusetts (1:24,000). The road log begins at the entrance of the Monument Mountain High School, Great Barrington, Massachusetts. The total mileage is 111 miles. Gas up before the trip.

00.0	Start of trip. Allow 1 hour for travel to assembly point in North Adams. Proceed north on Route 7. Departure from North Adams will be at 8:30 a.m. on Saturday. Sunday trip departs from the Monument Mountain High School parking lot at 7:30 a.m.
02.4	Stockbridge. Turn right on Route 7.
04.1	Pass under Massachusetts Turnpike.
15.5	Pittsfield center. Turn right. Follow signs for Route 7 and 9.
15.7	Left on Route 7 and 9.
16.4	Right on Route 9.
17.1	Bear left on Route 9.
18.9	Left on Route 8 by "MacDonalds".
22.3	Cheshire town line (type locality for the Cheshire Quartzite). View of Taconic Klippe on Cambrian and Ordovician carbonate rocks.
26.2	Cheshire center.
31.2	Intersection of Route 8 and 116. Continue on Route 8 (many gravel pits from Cheshire to North Adams are in kames).
34.5	Turn right on Route 8A (poorly marked). Hill directly ahead has, in inverted stratigraphic order, Hoosac Formation on Dalton Formation on Cheshire Quartzite at the base of the hill. The first bench is a kame terrace, which can be traced for 6 miles.
37.6	Intersection in North Adams. Turn right on Main Street (Route 8A signs have disappeared).
37.7	Turn left on Church Street by monument.
37.8	Turn right on Routes 2 and 8.
38.5	Fork right on Route 2.
39.6	View of west side of the Hoosac Range. "Flat-lying" but overturned Dalton Formation at base, Hoosac Formation above. The

regional strike is parallel to the ridge.

39.8 Power line - reassemble. Reset mileage to 00.0.

00.0 Start

00.4 Outcrop of gently west-dipping Dalton Formation overlain (not visible) by Hoosac Formation.

01.6 Hairpin turn. Continuous outcrop of Hoosac Formation for next mile.

02.3 STOP 1: Pull off to right in parking area. Be careful of traffic!

Rocks typical of the Hoosac Formation are exposed continuously for about a mile on the east side of the road. The dominant lithology is a quartz-albite-muscovite-biotite ± chlorite schist. Albite is typically porphyroblastic and black, containing appreciable amounts of graphite inclusions. The garnet isograd is an unknown distance to the southeast (three miles at the most). A few tan to gray fine-grained quartzite beds are very discontinuous. Many ribbons and lenses of white vein (?) quartz outline what appear to be recumbent isoclinal folds (F1) which plunge gently to the north. Small-scale kink folds (F2) without associated foliation are rarely present. More commonly, small faults have formed parallel to the north-striking axial planes of F2 folds. Axial surfaces dip about 45°E. Axes are subhorizontal. These faults commonly are marked by vein quartz. The quartz ribbons outlining F1 folds are interpreted to have formed early in F1 and were followed by the formation of a penetrative axial surface schistosity and refolding of the ribbons (see Raybould, 1975, for a supporting argument).

Continue east on Route 2.

02.5 Lookout. Taconic klippe to the west underlain in the valley by Cambrian and Ordovician carbonate rocks.

03.1 STOP 2: Park on right shoulder of Route 2. Be careful of traffic! Outcrop is on north side of road opposite "Bob's Variety Store". NO HAMMERS PLEASE!

The lithology exposed here is atypical of the Hoosac Formation. It has considerably less muscovite and ferromagnesian minerals than normal. Typical assemblages are quartz-albite-muscovite-biotite ± chlorite ± magnetite. The typical porphyroblastic albite is present. The well-displayed compositional banding in the sandier lithologies suggests bedding, and a graded bed or two are present. F1 isoclinal recumbent folds are outlined by quartz lenses and ribbons. F2 folds are conspicuous, commonly having an axial surface cleavage and axial surface quartz veins. The orientation of F2 structures is similar to that at STOP 1.

Continue east on Route 2.

04.8 Outcrop on left of Hoosac Formation, continuous outcrop for 0.2 miles to

05.0 Rowe Schist. Whitcomb Summit. Within this outcrop, F1 and F2 are nearly equal in intensity. F3 and F4 folds are unsystematic and cannot be differentiated with certainty. F1 foliation gets progressively steeper to the east. Here F2 axial surfaces dip about 60°E. To the east, across the Deerfield Valley one can see the Bear Swamp pumped storage facility which is entirely within the Hoosac Formation (Chidester et al., 1967).

