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Cross section of the Berkshire massif at 42 N.: Profile of a basement reactivation zone

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CROSS SECTION OF THE BERKSHIRE MASSIF AT 42^{o} N.: PROFILE OF A BASEMENT REACTIVATION ZONE[1]

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with Appendix presenting isotopic data by Douglas Mose[2]

Introduction

This trip will emphasize the structural geology and deformational history of Precambrian and Paleozoic rocks along a 30-km-wide traverse of the Berkshire massif at its widest point. The detailed stratigraphy of the Precambrian and Paleozoic rocks will not be treated here. These data were summarized in a previous N.E.I.G.C. trip (Ratcliffe, 1969) and can be found in the Stockbridge and Great Barrington quadrangle reports (Ratcliffe, 1974a, 1974b). Details of the blastomylonite and fold-thrust structures, as well as a general summary of the regional tectonics have been described by Ratcliffe and Harwood (1975). Bedrock mapping from 1967 to 1975 has been supported by grants from the Penrose fund of the Geological Society of America and by the U.S. Geological Survey in cooperation with the Massachusetts Department of Public Works.

The Berkshire massif, an area of Precambrian gneiss that extends from Adams, Massachusetts, south to Torrington, Connecticut, for a distance of about 100 km, forms one of the discontinuous exposures of basement rocks near the western limit of the intensely deformed and metamorphic core of the Appalachians from Newfoundland south to Alabama. This backbone of old rock in many places is at or near the contact between miogeosynclinal Cambrian and Ordovician shelf carbonate rocks and more eugoesynclinal rocks of the same age, and thus marks approximately the present locus of the Cambrian and Ordovician shelf edge at the eastern margin of the North American continent (Rodgers, 1968). At latitude $42^{o}15'$N. (figs. 1 and 2) the Berkshire massif is 25 km wide and tapers to the north and south where it apparently plunges beneath Paleozoic rocks (Herz, 1961; Gates and Christensen, 1965). Along the western contact, the gneisses overlie Lower Cambrian to Lower Ordovician shelf-sequence carbonate rocks of the Stockbridge Formation and the exogeosynclinal Walloomsac Formation (Middle Ordovician or younger) in low-angle thrust faults (Norton, 1969; Ratcliffe, 1969, 1974a, 1974b; Ratcliffe and Harwood, 1975). At the eastern contact of the massif, rocks of the Hoosac Formation (Lower? Cambrian or older) are thrust westward over the gneisses in a complexly interwoven fault zone (Trip B-4), although sedimentary contacts between gneiss and younger rocks may be preserved locally (Trip B-5). Thus, at this latitude, the mioeugeosynclinal transition and the shelf edge of Rodgers (1968) were originally located somewhere

[1] Publication authorized by Director, U. S. Geological Survey.
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above rocks that presently form the Berkshire massif, wherever they were located in Cambrian and Ordovician time. In addition, the depositional basin of the Taconic allochthon may also have been above gneissic rock now found within this zone (Zen, 1967). No data require this interpretation, and the depositional basin of the Taconic allochthon may well have been some unknown distance east of the restored position of the massif rocks.

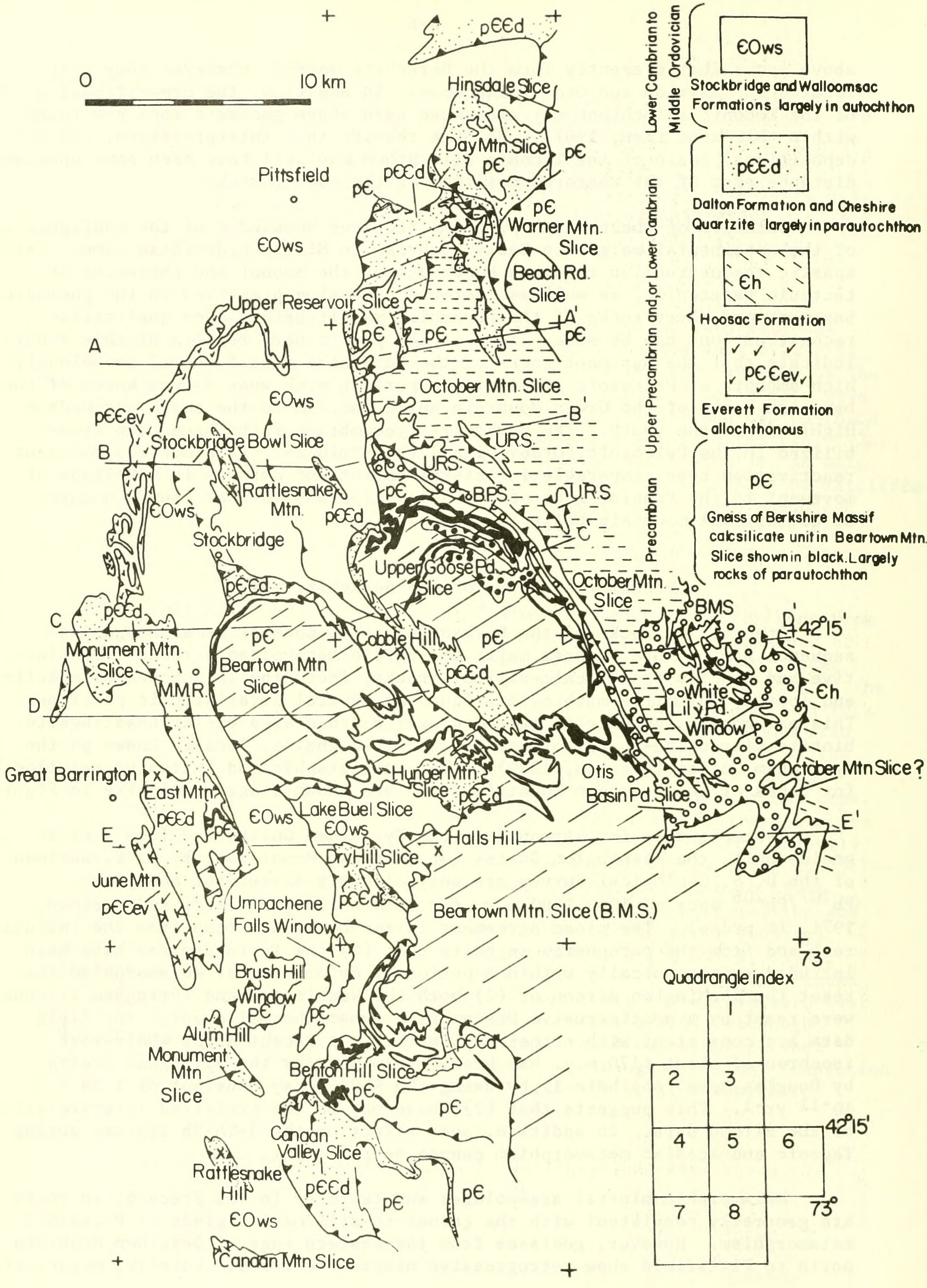
Solution of these major problems requires knowledge of the configuration of the continental margin in Early Cambrian to Middle Ordovician time. Palinspastic reconstruction requires knowledge of the amount and character of tectonic shortening, as well as tectonic bypassing preserved in the gneissic basement and cover rocks of the Berkshire massif before even qualitative reconstructions can be made. Some of the preliminary results of this study indicate that the basement rocks of the Berkshire massif record anomalously high amounts of Paleozoic strain in comparison with what is now known of the basement rocks of the Green Mountain anticlinorium to the north and Hudson Highlands to the south. The Berkshire Precambrian rocks have been remobilized in the Paleozoic (Ordovician?) (see Trip B-2) to produce a basement reactivation zone comparable in lateral extent and perhaps in magnitude of movement to the Pennine zone of the Swiss Alps and to that found in cores of collisional mountain belts in general.

Precambrian rocks of the Berkshire massif

Precambrian rocks of the Berkshire massif consist of a paragneiss sequence having interlayered mafic and felsic metavolcanic rocks. Distinctive and readily traced calc-silicate rocks, including thin zones of calcite and locally dolomitic marble, are found at several stratigraphic positions. This paragneiss sequence is intruded over a broad area by ferrohastingsite-biotite-microcline-quartz-oligoclase granitic gneiss, locally known as the Tyringham Gneiss (Emerson, 1899). The stratigraphic and intrusive relationships for rocks of the Beartown Mountain slice are shown diagrammatically in Figure 3.

Isotopic data for zircon from the Tyringham Gneiss and from a paragneiss unit, the Washington Gneiss (on Beartown Mountain), by R. E. Zartman of the U. S. Geological Survey are only slightly discordant and give Pb^{207}/Pb^{206} ages of 1040-1080 m.y. for both units (Ratcliffe and Zartman, 1971, in press). The close agreement in age between zircon from the intrusive rock and from the paragneiss suggests that (1) the Tyringham may have been intruded syntectonically within a period of dynamothermal metamorphism that reset the Washington zircon or (2) both the Washington and Tyringham zircons were reset by a postintrusive Precambrian dynamothermal event. The field data are consistent with either explanation. A recent Rb/Sr whole-rock isochron of about 1170 m.y. has been determined for the Tyringham Gneiss by Douglas Mose (Appendix 1) by using the Rb^{87} decay constant of 1.39×10^{-11} yr^{-1}. This suggests that (2) above may be the preferred interpretation of the zircon data. In addition, some effect on the U-Th-Pb systems during Taconic and Acadian metamorphism cannot be ruled out.

Metamorphic mineral assemblages and textures in the Precambrian rocks are generally consistent with the garnet-to-sillimanite grade of Paleozoic metamorphism. However, gneisses from the western edge of Beartown Mountain north to Pittsfield show retrogressive mineral textures. Locally, megacrysts


0
10 km
Hinsdale Slice
Day Mtn. Slice
Pittsfield
Warner Mtn. Slice
Beach Rd. Slice
Upper Reservoir Slice
October Mtn. Slice
Stockbridge Bowl Slice
Rattlesnake Mtn.
Stockbridge
Upper Goose Pd. Slice
October Mtn. Slice
BMS
Cobble Hill
Monument Mtn. Slice
M.M.R.
Beartown Mtn Slice
White Lily Pd. Window
Great Barrington
East Mtn
Hunger Mtn. Slice
Otis
Basin Pd. Slice
October Mtn Slice ?
Lake Buel Slice
Halls Hill
Dry Hill Slice
June Mtn
Umpachene Falls Window
Beartown Mtn. Slice (B.M.S.)
Brush Hill Window
Alum Hill
Monument Mtn Slice
Benton Hill Slice
Canaan Valley Slice
Rattlesnake Hill
Canaan Mtn Slice
URS
BPS
42°15'
73°
Lower Cambrian to Middle Ordovician
Upper Precambrian and, or Lower Cambrian
Precambrian
€Ows
Stockbridge and Walloomsac Formations largely in autochthon
p€€d
Dalton Formation and Cheshire Quartzite largely in parautochthon
€h
Hoosac Formation
p€€ev
Everett Formation allochthonous
p€
Gneiss of Berkshire Massif calcsilicate unit in Beartown Mtn. Slice shown in black. Largely rocks of parautochthon
Quadrangle index
1
2
3
4
5
6
7
8
42°15'
73°

STRUCTURAL STACKING SEQUENCE OF THRUST SLICES IN THE WEST-CENTRAL PART OF THE BERKSHIRE MASSIF IN MASSACHUSETTS

At $42^{\circ}15'$

October Mountain Slice
(Washington and Tyringham Gneiss with unconformable Dalton-Cheshire sequence)

Upper Reservoir Slice (URS)
Tyringham Gneiss and unnamed hornblende gneiss and amphibolite unit

Basin Pond Slice (BPS)
Tyringham Gneiss with minor amounts of Washington Gneiss, and layered paragneiss

Upper Goose Pond Slice
Tyringham Gneiss

June Mountain Slice
Everett? Formation, structural position uncertain, perhaps uppermost slice locally involuted in Beartown Mountain slice

Beartown Mountain Slice (BMS)
Thick Precambrian sequence includes paragneiss, an important calc-silicate unit, Washington and Tyringham Gneisses, with unconformable Dalton-Cheshire sequence, forms a large nappe with westward vergence

Monument Mountain Slice
Dalton and Cheshire sequence with Stockbridge through unit b. Exposed as outliers from Rattlesnake Mt. in north to Rattlesnake Hill in south

Dry Hill and Hunger Mountain Slices
Precambrian gneiss, with unconformable Dalton-Cheshire sequence and Stockbridge through unit b. May be equivalent to Monument Mountain slice

Lake Buel and Stockbridge Bowl Slices
Stockbridge units a through e and Walloomsac Formation

Everett Slice of Taconic Allochthon

Rocks of the Stockbridge Valley
Dalton, Cheshire, Stockbridge, and Walloomsac. Locally at Umpachene Falls and Brush Hill windows detached from underlying Precambrian basement gneiss

At $42^{\circ}22'30''$ (see Trip B-9)

Beach Road Slice
Tyringham Gneiss with distinctive ferrohastingsite rodded aplitic facies, Washington Gneiss

Warner Mountain Slice
Washington Gneiss with unusually thick and persistent calc-silicate unit

Hinsdale Slice
Well layered paragneiss

Day Mountain Slice
Well layered paragneiss, Tyringham and Washington Gneisses. Unconformable Dalton with important coarse conglomerate, Cheshire Quartzite. Local interbeds of Hoosac-like quartz schists

October Mountain Slice
Washington Gneiss with poorly developed calc-silicate unit, and Tyringham Gneiss. Unconformable Dalton-Cheshire sequence

Dutch Hill Slice
Tyringham Gneiss with augen-rich blastomylonite at sole (may be equivalent to the Upper Reservoir slice)

Beartown Mountain Slice (BMS)
Largely Dalton-Cheshire sequence, with thick western facies of Cheshire Quartzite, and coarse basal conglomerate

Rocks of the Stockbridge Valley
Stockbridge and Walloomsac Formations no deeper tectonic levels exposed

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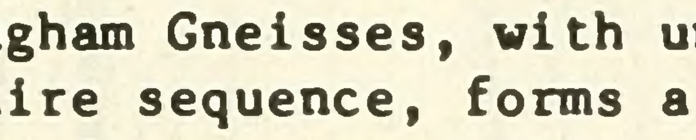
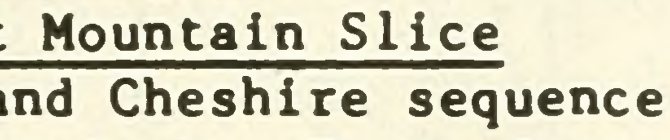
Fault symbols (teeth on higher plate, where faults are overturned teeth on original upper plate)



Premetamorphic (preM_1) thrust



Synmetamorphic (M_1) or older thrust with multiple movement history

Synmetamorphic (M_1) thrust formed during emplacement of Berkshire massif in Late Ordovician(?), thrust at base of Hoosac of preM_2 age

Index to numbered quadrangles and sources of data:

1. Pittsfield East (Ratcliffe, mapping in progress), 2. Stockbridge (Ratcliffe, 1974a), 3. East Lee (Ratcliffe, unpublished data), 4. Great Barrington (Ratcliffe, 1974b), 5. Monterey (Ratcliffe, 1975), 6. Otis (Ratcliffe, mapping in progress), 7. Ashley Falls (Ratcliffe and Burger, 1975), 8. South Sandisfield (Harwood, 1971, modified from Ratcliffe and Harwood, 1975).

