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Ratcliffe, Nicholas M.

Burton, William C

Sutter, John F.

Mukasa, Samuel

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STRATIGRAPHY, STRUCTURAL GEOLOGY AND THERMOCHRONOLOGY OF THE NORTHERN BERKSHIRE MASSIF AND SOUTHERN GREEN MOUNTAINS

Nicholas M. Ratcliffe, William C. Burton, John F. Sutter, and Samuel B. Mukasa*
U.S. Geological Survey, Reston, VA 22092; *Department of Geology
University of Florida, Gainesville, FL 32611

INTRODUCTION

The following text and generalized figures are intended to serve as the explanatory material for two fieldtrip guides, A-1 and B-1, contained in this volume. Trip A-1 covers an area at the northern end of the Berkshire massif in Massachusetts, and the southernmost end of the Green Mountains massif in Vermont and Massachusetts. Trip B-1 covers an area from Wilmington, Vt. in the Sadawga-Rayponda dome area, across the central Green Mountains to Bromley Mountain. Figures contained in the road log for Trip B-1 are numbered consecutively and follow those in the log for Trip A-1. References for both trips are cited at the end of the text in Trip A-1.

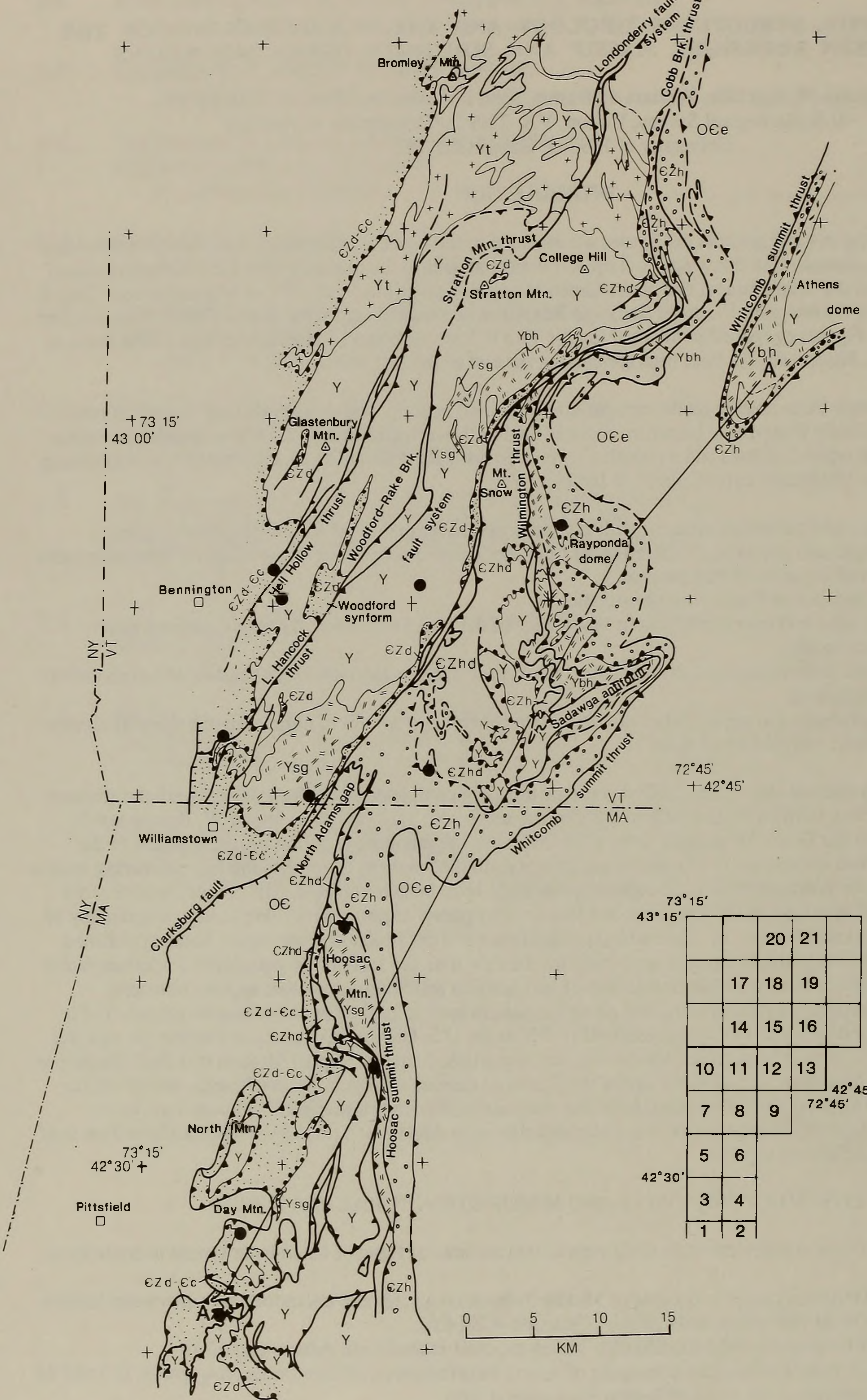
These two trips focus chiefly on the comparative structural geology and dynamothermal history of two major exposures of Middle Proterozoic basement rocks in the Northern Appalachians, as well as smaller exposures within the Sadawga-Rayponda domes and a complex zone of thrust faulted slivers of Middle Proterozoic rocks lying just east of the Green Mountains massif, south of Jamaica, Vt.

Stop locations and presentations are intended to present data related to the following general topics:
(1) Lithologic and chemical characteristics of the stratigraphic succession of the Middle Proterozoic rocks in each of the areas of basement rock;
(2) Characteristics of Proterozoic deformation;
(3) Stratigraphy and important facies relationships of the Late Proterozoic through Cambrian cover sequence rocks;
(4) Paleozoic deformation and dynamothermal effects of Taconic (about 460 Ma) and Acadian (about 380 Ma) orogenesis;
(5) The usefulness and applicability of 40Ar/39Ar mineral age spectra to unraveling the thermal history of complex polydeformed belts.

The results presented stem from detailed geologic mapping completed in the Berkshire massif and southern Green Mountains, before 1978 by N. Ratcliffe and S. Norton and recent 1:24,000 mapping by W. Burton and N. Ratcliffe in the area of the Green Mountains since 1986. Because the mapping is still in progress, much of the information in the Green Mountains is new and is preliminary. In the southern Green Mountains, pioneering studies by Skehan (1961) in the Wilmington, Vt., 15-minute quadrangle have been invaluable. His comprehensive work covered a large area of very complexly deformed, and locally, very poorly exposed rocks. We have adopted many of the basic elements of Skehan's work, but have added greater detail and definition in some areas. Recent published maps by Karabinos (1984) in the Jamaica area identify for the first time the location of potentially important faults along the eastern margin of the Green Mountains massif and Jamaica anticline, a zone that appears to extend southward into the Sadawga-Rayponda dome and along the eastern margin of the Green Mountains massif. U-Pb zircon studies conducted by Karabinos and Aleinikoff (1988) at the U.S. Geological Survey in Denver, on samples from basement rocks of the southern Green Mountains, and unpublished data of Samuel Mukasa and Beth Harding at University of Florida have helped resolve the age of the Stamford Granite Gneiss in Massachusetts, and of similar rocks in Vermont. 40Ar/39Ar data of Mukasa, from traverses across the Berkshire massif and southern Green Mountains (Sutter and others, 1985) have been supplemented by new data in the Green Mountains collected north of Mukasa's traverse in the area of trip B-1.

LITHOTECTONIC UNITS AND MAJOR STRUCTURAL FEATURES

Major lithotectonic units of concern for these field trips within the area of figure 1 listed from lowest tectonic level to highest are:
(1) Green Mountain massif consisting of Middle Proterozoic gneiss and unconformable quartzofeldspathic cover, Dalton Formation and Cheshire Quartzite (CZd-Cc);
(2) Miogeoclinal rocks of the Stockbridge Valley exposed in the North Adams gap (CO);
(3) Berkshire massif allochthon consisting of nested thrust slices of Middle Proterozoic gneiss (Y) and its unconformable cover rocks of Dalton Formation (CZd);


Bromley Mtn.
Londonderry fault system
Cobb Brk. thrust
OЄe
ЄZh
Yt
Y
ЄZd-Єc
Stratton Mtn. thrust
ЄZd
College Hill
Stratton Mtn.
ЄZhd
Whitcomb summit thrust
Athens dome
Ybh
Ysg
A'
+73 15'
43 00'
Glastenbury Mtn.
Woodford-Rake Brk. fault system
Wilmington thrust
Mt. Snow
Rayponda dome
Hell Hollow thrust
Bennington
Woodford synform
L. Hancock thrust
NY
VT
Sadawga antiform
72°45'
42°45'
MA
Williamstown
North Adams gap
Clarksburg fault
OЄ
Hoosac Mtn.
CZhd
Hoosac summit thrust
North Mtn.
73°15'
42°30'
Pittsfield
Day Mtn.
A
0
5
10
15
KM
73°15'
43°15'
20
21
17
18
19
14
15
16
10
11
12
13
42°45'
72°45'
7
8
9
5
6
42°30'
3
4
1
2

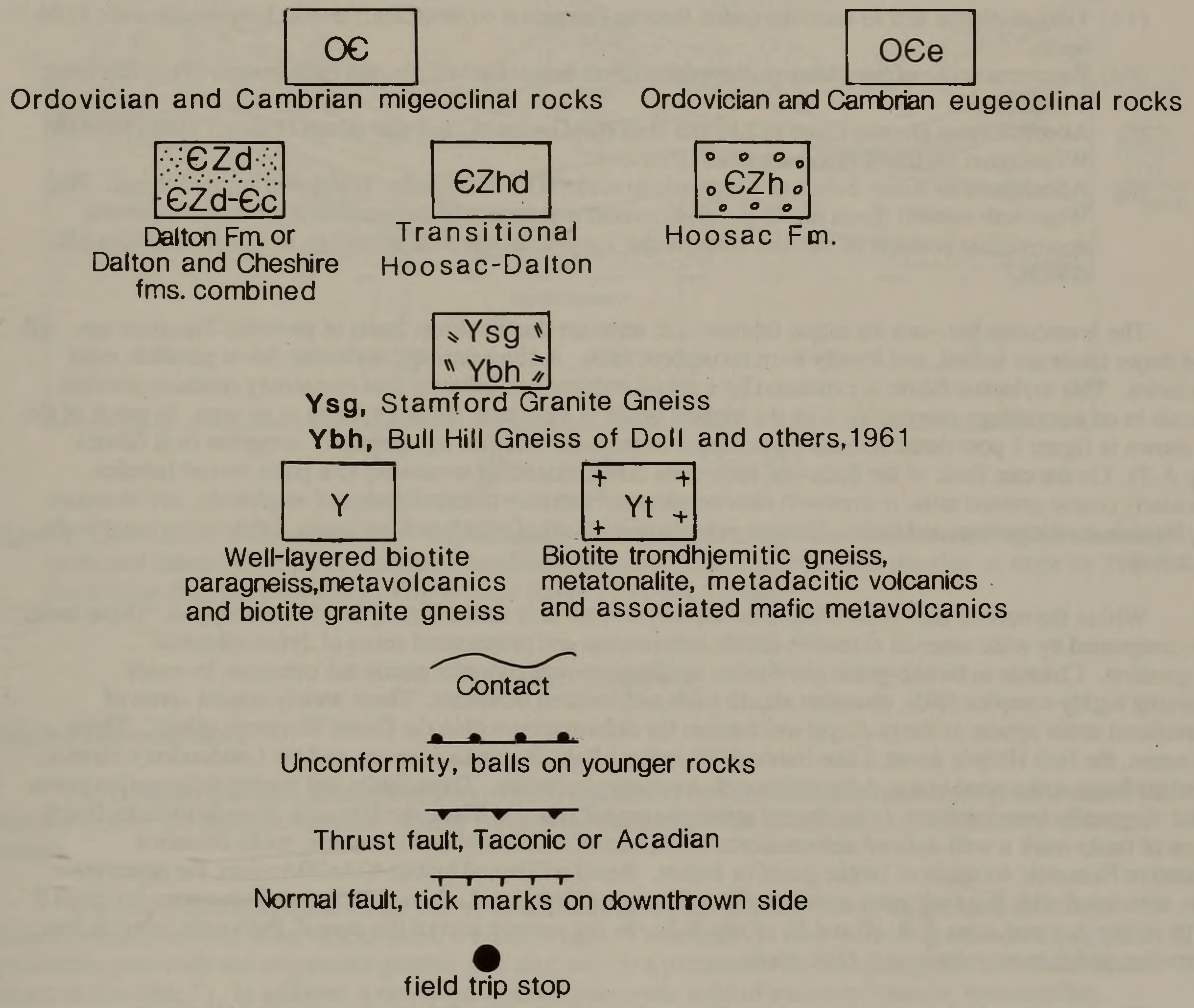


Figure 1. Generalized, regional geologic map of the northern Berkshire massif, southern Green Mountains and Sadawga-Rayponda dome areas of Middle Proterozoic gneiss, showing fieldtrip stops for trips A-1 identified by solid dots. Geology is based on mapping by Ratcliffe and Burton since 1986 in the following quadrangles: 21-Londonderry, 20-Peru, 17-Sunderland, 18-Stratton Mtn., 19-Jamaica, 10-Pownal, 11-Stamford, 12-Readsboro, by Burton in 17-Sunderland, 14-Woodford, by Ratcliffe in 13-Jacksonville, and 15-Readsboro; Arcas mapped previous to 1979, by Ratcliffe 1-East Lee, 3-Pittsfield East, 5-Cheshire, 7-Williamstown, 8-North Adams. Data in E. Dover (16), from Shehan, 1961; in Becket (2), Norton, 1974, in Windsor (6), Norton, 1961. Area just east of Jamaica (19) from Karabinos, 1984. (For more detailed map of the Green Mountains see figure 15, trip B-1).

(4A) Hoosac Nappe and its unconformable Hoosac Formation cover (CZhd) and its lateral equivalent to the north;
(4B) Basement rocks of the Sadawga-Rayponda dome below the Wilmington fault system (Ybg) and other Y units);
(5) Allochthonous Hoosac cover (CZh) and Bull Hill Gneiss of Doll and others (1961), (Ybh) above the Wilmington fault and Hoosac summit thrust;
(6) Allochthonous Rowe Schist and eugeoclinal rocks (OCe) above the Whitcomb summit thrust. The Whitcomb summit thrust marks the westernmost occurrence of eugeoclinal rocks and the present approximate position of the root zone for the Taconic allochthons according to Stanley and Ratcliffe (1985).

The boundaries between the major lithotectonic units are ductile thrust faults of probable Taconian age. All of the major faults are folded, and locally form recumbent folds. A characteristic, mylonitic fabric parallels most boundaries. This mylonitic fabric is expressed by a strong rodding and foliation that commonly contains oriented minerals in an assemblage compatible with the highest grade of Paleozoic metamorphism in an area. In much of the area shown in figure 1 post-thrust mineral assemblages of probable Acadian age generally overgrow fault fabrics (Stop A-3). On the east flank of the Sadawga-Rayponda dome, extending northward to a point east of Jamaica, particularly coarse-grained static overgrowth rims on garnets, randomly oriented sprays of amphibole, and abundant late plagioclase, microcline, and quartz feldspar pegmatitic pods all of which lack mylonitic fabric are present in the fault zones.

Within the core of the Green Mountains massif, several fault zones (fig. 1) have been mapped. These faults are accompanied by wide zones of extensive ductile deformation and pronounced zones of dynamothermal retrogression. Chlorite to biotite-grade phyllonites and sericite-rich mylonite gneiss are common, in zones containing highly complex folds, abundant sheath folds and lineated tectonites. These widely spaced zones of accumulated strain appear to the principal mechanism for deformation within the Green Mountain massif. Three such zones, the Hell Hollow thrust, Lake Hancock-Woodford-Rake Brook fault zones, and the Londonderry-Stratton Mountain faults strike northeast and dip moderately to steeply southeast. These faults and ductile deformation zones extend diagonally from northeast to southwest across the massif (fig. 1). The Lake Hancock-Woodford-Rake Brook system of faults mark a well-defined deformational front, east of which Middle Proterozoic rocks contain a penetrative Paleozoic foliation of biotite grade or higher. Based on limited biotite 40Ar/39Ar data, the penetrative fabric associated with this fault zone and east of it is Taconian (Sutter and others, 1985) (see discussions for stops 9 and 10 of trip A-1 and stops 5, 9, 10 and 11 of trip B-1). In the western part of the massif, Paleozoic fabric is less penetrative, and is more restricted to fault zones.

The Searsburg fault system forms a continuous thrust fault along the eastern margin of the Green Mountains massif from Jamaica south to the Massachusetts state line where it either merges with or is offset by the Clarksburg fault system. Brittle faults and associated open-work breccias, hematite-coated joint surfaces and sulfide mineralization mark certain exposures of the gently southeast-dipping Clarksburg fault from a point east of Williamstown north to near Stamford, Vermont, and late, low-angle Mesozoic(?) extensional faulting is likely along this zone (fig. 1). If this interpretation is correct, the older Searsburg thrust faults may correlate with the Hoosac fault and nested thrust faulting on the lower surface of the Hoosac slice seen at stop 3, trip A-1.