05.9 Pass over the Hoosac Tunnel (1,000 feet below) (see Pumpelly et al., 1894, for the geology of the tunnel). All outcrops from Whitcomb Summit to STOP 3 are in the Rowe Schist.

06.3 STOP 3: "Eastern Summit." Park on right shoulder of the road in front of cabins. Pavement outcrop between road and cabins.

The typical Rowe Schist exposed here is a quartz-muscovite-chlorite schist and accessory magnetite and rare garnet. Here, F1 and F2 foliations (the latter is most commonly a shear foliation in this area) are about equally developed. The intersection of the nearly parallel foliations produces an anastomosing fabric that gives the rock a rhombic patterned surface. F3 kink folds are present locally. Pleistocene features include well-developed glacial grooves and striations which are parallel to the topographic contours and the regional ice-movement direction. Additionally there are striations more or less parallel to the slope. Five suggestions are offered for their origin (take your choice):

(1) Downhill creep of till.
(2) Multiple glaciation.
(3) Ice disintegration flowlines perpendicular to the slope (T. Hughes, personal communication, 1975).
(4) Man's activities.
(5) All of the above (D.S. Harwood, personal communication, 1975).

Continue east on Route 2.

06.6 Turn right on Church Road (you are now in Florida!).

07.4 Turn right on South County Road.

08.0 STOP 4: Pavement outcrop on the north side of the road and outcrops to the northeast. Sign points to foot trail to Whitcomb Summit. NO HAMMERS PLEASE! (This outcrop may be omitted if the group is large or if we are running behind schedule).

The outcrop is near the top of the Hoosac Formation. The rock is a quartz-albite-muscovite-chlorite ± magnetite schist. Near the

road, the intersection of F1 and F2 foliations give the same anastomosing texture seen at STOP 3. In the woods at the north end of the outcrop is a small, postmetamorphic open upright fold interpreted to be F4. F3 folds are rare in the pavement outcrop but common in the outcrop about 150 feet to the northeast (also in the Hoosac).

Continue west on South County Road.

09.4 Turn left on Savoy Road (becomes New State Road). You are now within the Stamford Granite Gneiss of Herz (1961). All exposures between this point and STOP 5 are in this unit.

12.3 Keep left; Burnett Road forks right.

13.8 Turn left on Adams Road.

14.0 Turn right (Savoy Center) on Center Road.

16.9 Intersection with Route 116. Turn right.

17.1 Cross Savoy Hollow Brook, start of long road cut.

STOP 5: Roadcut on both sides of Route 116. Pull well to right.

(This outcrop is known privately as the type locality of the "Cuddly Bunny Formation").

The easternmost part of the outcrop consists of about 50 feet of cataclastic microcline augen gneiss. This rock is equivalent to the Stamford Granite Gneiss mapped by Herz (1961) in the southern part of the North Adams quadrangle and may be equivalent to the type Stamford. The contact with the Hoosac to the east is interpreted to be a premetamorphic fault zone (F1). West of the augen gneiss is a section of plagioclase-quartz-biotite gneisses, locally folded and faulted by postmetamorphic movement (F3?) (F5?). Garnetiferous schist of the Hoosac Formation is present in the middle of the roadcut. The septum, bounded on both sides by mylonite, may be traced northward and westward along the margin of one of the major thrust slices. Further west in the roadcut are well developed breccias and mylonites in Precambrian gneiss (Figs. 2 and 3).

Continue west on Route 116.

17.3 Left on Route 8A.

21.8 Intersection with Route 9. Turn left.

21.9 Turn right on Peru Road, just before school.

22.4 Bear left.

Figure 2: Pseudoconglomerate formed by the partial transposition of compositional banding (FO) in Precambrian gneisses by F1 faulting. STOP 5: Scale is 7 inches long.