Figure 1. Generalized geologic-tectonic map of a part of the Berkshire massif showing distribution of structural slices.

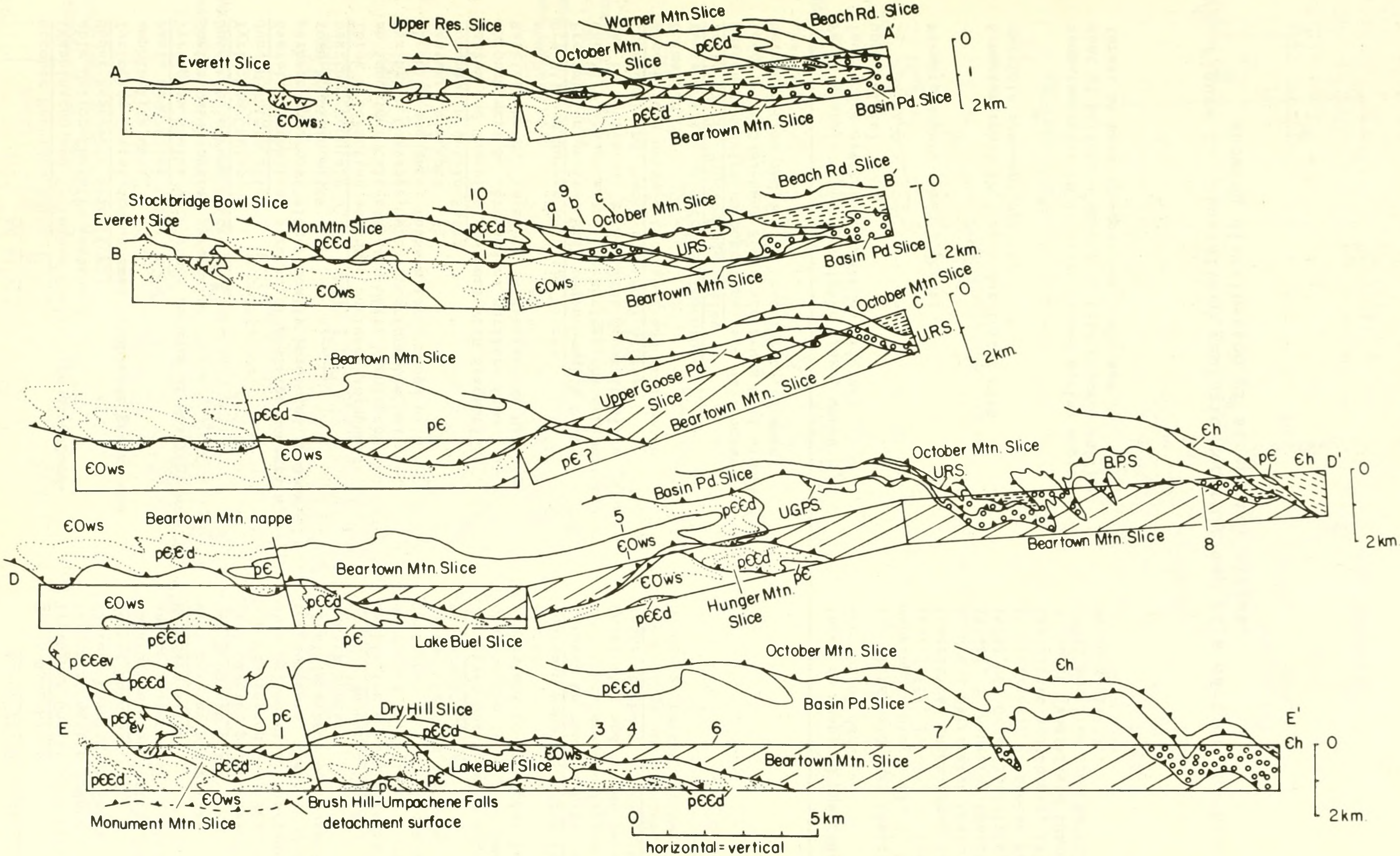


Figure 2. Cross sections of Berkshire massif to accompany geologic map, Figure 1. Fine dotted lines show form lines in Paleozoic rocks, symbols identified on Figure 1. Numbers indicate field trip stops, symbols for slices identified in explanation on Figure 1.

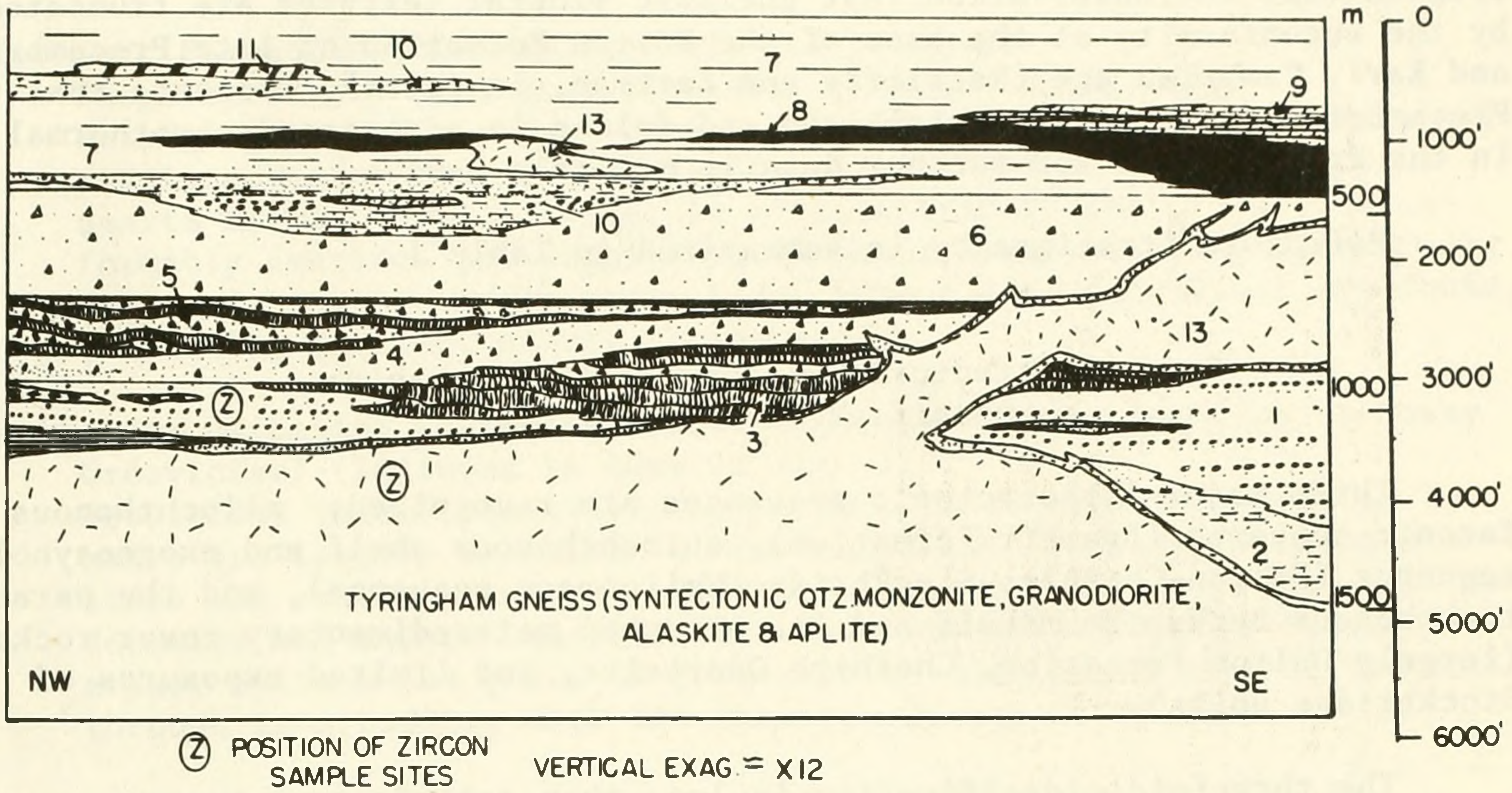


Figure 3. Composite stratigraphic section of the Precambrian rocks in the Stockbridge, Great Barrington, Monterey, and East Lee quadrangles, Massachusetts, showing inferred lateral relationships of lithologic units: 1 and 2, Washington Gneiss; 3, garnet-hornblende amphibolite; 4, leucocratic biotite gneiss and granulite; 5, garnet-hornblende-plagioclase amphibolite; 6, biotite-quartz-magnetite felsic gneiss; 7, biotite-quartz-plagioclase paragneiss (with interlayered lithologies 8 and 9); 8, calc-silicate rock and marble; 9, layered and spotted hornblende-plagioclase gneiss; 10, rusty-weathering schistose gneiss and granulite; 11, fine-grained garnet-hornblende amphibolite; 13, Tyringham Gneiss, intrusive biotite ferrohastingsite granodiorite with alaskitic chilled border facies.
Z shows position of zircon sample sites for U-Th-Pb study by R. Zartman (Ratcliffe and Zartman, 1971).

of perthitic alkali feldspar and sillimanite are preserved in the Paleozoic garnet and staurolite zones (Norton, 1969; Ratcliffe, 1969). This information, coupled with the observation that gneissic mineral textures are truncated by the unconformity at the base of the Dalton Formation of late Precambrian(?) and Early Cambrian age (Ratcliffe and Zartman, in press), indicate that the Precambrian rocks were crystallized and folded in a severe dynamothermal event in the Precambrian (for further details see Trip B-9).

Paleozoic stratigraphy is summarized in Table 1.

General structural geology of the Berkshire massif at 42° N. latitude

Three major lithotectonic sequences are recognized; allochthonous Taconic sequence (Everett Formation), autochthonous shelf and exogeosynclinal sequence (Dalton-Cheshire-Stockbridge-Walloomsac sequence), and the parautochthonous Berkshire massif and its attached metasedimentary cover rocks (largely Dalton Formation, Cheshire Quartzite, and limited exposures of Stockbridge units).

The threefold classification is less than satisfactory because nearly all the rocks are detached and, strictly speaking, are allochthonous. The terms "allochthonous," "parautochthonous," and "autochthonous" are therefore used in a general and relative way to signify rock sequences that differ in degree of tectonic displacement on the basis of either facies considerations and (or) geometric evidence of physical overlap. Although autochthonous shelf-sequence rocks are more or less in place, detachment from the basement rocks and intense imbrication by low-angle thrust faults are recognized.

Figure 1 shows the distribution, stacking order, and general stratigraphy of the major tectonic units. The "autochthonous" valley sequence, Stockbridge and Walloomsac Formations, crop out in the Stockbridge Valley west of the Berkshire massif from Pittsfield south to Canaan Mountain. Precambrian gneiss appears from beneath the Stockbridge in Umpachene Falls and Brush Hill windows. Here the Stockbridge is uncoupled from the basement along a detachment zone of unknown magnitude (Ratcliffe and Burger, 1975). These relationships suggest hat the autochthon may be entirely separated by low-angle faults from the true basement, and possibly no truly autochthonous rocks are present.

Many ancillary thrusts have formed in the "autochthon" along the western edge of the massif, and the area from Monument Mountain east to Halls Hill is dominated by low-angle overthrusts and by intense isoclinal and recumbent folding.

The Berkshire massif proper consists of a series of overlapping low-angle highly folded thrust slices, some of which contain an unconformable cover of upper Precambrian(?) and Lower Cambrian clastic rocks (Dalton Formation and Cheshire Quartzite). The lowest and most extensive slice of basement rocks, the Beartown Mountain slice, contains a distinctive stratigraphic sequence (fig. 3). Higher slices overlap one another to the north and east. Northeast of Otis, the October Mountain slice is downfolded in a major

Table 1. Brief summary of Paleozoic stratigraphy

Walloomsac Formation (Middle Ordovician or younger)
Exogeosynclinal sediments (included in €Ows in fig. 1).
Dark-gray to black, muscovite-biotite-plagioclase-quartz schist (Ow) and interbedded massive phlogopite-plagioclase microcline-calcite-quartz marble (Owm). Schist is sillimanitic in east. Unit unconformably overlies the Stockbridge Formation and bevels progressively deeper in eastern areas where local interbedded quartzites are found, indicating sediment source to the east.

Stockbridge Formation (carbonate shelf sequence) (Lower Cambrian to Lower Ordovician) (included in €Ows in fig. 1)
Subdivided into lithostratigraphic units a through g. Units a, b, and c are largely dolomitic containing minor interbedded metaquartzites and schists; units d and f are distinctive crossbedded siliceous dolomite and calcite marbles that have abundant diopside in eastern areas; units e and g are largely calcite marble. Unit a is transitional through interbedding with the Cheshire Quartzite below.

Cheshire Quartzite (Lower Cambrian) (part of p€€d shown in fig. 1)
Massive vitreous quartzite that interfingers with feldspathic quartzites of Dalton Formation below.

Dalton Formation (part of p€€d shown in fig. 1) (Upper Precambrian? and Lower Cambrian)
Heterogeneous assemblage of massive feldspathic metaquartzite, quartzite, well-bedded tourmaline,muscovite-quartz flagstone, quartz-pebble metaconglomerate, vitreous metaquartzite, basal quartz pebble and arkosic metaconglomerate. Locally aluminous dark-colored garnet-muscovite-biotite-plagioclase-quartz schist similar to the Hoosac Formation is interbedded on East Mountain, at Stockbridge, and in the Canaan Valley slice where it is sillimanitic. The Dalton unconformably overlies gneiss of the Beartown Mountain and Benton Hill slices (Harwood, 1972), of October Mountain and Day Mountain slices, and locally occurs in the autochthon. The original depositional site of the Dalton in the Berkshire massif was well east of its present position.

northwest-trending synform. A complementary antiform in the north-central part of the Otis quadrangle exposes rocks of the Beartown Mountain slice in the White Lily Pond window. East of the White Lily Pond window, rocks of the Basin Pond slice dip gently east beneath an unnamed slice of Precambrian rock that may correlate with the October Mountain slice.

Windows at the east edge of the massif (fig. 2, sections D-D' and E-E') and the gently dipping folded configuration of the higher slices at this point suggest that the Beartown Mountain slice might have a similar geometry and be floored by a shallow thrust. If such is the case, the massif could be entirely allochthonous. However, no data are available at present that require this interpretation. Deep-core drilling to depths of 5 km in the White Lily Pond window might resolve this problem.

Rocks of the Hoosac Formation overlap several thrust slices in the gneiss at the east edge of the massif. Within 500 m of the gneiss contact, the Hoosac contains inclusions of gneiss as much as 100 m long. At the contact with these slivers Precambrian rocks and the Hoosac show an anomalous concentration of minor folds and a well-developed mullion structure which suggests the inclusions are tectonic. The contact beneath the Hoosac is interpreted as a gentle to moderately steep east-dipping thrust fault.

Direction of overthrusting

Slipline data have been determined, by using the techniques outlined by Hansen (1971), from many localities on the basis of the rotation sense of minor folds associated with the zone of blastomylonite, observation of mullions and slickensides, and study of lineations folded by similar folds. Some of the results pertinent to this trip are shown in Figures 4, 5, and 6. The azimuths of sliplines are fairly consistent, despite the effect of postthrust folding along NNW. and NNE. trends. These results suggest westward and southwestward thrusting generally consistent with previous assumptions based on the sense of overlapping (Ratcliffe and Harwood, 1975). The one slipline determination from the thrust zone at the base of the Hoosac is consistent with the movement pattern of the slices of the massif and suggests, but does not require, contemporaneous movement on all faults. The northernmost slipline measurement at the sole of the Hinsdale and Warner Mountain slices suggests that the longitudinal thrust component may increase northward toward the end of the massif. Further study will be necessary to resolve this point.