A cross section drawn from the beginning of Trip A-1 in the Berkshire massif through the Sadawga and Rayponda domes to the Athens dome, shows diagrammatically, the correlation of lithotectonic units and major faults (fig. 2). Projected positions of fieldtrip stops for trip A-1 are shown. The Hoosac summit thrust, although well-defined on Hoosac Mountain (A-1, stop 3), cannot be correlated with complete confidence. In figures 1 and 2, the Hoosac summit thrust is connected along a highly contorted contact within the Hoosac Formation with the Wilmington fault system. The Wilmington fault system is continuous with the Cobb Brook thrust of Karabinos (1984). This zone of fault-intercalated rocks may reappear within the Chester-Athens dome as the inner contact between Bull Hill Gneiss and Hoosac Formation (shown as the Cavendish Formation in Doll and others, 1961).

The Whitcomb summit thrust is drawn through areas we have not mapped and both its location and its existence as a discrete fault is in part conjectural. In areas where we have mapped it, in the North Adams and Jamaica quadrangles, both physical evidence for faulting (mylonitic structures) and truncation of map units supports a fault within this part of the section.

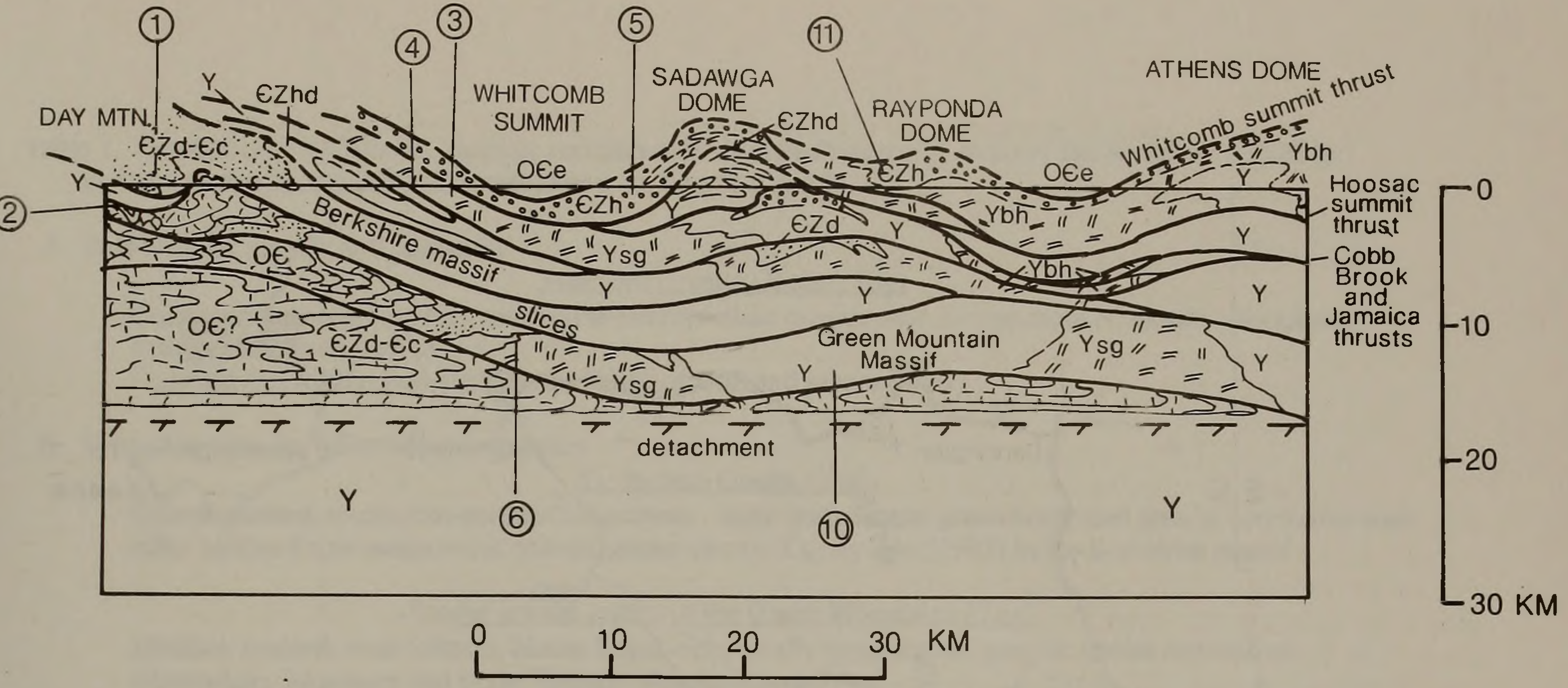


Figure 2. Generalized cross section from Day Mountain northeastward to the Athens dome showing correlation of faults and lithotectonic units, numbered localities refer to projected approximate position of stops on Trip A-1. For similar diagram pertinent to Trip B-1 see figure 17 in that trip log.

STRATIGRAPHY

Middle Proterozoic rocks

Hornblende granulite metasedimentary, metavolcanic, and syn-deformational granitoids greater than 1 Ga form the bulk of the parautochthonous Middle Proterozoic basement rocks of the Berkshire and Green Mountain massifs.

Middle Proterozoic rocks of the Green Mountains and Berkshire massifs may be grouped in 3 major categories based on field observations and U-Pb zircon ages. These are: (1) post-tectonic granites and pegmatite; (2) syntectonic granitoids and migmatitic granitic gneisses; and (3) a pretectonic layered paragneiss and metavolcanic sequence (see table 1). In addition, a newly recognized pretectonic suite of metatrondhjemite, metatonalite, metadacite and hornblende gneisses (meta-andesite and basalt) shown in table 2 is of uncertain stratigraphic position at present. It crops out in the central Green Mountains in the area of trip B-1, north of Stratton Mountain.

Mapping in the southern Green Mountains has confirmed that the sequence of Middle Proterozoic gneisses present in the Berkshire massif (Zen, 1983) is also present within the Green Mountains. Likewise, the basement gneiss within the Sadawga-Rayponda dome and in the small areas of gneiss between Mount Snow and Jamaica correlate with rocks present in the Green Mountains massif to the west. This stratigraphic and plutonic succession (table 1) is present in the Green Mountains as far north as Stratton Mountain. North of that point a belt of distinctive trondhjemitic and tonalitic gneisses approximately 10 kilometers wide as measured in a north- south direction extends across the full width of the massif (table 2).

The Stamford Granite Gneiss consists of coarse-grained to pegmatitic, microcline- microperthite-megacrystic, rapakivi granite; medium-grained, aplitic granite; hornblende-biotite monzonite, and locally ferromonzonitic mafic segregations and dikes. The rock clearly post-dates Grenville tectonism as it crosscuts folds in the gneisses and lacks the gneissic structure of the country rocks. The unit is present in the southern Green Mountains, on Hoosac Mountain and in the Green Mountains south of Jamaica from Wardsboro southeast to a point just west of Mount Snow. In the latter exposures, K-feldspar megacrystic biotite granite is largely transformed by Paleozoic shearing to biotite-augen gneiss. Mylonite and mylonite gneiss are co-extensive with the Bull Hill Gneiss as mapped by Doll and others (1961) near Wardsboro, Vt. and in the Sadawga- Rayponda dome. A concordant U-Pb zircon age of 959?Ma from the type Stamford Granite Gneiss (stop 5, trip A-1), (Karabinos and Aleinikoff, 1988) and similar but slightly more discordant ages by them from the Stamford-like rocks in the belt near Wardsboro and from the Bull Hill gneiss of Doll and others (1961) from the Chester and Athens domes indicate that all these granites are coeval. A U-Pb, concordia zircon age of approximately 960 Ma has also been determined by Beth Harding and Samuel Mukasa from the Stamford Granite Gniess on Hoosac Mountain. The Stamford Granite Gneiss

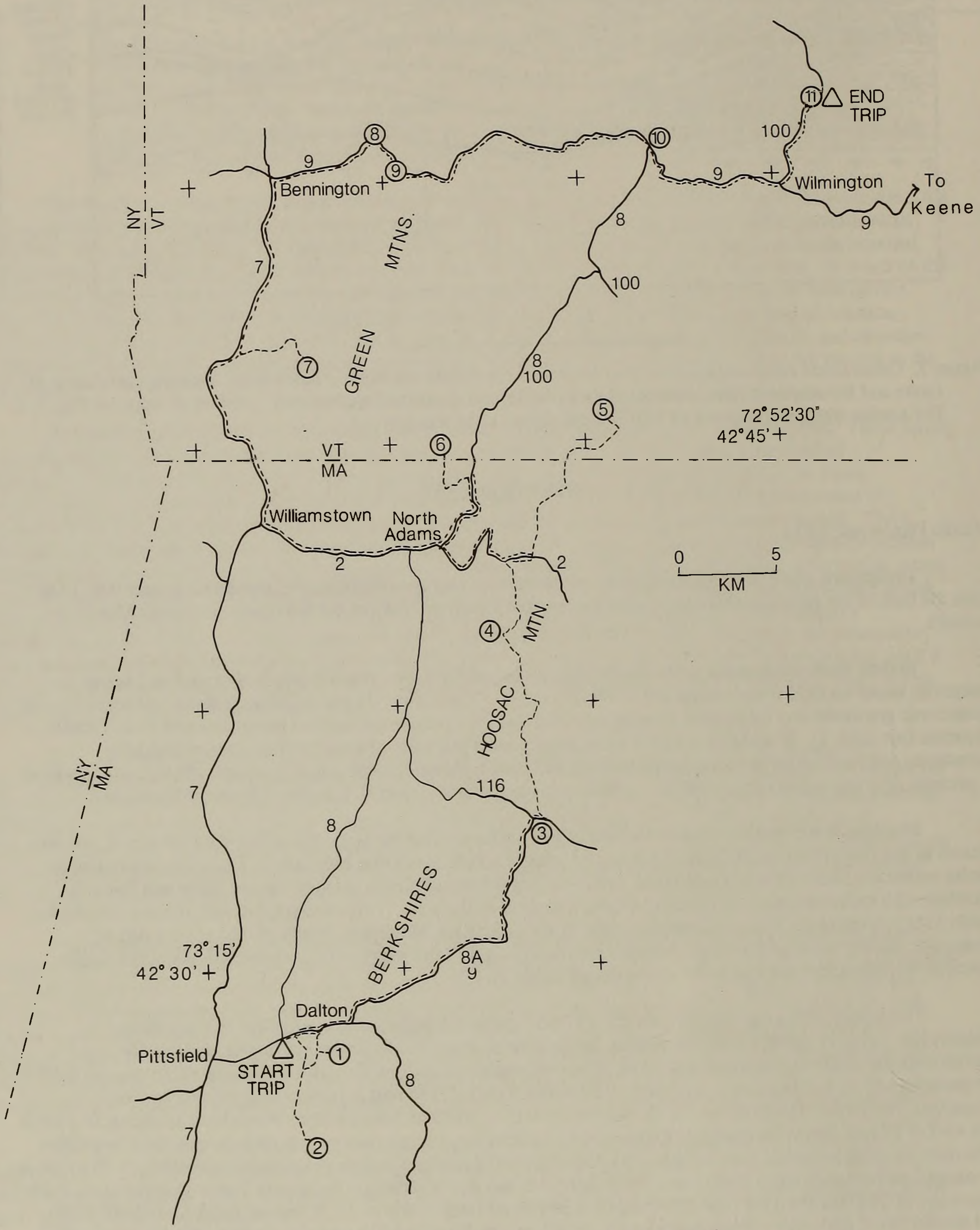


Figure 3. Map showing location of A-1 field trip.

Table 1. Generalized stratigraphic-plutonic succession for Middle Proterozoic rocks of the Berkshire massif and southern Green Mountains area (units shown on figures 5 and 6)

A. Post-tectonic granite and pegmatite

Stamford Granite Gneiss (Ysg)

Coarse-grained to pegmatite, microcline-microperthite megacrystic, biotite-rapakivi granite, associated ferromonzonite and aplite
Correlative with the Bull Hill Gneiss (Ybh) of Doll and others (1961)

B. Syntectonic biotite or hornblende granites

Tyringham Gneiss (Ytg)

Coarse-grained, microcline-perthite megacrystic, hastingsite-biotite granodiorite and granite correlative with other biotite-Kspar megacrystic granite gneiss shown Ygg by Zen (1983) in the Berkshire massif

Biotite granite gneiss of the Green Mountains (Ygg)

Medium-grained, well-foliated, biotite Kspar-rich, locally megacrystic, granitic gneiss exposed on Glastenbury Mountain and in the Stratton Mountain area (Ygg)

Biotite, migmatitic-K-feldspar-plagioclase gneiss (Ygm)

Medium-grained, biotite-plagioclase-Kspar-quartz, gneiss having ghost-like inclusions of well-layered 2 feldspar biotite gneiss

Biotite-K-feldspar megacrystic granite gneiss on College Hill (Ygc)

Exposed on a belt extending from College Hill in the Jamaica, Vt., quadrangle to a point west of Stratton Mountain

C. Layered paragneiss and metavolcanics gneisses (not necessarily listed in stratigraphic order)

Biotite-quartz-plagioclase gneiss (Ybg)

Well-layered, white and black, biotite-quartz-plagioclase gneiss and thin interlayered amphibolite, includes amphibolite, hornblende-pyroxene calcsilicate rocks, diopside- plagioclase gneiss, and rare beds of calcite-diopside marble

Quartzite (Yq)

White to steel-gray, vitreous, garnet-biotite-quartzite in beds up to 5 m thick, associated with garnet-rich, biotite-quartz plagioclase gneiss

Felsic gneiss (Yfg)

White-weathering, very fine-grained, magnetite-biotite-quartz-plagioclase-microcline gneiss, metarhyolite

Rusty-weathering, garnet-sillimanite, quartz gneiss (also shown as Yq)

Commonly retrograded to chlorite-muscovite-quartz phyllite that locally contains chloritoid in the Green Mountains

Amphibolite and amphibolite gneiss (Ya)

(In the Green Mountains)

Lee Gneiss (in the Berkshire massif)

Dark-colored, hornblende, biotite-plagioclase gneiss, amphibolite and dioritic gneiss (probable intermediate to mafic volcanics)

Washington Gneiss (Yw), (Yrr)

Rusty weathering, garnet-biotite-plagioclase quartz gneiss and schist, marked by coarse ribs of lavender quartz, (Yrr in the Green Mountains) associated with graphite-rich quartzite, metaconglomerate and sulfidic graphitic marble, and in Massachusetts, including a biotite quartz-plagioclase leucogneiss interpreted as metadacite and garnet amphibolite interpreted as mafic volcanic rocks

Table 2. Generalized sequence of rocks in the metatonalite-metatrondhjemite gneiss belt, central Green Mountains massif (Peru, Londonderry quadrangles)

Ytr	White weathering, massive, medium- to coarse-grained biotite trondhjemitic gneiss (well exposed near Rawsonville and on the crest of Bromley Mtn) characterized by 0.5 to 1 cm rectangular non-oriented clots of biotite and well-twinned subhedral grains of oligoclase
Ytm	White weathering, medium- to fine-grained, biotite-quartz-plagioclase granofels having indistinct layers accentuated by rare thin layers of pegmatitic granodiorite, giving rock a migmatitic appearance
Ytd	White weathering, very fine-grained, quartz plagioclase rock, having less than 5 percent biotite, and indistinct wispy biotite-rich laminae, locally, well-layered having biotite-rich, quartz-plagioclase interlayers up to 0.25 m thick, probably metadacite, well exposed at Bondville
Yt	Massive, coarse-grained, hornblende-biotite-quartz plagioclase metatonalite, characterized by 10-20% mafic minerals, distinct relict igneous textures, and zones rich in dioritic (cognate?) xenoliths, well-exposed at Cole Pond in the Londonderry quadrangle
Yta	Black, hornblende amphibolite and black and white equigranular hornblende plagioclase gneiss, locally very well-layered on a 0.5 m to 1 m scale, locally abundant veins of hornblende or biotite diorite or tonalite, well-exposed at South Londonderry

Table 3. Representative chemical analyses of Stamford Granite Gneiss from the Green Mountain and from Hoosac Mountain Analyses by rapid rock techniques described in Shapiro (1975). N. Rait, H. Smith analysts.