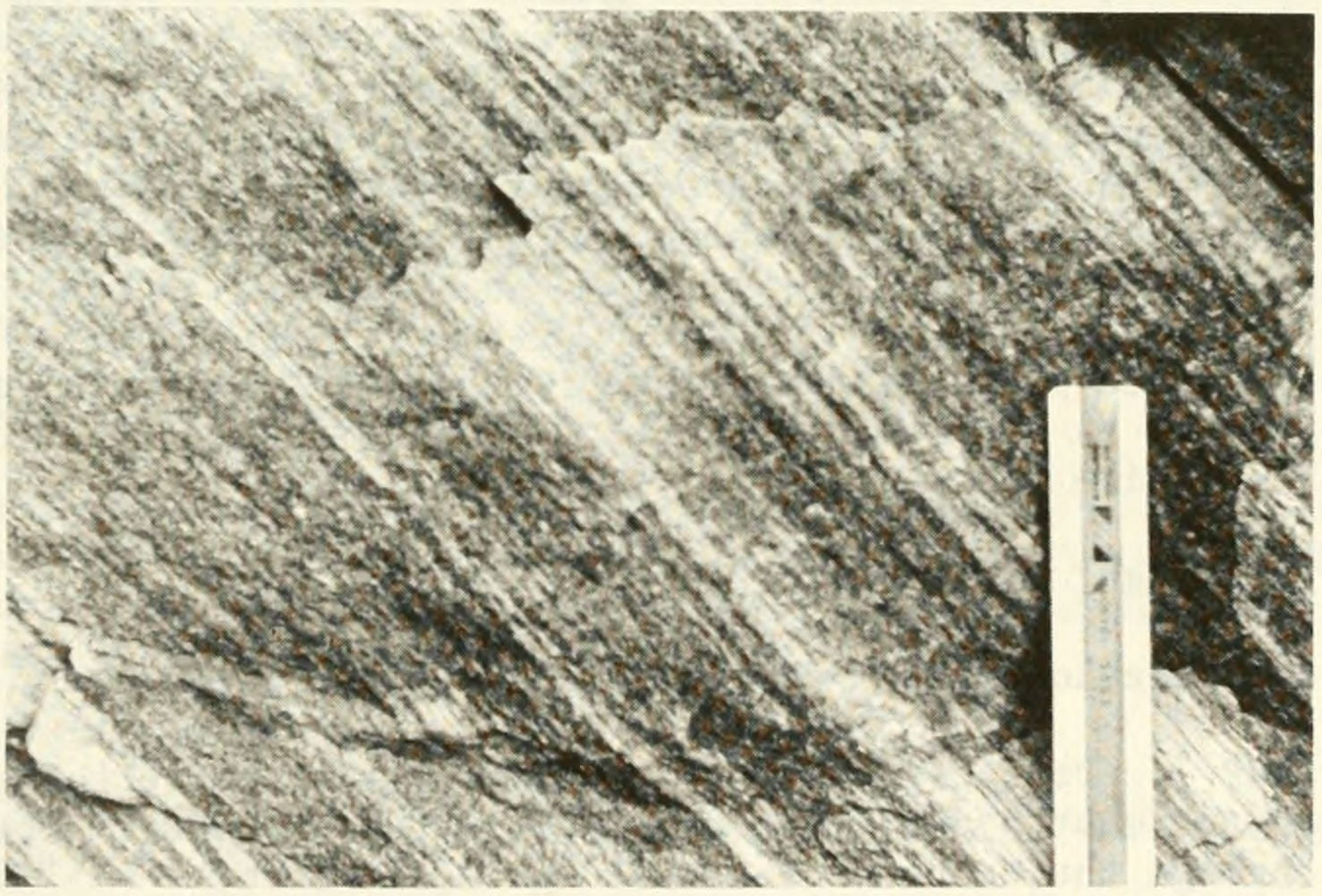

Figure 3: Mylonite formed within the gneiss near the Precambrian gneiss-Hoosac contact. STOP 5: Scale is 7 inches long.

24.5 Pass under powerline. Crop to east (left) of road is Hoosac schist within the Precambrian terrane.

25.0 Town line. Entering Peru. Road becomes Beauman Road.

26.1 Turn right on West Windsor Road.

26.5 Bear right.

28.0 Bear left on dirt road (North Road).

29.2 Route 143. Peru Center. Continue south across Route 143 on South Road.

30.0 Left at "T" junction.

30.2 Entrance to Dorothy Francis Rice Wildlife Sanctuary. Continue east on dirt road.

30.6 Parking area for visitors.

STOP 6: Park in field just before visitors' information center. Walk east on footpath, through swale, cross the wall, and stop at the cliffs on the north side of the trail -- about 1/4 mile from the information center.

Note the NE. strike (and NW. dip) of the Precambrian gneiss as you walk in. At the contact of the Precambrian gneiss with the Hoosac Formation, the gneiss is reoriented by folding and cataclasis so as to parallel the foliation within the Hoosac. Near the south end of the outcrop is slight angularity between the schist and gneiss. The gneiss is composed dominantly of quartz + plagioclase + microcline + biotite. The Hoosac is a quartz-albite-muscovite-biotite schist. F1 and F2 are indistinguishable here. One thin tectonic sliver of gneiss is found within the schist. F3 structures are well developed. They occur as open folds in the schist and pass into quartz-filled fractures in the gneiss.