Chronology of structural and metamorphic events

Figure 7, reproduced from Ratcliffe and Harwood (1975), shows our conception of tectonic and metamorphic events that have affected this area.

Precambrian dynamothermal metamorphism about 1 b.y. ago, $D_{p\text{C}}$, postdated intrusion of the Tyringham Gneiss and produced the gneissosity in the Precambrian rocks. $F_{p\text{C}}$ folds were generally east trending, having steep axial surfaces. Excellent exposures of the unconformity (seen on Trip B-9) at the base of the Dalton Formation of late Precambrian(?) and Early Cambrian age show a profound metamorphic and structural discontinuity.

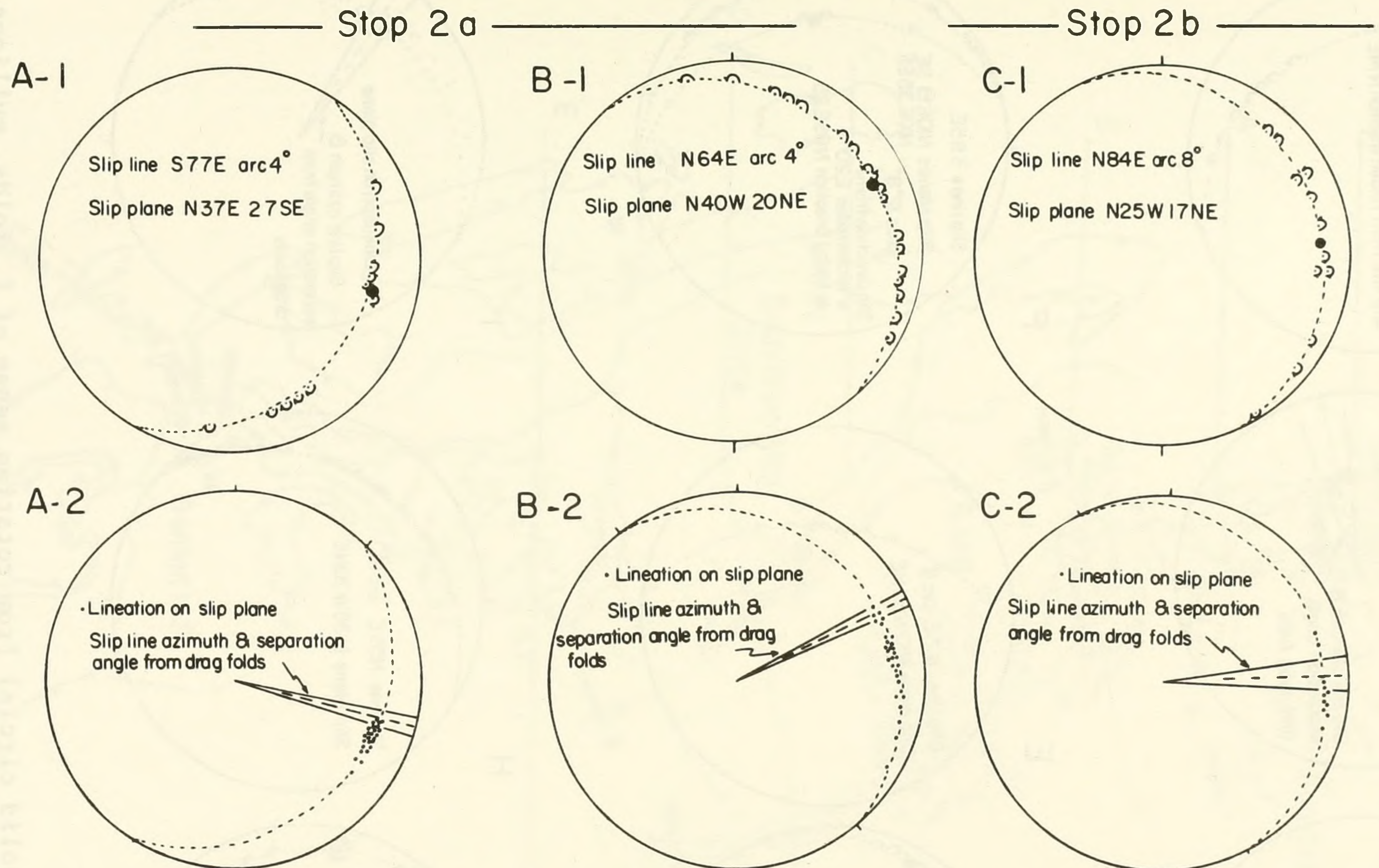


Figure 4. Lower hemisphere projections of plunge and rotation sense of F_3 minor folds at sole of Benton Hill slice at stops 2a and 2b. Lower diagrams show plunge of prominent mullion structures in blastomylonitic foliation and comparison with slipline and separation angle. Mullions approximate but do not agree with sliplines. Correspondence is greatest in most intensely deformed blastomylonite zones.

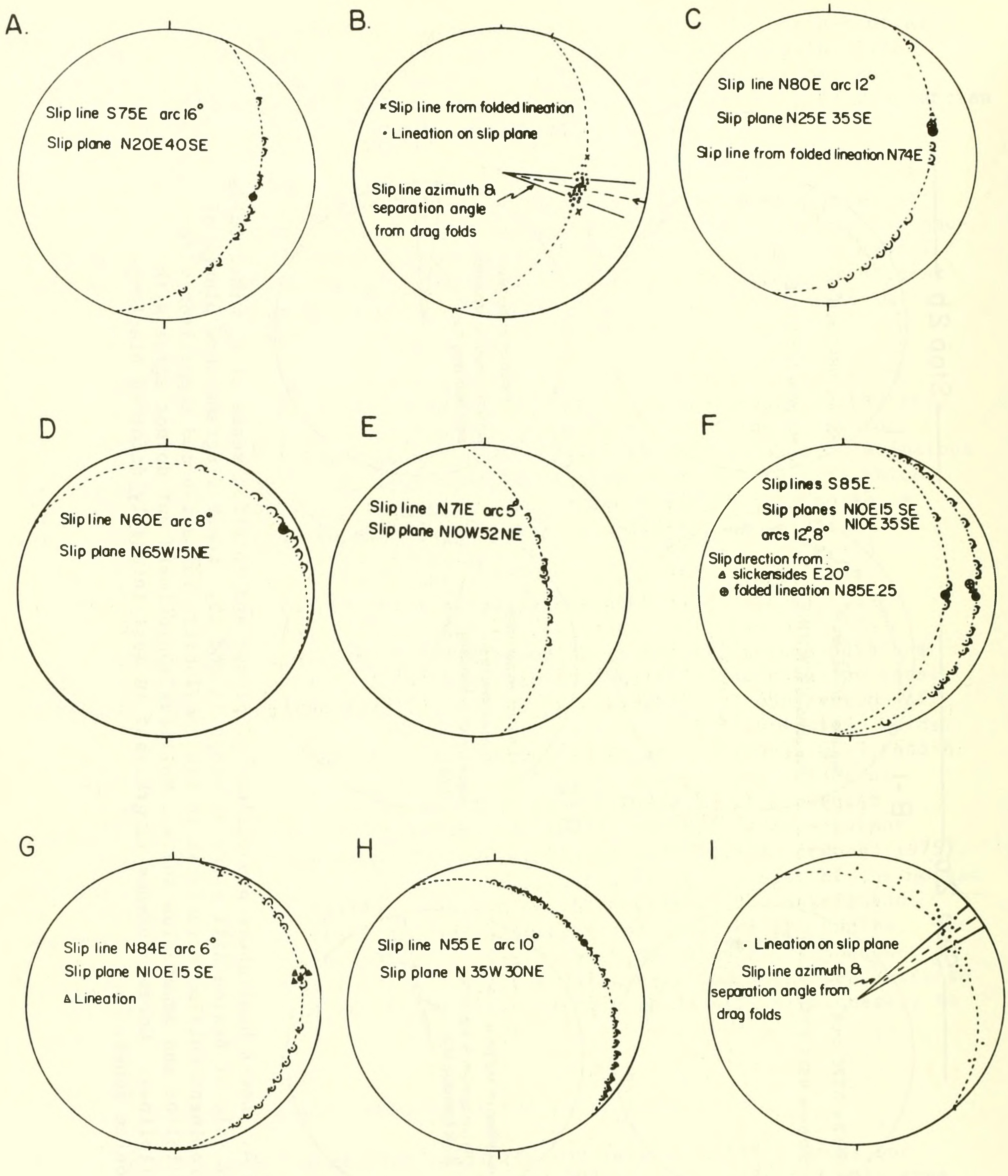


Figure 5. Slipline (solid circle) from rotation sense of F_3 folds, mullions or lineation dots, wear grooves, or slickensides identified on diagram. A and B (Stop 3), C (Stop 4, Halls Hill), D (Stop 6), E (Stop 7), F (Stop 9a), G (Stop 9c), H and I (Stop 10). Lower hemisphere.

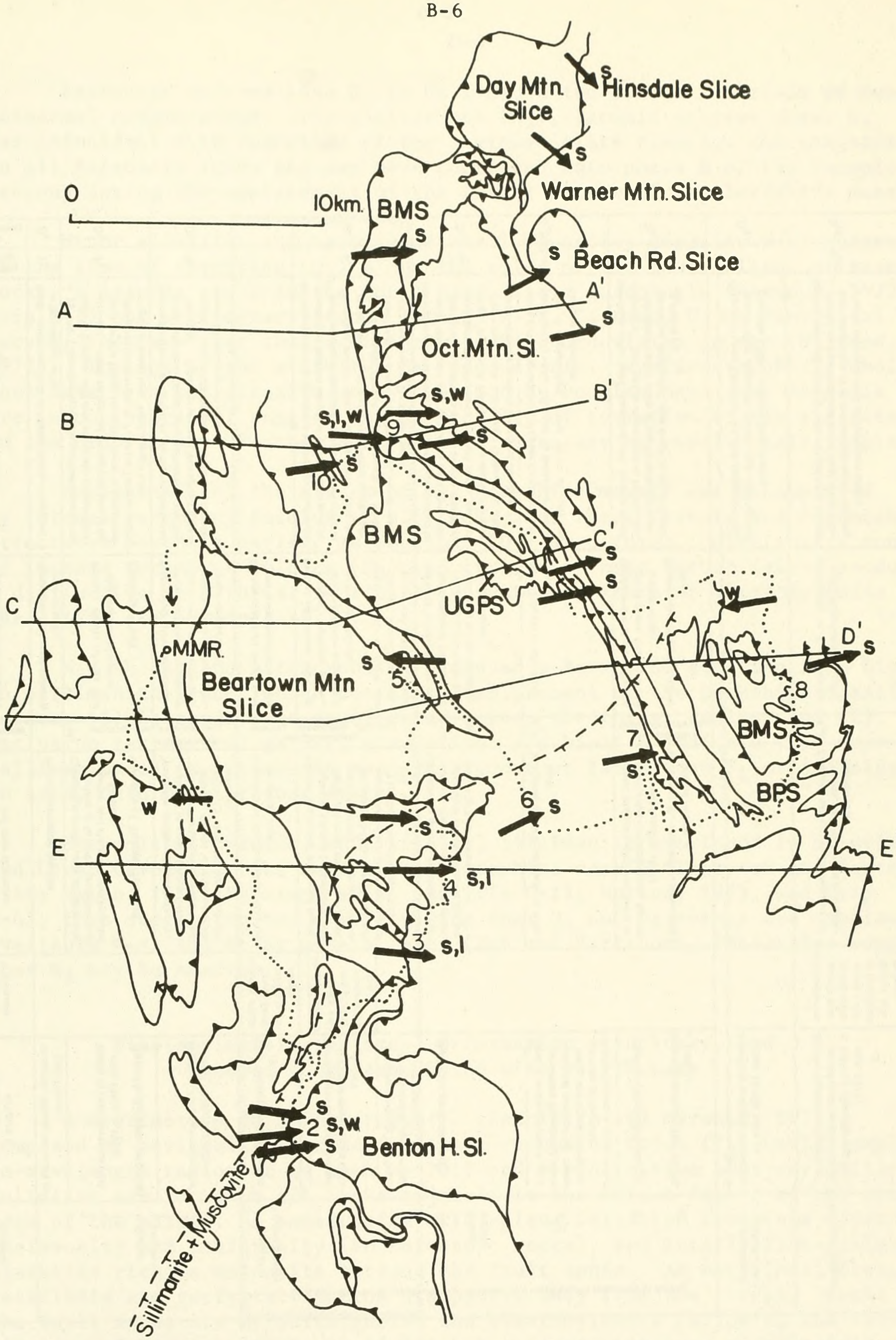


Figure 6. Generalized tectonic map showing thrust slices and slipline determinations: S (from separation angle of minor folds), W (from wear grooves), L (from folded lineation). Data for stops on this trip are presented in Figures 4 and 5. Stop locations and section lines of Figure 2 are identified. MMR--Monument Mountain Regional High School.