	--------------Stamford, VT---					------Hoosac Mtn.-----	
Sample No.	170	171	173	6	172	102-32	176
	--------rapakivi granite--------			border	dike		
Constituent wtg%							
SiO_2	67.6	69.2	70.7	64.5	50.5	68.0	69.4
Al_2O	16.0	16.4	14.9	14.8	14.9	15.4	14.0
Fe_2O	1.5	1.1	0.90	1.8	2.6	2.0	1.9
Feo	1.7	1.2	1.7	4.8	8.5	2.2	2.6
MgO	0.17	0.12	0.20	1.1	3.5	0.36	0.82
CaO	2.4	2.2	2.1	3.1	7.7	2.0	0.83
Na_2	3.5	3.5	3.2	3.2	2.2	3.6	2.8
K_2O	5.9	6.4	5.8	4.2	3.7	5.4	5.8
H_2O^+	0.55	0.32	0.37	0.62	1.0	0.16	0.04
H_2O^-	0.02	0.02	0.08	0.03	0.06	0.04	0.03
TiO_2	0.29	0.23	0.24	1.1	2.5	0.39	0.42
P_2O_5	0.15	0.14	0.14	0.45	1.0	0.19	0.18
MnO	0.04	0.03	0.04	0.07	0.15	0.06	0.04
CO_2	0.01	0.08	0.03	0.07	1.5	0.01	0.03
Totals%	99.83	100.94	100.40	99.94	98.9	99.86	98.89
Total S%	0.12	0.09	0.077	0.093	0.97	0.027	0.14
CIPW NORMATIVE MINERALS							
apatite	0.36	0.34	0.34	1.08	0.43	0.44	0.44
ilmenite	0.56	0.44	0.45	2.09	0.74	0.80	0.65
orthoclase	35.0	37.40	34.6	25.05	31.9	34.5	35.2
albite	29.9	29.4	27.3	27.06	30.5	23.9	26.5
anorthite	10.5	10.3	9.1	13.8	9.8	3.87	6.40
corundum	0.0	0.0	0.0	0.0	0.03	1.72	0.9
magnetite	2.2	1.59	1.02	2.64	2.9	2.75	3.08
diopside	1.14	0.43	0.0	1.11	0.0	0.0	0.0
hypersthene	1.80	1.52	2.8	7.26	2.70	4.6	0.86
quartz	18.43	18.58	24.3	20.0	20.78	27.10	25.61
Total	99.86	100.	99.91	100.09	99.78	99.68	99.64

on Hoosac Mountain, the Bull Hill Gneiss (of Doll and others, 1961) in the Chester and Athens domes and similar K-feldspar megacrystic granite gneiss in the Jamaica-Wardsboro area were originally believed to be metarhyolitic volcanic rocks interlayered with various cover sequence rocks, either the Hoosac Formation (Norton, 1969) or the Cavendish Formation (of Doll and others, 1961). The U-Pb data, coupled with the observations that: (1) the Stamford and Stamford-like rocks intrude Grenvillian basement, (2) they are unconformably overlain by the Hoosac Formation and (3) they form fault slivers within the cover sequence (fig. 1) suggest that rocks previously mapped as the Bull Hill Gneiss of Doll and others (1961) in the Chester and Athens domes may locally also be faulted into the cover sequence.

These very distinctive, coarse-grained, 960-Ma-old granites and pegmatite granites are unique in the Appalachians to the basement rocks of the southern Green Mountains, northern Berkshire massif, Sadawga-Rayponda, and Chester and Athens domes. Chemical data suggest that, although the granites are all very similar K-rich granites (fig. 4) each individual area is slightly different (see discussion stops A-3, 6). The field data suggest that many relatively small, separate rapakivi plutons formed in a general east-west belt across the Grenville-deformed basement rocks. Chemistry and structural setting suggest that these may mark a post-Grenville anorogenic event, much older than the start of the Late Proterozoic rifting event responsible for the formation of Iapetus.

The occurrence of these rocks within these areas indicates that until 960 Ma ago, the Proterozoic rocks of the Green Mountains-Chester Athens domes, Sadawga-Rayponda dome and Berkshire massif were all part of the pre-Iapetan, or Laurentian continent.

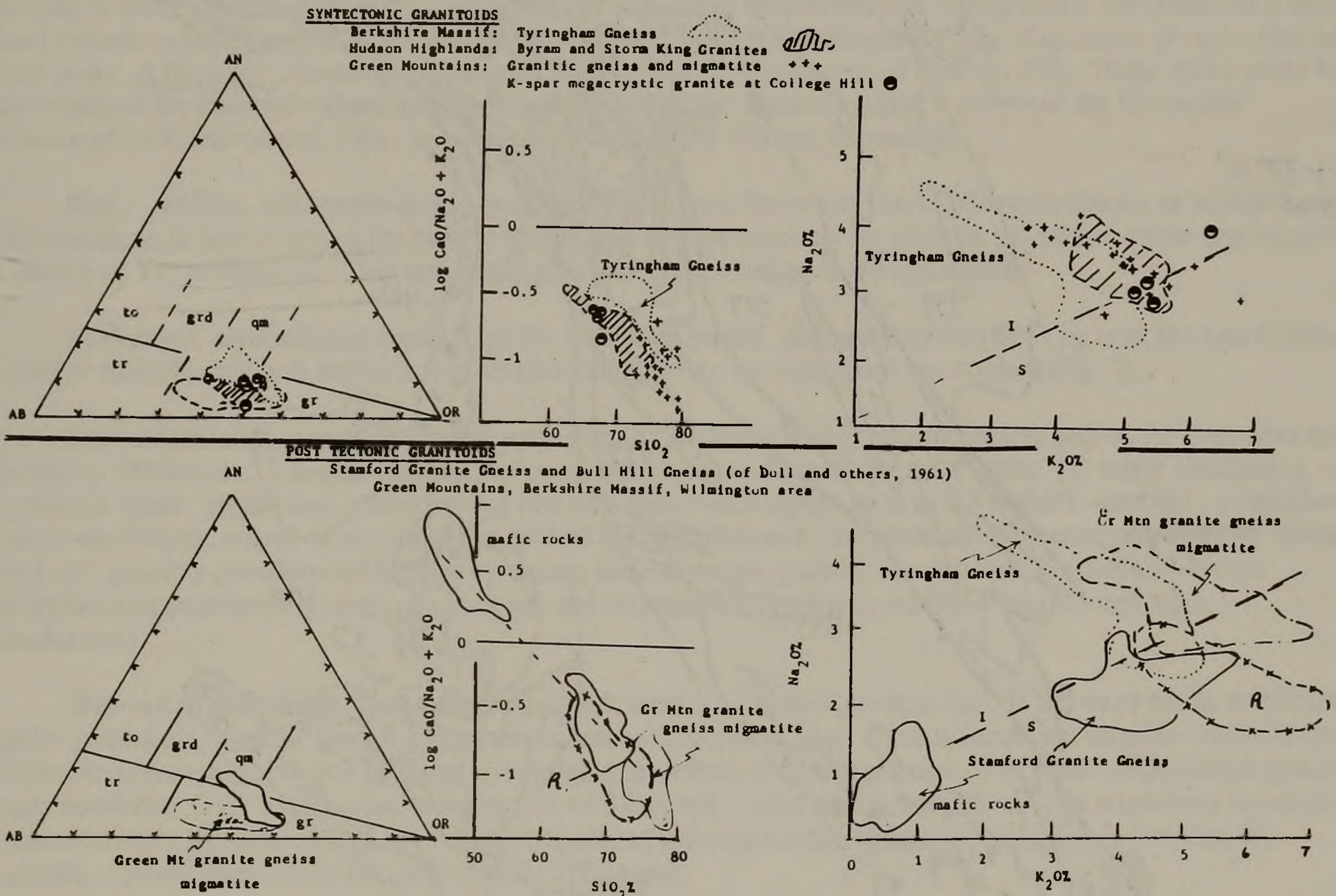


Figure 4. Selected chemical characteristics of syntectonic and post-tectonic granitoids in Green Mountains and Berkshire massifs. AN, AB, and OR - normative anorthite, albite, orthoclase diagram showing classification scheme of O'Connor, 1965; to = tonalite, tr = trondhjemite, grd = granodiorite, qm = quartz monzonite, gr = granite; I, S in Na_2O vs. K_2O plot refers to igneous and sedimentary granite fields of Chappel and White, 1974. Shaded fields identify granitic gneiss and migmatites from Green Mountains in relation to other rocks. Sources of data: Bryam and Storm King Granites (Drake, 1984; Lowe, 1950; Helenek and Mose, 1984); other data (Ratcliffe, unpub. data). R and dash-x'd field rapakivi granites of Finland from Nurmi and Haapala, 1986.

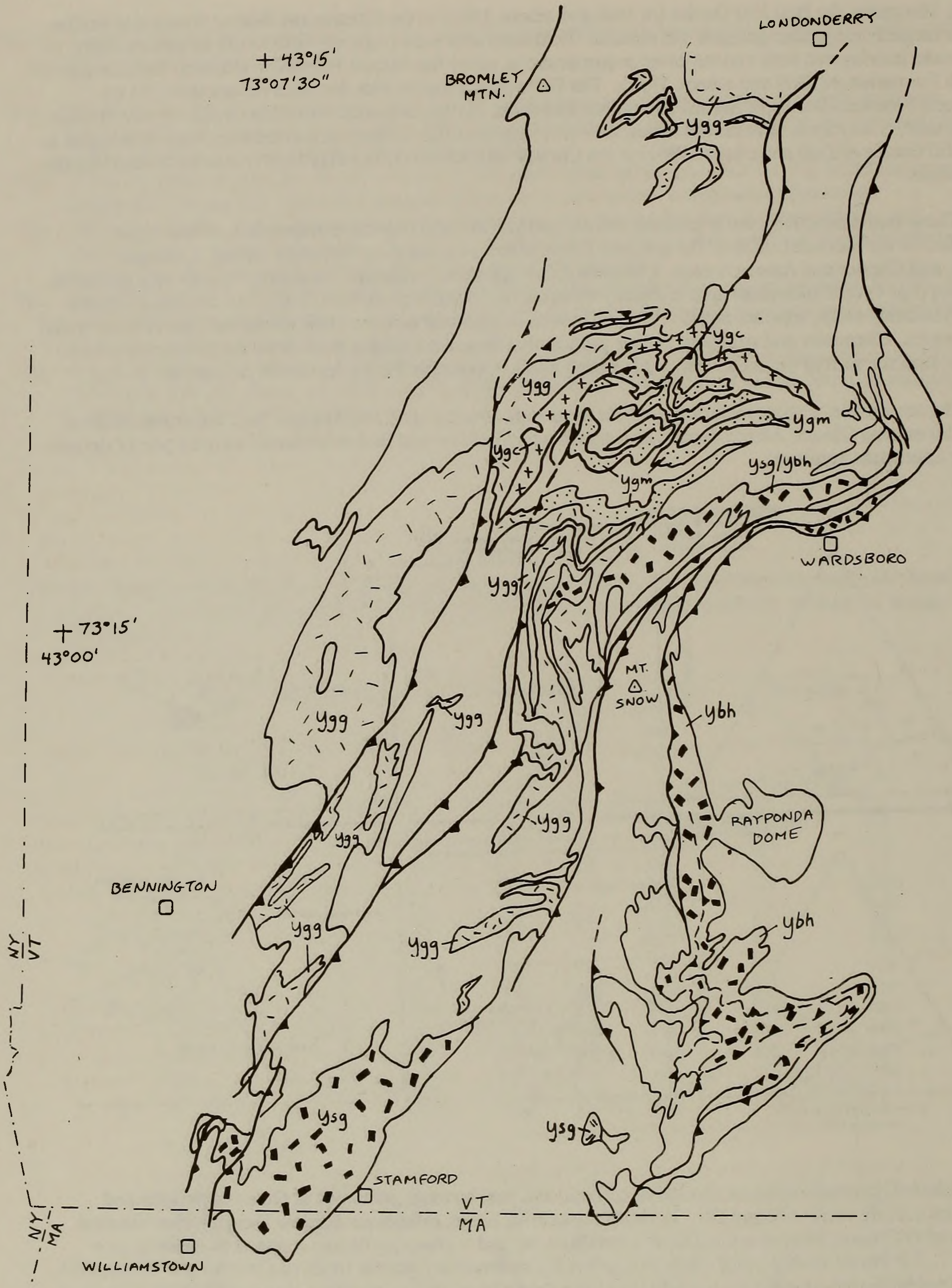


Figure 5. Generalized geologic map showing distribution of syntectonic and post-tectonic Middle Proterozoic granitoids in the Green Mountains and Sadagwa-Rayponda domes identified by symbol is table 1.

Granitic gneisses interpreted as syntectonic intrusives form approximately one third of the area of the Berkshire massif (the Tyringham and other granitic gneisses). These units are in contact with all paragneiss units and exhibit locally clear, crosscutting relationships across gneissic layering. Chemically similar crosscutting but highly deformed granitoids are common in the Hudson Highlands and Reading Prong (the Storm King Granite of Lowe, 1950) and the Byram Intrusive Suite of Drake (1984). Similar biotite granitoids in the Green Mountains (table 1) are also widely distributed (fig. 5). Chemical analyses (tables 4 and 5) show that the Green Mountain granitoids are all potassic granites (fig. 4) having restricted CaO/Na2O+K2O vs SiO2 ranges and calc-alkaline trends, similar to syntectonic granites in the Hudson Highlands and Berkshire massif. Migmatitic granite gneisses (Ygm) are all very SiO2-rich and range greatly in CaO/Na2O+K2O values, perhaps reflecting some sedimentary component in the local source rocks (table 5). These migmatitic gneisses do not show crosscutting relations to country rocks.

Paragneiss and metavolcanic rocks

A distinctive group of metasedimentary gneisses and metavolcanic rocks (rhyolites, andesites, and basaltic rocks) (table 1 and figure 6), are present in the Berkshire massif and Green Mountain massif as far north as Stratton Mountain. Distribution of selected units identified in table 1, are shown in figure 6. The bulk of the section (Ybg) is well-layered biotite plagioclase gneiss that forms the host for zones of calc-silicate rocks, marbles, and amphibolites, and garnet-rich-biotite-plagioclase gneiss. Locally, quartzites up to 10 m thick are present (Yq). Sillimanite-garnet gneiss and schist is present near the quartzites, as are abundant white, K-feldspar-rich pegmatites. Garnet-quartzites are typically mylonitic, having a high-grade ductile fabric in which broken, almond-shaped fragments of orangish red garnet float in a mylonitic matrix of quartz and sillimanite. Where intruded by pegmatite, sillimanite is retrograded to muscovite, and subsequent Paleozoic dynamothermal retrogression has produced a fine-grained chlorite-muscovite-chloritoid phyllite or phyllonite from the Proterozoic rocks. Exposures of rocks like this cap the peaks of Bromley Mountain, Stratton Mountain, and the peaks west of College Hill. These rocks could be easily mistaken for Paleozoic aluminous cover rocks such as the Gassetts Schist member of the Cavendish Formation of Doll and others, 1961, or aluminous rocks in the Hoosac Formation.

Rusty, sulfidic, sillimanite-biotite-quartz-ribbed gneiss, known as the Washington Gneiss in Massachusetts and Connecticut, is interpreted as the base of the section and is present as far north as the Mount Snow quadrangle. It is shown as Yrr in Figure 6. This unit appears to thin northward from Massachusetts.

Pretectonic metavolcanic rocks from the Berkshire massif, contained within the Ybg unit, the Lee Gneiss, and a felsic metarhyolite unit define a calc-alkaline suite having moderate iron enrichment (fig. 7).

The metatonalite-metatrondhjemite sequence (Yt on figs. 1 and 6) is only present within the basement rocks of the Green Mountains. It is characterized by equal abundance of three major rock types: (1) white weathering, very fine-grained, quartz plagioclase gneiss having rare thin biotite-rich layers 1 cm to 0.5 m thick--probably a metadacite; (2) white weathering, coarse- grained, biotite spotted metatrondhjemite, characterized by rectangular spots of biotite 0.5 to 1 cm, possibly pseudomorphic after pyroxene; and (3) coarse-grained, non-layered, hornblende- biotite metatonalite and associated hornblendic gneisses and amphibolite, (probably intrusive tonalite and mafic metavolcanics).

Within this suite (table 2), the coarse-grained, more leucocratic gneisses intrude the more mafic members. Irregular inclusions of mafic dioritic gneiss are common throughout, and, at some localities, angular xenoliths exist. Metatonalite commonly contains irregular to subrounded inclusions of what appear to be hornblende-biotite diorite as cognate xenoliths. Over broad areas, a distinctive well-layered, biotite gneiss, calcsilicate and aluminous quartzite sequence parallels the contact with the adjacent metatonalite/metatrondhjemite suite, thus suggesting that the paragneiss sequence may unconformably overlie the Yt unit.

Limited chemical data, table 6 and figure 5, indicate the rocks of the Yt suite are closely related, as they define a tight linear array on log CaO/Na2O+K2O and AFM diagrams (fig. 7), indicative of a calc-alkaline to calcic plutonic suite. In normative An-Ab-Or classification, these rocks are tonalites and trondhjemites (or dacites and keratophyres).

The suite has the same very high Na2O/K2O values and overall chemistry as members of the Losee Metamorphic Suite and related rocks of the Reading Prong-Hudson Highlands of New York, New Jersey, and Pennsylvania (fig. 7), generally held to be dacitic and quartz keratophyric volcanic rocks (Drake, 1969).