31.0 Return to paved road and turn left (south) on South Road.

31.6 Phone line crossing.

32.0 Turn right on South Road.

32.5 Intersection with Middlefield Road. Turn left.

33.1 STOP 7: Pull off to the right shoulder opposite the green house on the east side of the road (The SKY LINE CLUB). Traverse through the woods to the west for 1,500 feet.

Several lithologic variations of Precambrian gneiss are present. From 1,000 feet to 1,500 feet, we will pass through a zone of

extensive brecciation and mylonitization with a few septa of schist, interpreted to be Hoosac schist. This particular zone has been followed for about 10 miles to the south. The zone generally parallels the Precambrian-Hoosac boundary at the east margin of the massif but locally truncates Precambrian stratigraphic units.

Continue south on Middlefield Road.

34.0 Town line. You are now in Middlefield on Main Road.

34.1 Prominent ridge on left is capped by the lower units of the Hoosac. The Precambrian-Cambrian contact is at the break in slope at the base of the ridge.

37.9 Town Hill Road to right, Middlefield Center.

STOP 8: Pull off to right opposite Mobil Station. Traverse will start just south of the town hall where low outcrops of well-banded contorted gneiss (interpreted to be Precambrian) are exposed. This band of gneiss noses out within 500 feet to the north but widens to more than 200 feet within 1,000 feet to the south. The contacts between the gneiss and bounding schist are razor sharp. Walking westward, one goes through a highly aluminous quartz-muscovite-garnet-biotite-staurolite ± kyanite schist, typical schist of the bulk of the Hoosac (quartz-muscovite-garnet-biotite), more aluminous schist (quartz-muscovite-garnet-biotite), typical albite schist, and finally into cataclased quartz-plagioclase-microcline gneiss with conspicuous magnetite octahedra. The magnetite postdates the cataclastic foliation and is responsible for prominent magnetic anomalies of the area. This contact is interpreted to be a major premetamorphic thrust fault (also seen at STOP 6), which extends from the north to the south end of the Berkshire massif, along the east margin. F1 is not distinguishable here. The isoclinal folds outlined by quartz ribbons are interpreted to be F2 in age. F3 folds contort the schistosity and have cracked the garnet porphyroblasts. Meta-igneous rocks from a drill hole 4,000 feet west of this locality yielded a Rb/Sr age of 895 m.y. (Brookins and Norton, 1975).

38.0 Turn around and head west on Town Hill Road.

39.2 Cross Factory Brook. Colesbrook Limestone (Precambrian) is exposed here and has been traced for approximately 7 miles parallel to the Paleozoic regional strike and parallel to the faults in the area.

41.2 Cross Factory Brook.

41.4 Crop on left. Hoosac structurally overlain to the east by Precambrian gneiss.

41.7 Bridge arch constructed from "Becket Granite Gneiss" (Emerson, 1899).

41.9 Crop on right. Hoosac in contact to east with Colesbrook Limestone. Compare with mile 41.4, 1,200 feet northeast along strike.

42.1 Cross the West Branch of the Westfield River. Now on Bancroft Road.

47.8 Crop on left, starts in Precambrian rocks, ends in Hoosac. Rocks on both sides of the contact are structurally conformable.

47.9 Route 20. Turn right.

48.0 Cross Walker Brook. The Precambrian-Cambrian contact is exposed in the brook at several localities.

48.4 Hard left on Quarry Road.

49.3 Gates across dirt road to left (on North side of small hill).

STOP 9: Park well on right off road. Walk southeast 2,200 feet on dirt road on quarry in quartz monzonite.

Flaggy well-bedded quartz-plagioclase-biotite-muscovite gneiss of the Hoosac Formation is in sharp contact with weakly foliated quartz monzonite. The quartz monzonite contains no inclusions of Hoosac nor does it crosscut it. The development of foliation in the quartz monzonite is greatest at the contact. These relationships suggest that the Hoosac and quartz monzonite are in fault contact. A Rb/Sr age of 605 m.y. (Brookins and Norton, 1975) and a zircon date of 760 m.y. (Zartman, oral communication, 1973) suggest that the upper Precambrian plutonic rock may be nearly concurrent with the commencement of the deposition of the Hoosac. Later faulting (Taconic) placed them in contact.

Turn around and return to Route 20.

50.2 Left on Route 20.

52.0 Route 8 goes right. Continue west on Route 20 and 8.

57.2 Route 8 goes left. Continue west on Route 20.

64.1 Left on Route 102, just before toll booth for Massachusetts Turnpike.

66.8 East Lee.

68.5 Route 102 joins Route 7. Continue on Route 7.

68.9 Center of Stockbridge. Red Lion Inn. Follow Route 7 to the left.

71.3 Monument Mountain High School.