Deformational event	Number of fold system	Types of folds and areal extent	Important tectonic features	Metamorphic event	Important crystalloblastic and other structures	Igneous intrusion	Probable age of rocks in figure 1	Orogeny
D_6	F_6	North-south open folds of foliation locally recognized in Stockbridge valley	Northwest- and north-trending normal faults		Hematite-cemented breccias		Uncertain (Middle Devonian to Late Triassic)	
D_5	F_5	N. 25°-40° E.-trending upright to northwest overturned folds of foliation, with axial planar slip or crenulation cleavage. Folds recognized throughout area of figure 1 west to Mount Ida in SW corner of Kinderhook 15-minute quadrangle, N. Y., where Taconic unconformity is folded by N. 40° E. upright folds	Refolds thrust sheets and blastomylonitic foliation **Chatham fault**	M_2 Thermal maximum Acadian metamorphism	Crenulation of sillimanite alined in axial surface of F_4 folds; granulation of garnet and staurolite that includes F_4 foliation **mylonite of Taconic foliation**		Middle to Late Devonian (Ratcliffe 1969a, b, 1972) **Ratcliffe, Bahrami (in press)**	Acadian orogeny
D_4	F_4	Northwest-trending upright to southwest-overturned folds with axial planar slip, crenulation, and flow cleavage. Folds recognized throughout area of figure 1, west to Chatham, N. Y., in center of Kinderhook 15-minute quadrangle	Folds thrust sheets and blastomylonitic foliation resulting in local overturning of thrusts; northwest-trending high-angle reverse faults	Thermal maximum Acadian metamorphism	Muscovite, biotite realined and recrystallized in axial surface foliation; coarse sillimanite crystallized in foliation. Garnet, staurolite include folded F_2 fabric, and blastomylonitic foliation		Middle to Late Devonian (Ratcliffe 1969a, b, 1972)	Acadian orogeny
			Granite crosscuts thrust fault and blastomylonitic foliation	Thermal maximum Taconic metamorphism	Granite lacks blastomylonitic foliation in country rocks	Granite stock, South Sandisfield quadrangle	Late Ordovician(?) (Harwood, 1972)	Phases of Taconic orogeny
D_3	F_3	Northwest-trending recumbent to strongly southwest-overturned folds of basement gneiss and large-scale southwestward thrusting of Precambrian rocks of Berkshire massif across autochthon. Fold and thrust style recognized from Windsor quadrangle, Massachusetts (Norton, 1969), south to Norfolk quadrangle, Connecticut (Harwood, unpub. data), along west front of Berkshire massif	Faulted recumbent folds and nappes, mylonite gneiss, blastomylonite associated with major thrusts Thrust sheets at June and Canaan Mountains transported with Berkshire massif	Thermal maximum Taconic metamorphism	Alaskite has weakly developed blastomylonitic foliation but intrudes more highly cataclastic rock in fault zones; mylonite gneiss, blastomylonite has muscovite, biotite, hornblende with lepidoblastic texture, cataclasis of F_2 foliation, thrusting synmetamorphic	Alaskite sills in faults and magnetite mineralization	Synchronous with latest movements or thrusts (Late Ordovician?) Thrusting probably late Ordovician based on age of cross-cutting granite	D
D_2	F_2	Isoclinal northeast-trending northwest-overturned to nearly recumbent folds with strong axial planar foliation which is dominant foliation in most autochthonous and allochthonous (Taconic) rocks, but not clearly present in Paleozoic rocks attached to Berkshire massif. Folds extend west to Mount Ida where unconformable beneath lowermost Devonian	Folding of Taconic thrust contacts, regional foliation and refolding of slump or soft-rock folds in Taconic allochthonous rocks	M_1	Lepidoblastic muscovite, chlorite, biotite, and ilmenite in foliation; chloritoid, albite include foliation but are kinked by F_4 structures		Middle to Late Ordovician(?)	C Taconic orogeny
D_2(?)	F_2(?)	Folding and metamorphism of Lower Cambrian metasedimentary rocks attached to Berkshire massif and in independent thrust slices at June and Canaan Mountains	Coarse foliation or schistosity formed	M_1(?)	Muscovite, biotite lepidoblastic in schistosity		Time of metamorphism very uncertain depending upon original position of these rocks, and timing of tectonic events at that site (Middle Ordovician to Cambrian?)	(C)?
D_1	F_1	Intrafolial minor folds associated with Taconic thrust contacts. Soft rock or slump folds in Taconic allochthonous rocks; scale of pre-F_2 folds not determined but widespread, area shown in figure 1, west to Mount Ida	Emplacement of upper Taconic slices (here, Chatham and Everett slices) Emplacement of lower Taconic slices	No metamorphism recognized	Tectonic breccias with inclusions of Stockbridge Formation along thrusts (Zen and Ratcliffe, 1971) Wild-flysch-like sedimentary rocks along base of thrusts		Uncertain (Middle Ordovician?) Middle Ordovician (Zen, 1972b, table 1)	B A
		Middle Ordovician unconformity						
D_0		Warping of Lower Cambrian to Lower Ordovician carbonate shelf sequence, locally dips near vertical (Ratcliffe, 1969a); possible block faulting					Late Early to Middle Ordovician (Zen, 1972b, table 1)	Pre-Taconic disturburance
		Pre-Dalton unconformity						
$D_{p€}$	$F_{p€}$	Isoclinal east-west-trending folds with generally steeply dipping axial surfaces and strong axial planar foliation; deformation of all Precambrian rocks including granitic intrusions such as Tyringham Gneiss	Gneissosity in Precambrian rocks of Berkshire massif	$M_{p€}$	Diopside, sillimanite, hornblende, microcline, perthite formed in dynamothermal event	Granodiorite-quartz monzonite intrusions such as Tyringham Gneiss, syntectonic	Dynamothermal event and granite intrusion approximately 1.04 b.y. (Ratcliffe and Zartman, 1971)	Grenville orogeny
		Pre-Tyringham foliation						

Degree of basement participation and intensity of deformation increasing with time →

Figure 7. Chronology of tectonic events recognized in southwestern Massachusetts, northwestern Connecticut, and adjacent eastern New York (reproduced from Ratcliffe and Harwood, 1975).

Paleozoic deformations D_0 to D_5 include two distinct periods of dynamothermal metamorphism. The earlier one (M_1), Taconic orogeny phase C, was coincident with formation of the regional slaty cleavage and schistosity in all Paleozoic rocks and may have continued into phase D of the Taconic orogeny during the emplacement of the thrust slices of the Berkshire massif.

Minor alaskites and associated small magnetite deposits were generated at the time of thrusting (D_3) along the soles of the lower slices of basement rock. A granite stock in the South Sandisfield quadrangle (Harwood, 1972; Trip B-2) and preliminary zircon data by R. E. Zartman, U. S. Geological Survey, indicate that the granite may be Late Ordovician in age (Harwood, 1972). The age of the alaskites is less certain. Preliminary Rb/Sr whole-rock data from the alaskite zone at Stop 6 by Douglas Mose (see Appendix 1) are inconclusive but suggest the possibility of formation of the alaskite in the Ordovician. Further work will be necessary to resolve this problem.

Emplacement of the slices of the Berkshire massif was accompanied by intense recumbent folding of all rocks, but these thrusts and recumbent structures postdate earlier metamorphic (D_2) structures. Distinctive zones of intense recumbent folding (F_3) and cataclasis near thrust faults produces a distinctive fold-thrust fabric, accentuated by seams of blastomylonite (Ratcliffe and Harwood, 1975).

M_2, the second metamorphism, produced a Barrovian zonation from biotite to sillimanite grade, which postdates emplacement of the Berkshire massif because (1) isograds pass undeflected across the thrust faults, and (2) inclusion textures in garnet, staurolite, and biotite indicate that crystallization of (M_2) minerals was synchronous or later than F_4 cross folds that, in turn, deform the thrust slices.

Staurolite, kyanite, and, locally, sillimanite are found in Silurian and Lower Devonian rocks east of the Berkshire massif (Thompson and Norton, 1968; Hatch, 1972; Stanley, 1975, and Trip C-11; Norton, 1975, and Trip B-4), thus suggesting but not requiring that D_4 and D_5 events are Acadian. Available K-Ar and Rb-Sr mineral ages (Zen and Hartshorn, 1966) also suggest that M_2 may be Acadian.

Blastomylonitic textures, deformation structures, and igneous rocks associated with overthrusts

A distinctive fold-thrust fabric (Ratcliffe and Harwood, 1975), composed of vertically stacked isoclinal recumbent folds (F_3) having amplitude-to-wavelength ratios of as much as 20:1 and a penetrative blastomylonitic foliation are found in all rocks adjacent to the thrust faults at the west edge of the massif. A penetrative axial-plane foliation crosscuts older gneissosity and schistosity (in Paleozoic rocks), and locally fine-grained alaskites rich in magnetite intrude the fault zones. At many localities, the cataclasis and recrystallization disappears away from the thrust. Rocks in the fault zones are mylonite gneiss and blastomylonite following the terminology of Higgins (1971, p. 11-13). Excellent exposures of this fold-thrust fabric associated with different slices will be examined at many stops on this trip and on Trip B-2. The faults are folded, and, locally, the fold-thrust fabric and the faults are overturned.

Exposures of the fold-thrust fabric in the eastern part of the massif at the latitude of this trip contain abundant stringers of granite and larger bodies of foliated biotite-spotted quartz monzonite of uncertain age and origin (Stop 8).

Magnitude of overthrusts and regional implications

Cross sections (fig. 2) across the Berkshire massif near 42° N. show my present structural interpretation. Sections are drawn approximately parallel to the determined sliplines. Sections D and E show that combined Beartown and Monument Mountain slices overlap the underlying autochthon for a distance of 21 km. In addition, the lower Lake Buel slice overlaps the autochthonous rocks for approximately 6 km, and the Dry Hill slice-Hunger Mountain slice overlap the Lake Buel slice by 5 km. This indicates a minimum shortening of 11 km in the "autochthon" beneath the Beartown Mountain slice. Detachment of the "autochthon" in the Brush Hill and Umpachene Falls windows requires additional shortening of unknown magnitude.

The 21-km movement for the Beartown Mountain slice serves as an estimate for minimum westward displacement of the Berkshire massif as a whole. The Dalton-Cheshire sequence and unit a of the Stockbridge are exposed well east of the leading edge of the Beartown Mountain slice, east of Tyringham (fig. 2, sec. D). The bank edge for Early Cambrian time must have been 21 km farther east than the present easternmost position of these rocks in the Beartown Mountain slice. Additional shortening of 7 km in the Paleozoic cover sequence attached to the Beartown Mountain slice indicates that the restored position actually is at least 28 km rather than 21 km to the east. This minimum position is shown in Figure 8. This reconstructed position lies approximately at the present position of the eastern edge of the Berkshire massif and above the crest of the regional Bouguer gravity anomaly.

Additional internal strain in the Berkshire massif, as recorded by the successively higher slices, is appreciable and may be used to estimate the original width of the Grenville basement now telescoped in the massif.

If we assume that the individual higher slices did not all root in the same zone, as the varying stratigraphy of the slices (fig. 2) suggests, the cumulative displacement may be summed to estimate the amount of shortening. The displacements calculated from the cross sections will yield minimum figures. However, estimates of lateral shortening must be less than the displacement if the original thrusts were not horizontal. Because of geologic uncertainties, the estimates obtained can only be regarded as approximate.

The Basin Pond slice overlaps and truncates structures in the Beartown Mountain slice for a distance of approximately 15 km, measured along its presently folded contact with the Beartown Mountain slice. Likewise, the October Mountain slice may overlap both Beartown Mountain and Basin Pond slices for an additional 16 km.

The part of the Beartown Mountain slice now exposed, after consideration of shortening resulting from Paleozoic folding, represents an estimated width of approximately 30 km. Therefore, the original width of the basement rocks in the Berkshire massif at 42°15'N. could easily have been 60 km before Paleozoic thrust faulting. The entire massif must have been at a point at least 21 km east of its present position, thus placing the east edge 80 km east of Great Barrington.

A generalized palinspastic map of the Berkshire massif for the Early Cambrian, incorporating the estimates above (fig. 8), places the massif squarely above the crest of the regional Bouguer gravity anomaly (Kane and others, 1972). In addition, the eastern extent of the Dalton-Cheshire shelf facies, the shelf edge, and depositional basin for Taconic rocks are shown to lie at or east of this anomaly. In areas such as the northern end of the Green Mountain-Sutton Mountain anticlinorium and in the Manhattan Prong, where the basement rocks are regarded as essentially autochthonous, the position of the bank edge proposed by Rodgers (1968) coincides with the positive gravity anomaly. This suggests the possibility that the gravity anomaly, believed to be of deep crustal origin (Diment, 1968), may represent the long-preserved results of extensional necking of sialic crust and concomitant intrusion or upward flow of dense subcrustal rocks in the initial breakup of the North American continent in the latest Precambrian.

Although volcanic rocks are not common in Cambrian rocks east of the massif at this latitude, metabasalts are sparingly present in the Hoosac-Rowe sequence and in the Nassau Formation of the Taconic allochthon. The coarse graywackes of Rensselaer associated with Taconic basalts were derived from a western source area of Grenvillelike gneiss and could well have been deposited either above rocks now making up the higher slices of the Berkshire massif or above the eastern edge of the Beartown Mountain slice. Thus, what Cambrian volcanic rocks are present at this latitude could originally have formed at or near the present position of the positive Bouguer anomaly.

Alternately, this anomaly could represent the root zone of the Berkshire massif, in which deep crustal rocks, initially emplaced during drifting, were brought nearer the surface by a combination of high-angle faulting and warping during continental and (or) island-arc collision in the Taconic orogeny.

Origin of the anomalously high strain in basement rocks of the Berkshire massif

In intensity of basement reactivation, grade of dynamothermal metamorphism, and prevalence of recumbent folds, the Berkshire massif differs markedly from the Green Mountain anticlinorium to the north and from the northern end of the Reading Prong to the south. All these areas were deformed in the Ordovician. Basement reactivation in the Berkshires also is an Ordovician rather than Devonian event (Harwood, 1972; Ratcliffe and Harwood, 1975).

An uneven pattern of strain recorded in the basement rocks of western

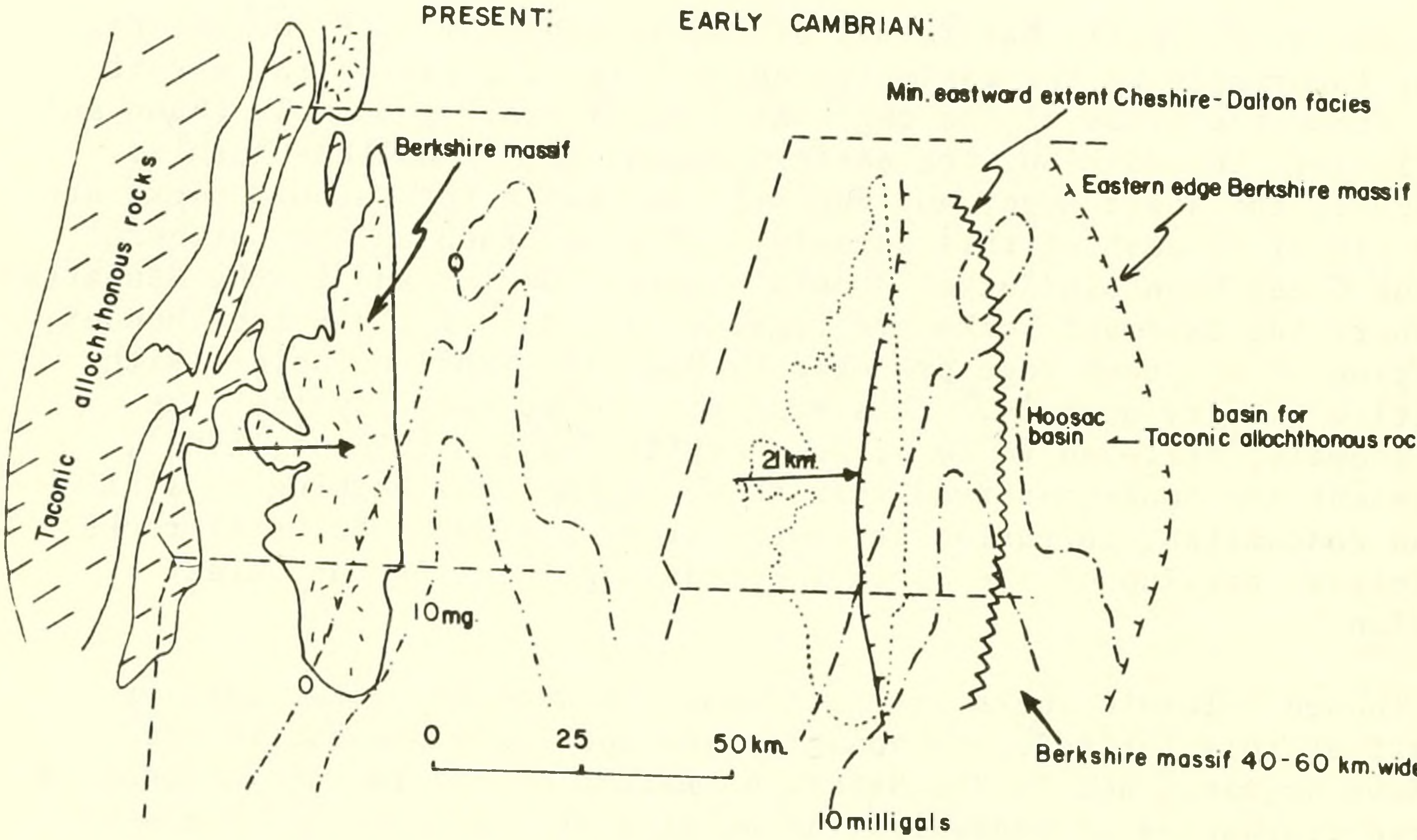


Figure 8. Palinspastic map showing approximate position in Early Cambrian time for Precambrian rocks of the Berkshire massif, minimum eastward extent of Dalton-Cheshire shelf facies, and possible position of depositional basin of Taconic allochthonous rocks with respect to the crest of the positive regional Bouguer gravity anomaly. Dot-dash lines represent 0 and 10 milligal gravity contours.