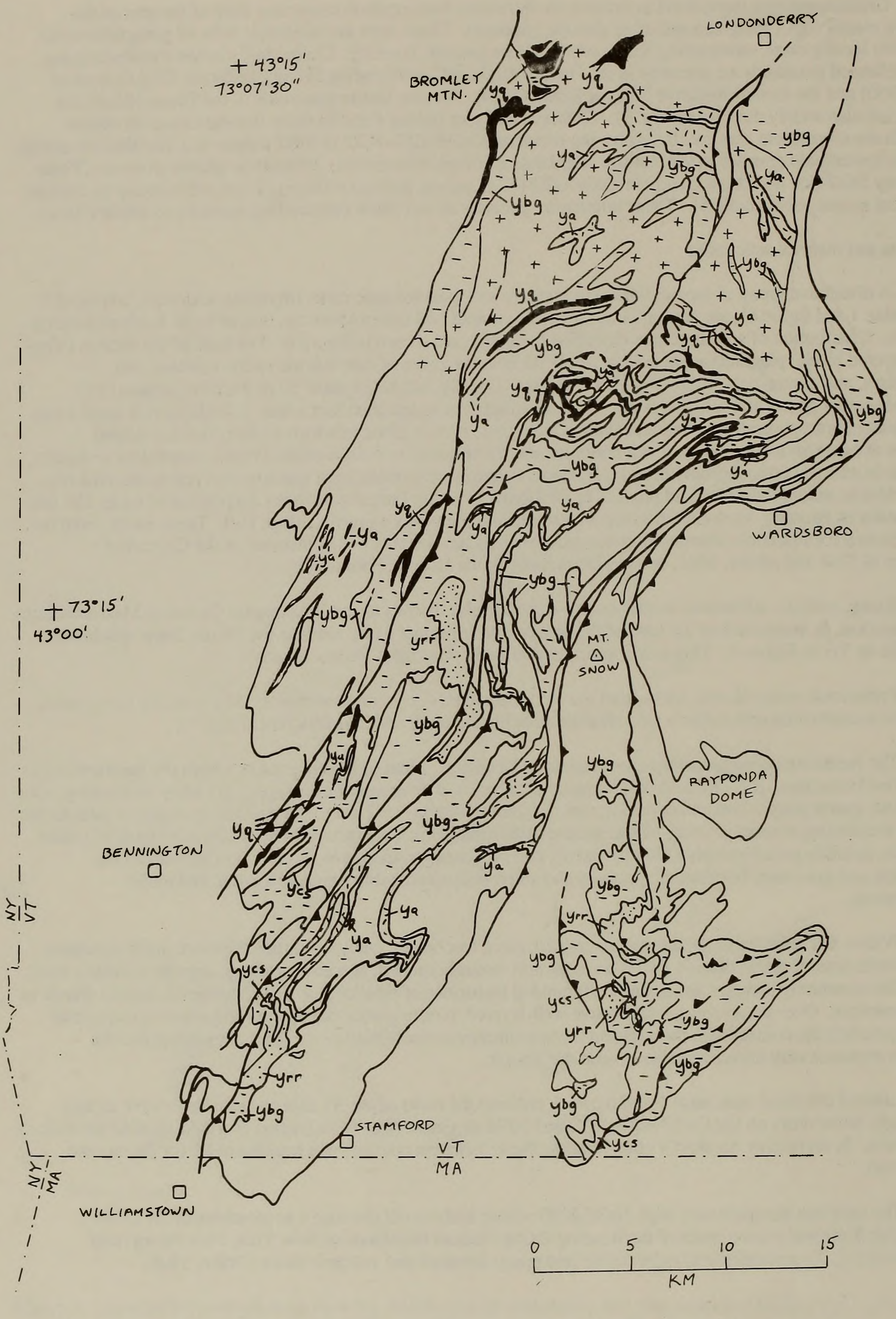


Figure 6. Generalized geologic map showing distribution of pretectonic Middle Proterozoic paragneiss and metavolcanic units in the Green Mountains and Sadagwa-Rayponda domes identified by symbol in table 1.

Table 4. Chemical analyses of biotite-plagioclase-microcline granitic gneiss at College Hill, Peru quadrangle, VT (Ygc) and biotite granite gneiss (Ygg)

Sample	3348A	3348B	3348C-1	3348C-2	849	851	444	910	930	241
	Ygc				Ygg					
constituent										
SiO_2	69.9	68.9	67.8	68.5	73.70	76.10	78.30	72.70	71.60	73.30
Al_2O_3	15.2	13.7	13.3	13.5	12.70	12.90	10.80	14.20	14.20	14.00
FeO	0.66	1.42	1.36	1.40	1.50	0.45	0.99	0.44	1.20	0.21
Fe_2O_3	1.2	2.9	4.0	3.5	0.92	0.23	0.53	0.98	0.82	0.54
MgO	0.53	0.56	0.77	0.69	0.28	0.33	0.15	0.34	0.53	0.17
CaO	0.69	1.81	2.17	1.91	1.02	0.46	0.78	1.26	1.38	0.75
Na_2O	3.97	3.22	3.12	2.88	3.12	3.14	2.56	3.33	3.23	2.83
K_2O	6.38	5.34	4.91	5.51	5.20	5.71	4.65	5.33	5.47	6.65
Tio_2	0.21	0.59	0.80	0.72	0.31	0.05	0.17	0.22	0.31	0.07
P_2O_5	0.07	0.19	0.29	0.23	0.07	0.05	0.05	0.07	0.12	0.05
MnO	<0.02	0.06	0.08	0.07	0.03	0.02	0.02	0.02	0.02	0.02
H_2O^+	0.30	0.35	0.45	0.53	0.40	0.33	0.30	0.27	0.33	0.51
H_2O^-	0.06	0.25	0.31	0.24	0.11	0.11	0.22	0.18	0.18	0.16
CO_2	0.01	0.01	0.02	0.03	0.0	0.0	0.0	0.0	0.0	0.0
Total	99.20	99.30	99.38	99.71	99.36	99.98	99.52	99.34	99.39	99.26
CIPW Norms										
constituent										
Q	20.0	24.6	24.2	24.7	32.9	34.6	43.7	30.4	28.3	30.1
C	0.7	0.0	0.0	0.0	0.3	0.8	0.3	0.9	0.8	0.9
or	38.2	32.0	29.5	33.0	30.1	33.9	27.8	31.9	32.7	39.8
ab	34.0	27.7	26.8	24.7	26.7	26.8	21.9	28.5	27.6	24.3
an	2.9	7.3	7.9	7.7	4.6	2.0	3.5	5.7	6.0	3.4
di	0.0	0.4	0.8	0.1			0.0	0.0	0.0	0.0
hy	2.7	4.5	6.7	5.9	2.2	1.4	1.5	0.9	2.4	0.4
mt	1.0	2.1	2.0	2.1	1.3	0.3	0.8	0.9	1.2	0.5
il	0.4	1.1	1.5	1.4	0.6	0.1	0.3	0.4	0.6	0.1
hem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.2
ap	0.2	0.4	0.7	0.5	0.2	0.1	0.1	0.2	0.3	0.1
cc	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
total	100.1	100.1	100.2	100.2	99.9	100.0	99.9	99.8	99.9	99.8

Table 5. Chemical analyses of migmatitic biotite feldspar gneiss (Ygm), Jamaica and Stratton Mountain quadrangles, VT

Sample	2831	1060A	1060B	1061	1058A	675
constituent						
SiO_2	73.3	75.9	75.80	76.20	76.30	71.00
Al_2O_3	13.0	12.10	12.10	12.20	13.50	13.80
FeO	1.2	1.15	1.49	0.57	0.28	1.40
Fe_2O_3	1.2	0.81	0.66	1.10	0.43	2.30
MgO	0.35	0.21	0.10	0.18	0.10	0.11
CaO	0.77	0.47	0.35	0.78	0.83	0.63
Na_2O	3.02	3.45	3.76	3.58	3.94	3.43
K_2O	5.56	5.11	4.84	4.36	3.78	6.02
TiO_2	0.28	0.19	0.21	0.16	0.02	0.26
P_2O_5	0.06	0.05	0.05	0.05	0.18	0.07
MnO	0.02	0.02	0.02	0.02	0.08	1.20
H_2O^+	0.11	0.31	0.25	0.48	0.27	0.33
H_2O^-	0.27	0.10	0.11	0.10	0.20	0.12
Co_2	0.01	0.00	0.00	0.00	0.00	0.00
Total	99.15	99.87	99.74	99.78	99.91	99.49
CIPW Norms						
constituent						
Q	32.6	34.7	34.2	36.6	37.4	26.9
C	0.8	0.2	0.2	0.3	1.9	0.8
or	33.3	30.4	28.8	26.0	22.5	35.9
ab	25.9	29.4	32.1	30.6	33.5	29.3
an	3.4	2.0	1.4	3.6	3.0	2.3
hy	1.7	2.0	1.8	1.7	1.0	0.6
mt	1.8	1.0	1.1	0.9	0.4	3.3
il	0.5	0.4	0.4	0.3	0.0	0.5
ap	0.1	0.1	0.1	0.1	0.4	0.2
Total	100.1	100.2	100.1	100.1	100.1	99.8

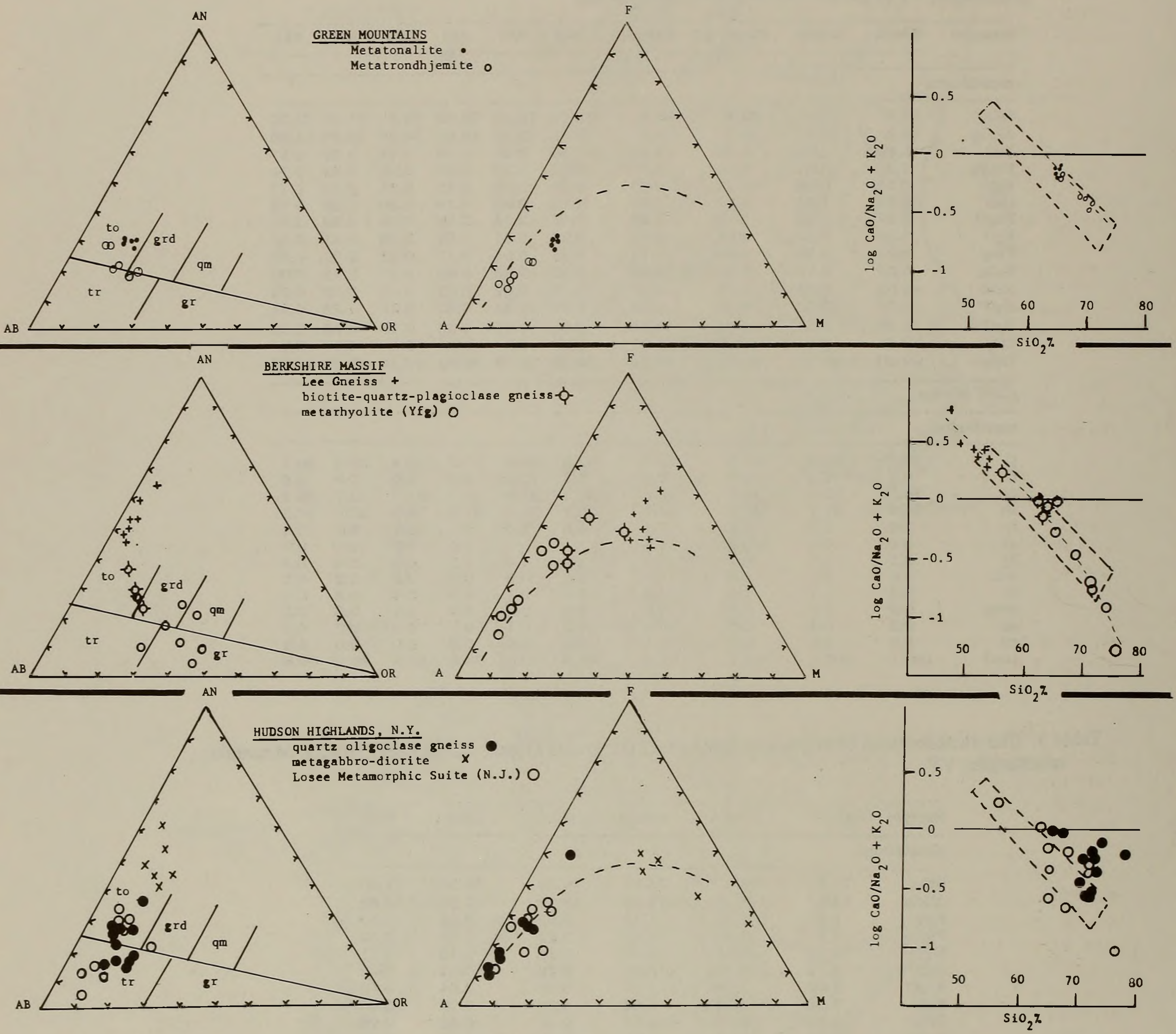


Figure 7. Selected chemical characteristics of some pretectonic metavolcanic rocks from the Grenvillian basement rocks of the northern Appalachians. Losee Metamorphic Suite from Drake (1969, 1984), all other Ratcliffe (unpub. data). AN, AB, and OR - normative anorthite, albite, orthoclase diagram showing classification scheme of O'Connor, 1965; to = tonalite, tr = trondhjemite, grd = granodiorite, qm = quartz monzonite, gr = granite; AFM - $Na_2O = K_2O$, FeO total iron, Mgo, dashed line shows boundary between tholeiitic (above) and calc-alkaline suites (below) from Irvine and Baragar (1971); alkali-lime versus silica diagrams shows reference field for calc-alkaline andesite to felsic rocks after Brown (1982).

This previously unrecognized group of rocks in the Green Mountains (Yt) is also similar to K-feldspar-poor metatrondhjemite and metatonalites present in the Adirondack Highlands, especially in the southern and eastern Adirondacks as described by McLelland and others (in press), and reported by them to be approximately 1.3 Ga old based on U-Pb zircon ages. It is important to note that this Yt suite present as a discrete belt of rocks in the central Green Mountains massif, is absent from the southern Green Mountains southward to the Hudson Highlands where similar, but not necessarily correlative rocks, reappear as the quartz plagioclase gneiss and associated gabbroic rocks east of the Canopus fault system, and as the Losee Metamorphic Suite farther south in New Jersey (Drake, 1984).

In the Green Mountains, the age and stratigraphic position of the tonalite-trondhjemite gneiss belt is uncertain. In some respects the amphibolite-rich gneisses and dacitic rocks are similar to volcanics in the very thick Washington Gneiss section of central-western Massachusetts. The rusty quartzite and impure calc-silicate rocks that immediately overlie the tonalite-trondhjemite gneiss belt may be thinned equivalents of the pelitic-quartz-rich facies of the Washington Gneiss. Alternately, other explanations not withstanding, the tonalite- trondhjemite gneiss belt may unconformably underlie the biotite quartz plagioclase gneiss along a prevously unrecognized unconformity.

Late Proterozoic and Paleozoic cover sequence rocks

Cover sequence rocks overlie basement in many areas with unconformity as shown by the special contact in figure 1. The nature of the cover sequence rocks differ markedly in different lithotectonic units across the area. However, these variations are progressive rather than abrupt, except for the Whitcomb summit thrust, across which the stratigraphic succession is markedly different.

These two trips will present an opportunity to see representative sampling of cover sequence rocks from east to west exposed at or near the unconformity with basement. Quartzofeldspathic cover rocks of the Dalton Formation are well represented at the type section on and near Day Mountain (Stop 1, A-1) and at the western margin of the Green Mountain (Stop 9, A-1). Exposures of cover sequence rocks on Hoosac Mountain and in the Sadawga-Rayponda domes will be seen on trip A-1, stops 3 and 4, and on trip B-1, stops 1 and 2.

Cover sequence rocks of probable Late Proterozoic through Early Cambrian age form part of the base of the westward-thinning, transgressive clastic sequence developed on the eastern margin of North America following rifting. Within the area of these trips, the principal units are lithostratigraphic subdivisions of the Dalton Formation and its lateral, but partly older, eastern equivalent the Hoosac Formation.

The simplified nomenclature used on figure 1 shows three different sequences, following the usage on the Massachusetts State map. These are the Dalton Formation and Cheshire Quartzite (CZd-Cc) in the west, the autochthonous Hoosac section that overlies rocks of the Hoosac slice (CZhd) and the allochthonous Hoosac above the Hoosac summit thrust (CZh) to the east.

Important west to east facies changes within this belt are diagramatically shown in figure 8. Coarse conglomeratic, arkosic conglomerates (CZdc) as seen at A-1, stop 1, pass upwards into feldspathic quartzites and flagstones typical of the Dalton Formation (CZd) as a whole. Two principal horizons of dark biotite schist (CZdb) appear within the section in the Berkshires and on the southern and western margins of the Green Mountains. To the east, the percentage of dark phyllitic rocks increases as shown for the Woodford-Stratton Mountain sections, with decreasing abundance of typical (CZd) feldspathic quartzites. On Hoosac Mountain, and in the area east of the Searsburg thrust from Mount Snow south to Hoosac Mountain the basal units of the Hoosac Formation contain locally excellent Dalton-like pebbly-quartz conglomerate as well as a distinctive albite-rich granofels and a gneiss-boulder unit (CZhdc) (A-1, stop 4). Locally, black phyllite and tan weathering vitreous quartzite-similar to CZdb and CZd, respectively--are present beneath a discontinuous, beige and salmon pink weathering dolostone (CZhm) (B-1, stops 1, 2). Above or replacing this locally are discontinuous greenstones (the Turkey Mountain member of the Hoosac Formation (CZhv) of Skehan, 1961). Either above a zone of black carbonaceous phyllite or schist (CZhb) or directly resting on albite granofels (CZhab) is a coarse-grained, lustrous muscovite-paragonite(?)-chlorite-chloritoid large-garnet schist (CZhgt). Laterally, this garnet schist is replaced by or contains beds of pebbly quartz conglomerate. On Mount Snow and on the ridges south of Route 9 in the Readsboro quadrangle, these units are overlain by a thick section of fine-grained, coaly-black, lustrous, biotite-muscovite-albite-carbonaceous quartz-phyllite (CZhbc) locally containing small-garnet bearing, dark-gray, chlorite-chloritoid-muscovite phyllite. Above this unit is a second greenish-gray, fine-grained, lustrous, chlorite-chloritoid large-garnet-quartz schist (CZhg). This second garnet schist may be equivalent to the Rowe Formation or a second garnet schist within the Hoosac Formation.