New England and New York suggests collisional effects of one or perhaps two plates having irregular margins after the general mechanism outlined by Dewey and Burke (1974). Analysis of this strain and reconstruction of the Cambrian shelf facies suggest that the continental edge of Cambrian and Ordovician North America may have extended oceanward in a promontory at the present latitude of the Berkshire massif.

The model proposed for the evolution of the Berkshire massif undoubtedly has imperfections, but the basic framework is based on detailed field data. The interpretations regarding net movement and geometric complexities are intentionally conservative and suggest approximate minimum constraints. The level of strain seen in the Berkshire massif seems to require continental and (or) arc collisional tectonics presumably in the Ordovician.

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Road Log

Mileage

0.0 Start log in parking lot Monument Mountain Regional High School, Rt. 7, Great Barrington. Turn left on Rt. 7.

3.8 Turn left (east) on Rt. 23 at yellow blinking light.

6.0 Park at second large roadcut on Rt. 23, just past entrance to Butternut Basin.

Stop 1. Outlier of Precambrian gneiss (pCbg, fig. 6) brow of Beartown Mountain nappe.

These exposures mark the westernmost extent of the core rocks of the Beartown Mountain nappe that here are detached from the Dalton and are thrust out over the Paleozoic rocks. Here the thrust surface is folded and dips northwest.

A large F_4 antiform plunges northwest, having an axial plane of N. 45° W., 75° NE. The dominant feature in outcrop is the folded gneissic layering, a relict of Precambrian dynamothermal metamorphism. However careful examination reveals that a relatively strong cataclastic and metamorphic (blastomylonitic) foliation outlined by several zones of bull quartz actually crosscuts the older structure to form cataclastic seams. Both are folded by the F_4 antiform and the blastomylonitic foliations dip SW., NW., and locally NE. Minor isoclinal folds and the blastomylonite are related to small dislocations that probably are subparallel to the major fault (perhaps 200 feet) beneath this outcrop.

Examination of the gneiss near the quartz pods reveals two kinds of lineation on the micaceous blastomylonitic surfaces: (1) an intersection lineation (gneissic layering x blastomylonite) that commonly plunges NNW. and (2) a wear-groove and mineral lineation that trends roughly E. The second lineation is consistent with the regionally determined slipline determinations (fig. 6) and probably records movement direction on the Beartown Mountain nappe at this point. Both lineations are folded in the antiform and locally are bent in minor folds that crenulate the blastomylonite.

This outcrop illustrates the relatively subtle thrust fabrics found in many rocks, and these features are easily overlooked. The late folding in the northwest direction produces axial-planar slip cleavage in the pelitic rock; biotite, garnet, chloritoid, and staurolite locally show inclusion textures, indicating that crystallization outlasted the crenulation. This late refolding probably is Acadian (M_2 of fig. 7).

As we walk southeastward up the plunge of late folds, the underlying Dalton appears from beneath the thrust. Within approximately 100 feet of the Dalton, the gneiss and Dalton are progressively more cataclastically deformed and difficult to tell apart. Excellent exposures of silvery-gray tourmaline-rich muscovite-biotite-plagioclase-quartz blastomylonitic schist (probably sheared Dalton) having abundant isoclinal F_3 "foldthrust" folds can be seen in the outcrop to the east on the south side of the road. Again, however, a late F_4 antiform has folded the blastomylonite and the axial surfaces of the F_3 folds. This rock is illustrated in Ratcliffe and Harwood (1975, fig. 6). Highly deformed, more normal Dalton underlies the gneiss 200 feet south of the highway behind the houses.

6.3 Proceed east on Rt. 23 0.3 mi. to Lake Buel Rd. Turn right. In 3.2 miles, at triangle, turn right onto Mill River Rd. Turn is poorly marked. Follow Mill River Rd. 1.9 mi. south and bear left at next triangle (avoid turn to Sheffield Rd.). Stay on Mill River Rd.

12.8 Turn right at Mill River onto Clayton Rd. at "T" intersection. Cross bridge immediately, bear left (south) on Clayton Rd.

14.2 Turn left onto dirt road (first intersection south of Mill River; red house and barn on right side of road). Cross Konkapot River, past Umpachene Falls. The excellent exposures of sheared Precambrian gneiss and overlying Dalton-Cheshire-Stockbridge sequence were described previously (Ratcliffe, 1969, Stop 10). However, the "pebble conglomerate" at the base of the Cheshire is now identified as porphyroclastic mylonite gneiss, and the contact here is not a normal stratigraphic one, as I believed earlier. Although the geology is locally complicated by thrust faults of gneiss over Paleozoic rocks, I now believe that the Paleozoic rocks are detached from the basement by a major fault. In this area we are seeing the lowest tectonic level exposed in the Berkshires. Rocks of the Benton Hill area (Beartown Mountain slice), Stop 2, project over our heads.

14.8 At bridge turn right, bear right heading south onto Canaan-Southfield Rd.

15.8 Road branches in 1 mile by red barn; bear left.

17.3 At first intersection turn left onto Cross Rd. to Canaan Valley.

17.9 0.6 mi., pull into circle on left of road by cottages. Stop 2, Benton Hill--Torano property. Please obtain permission if you plan to return.

Stop 2. Benton Hill. Imbricate slices beneath Benton Hill slice, blastomylonite and fold thrust (F_3) fabric. See inset (fig. 9) for traverse and location of substops.

This traverse begins in OCsa of the Stockbridge. The carbonate rocks here actually are detached by a major thrust from the basement rocks that appear in the Umpachene Falls and Brush Hill windows. Above the dolomite marble are exposures of the Walloomsac (Owm-basal, feldspathic micaceous marble unit, and Ow-sillimanite-biotite-plagioclase-quartz schist). The Walloomsac here forms a parautochthonous sliver above the slice of Stockbridge but below three additional slices at the sole of the Beartown Mountain slice: (1) a small sliver of amphibolite gneiss, (2) a slice of Dalton, and (3) the uppermost Beartown Mountain slice that consists of a sequence of layered gneisses. The upper slice truncates all three of the lower slices and rests, in turn, on Stockbridge, Walloomsac, amphibolitic gneiss, and Dalton. Throughout the entire stack, an intense late east-dipping fold-thrust foliation has formed as the axial plane of (F_3) folds of schistosity and gneissosity. Near the base of the upper slice, intensely developed zones of blastomylonite can be seen parallel to the exposed thrust.

2a. Exposures of contact of Beartown Mountain slice on Walloomsac (Owm). In the small cliffs above are highly deformed gneiss having abundant F_3 folds and black blastomylonitic seams. Slipline determination using the rotation sense of minor folds and a plot of the prominant mullion structure are shown in Figure 4, A-1, A-2. To the north at the sinkhole and collapsed cliff the contact of the gneiss and the underlying Owm is exposed in an upright late F_5 antiform. The contact is marked by a whitish zone of diopside, and tremolite-actinolite-calc-silicate about 8 cm thick. At the actual contact, no shearing is recorded; instead, the contact is healed by postthrust recrystallization (possibly a metamorphosed gouge). Benton Hill is east of the (M_2?) sillimanite isograd, which postdates the thrusting. Thus, we are looking at the effect of postthrust folding and metamorphism. Mullions are folded by the F_5 fold. Slipline determination and mullions from the cliff above the collapsed zone are shown in Figure 4, B-1 and B-2.

2b. Walk south along cliffs to excellent exposures of banded blastomylonite and, locally, quartz-potash feldspar segregations in blastomylonite. Surfaces of the quartz pods have wear grooves plunging S. 88° E. at 20° consistent with the slipline determination (fig. 4, C-1, C-2). Various kinds of blastomylonite showing various degrees of recrystallization can be seen.

Walk west back down hill toward cars.

2c. Amphibolitic gneiss of lowest sliver resting on Walloomsac having highly deformed schistosity. At base of the gneiss is "pebbly" looking biotite gneiss that actually is porphyroclastic blastomylonite. Fifty feet to the south a sliver of highly folded quartzitic Dalton (pCCdq) rests on the amphibolite and shows excellent F_3 folds and intense shearing. The Dalton is overlain by gneisses of slice 3.

18.5 Return on Cross Rd. to Canaan-Southfield Rd. and turn right.

19.5 Turn left and cross bridge onto Hadsell Rd. Follow Hadsell Rd. north 0.9 mile to intersection with two paved roads.

20.4 Turn right onto second paved road (northernmost), the Southfield-Mill River Rd.

21.6 In 1.2 miles Y intersection and stop sign. Turn left on road to New Marlborough.

23.0 Town of New Marlborough. Stop sign intersection with Rt. 57. Continue straight on dirt road headed north, New Marlborough-Monterey Rd. Slow down near crest of hill. Descend to flat and park alongside dirt road. Exposures are in small cliffs east of road.

25.1 Stop 3. Optional stop (parking here presents real problems). Sheared Washington Gneiss sole of Beartown Mountain slice. Ledges above road are rusty biotite-muscovite-plagioclase-quartz gneiss of the Washington Gneiss. An intense blastomylonite foliation and F_3 folds have formed. Locally amphibolite marker beds show the intense deformation. Slipline determination from rotation sense of F_3 minor fold is shown in Figure 5, A,B. To the west are rocks of the Dry Hill and Lake Buel slices.

26.1 Intersection at base of hill. Continue straight on narrower dirt road.

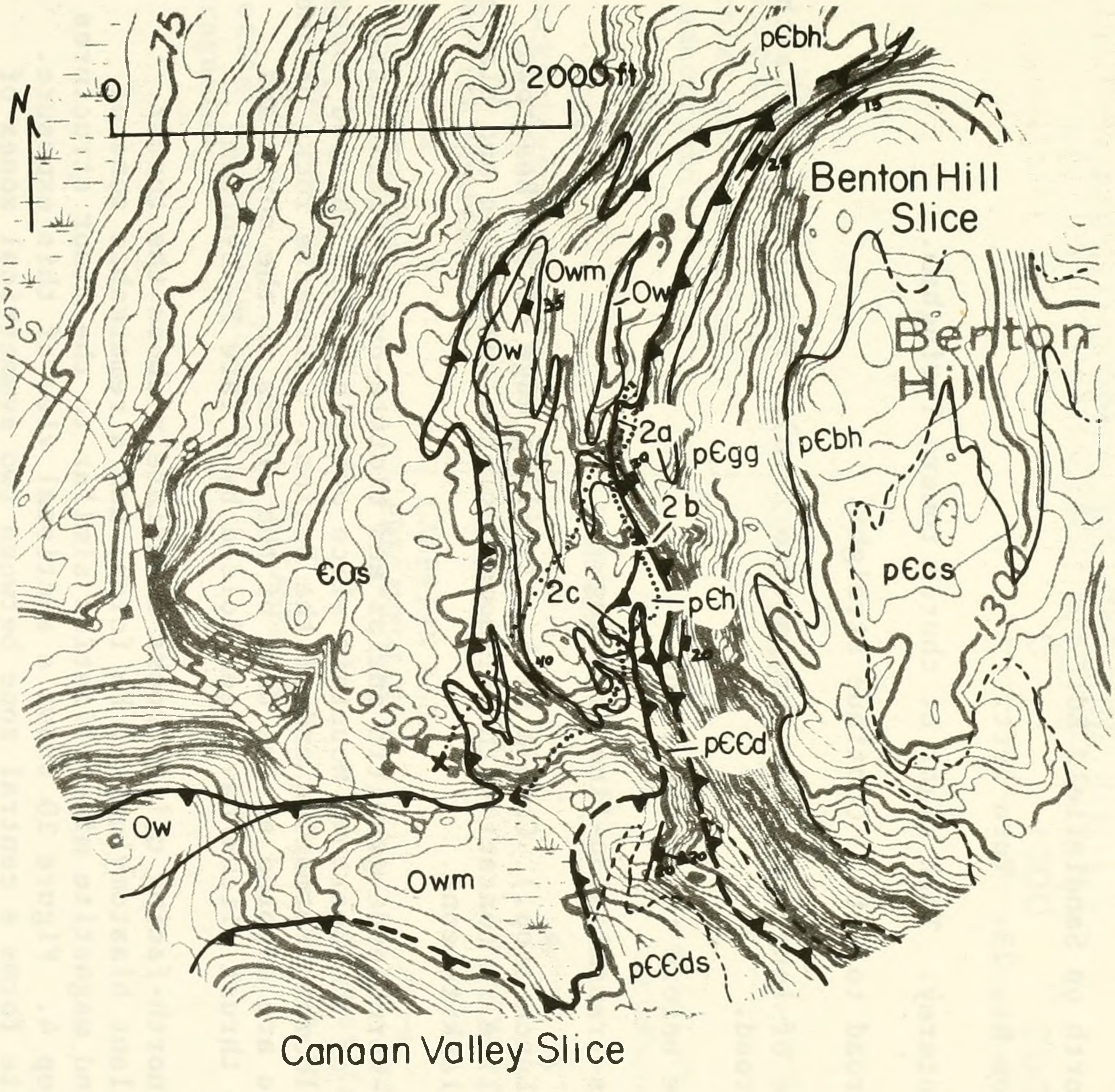


Figure 9. Generalized geologic map of the Benton Hill are
shows traverse.

Ow, Owm
Walloomsac Formation
(Sillimanite schist and
phlogopite marble) — ORDOVICIAN

COs
Stockbridge Formation — CAMBRIAN

pCCd, pCCds
Dalton Formation
(metaquartzite and schist) — CAMBRIAN AND PRECAMBRIAN(?)

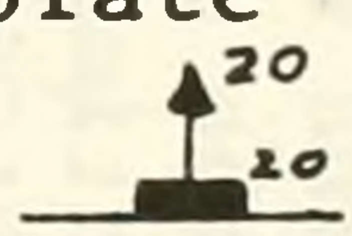
pCgg
Granite gneiss

pCbh
Biotite-hornblende gneiss

pCcs
Calc-silicate rock and marble

pCh
Hornblende gneiss — PRECAMBRIAN

Thrust fault, teeth on
upper plate



Strike and dip of axial plane
of fold-thrust fabric, plunge
of axis of reclined F_3 fold.

a, Stop 2. Dotted line

26.9 Intersection with paved road (Sandisfield Rd.). Turn left, 0.1 mi. Park just past house on left.

27.0 Stop 4. Halls Hill. Exposures of Tyringham-like granitic gneiss and fold-thrust fabric.

A small F_3 recumbent and reclined fold of gneissic layering is exposed in roadcut. In the axial part of the fold, a strong secondary metamorphic fabric has new oriented biotite parallel to zones of blastomylonite. The mineral textures in this rock, pictured in Figure 13 of Ratcliffe and Harwood (1975), indicate recrystallization of new brown biotite, apatite, clinozoisite, granulated quartz, and magnetite in the seams of blastomylonite. Superb F_3 folds can be seen in the cliffs in the woods to the east of the road. Locally sheared-off limbs of F_3 isoclines contain fine-grained "alaskitic" seams having parallel borders of black blastomylonite. Structures like this were seen at Benton Hill and will be seen at Cobble Hill (Stop 5) and at Stop 9. Evidently, the process that produces the "alaskites" operates over distances of centimeters to tens of meters. Slipline determinations from the cliffs northeast of the road are shown in Figure 5C. Analysis of folded lineations provides an independent determination of the slipline in agreement with that determined from the separation angle.

Continue north on Sandisfield Rd.

28.3 Intersection Rt. 23. Turn left.

28.5 Town of Monterey. Turn right at church toward Tyringham.

29.1 Branching road to left. Continue straight.

32.0 At the base of long downgrade (prepare to turn). Turn left on McCarthy Rd., dirt road.

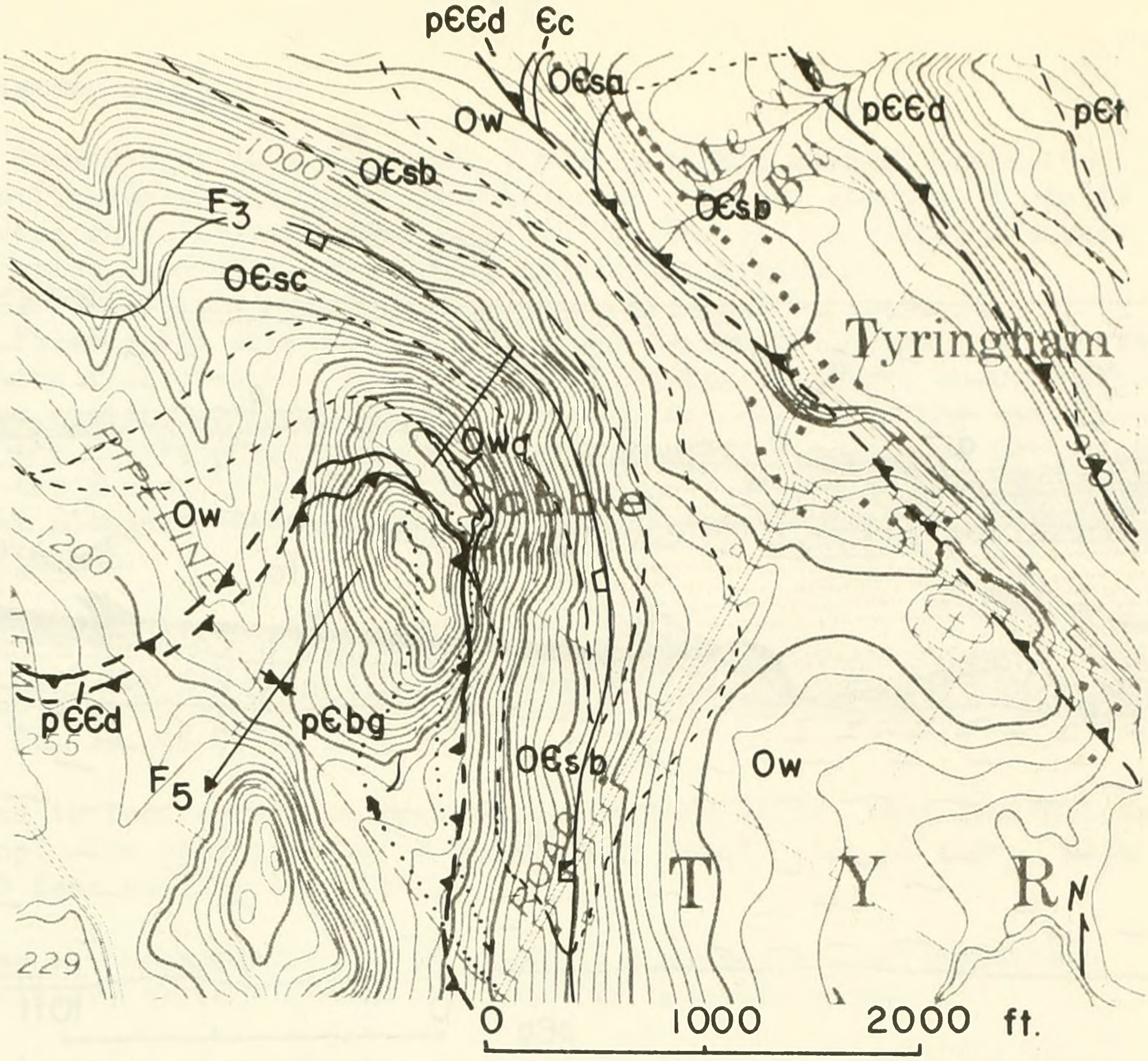
33.3 At triangle before farm turn right.

33.6 Park at gas-transmission-line crossing.

Stop 5. (Lunch stop.) Cobble Hill. Trailing edge of the Beartown Mountain slice in contact with Walloomsac of the autochthon and blastomylonite-alaskite zone.

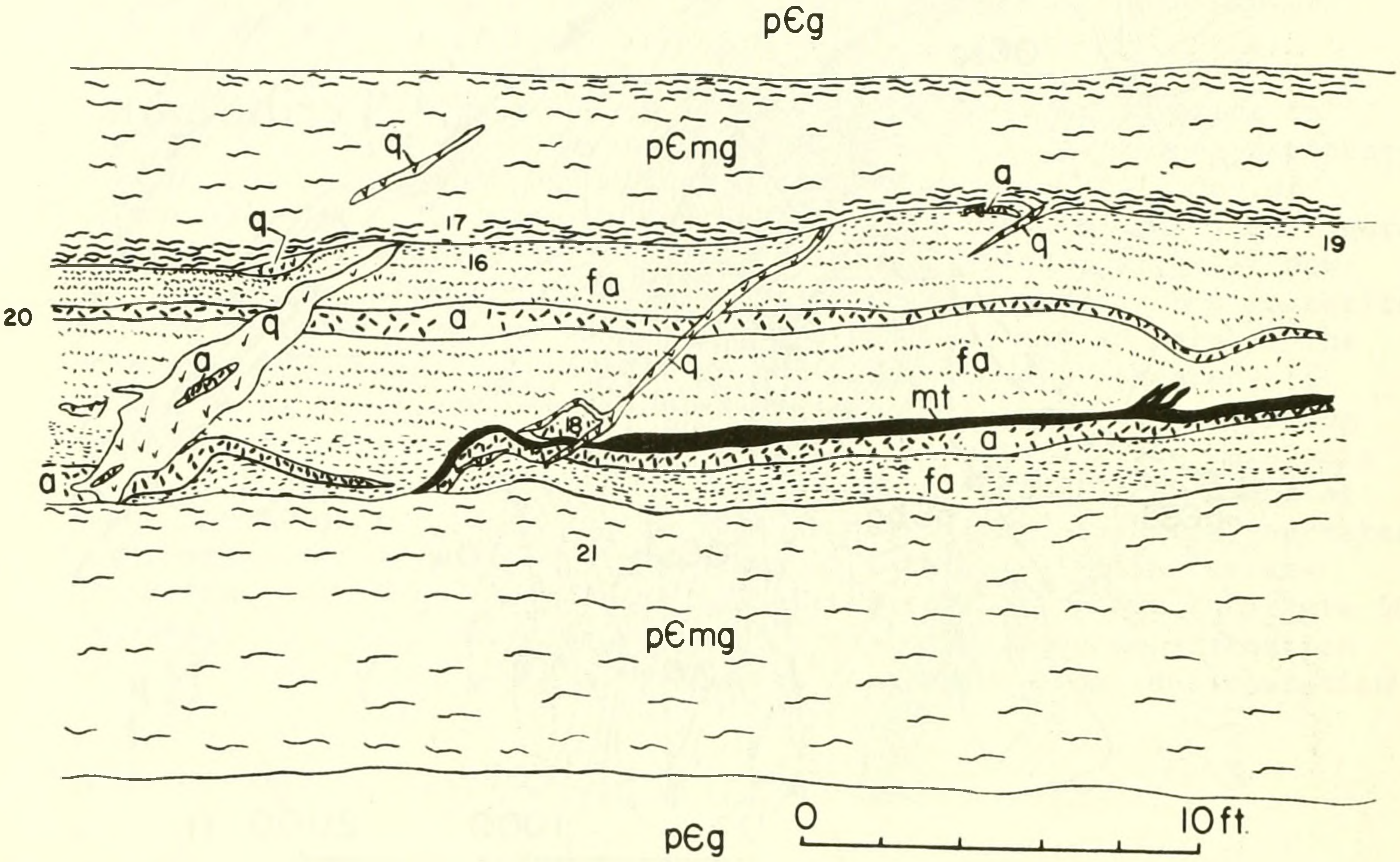
Biotite-hornblende-granitic gneiss and biotite-quartz-plagioclase paragneiss of the Beartown Mountain slice overlie highly sheared rocks of the Walloomsac Formation and of the Dalton. Carbonate rocks of the Stockbridge are exposed at the base of the cliffs to the north and east. The thrust slices have been folded by a late F_5 synform.

At the north-facing cliff, rocks immediately above the thrust show excellent blastomylonite, F_3 folds, and a remarkable zone of alaskite and magnetite mineralization similar to the minor structures seen at Stop 4. Figure 10 shows a sectional view of this exposure. The alaskite forms a central zone between two symmetrical zones of



Ow Owq Walloomsac Formation schist and quartzite	ORDOVICIAN	
unconformity		Axial trace F_3 recumbent fold
OCsc OCsb OCsa Stockbridge Formation	CAMBRIAN	
Cc Cheshire Quartzite	CAMBRIAN	F_5 synform
pCCd Dalton Formation	CAMBRIAN AND PRECAMBRIAN(?)	
pCt Tyringham Gneiss pCbg Biotite quartz plagioclase paragneiss	PRECAMBRIAN	Thrust fault, teeth on upper plate

Figure 10. Sketch map of Cobble traverse, Stop 5. Dotted line shows traverse.



pЄg - biotite-microcline-plagioclase-quartz gneiss containing layers of hornblende gneiss, rocks show relict Precambrian gneissosity

pЄmg - dark-gray mylonite gneiss and hornblende gneiss containing abundant seams of fine-grained blastomylonite; more closely spaced symbols show zones of intense shearing

fa - light-gray to white, finely laminated and weakly foliated, biotite-muscovite-microcline-oligoclase-quartz "alaskite" containing scattered magnetite; more closely spaced symbols show better foliated rock.

a - light-gray, massive, poorly foliated, biotite-muscovite-oligoclase-quartz alaskite having allotriomorphic granular texture

mt - magnetite, biotite-rich alaskite and magnetite quartz rock locally replaces a and fa

q - vein quartz

Numbers refer to sample site for geochronologic study by Mose (see Appendix 1).

Figure 11. Blastomylonite-mylonite-gneiss zone with alaskite near sole of Beartown Mountain slice, Cobble Hill, Stop 5 (east to right).

blastomylonite.

Twenty-five feet below the alaskite highly sheared muscovite-biotite-quartz schist of the Dalton(?) contains abundant F_3 folds having axial planes subparallel to the thrust. A slipline determination from this locality is plotted on Figure 6.

Feldspathic schistose marble (Owm) of the Walloomsac can be seen in the field below. The contact of the gneiss, first on the Dalton, then resting on the Walloomsac, can be traced around the east face of the cliffs where the contact is exposed. The intense foliation at the thrust is parallel to the contact. Return to cars by walking east along cliffs following the exposed fault. Continue downhill to Tyringham.

34.4 Tyringham. Turn right on paved road.

35.9 Road sign at crossroads to Monterey. Continue straight on road to Rt. 23 and Otis.

39.2 Bend in road--past the Tyringham-Otis town line. Park for optional stop. The only parking is on opposite (east) side of road. Walk 500 feet east to low cliffs.

<u>Stop 6.</u> Recumbent folds in paragneiss sequence associated with ancillary thrusts within the Beartown Mountain slice.

A series of northwest-trending gentle northeast-dipping thrust faults have formed in the paragneiss sequence east of Monterey in rocks of the Beartown Mountain slice. Detailed mapping of the calc-silicate and amphibolite units has shown that there is no great separation on these faults but that the strain has been largely taken up by D_3 ductile behavior. Excellent exposure of recumbent and reclined F_3 folds can be seen east of the road, where gray biotite gneiss in a thrust sheet overlies intensely deformed hornblende-plagioclase gneiss. Hornblende in the amphibolite has recrystallized within the blastomylonitic fabric. Slipline data for this stop are shown in Figure 5D.

Continue south.

40.2 East Otis and intersection with Rt. 23. Turn left.

43.7 Intersection of Rt. 8 at Otis. Turn left, north on Rt. 8.

44.9 Turn right into Otis Ski Mobile Club, just before green house.

<u>Stop 7.</u> Exposure contact of Basin Pond slice with Beartown Mountain slice (Otis quadrangle).

The detailed stratigraphic units of the Beartown Mountain slice have been mapped from the Great Barrington and Monterey quadrangles eastward into the Otis quadrangle. Continuity of map units, including a very distinctive paragneiss-calc-silicate stratigraphy, reveals complex isoclinal and recumbent folds. However, no major detachment zones exist. North of this point, in the East Lee quadrangle, a series of higher slices without the distinctive stratigraphy override the Beartown Mountain slice; in sequence these are: Upper Goose Pond, Basin Pond, Upper Reservoir, and October Mountain slices. The contact between the Upper Reservoir and Basin Pond slices is marked by abundant development of alaskite, biotite granodiorite, and magnetite mineralization that is responsible for the marked northwest-trending magnetic anomaly (Popenoe and others, 1964). At Stop 9 we will make a traverse across these three higher slices.

The contact of the Basin Pond slice with the Beartown Mountain slice has been traced southward to this point.

The contact between the diopside-calc-silicate unit of the Beartown Mountain slice and a very tectonized and granite-infiltrated garnet-biotite granitic gneiss (perhaps Tyringham) is exposed above the brook. Above the sillimanite isograd, small granitic stringers and pods are commonly found in or near thrust faults. The granite layers are foliated with the blastomylonitic (F_3) fabric and locally appear to be folded, although the granite most commonly is intruded parallel to the limbs of the F_3 folds in much the same habit as the thin alaskites seen at Halls Hill. This intense folding with granitic stringers produces a different kind of fold-thrust fabric that characterizes the fault zones in higher grade rocks of the Otis quadrangle.

Slipline data from this locality are shown in Figure 5E.

Log resumes at Rt. 8. Turn left toward Otis and follow Rts. 8 and 23 into Otis.

46.2 Turn left on Rt. 23 at center of Otis. Follow Rt. 23 through East Otis.

50.6 At bend in road to left, 0.2 mi. out of East Otis, turn left onto Algerie Rd. by small white house on left.

50.7 At "T" intersection, turn left, still on Algerie Rd.

54.2 Intersection of Lee and Westfield Rds., continue straight.

55.1 Turn right at dirt road, entrance to Williams granite quarry.

Stop 8. Williams granite quarry (fig. 12).