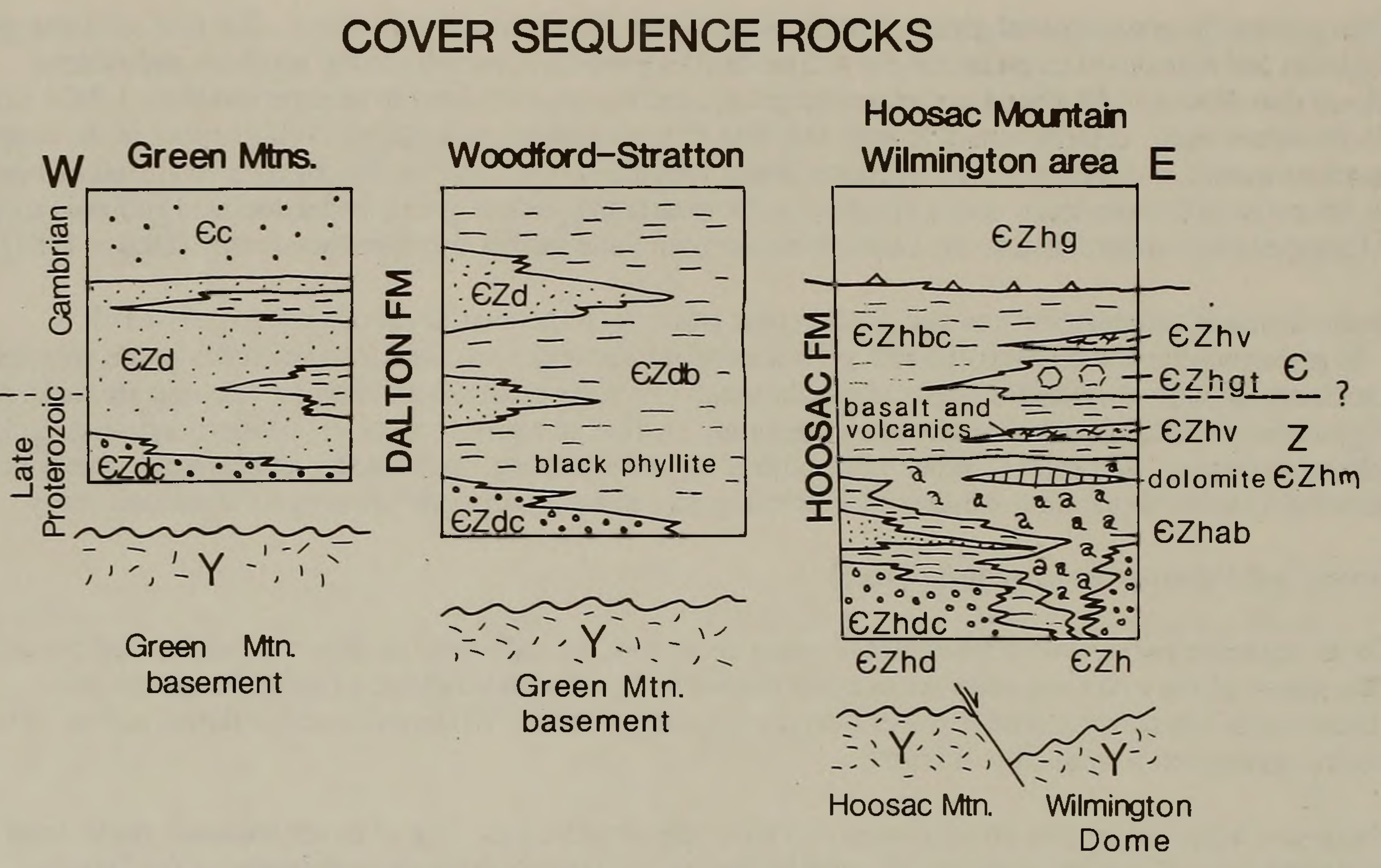


Figure 8. Generalized W to E facies variation diagram showing nomenclature for Upper Proterozoic and Lower Cambrian cover sequence rocks

The Hoosac section resting on the east side of the Rayponda dome, i.e. above the Bull Hill Gneiss (of Doll and others, 1961) contains a greater abundance of dark, coarse albite muscovite schist, several zones of hornblende-epidote greenstone and no beds of Dalton-like quartzite or black carbonaceous phyllite.

In remapping the Mount Snow and Readsboro quadrangles (part of Skehan's 1961 Wilmington 15- minute quadrangle) we have reassigned the lithologic units previously assigned to the Cavendish Formation of Doll and others, 1961, i.e. the Searsburg Conglomerate, Readsboro Formation, and Heartwellville Schist of Skehan (1961) to the Hoosac Formation based on the fact that the Hoosac Formation, as defined on Hoosac Mountain, contains all of the units present in the Cavendish Formation (Ratcliffe, 1979). The basal units of the Hoosac Formation on Mount Snow and environs (CZdc, CZhab) are roughly equivalent, therefore, to the Tyson Formation (of Doll and others, 1961), except that albitic granofels typical of the Hoosac Formation both underlies and overlies lithologies typical of the Tyson. Two aluminous-large-garnet schists, both locally containing chloritoid, appear within the section here mapped as the Hoosac Formation. The lower aluminous schist unit (CZhgt) is in the position of the Gassetts Schist member of the Cavendish Formation of Doll and others (1961), the second appears above coaly black schist and phyllite (CZhg) and may or may not be equivalent to the Rowe Formation (or Pinney Hollow Formation).

PROTEROZOIC STRUCTURES

From Connecticut northward, Middle Proterozoic folds trending generally east-west are common in basement massifs. Locally axial traces of these folds have been mapped in Massachusetts (see A-1, stop 1). Similar kinds of folds having steep axial surfaces are present in the Green Mountains. These folds are responsible for the gross distribution of the map units in the Green Mountains as illustrated in figures 5 and 6. Fold axes of Proterozoic folds are only locally well known, but tend to plunge at gentle angles east or west within the east-west axial surfaces (see B-1, stop 9). Several generations of Proterozoic folds are known to exist, and the latest folds are well illustrated in migmatitic gneisses where thin pegmatite and aplite is intruded parallel to the axial surfaces of the latest folds. The regional distribution of these folds is presently not known. Post tectonic granitoids such as the coarse pegmatites and the 960 Ma old rapakivi granites (Ysg-Ybh) do not contain the Proterozoic structures, setting an upper limit on Grenvillian penetrative deformation. Sillimanite plus microcline-perthite and locally hypersthene have been found in members of the paragneiss suite, which coupled with the widespread occurrence of coarse brown hornblende suggests that Middle Proterozoic metamorphism of hornblende granulite grade was attained.

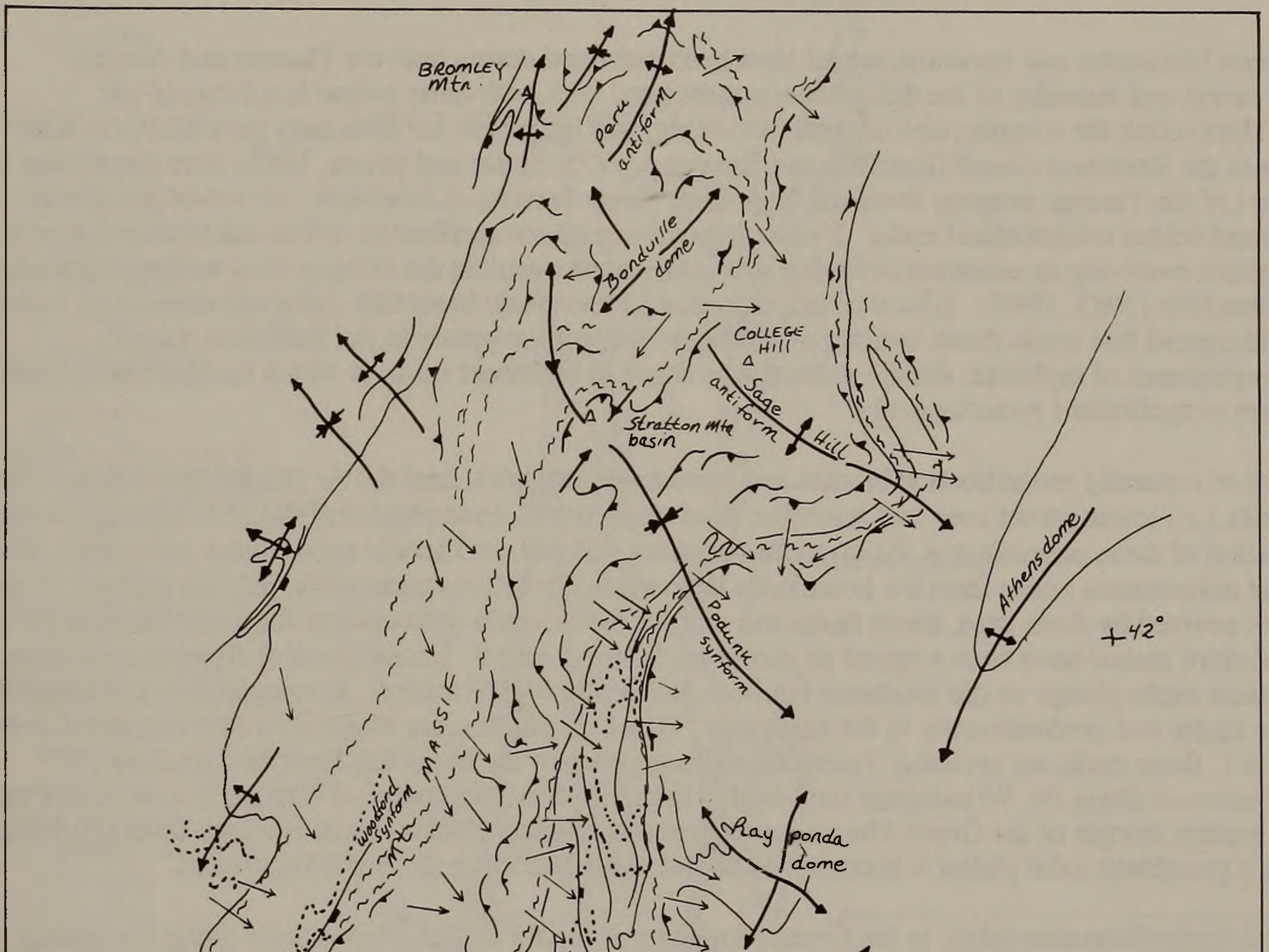


Figure 9. Simplified tectonic map showing Taconian and Acadian structures.

PALEOZOIC STRUCTURES

The Green Mountains and Berkshire massif have been deformed during both the Taconic and Acadian orogenies. The extent and intensity of the deformations associated with both these events is a focus of our investigations. Unraveling the complexities of each is not easy, and at present we have only preliminary results. Previous studies in the Berkshire massif (Ratcliffe and Harwood, 1975; Sutter and others, 1985) have shown that the culminating effect of the Taconic orogeny involved large-scale thrust faulting of basement rocks over previously metamorphosed and folded miogeoclinal rocks. This deformation has been ascribed to collisional tectonics in which an accretionary prism overlying an oceanward-dipping subduction zone overrode the miogeoclinal wedge as described by Stanley and Ratcliffe (1983, 1985). Effects of this closure on Proterozoic basement rocks and their cover include:

(1) widespread low angle thrust faulting of imbricate slices of basement in the Berkshire massif
(2) development of mylonitic ductile deformation zones in basement rocks in which hornblende and biotite were reequilibrated syntectonically.

Samples of texturally reequilibrated biotites and hornblende that grew near the Ar closure temperatures for these two minerals, *i.e.*, lower garnet zone and staurolite zone respectively, have yielded 40Ar/39Ar plateau spectra indicating formation of these minerals and the mylonites at about 465 Ma, or Taconic ages (Sutter and others, 1985). Mylonitic ductile deformation zones form the boundaries between major lithotectonic units. Within the area of the Green Mountains covered by these trips, thrust faults and narrow semi-ductile deformation zones similar to these found in the Berkshire massif have been mapped as shown on figures 1 and 9. Lineations and mylonitic foliation within the basement rocks plunge or dip southeast but both are locally highly folded. A compliation map suggests that slip on these faults was predominantly to the northwest. Based on preliminary 40Ar/39Ar data discussed in the roadlog for trip B-1, these faults are probably Taconian, although none of the faults has been directly dated. Imbrication of basement along the Wilmington fault is also interpreted as Taconic. It is important to note that these faults along the eastern margin of the Green Mountains disrupt and crosscut earlier sets of isoclinal folds (F1 folds of figure 9) having a prominent axial planar schistosity, as do the faults bounding the Berkshire massif.

The penetrative Paleozoic fabric in the Green Mountains is highly folded. Broad areas along the central, north-south spine of the massif have subhorizontal foliation and thrust faults, forming foliation domes and basins (fig. 9). Refolds of the mylonitic foliation trend N. 25° to N. 5° E. and N. 30° to 50° W. The northeast trending folds exhibit excellent crenulation cleavage having subvertical to moderately steeply southeast-dipping axial-surfaces. This general trend forms the Green Mountain-phase folds responsible for the south-plunging antiformal closure of the Green Mountains. The northwest-trending folds rarely exhibit any cleavage, except in the schistose rocks east of the Berkshire massif and Green Mountains. Both the northeast and northwest trending folds are probably Acadian (fig. 9).

THERMOCHRONOLOGY

In general all types of K/Ar mineral dates from metamorphic rocks should be interpreted as the time of cooling to a temperature equal to the argon closure temperature for that mineral for a particular rate of cooling. In general, the slower the rate of cooling, the lower the argon closure temperature for that mineral. In greenschist-facies rocks, the common minerals dated by the K/Ar techniques are biotite and muscovite. Although good argon diffusion data are lacking for natural biotites and muscovites, empirical studies show that for rapid cooling rates (i.e., contact metamorphism), argon is quantitatively retained in muscovite below about 350°C and in biotite below about 300°C. For slow cooling rates (i.e., regional metamorphism), the temperatures are about 320°C and 260°C, respectively. For these minerals to be separable from a prograde metamorphic mineral assemblage in a pelitic unit, that unit generally has been metamorphosed to biotite-garnet grade. The best approximation of the temperature needed to reach this grade in an aluminous metasediment is on the order of 400-450°C for moderate pressures.