Between Otis and East Otis, we crossed the axis of a major northwest-trending F_4 synform that downfolds the nested Basin Pond, Upper Reservoir, and October Mountain slices. North of East Otis, is a broad expanse of the Basin Pond slice, composed almost entirely of the distinctive garnet-bearing granitic gneiss unit seen at Stop 7. West of our present location, typical Beartown-Mountain-slice rocks reappear from beneath the Basin Pond slice in the White Lily Pond window. The stratigraphic units and the structural sequence match those last seen west of the major F_4 synform. This suggests that rocks of the

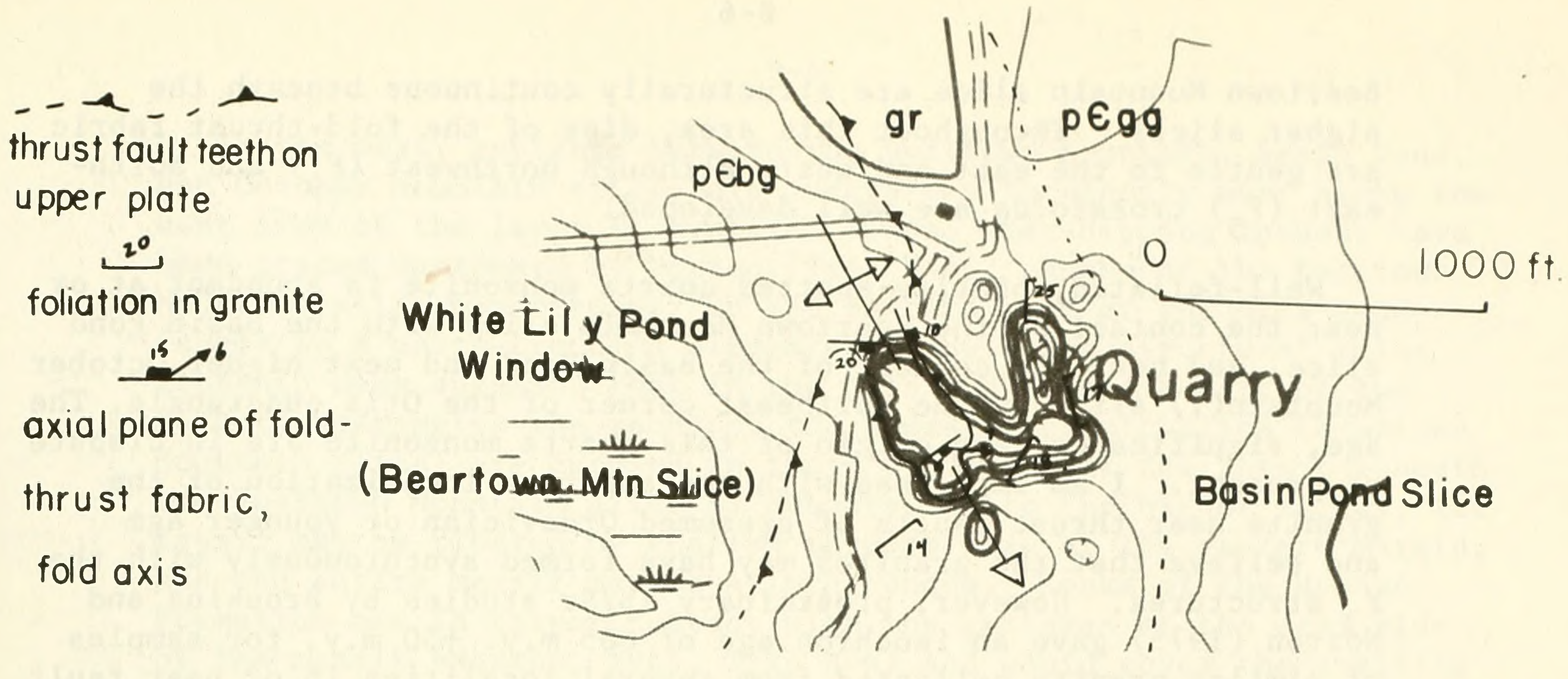


Figure 12. Geologic sketch map of the William granite quarry, Otis quadrangle, Massachusetts. pЄbg=biotite quartz microcline plagioclase paragneiss and amphibolite; gr=gray, biotite-flecked, foliated quartz monzonite of uncertain age; pЄgg=biotite granitic gneiss.

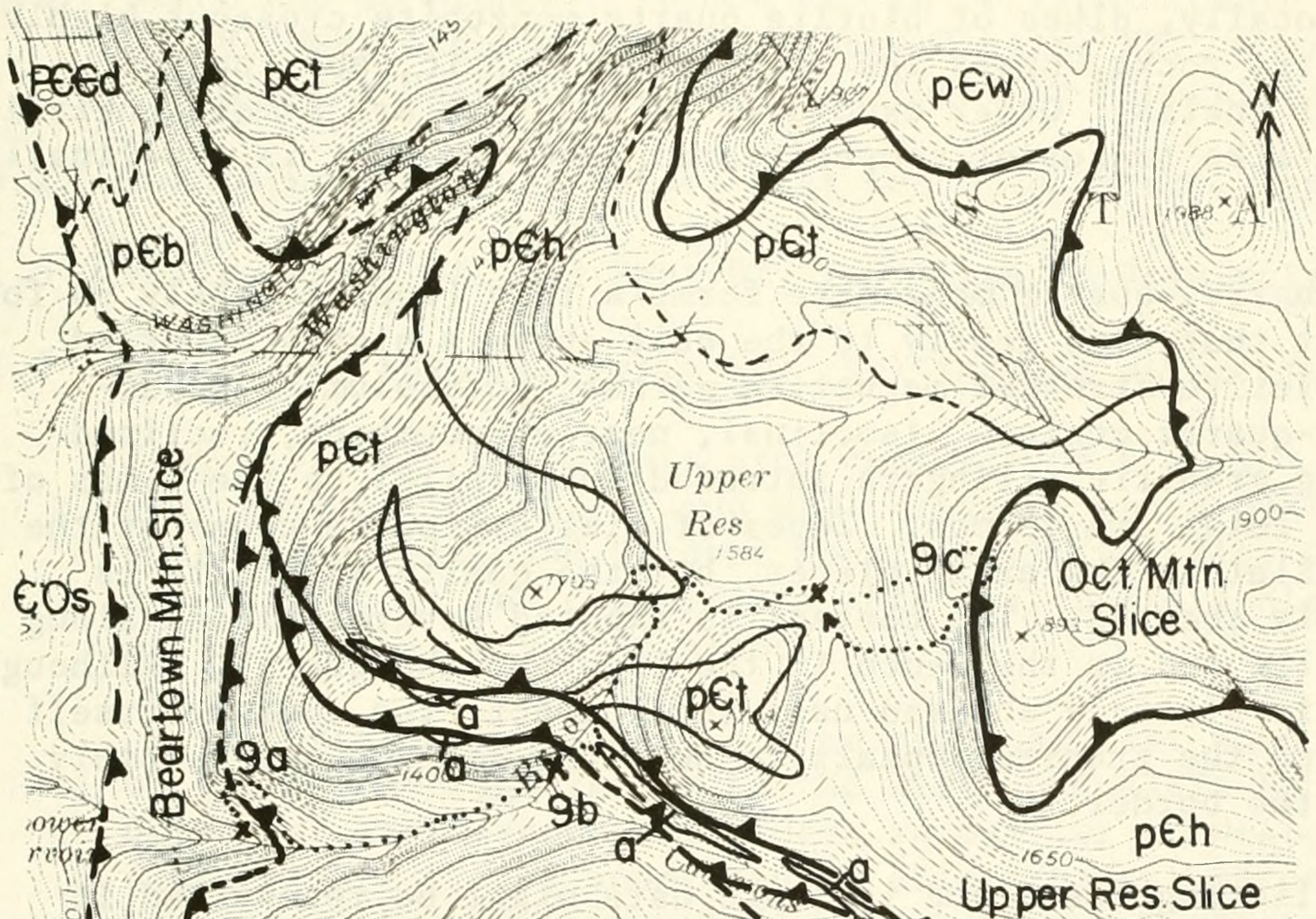


Figure 13. Generalized geologic map of stops 9a, 9b, and 9c, East Lee quadrangle (Basin Pond, Upper Reservoir, and October Mountain slices). pЄw=Washington Gneiss, pЄh=hornblende gneiss, pЄt=Tyringham Gneiss, pЄb=biotite paragneiss, a=alaskite, pЄЄd=Dalton Formation, ЄOs=Stockbridge Formation.

Beartown Mountain slice are structurally continuous beneath the higher slices Throughout this area, dips of the fold-thrust fabric are gentle to the east and west, although northwest (F_4) and north-east (F_5) crossfolds are well developed.

Well-foliated, biotite-spotted quartz monzonite is abundant at or near the contact of the Beartown Mountain slice with the Basin Pond slice, and near the contact of the Basin Pond and next higher October Mountain(?) slice in the northeast corner of the Otis quadrangle. The age, significance, and origin of this quartz monzonite are in dispute at present. I am impressed with the apparent localization of the granite near thrust faults of presumed Ordovician or younger age and believe that the granites may have formed synchronously with the F_3 structures. However, preliminary Rb/Sr studies by Brookins and Norton (1975) gave an isochron age of 605 m.y. $\pm$50 m.y. for samples of similar granite collected from several localities in or near fault slivers in the Middlefield thrust zone. Likewise, preliminary U-Pb analysis of zircon from a nearby quarry also suggests late Precambrian rather than Paleozoic age (R. Zartman, personal communication, 1974).

Rb/Sr whole-rock data by Douglas Mose for granitic rocks collected from four quarries in the Otis quadrangle, shown in Appendix 1, Figure 3, show marked nonlinearity and yield an approximate isochron of 486 m.y. Locally, dikes of biotite quartz monzonite crosscut highly folded country rocks, cross the fold-thrust fabric, and include zenoliths of gneiss. Other exposures of the rock are almost gneissic, having ghostlike traces of compositional layering that is isoclinally folded.

In the quarry, quartz monzonite forms a thin (approximately 90 foot-thick) sheet that dips gently to the east above a highly deformed dark-gray biotite-streaked magnetite-garnet, potassium feldspar-plagioclase-quartz gneiss. Isoclinal, nearly recumbent, reclined folds having granitic stringers intruded subparallel to the limbs of sheared-off folds are common. Zones of blastomylonite crosscut the gneiss parallel to the axial planes, but the quartz monzonite is not similarly sheared. The contact is exposed several places along the west walls and in the bench in the floor of the quarry. Although the gneiss is strongly sheared near the contact, the contact itself is sharp, and the granite appears to be finer grained and possibly chilled at the border.

The conflicting field and isotopic data might be reconciled if the rock we have mapped as a foliated biotite quartz monzonite is anatectic rock remade from 1 b.y.-old gneiss or from Avalonian granite in Paleozoic fault zones.

Log resumes at Algerie Rd.

55.1 Turn right (north) onto Algerie Rd.

56.5 Follow "T" intersection. Turn left.

57.8 Turn left onto Rts. 8 and 20 at Bonny Riggs Corners.

To the west, contacts between the Beartown Mountain, Basin Pond, and October Mountain slices dip moderately to steeply west along the east limb of the large F_4 synform. These west-dipping thrusts have been traced northward by Norton (Trip B-4). Rocks of the Beartown Mountain slice may reappear in the eastern part of the Otis quadrangle in a north-trending elongate window. The structural relationship here suggests that in the Otis and southern part of the Becket quadrangles the rocks of the lowest tectonic slice (Beartown Mountain slice) are exposed in these windows. If the thrust beneath the Beartown Mountain slice is subparallel to the higher slices, the massif may be floored by shallow thrusts even at its eastern margin, and the entire massif may be allochthonous. Rocks of the Hoosac Formation are in thrust contact with the gneisses at the east side of the massif (Norton, 1969, Trip B-4) and would cover the trailing edge of the Beartown Mountain slice, so this problem may never be satisfactorily resolved without deep drilling.

61.0 At bend in Rt. 8 by powerline crossing, we are passing back down through the October Mountain, Upper Reservoir, and Basin Pond slices along the west limb of the F_4 synform.

63.2 Rt. 8 and 20 branch. Follow Rt. 20 to right toward Lee. Hill to right of TV tower exposes stacked slices dipping NE., whereas hills to left contain the Upper Goose Pond and Beartown Mountain slices.

69.2 Branching road just before East Lee Steak House, Maple St. Turn right.

71.5 Follow Maple St. and East St. 2.3 miles to Reservoir St.

71.5 Turn right onto Reservoir St. Log resumes at Reservoir and East St.

Stop 9. (Fig. 13.) This stop consists of a series of substops at the west edge of the massif and will traverse rocks of the Basin Pond, Upper Reservoir, and October Mountain slices (fig. 13). Stop at gate into reservoir and consolidate into most durable high-carriage vehicles, as the road is rough in places.

9a. Park in road near borrow pit just past pump house. View of the Stockbridge Valley to the west, underlain by autochthonous rocks. Dalton of Rattlesnake Hill forms an outlier to west, and in the distance are ridges underlain by allochthonous Taconic rocks of the Everett slice. We are standing on Beartown Mountain slice below the overlying Basin Pond slice. Cliffs to north are highly sheared Tyringham Gneiss of the Basin Pond slice. Gently east-dipping fold-thrust fabric, nearly recumbent folds having a strong blastomylonitic fabric are sheared off along a 10- to 20-cm-thick zone of jet black blastomylonite. Dikes of bull quartz and pink alkali feldspar intrude the shear zones and show a strong lineation that agrees closely with the slipline from separation angle of F_3 folds (fig. 5F). Return to cars.

Continue up dirt road to large cleared area on right.

9b. Optional stop. Exposures of shear zone and alaskite in fault zone at contact of Basin Pond and Upper Reservoir slice. In the field can be seen intensely sheared Tyringham Gneiss having a gently to moderately northeast-dipping blastomylonitic foliation. Fine-grained, mica-poor alaskite locally crosscuts the sheared gneiss and at other localities is foliated with the blastomylonite. This suggests that the alaskite was generated or intruded at the time of the shearing. To the southeast, pods of alaskite locally rich in magnetite are found in this fault zone. This magnetite mineralization is responsible for the sharp aeromagnetic anomaly shown by Popenoe and others (1964). Return to cars and drive across reservoir following dirt road to spillway overflow. At east end of Upper Reservoir.

9c. Rocks at spillway are well-layered biotite, hornblende, and garnet gneiss distinct from the Tyringham. The general trend of the Precambrian gneissosity is approximately east and vertical. This is cut by a gently northeast-dipping blastomylonitic foliation much less intense than at 9b.

Walk northeast to clearing in which hornblende, spotted and streaked garnet biotite gneiss, and amphibolite crop out. Continue northeast over first small ridge which has well-layered hornblende gneiss to a marked north-trending bench, which marks the trace of the thrust zone beneath the next higher slice (the October Mountain slice). Small crops and float of amphibolite and amphibolitic gneiss are found in the bench. Climb the slopes to the east to see the rusty-weathering rocks of the Washington Gneiss. At the base of the slope, blastomylonitic foliation dipping 30° E. has largely obliterated the Precambrian gneissosity. Farther up the slope are blue quartz ribs and distinct beds of the Washington Gneiss.

A slipline of N. 80° E. (fig. 5G), using the rotation sense of minor folds, agrees closely with the N. 75°-80° E. lineation seen on the undersides of blastomylonite zones.

After examining the Washington Gneiss, begin to return to the cars by walking south along the bench following the Washington contact.

About 300 feet south, where the bench terminates, are magnificent exposures of the sheared rocks at the top of the Upper Reservoir slice.

Nearly recumbent folds of biotite hornblende gneiss have a blastomylonitic axial-planar foliation that dips 25°E. Fifty feet east of this crop are exposures of blastomylonite containing small augen of pink feldspar in an even-textured gray foliated blastomylonitic matrix having strong lineation, outlined by pink potassium feldspar streaks; the streaks plunge N. 75° E. at 30°.