Two conclusions are clear concerning the meaning of K/Ar dates on muscovite and biotite separated from prograde mineral assemblages in aluminous rocks. One is that muscovite should record an older apparent age than its coexisting biotite (this conclusion is generally true from empirical observations). The other is that both minerals must cool through a significant temperature to reach their respective closure temperatures. For slow cooling rates (regional metamorphic terrances), this cooling can last a significant amount of geologic time, and, therefore, the K/Ar dates can be significantly younger than the time of formation of a mineral, especially for biotite. For instance, if a pelitic sedimentary rock underwent prograde metamorphism to a temperature of 450°C, 465 m.y. ago and then cooled slowly at an average rate of 5°C per million years, muscovite and biotite would be expected to record apparent ages of 439 m.y. and 427 m.y., respectively, if each mineral retained all its radiogenic argon once it reached its

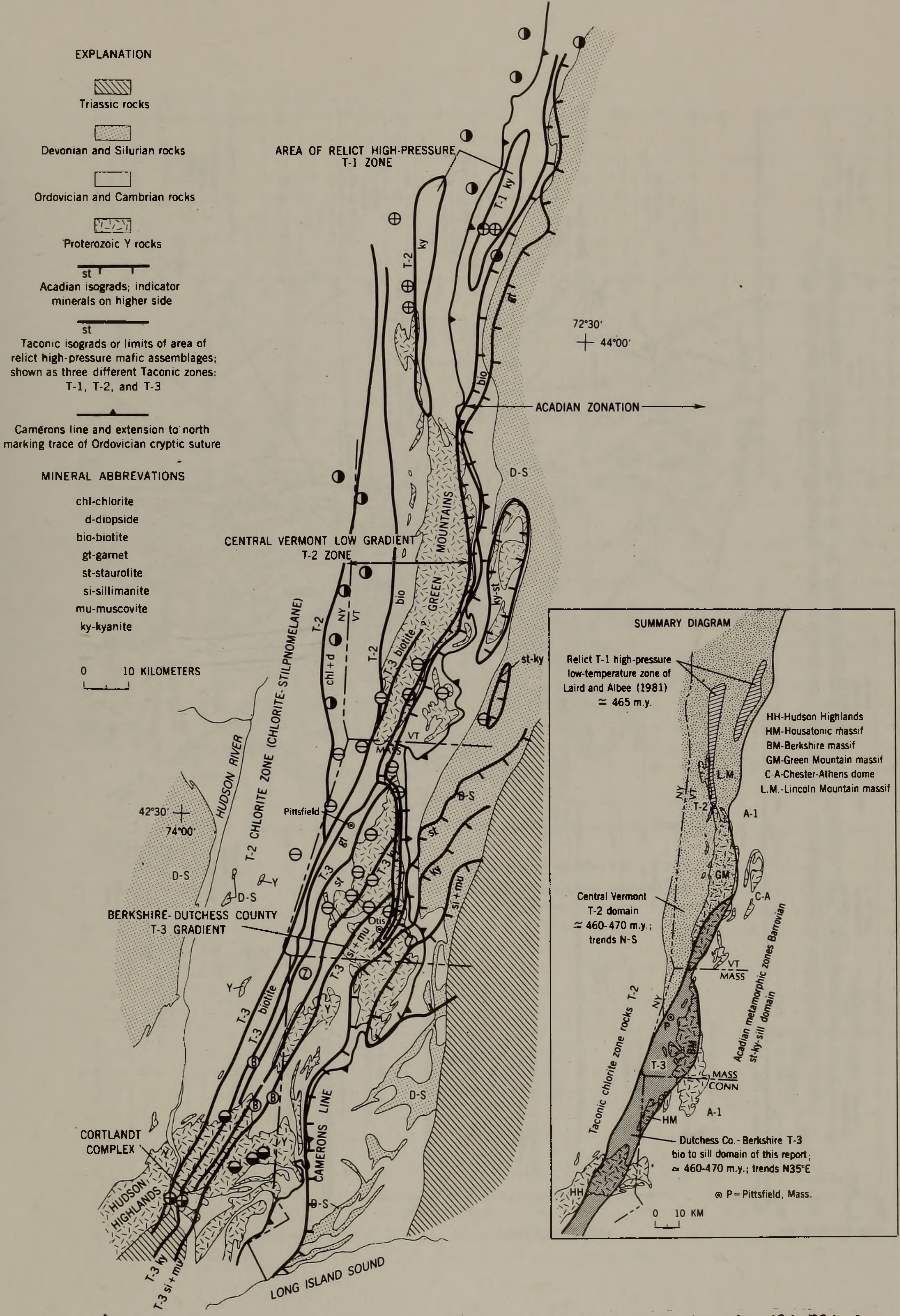
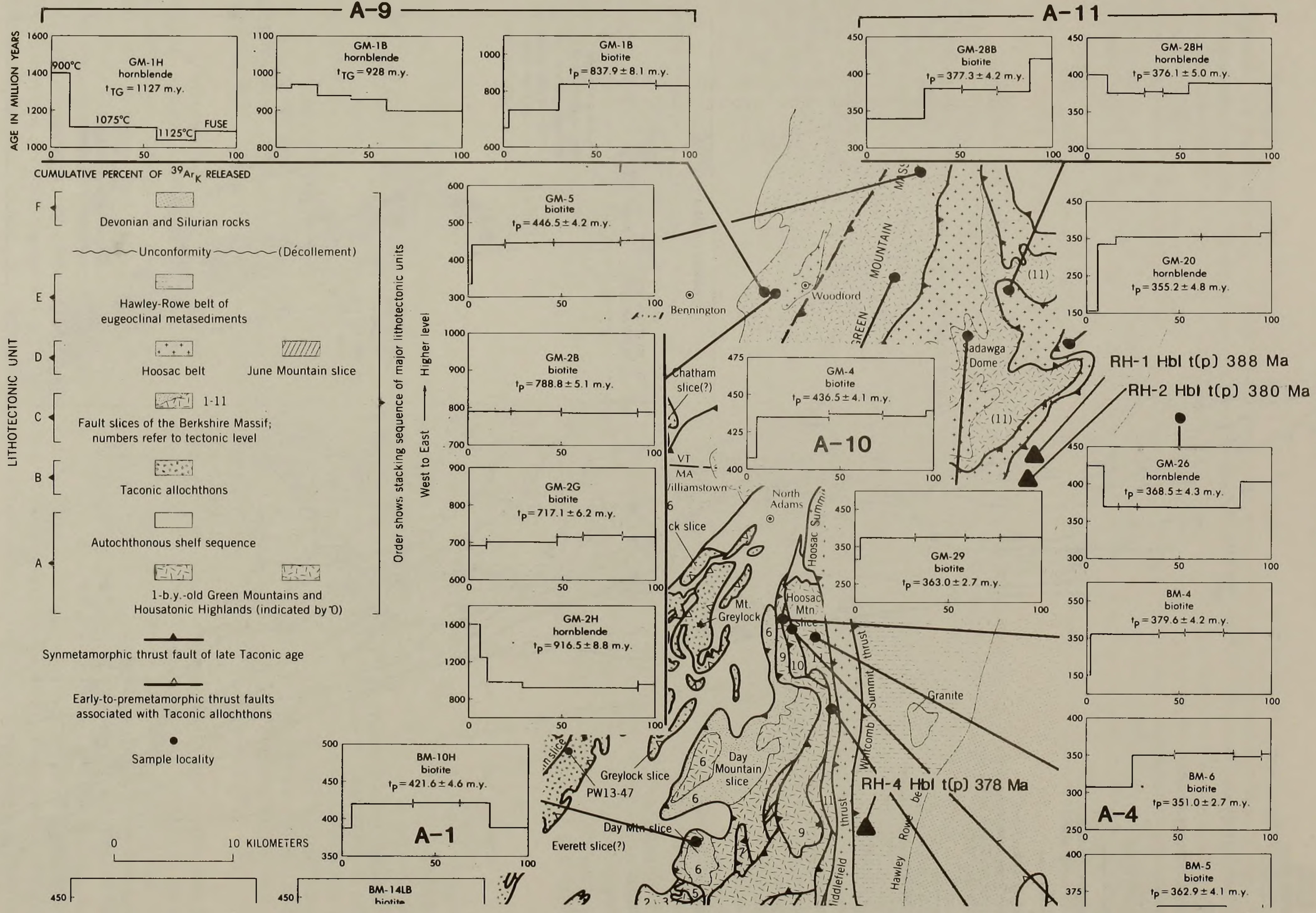


Figure 10. Suggested Taconian and Acadian metamorphic zones in western New England based on 40Ar/39Ar data reproduced from Sutter and others, 1985.


A-9
A-11
AGE IN MILLION YEARS
GM-1H hornblende tTG = 1127 m.y.
900°C
1075°C
1125°C
FUSE
GM-1B hornblende tTG = 928 m.y.
GM-1B biotite tp = 837.9 ± 8.1 m.y.
GM-28B biotite tp = 377.3 ± 4.2 m.y.
GM-28H hornblende tp = 376.1 ± 5.0 m.y.
CUMULATIVE PERCENT OF 39ArK RELEASED
LITHOTECTONIC UNIT
F
Devonian and Silurian rocks
Unconformity (Décollement)
E
Hawley-Rowe belt of eugeoclinal metasediments
D
Hoosac belt
June Mountain slice
C
1-11
Fault slices of the Berkshire Massif; numbers refer to tectonic level
B
Taconic allochthons
A
Autochthonous shelf sequence
1-b.y.-old Green Mountains and Housatonic Highlands (indicated by 0)
Order shows stacking sequence of major lithotectonic units
West to East → Higher level
Synmetamorphic thrust fault of late Taconic age
Early-to-premetamorphic thrust faults associated with Taconic allochthons
Sample locality
0
10 KILOMETERS
GM-5 biotite tp = 446.5 ± 4.2 m.y.
GM-2B biotite tp = 788.8 ± 5.1 m.y.
GM-2G biotite tp = 717.1 ± 6.2 m.y.
GM-2H hornblende tp = 916.5 ± 8.8 m.y.
BM-10H biotite tp = 421.6 ± 4.6 m.y.
A-1
BM-14LB biotite
GM-4 biotite tp = 436.5 ± 4.1 m.y.
A-10
GM-29 biotite tp = 363.0 ± 2.7 m.y.
GM-20 hornblende tp = 355.2 ± 4.8 m.y.
GM-26 hornblende tp = 368.5 ± 4.3 m.y.
BM-4 biotite tp = 379.6 ± 4.2 m.y.
BM-6 biotite tp = 351.0 ± 2.7 m.y.
A-4
BM-5 biotite tp = 362.9 ± 4.1 m.y.
RH-1 Hbl t(p) 388 Ma
RH-2 Hbl t(p) 380 Ma
RH-4 Hbl t(p) 378 Ma
Bennington
Woodford
GREEN MOUNTAIN
Sadawga Dome
(11)
Chatham slice(?)
VT
MA
Williamstown
North Adams
Hoosac Summit
Hoosac Mtn slice
Mt. Greylock
Greylock slice
PW13-47
Day Mountain slice
Day Mtn slice
Everett slice(?)
Whitcomb Summit thrust
Middlefield thrust
Hawley Rowe belt
Granite
6
9
10
11

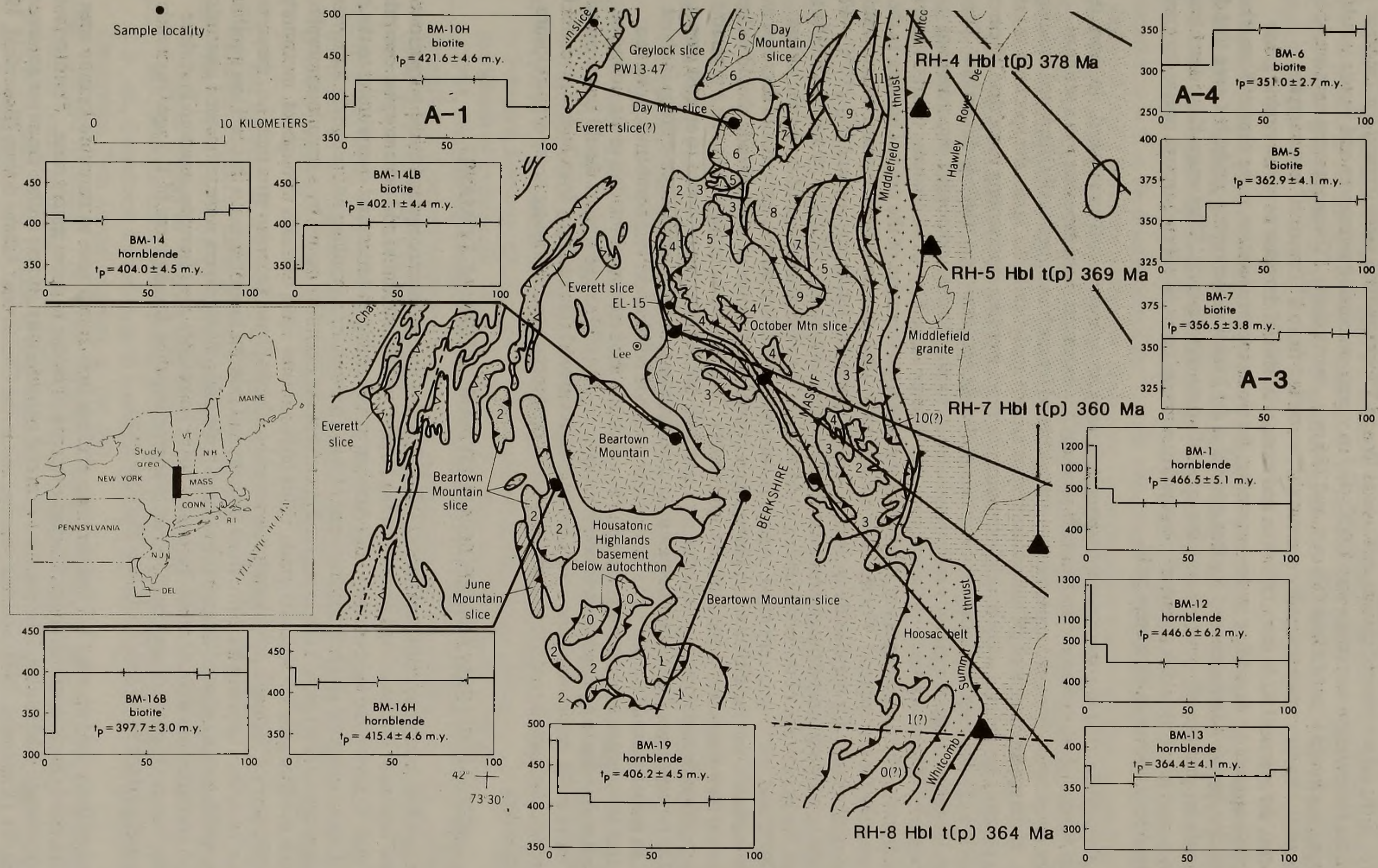


Figure 11. 40Ar/39Ar release spectra for samples from the southern Green Mountains and northern Berkshire massif from Sutter and others, 1985, additional data from Sutter and Hatchk, 19--, in the Rowe-Hawley zone shown by solid triangles.

closure temperature. If the time-averaged cooling rate was as low as 3°C per million years (typical for Taconian domain T-3) and if the temperature maximum was 500°C, 465 m.y. ago, coexisting muscovite and biotite would be expected to record argon closure ages of about 405 m.y. and 385 m.y., respectively. These apparent ages could be construed to be "Acadian" on face value but really represent slow cooling from a "Taconian" metamorphic maximum. In general, the apparent K/Ar dates of biotite and muscovite should decrease as metamorphic grade increases in a prograde sequence. According to this reasoning, the closest approximation to the time of formation of each mineral will be the apparent date measured for that mineral at the lowest metamorphic grade, but even that date can be (and commonly is) significantly younger than the mineral's time of formation. Thus, mica K/Ar dates from rocks above biotite-garnet grade should not generally be used to estimate times of mineral growth unless the cooling rate following formation is known to have been rapid.

The use of the 40Ar/39Ar age spectrum technique in thermochronology is well established. In short, the argon present in the mineral (both radiogenic and neutron-produced) is extracted in the laboratory in a series of progressively higher temperature steps and apparent ages are calculated for each and graphically displayed as an age spectrum diagram. If the apparent ages of all temperature steps are not analytically the same, the spectrum is said to be discordant. Age plateaus are defined when multiple temperature steps, together representing more than 50 percent of the total argon in the sample, yield the same age even though the age spectrum as a whole is discordant. The age spectra of biotite and hornblende from regionally metamorphosed rocks are generally somewhat discordant but usually form age plateaus. The discordance of the age spectrum is often caused by small amounts of argon loss or argon gain (excess argon). The plateau ages are taken to be the best approximation of the time of cooling to the argon closure temperature for that mineral. For the slow cooling rates often encountered in regional metamorphic terranes, the closure temperature for hornblende is about 480-500°C, and that for biotite is about 260-280°C. When coexisting biotite and hornblende from a prograde metamorphic mineral assemblage are dated by the 40Ar/39Ar age spectrum technique, the plateau age of the hornblende should be older than the plateau age of the biotite unless cooling between 480°C and 260°C was very rapid. Again, hornblende and biotite plateau ages should decrease as metamorphic grade increases, and the difference in plateau ages of coexisting biotite and hornblende should reflect the rate of cooling between their respective argon closure temperatures. In addition, for hornblende to be a separable mineral phase from a prograde metamorphic rock, that rock generally has been metamorphosed to at least garnet-staurolite grade. The best estimate for the minimum temperature necessary for this metamorphic grade is about 500°C. Therefore, in garnet-staurolite-grade rocks that contain prograde hornblende, that hornblende grew at a temperature very near to its argon closure temperature. Thus, to make the best approximation to the timing of arrival at the thermal maximum in a prograde metamorphic sequence, 40Ar/39Ar age spectra should be measured on hornblendes from rocks in the garnet-staurolite zone. In addition, hornblende plateau ages from higher grade rocks, together with petrologic data, can be used to estimate the rate of post-metamorphic cooling to the argon closure temperature of hornblende.

METAMORPHISM AND REGIONAL DYNAMOTHERMAL DOMAINS

Three Taconian metamorphic/structure zones (T-1, T-2, T-3 in fig. 10) are recognized in the polydeformed belt of western New England. On these trips we are dealing largely with the structural and metamorphic overprint fabrics associated with T-3 zone and the boundary with Acadian metamorphic and structural overprinting to the east. The T-3 zone is a discrete structural and petrographic zone of late-Taconian thrust-faulting and prograde Barrovian metamorphism characterized from New York to the northern end of the Berkshire massif by a steep metamorphic gradient from biotite to sillimanite + muscovite grade. This high-gradient zone, contains throughout, metamorphic textural features indicative of Taconian polymetamorphism and multiple-phase Taconian structure, i.e., the most complex part of the Taconian metamorphic belt. Rock textures and mineral assemblages in this belt last equilibrated in the T-3 event in which mobilization of basement and large-scale sialic thrust slivers were imbricated upwards into the already accreted allochthonous terrains of the Taconics. Ar/Ar hornblende ages from the southern Berkshire massif and from the Hudson Highlands have been shown to approximate the development of T-3 aged mylonitic rocks in basement rocks remobilized during this late Taconian event.

In the area of these field trips the T-3 metamorphic gradient from garnet zone to staurolite-kyanite zone disappears beneath a nearly north-south-trending Acadian overprint of biotite to upper garnet zone. The distribution of pre-Acadian T-3 zonation is unknown. The presence of zoned unconformity garnets within the cover sequence rocks near Jamaica, Vt. (Karabinos, 1984, and this volume) and in the Chester and Athens domes (Rosenfeld, 1968, and this volume) indicates that the Taconian garnet zone (probably T-3) extends northward under the Acadian overprint along strike of the isograd projected from the south. However, no relict Taconian mineral assemblages of staurolite-kyanite or higher grade are recognized in the cover rocks of the Sadawga-Rayponda or Chester-Athens domes, thus leaving open the question of the regional extent of these higher T-3 zones. The high T-3 zones are thought to reflect higher tectonic loads resulting from greater sialic imbrication from Vermont southward to New York. If this interpretation is correct, then T-3 zonation greater than garnet zone may have closed to the north and never been present in the cover rocks of Vermont. A corollary of this is that net amount of basement imbrication descreases northward, and that an increasing amount of net-throw was transferred northward onto the lower, Champlain thrust.

From New York to the central part of the Berkshire massif T-3 age thrust faults have sliplines indicative of movement from northeast to southwest, *i.e.*, faults have a component of right-lateral strike-slip motion. From the northern Berkshire massif northward, similar basement overthrusts and the Champlain thrust have movement from the southeast to the northwest or a component of left-lateral strike-slip motion. Ratcliffe (1988) has suggested that this variation as well as the distribution of the Taconic allochthons can all be explained by the accretionary- collapse of an eastward-facing Berkshire promontory during the Taconian collisional event (Stanley and Ratcliffe, 1985). The remains of the Berkshire promontory are now present in the accumulated imbricate slices of sialic basement rocks making up the Berkshire massif and recumbently folded areas of the Manhattan Prong. The promontory, therefore has been inverted to produce a large structural salient verging to the west.

The change in thrust fault movement to the northwest and the lesser extent of internal thrust faulting within the Green Mountains, as opposed to that in the Berkshire massif, is consistent with that model. On these field trips we will try to evaluate many of these concepts by discussion of both weaknesses and strengths of these arguments.

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ROAD LOG TRIP A-1

Assembly point 600 feet south of intersection of routes 8 South and 9 in the town of Coltsville, 2 miles east of Pittsfield, Mass. Assemble in parking lot of supermarket just south of light on the east side of road that is the extension of route 8 to the south.

Assembly time 8:30 am, Friday October 14th
If you should arrive late, follow roadlog to first stop and follow flagging down and up slope to first locality. We will be at Stop 1 until 9:15 am.

Mileage (cumulative)

0.0 Intersection route 9 and 8 south Coltsville turn right (east) on 8 south and follow 1.3 miles to Dalton.

1.3 Turn right onto South Street at Crane Paper Company Museum Turn left on Grange Hall Rd. drive up hill 0.9 mile to point just past mailbox and driveway to the right

3.0 STOP 1. Day Mountain unconformity and Taconian staurolite grade rocks.

Unconformity of Dalton Formation conglomerate on Middle Proterozoic gneiss. Day Mountain Pittsfield East quadrangle. Starting from road walk north into brook to exposures of hornblende and biotite layered gneiss showing subvertical Proterozoic layering. Biotite from this rock (BM10H) gives a Ar/Ar plateau age of 421.6 Ma (fig. 11). Because aluminous rocks underneath the Day Mountain slice at the foot of North mountain in Dalton contain staurolite, temperatures exceeded the closure temperature of biotite here and the 422 Ma age is interpreted as a Taconian cooling age. Follow gneiss outcrops diagonally (NNE) up the slopes to large ledges of gneiss and overlying conglomerate. This is one of the two best exposures of the unconformity between the Dalton Formation and the basement gneiss in western Massachusetts. B. K. Emerson (1899) described this locality as his Dalton Club House locality. Few words are necessary at this exposure. Walk along the low cliffs and locate the unconformity and the angular discordance. This outcrop is figured in Ratcliffe and Zartman (1976); the geology in Ratcliffe (1984).
Return downhill to left turn onto South Street Turn left (0.9 mi) at Division Street
Turn left on Washington Mtn. Rd., head up hill and bear right at Y park near bend in road to right

7.9 STOP 2. Thrust fabric in gneiss and discussion of fault structures in Pittsfield East quadrangle.

Outcrops by road are mylonitic, augen gneiss derived from the Tyringham Gneiss, a Middle Proterozoic augen gneiss interpreted as a syntectonic Middle Proterozoic biotite granite. Structures and textures in the Tyringham regionally show that it participated in the intense Grenvillian deformation that preceeded the deposition of the Dalton Formation (Ratcliffe and Zartman, 1975). In this regard the Tyringham differs from the 950 to 900 Ma old Stamford Granite Gneiss and granitoids to be seen later, because the latter lacks a Middle Proterozoic fabric. Granitic gneiss at this outcrop are thus twice deformed or 2x augen gneiss, as opposed to 1 cycle augen gneisses derived from the Stamford seen at Stop 2. Thrust fault fabric strikes northwest and dips southwest parallel to the contact with the underlying Dalton Formation. In the northern Berkshire massif numerous thrust faults are marked by similar zones of mylonite. These faults stack up to the north-northeast. Paleozoic shortening through structural overlap amounts to about 47 km in the 10 km long section illustrated in Ratcliffe (1984). The complex, nested-thrust fault style seen in the Pittsfield East quadrangle is typical of the Berkshire massif as a whole and atypical of the structures developed in the Green Mountains massif. In the Green Mountains few if any through-going thrust faults are recognized. This difference in tectonic style is an important contrast to be developed on this field trip and Saturday's trip through the Green Mountains. The complex slivering of basement and cover rocks characteristic of the Berkshire massif continues northward into the Wilmington area and further northward to the eastern margin of the Green Mountain massif at Jamaica, Vt. From this point north regionally important thrust faults may re-enter the Green Mountain basement as suggested by Karabinos (1987), although Ratcliffe suspects that the bulk of the faulting is in and around the repeated slices of basement rocks east of Jamaica and in the Chester-Athens domes, along the Cobbe Brook fault of Karabinos (1984).

Turn around and head downhill to turn right on Division Street and continue 1.6 miles to traffic light, continue across and follow road north to Rt. 8 south. 1

2.3 Turn right on Rt. 8 south, proceed E through town of Dalton then turn left on routes

14.2 8A and 9. Follow 8A and 9 to Windsor 6.3 miles and turn left on route 8A, follow route 8A (4.4 mi) to the intersection with Rt. 116 and park

24.9 STOP 3. The Cuddleybunny outcrop. Mylonitic fabrics and Acadian overprint.

This outcrop in the Windsor quadrangle was previously described by Norton (1975), who mapped this quadrangle (Norton, 1967). These road cuts of biotite plagioclase gneiss are all strongly tectonized and contain strong Paleozoic overprint and mylonitic foliation dipping northeast beneath the overlying Stamford Granite Gneiss exposed at the east end of the cut. Norton mapped these rocks as forming the northeastern upright limb of a nearly recumbent antiform cored by biotite plagioclase gneiss and unconformably overlain by a transitional facies of schistose Hoosac, a biotite muscovite garnet schist and thin discontinuous vitreous quartzite. Within the roadcut one belt of muscovitic biotite-garnet schist is interpreted by Norton as a folded fault sliver of Hoosac Formation, that in turn is overridden to the east by mylonitic Stamford Granite Gneiss.

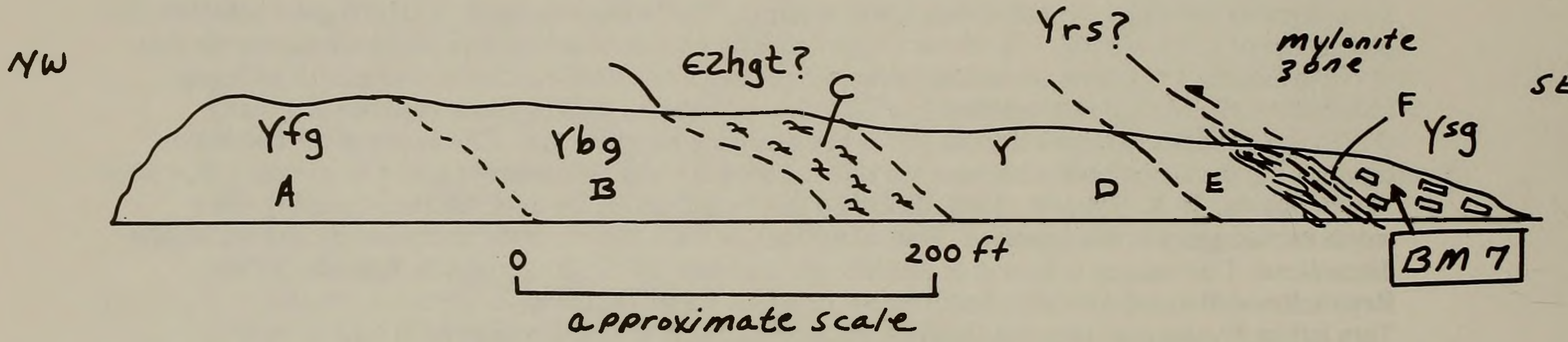

FIgure 12. Sketch of roadcut at Stop A-3 showing location of analytical samples in table 6.

Chemical analyses of rocks from the cut (fig. 12) are given in table 7. Light colored felsic gneiss (Yf, samples A and D) well-layered biotite-quartz-plagioclase gneiss (Ybg, sample B) dark biotite mylonitic gneiss (Ybm, sample E) are typical of the metavolcanic plagioclase quartz gneiss present in the Berkshire massif, comparable to the calc-alkaline suite shown in table 6. Garnet schist possibly of the Hoosac Formation is sample C. Two samples F1 and F2 are fine-grained dark mylonitic and coarser Stamford Granite Gneiss. Dispite the markedly differ appearance of the dark and light colored layers their major element, and REE abundances are identical suggesting mylonitization was isochemical involved no differential volume change (between the two layers).

Biotite sample BM7 from mylonitic Stamford Granite Gneiss (tp = 356.5 Ma) is Acadian and indicates that Acadian metamorphism at least of biotite grade affected these rock. The progression in age from samples from BM4, BM6, BM5 (379 to 356 Ma) suggests that all of these samples represent cooling ages from Acadian remetamorphism in the biotite through garnet zone. Garnets in the muscovite-biotite-plagioclase-quartz schist (C) have inclusion rich cores, and clear euhedral overgrowth rims. The cores probably are Taconian, the overgrowths Acadian. Continue E on route 8A and 116 0.5 mi and turn left on Center Rd., in 2.9 mi take left at intersection following sign to Savoy Mtn. State Forest and 0.2 further bear right

29.1 At Y intersection; following sign to Savoy Mtn. State Forest; take left "Y" on Burnett Rd. and then right onto Florida road past entrance to Savoy Mt. Forest, go past North Pond and look for dirt road turning left from sharp right hand bend in road pull into dirt road to clearing

31.1 STOP 4. Stamford Granite Gneiss and unconformable cover sequence, north end of Hoosac Mountain, North Adams quadrangle.

Table 6. Chemical analyses of biotite quartz plagioclase leucogneiss (metatrondhjemite), Jamaica and Peru quadrangles,VT, and metatonalite at Cole Pond

Sample	2755	2750	2754	3025	1230	3153	3016A	3016B	3016C	3016D	3016E
	metatrondhjemite					metatonalite					
constituent											
SiO_2	66.6	66.6	70.0	69.9	71.5	70.8	65.2	65.5	65.3	66.0	66.1
Al_2O_3	18.1	18.1	16.3	16.4	15.50	16.0	17.1	17.2	17.1	16.6	16.8
FeO	1.2	1.1	0.92	0.52	0.40	0.56	2.0	1.90	1.6	1.8	1.7
Fe_2O_3	.9	1.0	0.57	1.0	0.94	0.63	1.23	1.15	1.6	1.4	1.3
MgO	1.05	1.13	0.77	0.81	0.46	0.80	1.82	1.69	1.90	1.56	1.45
CaO	4.18	4.17	2.99	2.91	2.60	2.45	4.52	4.28	4.60	4.81	4.97
Na_2O	5.12	5.32	5.03	4.94	4.53	4.92	4.59	4.52	4.53	4.25	4.42
K_2O	1.21	1.12	1.76	1.68	2.51	2.30	1.71	2.08	1.75	1.94	1.61
TiO_2	0.24	0.26	0.18	0.20	0.14	0.18	0.45	0.39	0.45	0.23	0.23
P_2O_5	0.12	0.13	0.08	0.08	0.07	0.09	0.15	0.14	0.15	0.13	0.12
MnO	<0.02	0.02	0.02	<0.02	0.02	<0.02	0.04	0.05	0.05	0.06	0.06
H_2O^+	.48	0.15	0.20	0.20	0.44	0.34	1.3	0.47	0.53	.52	0.39
H_2O^-	0.21	0.21	0.17	0.16	0.08	0.26	0.08	0.10	0.08	.04	0.05
CO_2	<0.01	<0.01	0.02	0.01	0.01	<0.01	0.11	0.13	0.09	.22	0.25
Total	99.11	99.32	99.01	98.83	99.47	99.38	100.3	99.6	99.73	99.56	99.45
CIPW Norms											
constituent											
Q	21.8	21.0	26.7	28.0	29.9	27.5	19.6	19.6	20.0	21.9	22.2
C	1.1	0.9	0.9	1.4	0.8	1.2	0.1	0.4	0.0	0.0	0.0
or	7.2	6.7	10.6	10.1	15.0	13.8	10.2	12.4	10.5	11.6	9.6
ab	43.9	45.5	43.2	42.5	38.9	42.2	39.4	38.7	38.8	36.5	37.9
an	20.2	20.0	14.4	14.1	12.6	11.7	21.0	19.7	21.4	20.8	21.5
di	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	0.9
hy	3.8	3.7	2.9	2.1	1.2	2.3	6.6	6.3	5.7	5.4	5.0
mt	1.3	1.5	0.8	1.2	1.0	0.9	1.8	1.7	2.3	2.1	1.9
hm	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
il	0.5	0.5	0.3	0.4	0.3	0.3	0.9	0.7	0.9	0.4	0.4
ap	0.3	0.3	0.2	0.2	0.2	0.2	0.4	0.3	0.4	0.3	0.3
cc	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.3	0.20	0.5	0.6
Total	100.1	100.1	100.1	100.2	100.2	100.1	100.3	100.1	100.3	100.3	100.3

Table 7. Chemical analyses of gneissic rocks at road cut Rt. 116 and 8A in Windsor Quadrangle

Sample	1508A	1508B	1508C	1508D	1508E	1508F$_1$	1508F$_2$
constituent		schist				Stamford	
SiO_2	74.50	65.60	46.70	76.0	62.8	66.5	67.2
Al_2O_3	13.80	15.50	25.60	12.40	15.40	14.1	14.1
FeO	0.44	3.90	8.80	0.84	4.70	4.4	4.0
Fe_2O_3	0.25	1.09	2.11	0.54	1.75	1.29	1.57
MgO	0.20	1.18	2.31	0.57	0.46	1.43	0.63
CaO	1.08	3.08	1.42	0.38	3.61	1.57	2.01
Na_2O	3.49	4.28	1.33	3.60	3.38	2.65	3.12
K_2O	4.93	2.44	5.51	4.49	4.43	4.84	4.67
TiO_2	0.05	0.72	1.43	0.72	0.79	0.64	0.64
P_2O_5	0.05	0.22	0.25	0.05	0.34	0.21	0.20
MnO	0.02	0.02	0.25	0.02	0.09	0.05	0.08
H_2O^+	0.36	0.70	2.60	0.29	0.68	0.72	0.79
H_2O^-	0.12	0.11	0.16	0.12	0.08	0.18	0.21
CO_2	0.06	0.05	0.01	0.02	0.66	<0.01	0.01
Total	99.89	98.89	98.48	99.44	99.17	98.58	99.22
CIPW Norms							
consitituent							
Q	33.2	21.9	6.7	36.4	18.2	25.6	24.7
C	1.0	0.9	16.2	1.1	0.8	2.2	0.8
or	29.5	14.7	34.1	26.8	26.8	29.3	28.1
ab	29.9	37.0	11.8	30.8	29.3	23.0	26.9
an	4.7	13.8	5.6	1.4	11.8	6.5	8.8
hy	1.1	8.2	19.1	2.4	7.4	9.9	6.8
mt	0.4	1.6	3.2	0.8	2.6	1.9	2.3
il	0.1	1.4	2.8	0.2	1.5	1.3	1.2
ap	0.1	0.5	0.6	0.1	0.8	0.5	0.5
cc	0.1	0.1	0.0	0.1	1.5	0.0	0.0
Total	100.1	100.1	100.1	100.1	100.7	100.2	100.1

Gray, albitic granofels and quartz pebble conglomerate of the Hoosac Formation unconformably overlies Stamford Granite Gneiss. This basal unit is well developed here as well as on the west side of the Wilmington antiform where it forms a distinctive unit previously mapped locally by Skehan (1961) as Searsburg Conglomerate. This albitic conglomerate contains clasts of pegmatitic Stamford up to 3 feet in diameter locally. Elsewhere lensoidal albitic "clasts" may be disarticulated beds producing a pseudoconglomerate. Dalton-like feldspathic quartzite and dark biotite schist (CZdbs) overlies this albitic facies, thus suggesting that the basal Hoosac is an eastern and older part of the Dalton-Cheshire transgressive quartzofeldspathic sequence. Walk along logging road to contact of basal Hoosac and Stamford at the stream. Samples of typical Stamford are located near the unconformity.