71.6 Turn right onto East St., and in 0.1 mile turn left again onto Bradley.

71.8 In 0.2 mi. bear right onto Columbia.

73.0 Intersection Columbia and High St. Turn left.

73.3 Turn left into parking lot of Lee Junior High School.

Stop 10. The Pinnacle - St. Mary's School, Lee. Dalton of the Monument Mountain-Rattlesnake Hill slice.

Tan-weathering muscovite, boitite-flecked feldspathic metasandstone of the Dalton Formation crops out in large cliffs overlying the Cheshire Quartzite seen at the edge of the parking lot. The distinctive spaced foliation seen in the Dalton expresses the fold-thrust fabric. Minute folds of an earlier foliation can be seen as isolated noses of rootless folds. This rock is illustrated in Figure 4 of Ratcliffe and Harwood (1975).

Slipline from separation angle of minor folds and lineations taken from 100-foot section at the base of the cliff is shown in Figure 5I. The slip direction agrees fairly well with the well-developed but variable lineation produced by streaks of pre-existing bedding and foliation in the plane of the thrust fabric.

Muscovite, biotite, granulated quartz feldspar, and recrystallized quartz are oriented in the blastomylonitic foliation. Larger recumbent and reclined folds of quartzite can be seen near the crest of the hill.

The fold-thrust fabric postdates an older schistosity. The Paleozoic rocks in the Berkshire massif were metamorphosed before emplacement. In addition, the faults override and truncate metamorphic (M_1) fold structures in the autochthon. Similar textures and structures are found in the rocks of the Monument Mountain slice.

To return to Great Barrington and Stockbridge, turn left on High St. In 0.3 mile, turn left onto Rt. 20. Follow Rt. 20 1.1 miles to intersection with 102. Turn right. Follow 102 to Stockbridge and take Rt. 7 south out of Stockbridge to Great Barrington.

End of Trip

Appendix 1

Rb/Sr WHOLE-ROCK DATA FROM SELECTED GRANITIC ROCKS IN THE BERKSHIRE MASSIF

Douglas Mose
George Mason University

Rb/Sr whole-rock data for the Tyringham Gneiss is shown in Figure 1. The data reveal that crystallization of the granite occurred about 1170 m.y. ago. Geologic data indicate that the Tyringham Gneiss intrudes Washington Gneiss and other paragneiss units but was involved in the intense pre-Dalton dynamothermal metamorphism (see fig. 7 of text); it thus can be considered a pre- to syntectonic granite.

Rb/Sr whole-rock data for the Cobble Hill mylonite zone (Stop 5) are shown in Figure 2. Although the best fit line yields a somewhat reasonable calculated age, the scatter of the data shows that isotopic equilibrium was not reached throughout the zone of cataclasis. At best, the Rb/Sr whole-rock data show that other means must be used to determine the chronology of faulting. The location of samples is shown in Figure 10 (of text).

Rb/Sr whole-rock data obtained from the Williams Quarry, New Whiting Quarry, and Winn Quarry are shown in Figure 3. The best fit line to all the isotopic data suggests that these granites crystallized in Ordovician time. The data are quite non-linear, so the age estimate is very tentative. The magnitude of scatter from a 486 m.y. isochron is itself unusual, and probably indicates that the granite magmas were not isotopically homogeneous. This inhomogeneity could have been produced if strontium which was absorbed from the surrounding Precambrian gneisses and therefore enriched in radiogenic ^{87}Sr was not homogenized with the strontium within the magma.

Data from Stop 8 are shown in Figure A. Further isotopic investigation will be necessary before the age of these granites is finally resolved.

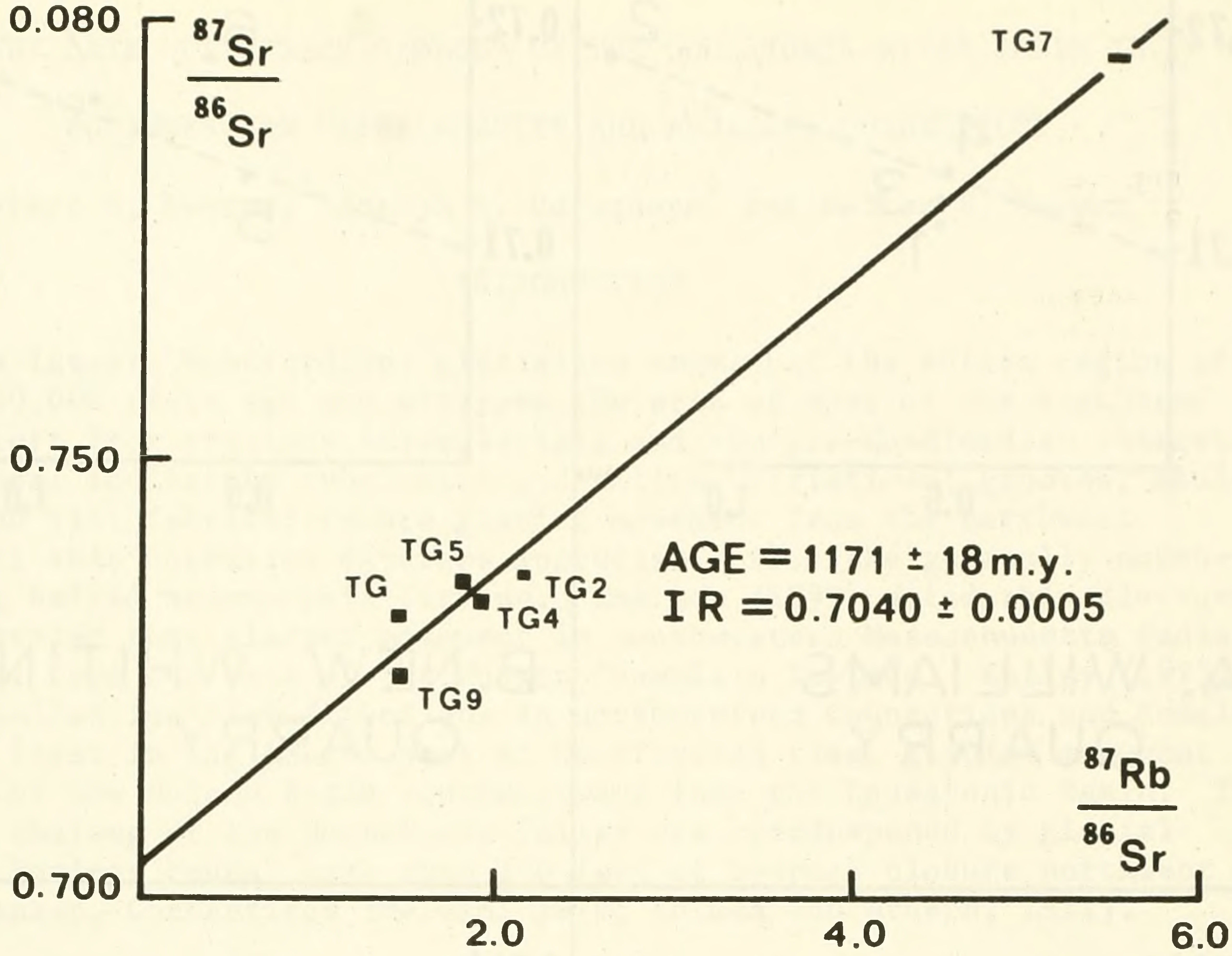


Figure 1. Rb/Sr whole-rock data for Tyringham Gneiss, Monterey, Great Barrington and Stockbridge quadrangles, Massachusetts.

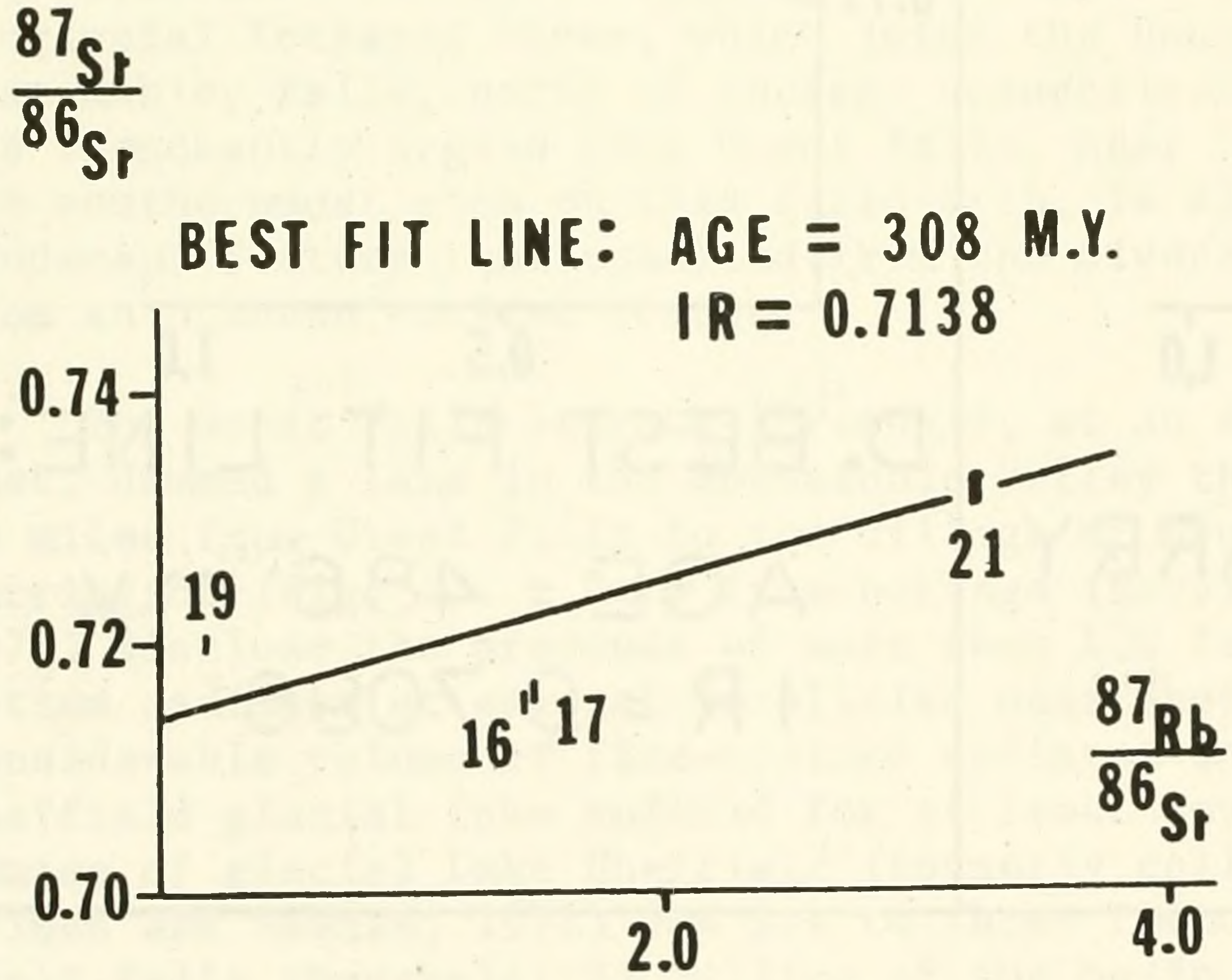


Figure 2. Rb/Sr whole-rock data for alaskite and blastomylonite, Cobble Hill, Stop 5.

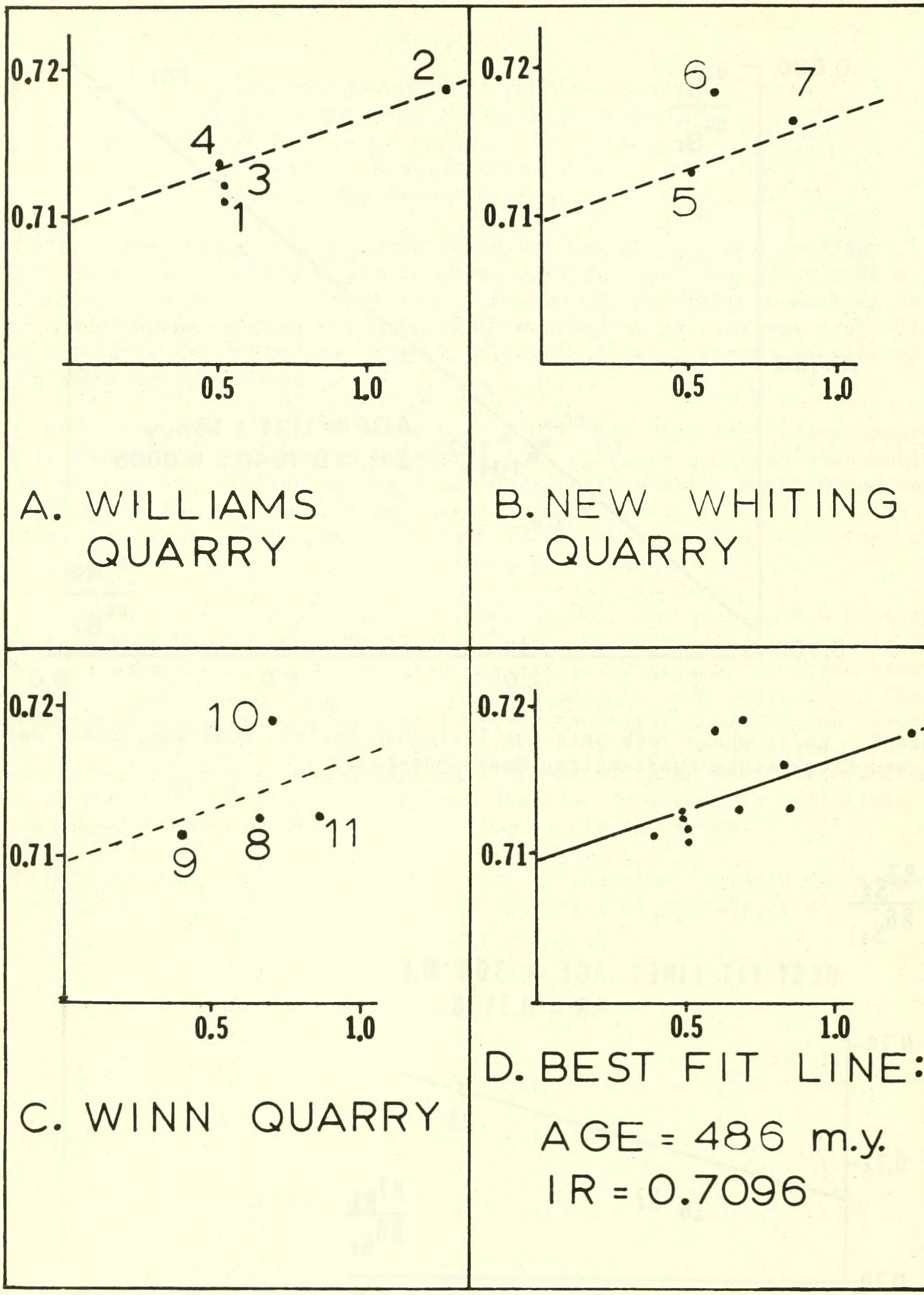


Figure 3. Rb/Sr whole-rock data for biotite quartz monzonite from three quarries in the Otis quadrangle, Massachusetts. A. Williams Quarry, Stop 8. D. shows combined data.