Continue north on Florida Rd., then take left on So. County Rd. in (0.9 mi), right at first Y intersection, go past Hoosac tunnel ventillation shaft, bear left at next Y intersection.

34.1 Turn right on Rt. 2, 1 mile east turn left opposite Florida Fire Dept. on Tilda Hill Rd., follow paved Rd. 2.9 miles, turn left on Turner Hill Rd., follow 1.6 miles to first right turn, follow this dirt road 1.8 mile downhill past P.O. Box 158, turn left, in 0.5 mile turn right onto narrow dirt road parallel to Beaver Brook, continue 0.6 mile to power line and park.

50.9 STOP 5. Basal albitic conglomerate of the Hoosac Formation Readsboro quadrangle.

Excellent near crops of very coarse-grained albitic granofels and conglomerate typical of the basal Hoosac can be seen at the base of the slopes leading up the powerline. Scattered crops of biotite plagioclase gneiss and probable calc-silicate gneiss are found to the north below the conglomerate. Albitic granofels passes upward into dark black to gray, garnet-biotite- plagioclase-quartz schist and rusty muscovitic garnet schist. At the crest of the hill light green, very aluminous garnet-chlorite-chloritoid-muscovite (paragonite?) quartz schist and large garnet schist assigned to the allochthonous Hoosac overlies the albitic Hoosac. This contact is interpreted as the Hoosac Summit Thrust on figure 1.

Right turn on Rt. 2. Follow Rt. 2, over crest of hill and down to hairpin turn. Excellent views of Mount Greylock to the southwest and Clarksburg Mount and the southern end of the Green Mountains to the west. The aluminous Hoosac Formation schists exposed in the road cuts form part of the allochthonous Hoosac section that lies above the Hoosac summit thrust (see map).

55.3 Turn right on Rt. 8, in 3.0 miles turn left on Middle Rd., in 1.0 mi turn right on Horrigan Rd., and in 1.3 miles take left on Lesure Rd.

Park 300 feet up road.

60.6 STOP 6. Stamford Granite Gneiss and unconformable Dalton Formation cover.

This tired, old, but excellent exposure is always willing to entertain geologists--apologies to those of you who have been here 16 times already! A U-Pb zircon age of 958+4 Ma has been obtained from samples at this spot. The nearly concordant age (Karabinos and Aleinikoff, 1988) is exceptionally important. Our mapping of the Stamford here and on Hoosac Mountain indicates that the Stamford crosscuts Grenvillian sillimanite grade (hornblende granulite facies rocks) but is not deformed in the Proterozoic, i.e. lacks the gneissic fabric characteristic of other Middle Proterozoic granitic rocks such as the Tyringham and granitic gneisses of the Green Mountains. Chemical characteristics of the Stamford are presented in table 3 and figures 5 and 13. Mafic to intermediate dikes and irregular masses within the granite suggest that gabbroic to monzonitic liquids are associated with the coarse rapakivi granite, which is a K-feldspar cumulate. A strong positive Eu anomaly characterizes the Stamford here and on Hoosac Mountain. Where mafic dikes crosscut or are in contact with the coarser grained granite, K-feldspar megacrysts, quartz and plagioclase have resorption features and a new generation of K-feldspar having rapakivi structure form in the matrix. The mafic rocks are interpreted as comagmatitic liquids that intruded and reacted with the feldspar cumulates. 150 yards up the road one of these mafic dikes crosscuts the Stamford. On the Massachusetts State Map (Zen and others, 1983) this dike is assigned to the Late Proterozoic. Chemical analyses of this dike (table 3) and comparison with Late Proterozoic basaltic volcanics in the Hoosac Formation indicate that this should not be correlated with Late Proterozoic metadiabase dikes and flows. The chemical data (fig. 13) shows that each area of Stamford-like exposure is chemically slightly different and therefore each area may be considered separate plutons, of 960 Ma old granite. Coarse quartz pebble conglomerate (Cdsc) very similar to that seen at Stop 1 on Day Mountain overlies the Stamford.

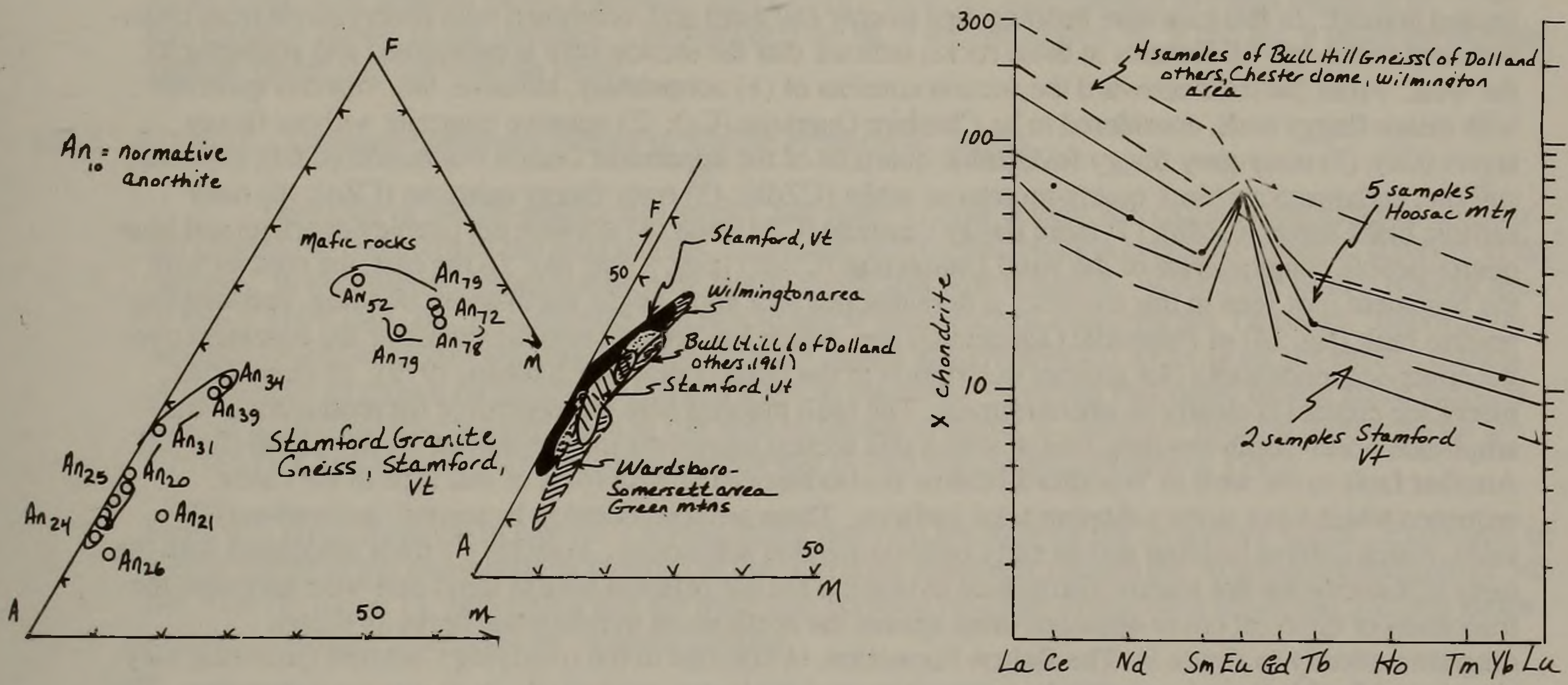

Figure 13. Some chemical characteristics of 960 Ma old post-tectonic granitoids Stamford Granite Gneiss and Bull Hill Gneiss of Doll and others , 1961, showing variable major element and trace element geochemistry of separate plutons.

We will return to Rt. 8, go south to Rt. 2 and follow Rt. 2 through North Adams and Williamstown and take Rt. 7 north toward Bennington. A partial log follows: from intersection Rt. 7 and 2, west of Williamstown, travel 7.2 miles north on route 7 to Pownal Center. At Pownal Center (brown furniture barn on right) turn right on Barber Pond Rd.,in 2.2 mi turn right on dirt road (County Rd.), 0.4 mi bear left at Y and proceed 0.9 mi uphill to park on right at sharp bend to left (total approx. 18 miles from Stop 6.

78.6 STOP 7. Lake Hancock thrust and cover sequence on the southwest flank of the Green Mountains, Pownal quadrangle.

These excellent exposures of a fault zone were first shown to Ratcliffe by Jack MacFadyen in 1959 who mapped this area (MacFadyen, 1956). Mylonitic dark schist of the Dalton Formation overlies black carbonaceous phyllites of the Middle Ordovician Walloomsac Formation. Abundant minor, fold-thrust folds, mullion structure and asymetric minor folds indicate thrusting from the southeast approximately S. 75° E. This fault can be traced northeastward where it is expressed by muscovite-chlorite rich phyllonite and mylonite gneiss in the basement gneiss. We can trace the mylonite zone associated with this fault northward to the eastern margin of the Woodford synform. Southeast plunging lineations are common on all faults in the Green Mountains and in the gneiss domes to the east and we believe these are all data from the same, late Taconian thrust fault event (fig. 9).

Retrace route to Rt. 7 via Barber Pond Rd.

82.1 Turn right on Rt. 7

88.4 Follow Rt. 7 to Rt. 9 intersection, downtown Bennington, turn right, go 3.9 miles to Woodford Hollow and park on L by white church

92.3 STOP 8. Traverse through a section of cover-sequence rocks, western margin Green Mountains massif.

Along the north side of City Stream just east of Harbor Road in Woodford Hollow is a well-exposed section of the late Precambrian to Cambrian cover-sequence rocks (Dalton Formation and Cheshire Quartzite) which overlie the gneisses at the western margin of the massif in unconformable or locally faulted contact. In this exposure bedding dips steeply eastward and, combined with observations from cross-beds and scour-and-fill features in these rocks, indicate that the section here is overturned and younging to the west. From the road eastward the section consists of (1) nonpebbley, massive, tan, vitreous quartzite with minor flaggy beds, considered to be Cheshire Quartzite (Cc); (2) massive quartzite without flaggy layers (Cc); (3) rusty-grey flaggy feldspathic quartzite of the uppermost Dalton Formation (CZd); (4) rusty, sulfidic, carbonaceous black quartz-muscovite schist (CZdb); (5) rusty flaggy quartzite (CZd); (6) rusty sulfidic black schist (CZdb); (7) more flaggy quartzite (CZd); and (8) massive tan pebbley quartzite and blue-quartz-pebble conglomerate of the basal Dalton unit (CZdc) (figs. 8 and 14). To the east, the contact with the basement (not seen in this traverse) is here mapped as a high- angle, north-south trending, east-dipping reverse fault (fig. 14) of Paleozoic (Taconian?) age, which has brought granitic gneiss of the basement over the cover-sequence rocks (for another description of the basal contact see Skehan, 1972). In many other places the contact is clearly an unconformity. The fault mapped here is responsible for producing a large-amplitude north- south-trending fold of which this section represents the overturned western limb (fig. 14). Another fault to the west in Woodford Hollow is also associated with folds of this type in the cover sequence which have steeply dipping axial surfaces. These are considered to be second- generation (F2) folds, which deform bedding and an early bedding-parallel schistocity. Possible F1 folds associated with the early schistocity are not readily visible here in outcrop but are believed here to trend east-west andcause the truncation of different cover-sequence units against the north-south trending late faults as shown diagrammatically in figure 9. The Dalton Formation, in contrast to the overlying Cheshire Quartzite, may show considerable lateral variation in composition and thickness, particularly in an east-west direction. The Woodford inlier, three kilometers to the east, contains a similar basal section of conglomerate and flaggy quartzite which however, is followed by a very thick section of black phyllitic schist, with the total thickness of the Dalton in the inlier being much greater than that of the section exposed here (figs. 8 and 14, see Skehan, 1972, for description of some of the Woodford inlier rocks). The sequence and general character of the lithologies is more uniform from north to south. In fact, strong similarities exist between the type Dalton section at Stop A-1 and rocks exposed along the western margin of the Green Mountains at least as far north as Manchester, Vt.

93.8 STOP 9. Roadcut in layered basement gneiss of the core of the Green Mountains.

This large exposure shows the strong gneissic banding and some of the compositional variation typical of the layered paragneisses mapped in the southern Green Mountains as the Harmon Hill Gneiss of Skehan (1961). The layered paragneisses have been subdivided in this study into banded biotite-rich rocks (Ybg), fine-grained hornblende amphibolites (Ya), diopside-bearing calc-silicates with minor marbles (Ycs), and rusty-ribbed garnetiferous blue vitreous quartzite (Yq) (fig. 6). Typical "Ybg" as displayed here contains alternating quartzofeldspathic and mafic (biotite plus or minus hornblende) layers on a scale of one to several centimeters. In this outcrop the general composition ranges from a quartz-poor rock with equal amounts of biotite and hornblende at the western end of the outcrop to a more felsic gneiss with only biotite as a mafic mineral at the eastern end. The quartzofeldspathic layers consist both of quartz-plagioclase- rich zones probably derived from a sedimentary protolith and quartz-plagioclase-microcline (aplite and pegmatite) lenses and stringers injected as a granitic melt, possibly derived from the large body of biotite granite gneiss (Ygg) mapped to the north and west or alternately derived migmatitic lenses (Microcline Gneiss of Skehan, 1961). The concordance of these lenses and stringers with the overall gneissosity testifies to the fact that intrusion of the granitic material and/or partial melting occurred during or prior to the major deformational episode that produced the gneissic fabric and the tight folds seen in the exposure. Samples of hornblende and biotite from this outcrop were dated using the $^{40}Ar/^{39}Ar$ technique by Samuel Mukasa (Sutter and others, 1985). Two hornblende separates yielded total-gas ages of 1127 Ma and 928 Ma, and a biotite gave a plateau age of 837 Ma (fig. 11). Thin-sections of the samples from which the dates were obtained show a fabric typical of undisturbed Middle Proterozoic rocks in which embayed interlocking grains with triple-junction boundaries occur in a flattened, granoblastic texture. The lack of textural evidence in the samples for a biotite grade Paleozoic deformational event therefore agrees well with age data. Throughout the Appalachians basement, rocks having similar relict Middle Proterozoic biotite and hornblende textures yield Proterozoic cooling ages. Paleozoic deformation is evident in this outcrop, however, in the form of a mylonitic zone in the middle of the exposure which parallels the high-angle west-dipping gneissosity and as a faint cleavage locally crosscutting foliation at the east end of the outcrop. In these zones a secondary flattening of grains can be seen in thin section accompanied by extensive retrogradation of plagioclase to epidote and sericite and quartz ribboning. Biotite has abundant epidote inclusions and a pale red to green color, with no evidence of having been recrystallized. Although cover rocks to the west contain biotite Paleozoic temperatures were not high enough to either degas or to recrystallize biotite in the gneisses. Continue east on Rt. 9 to intersection Rt. 8 and Rt. 9 outcrops of rusty sulfidic gneiss and calc-silicate rocks

105.5 STOP 10. Taconian retrograde fabrics in Middle Proterozoic Gneiss.

Outcrops of biotite-plagioclase gneiss, and rusty sulfidic schists and calc-silicate rocks of unit Yrr are exposed to the north of the intersection. Mylonitic retrograde foliation crosscuts gneissic layering in the outcrop. In thin section lepidoblastic new biotite forms this new foliation. 40Ar/39Ar biotite plateau age of 436.5 Ma (GM4, fig. 11) indicates that this foliation and structual overprint are Taconian. Importantly Acadian overprint greater that biotite grade does not appear to have affected rocks along the eastern margin of the massif as shown by samples BM4 and BM5 to the north. A strong Paleozoic biotite grade fabric is present in ductile deformation zones in this area as shown in figure 9. Strongly foliated biotite gneiss at GM-5 to the north produced a Taconian cooling age of 446 Ma (Sutter and others, 1985).

From this point continue to east on 9 across valley marking the trace of the Searsburg thrust. Exposures of biotite gneiss at the sharp bend in the road at the Harriman Reservoir yielded the Acadian cooling age of 363 Ma (GM29) figure 11, suggesting that the transition between Acadian overprinted zones and Taconic zones is abrupt and may be affected by Acadian faulting.

113.6 continue east to intersection of Rt. 9 and Rt. 100, downtown Wilmington. Turn north on Rt. 100 and proceed north 1.7 miles to Elementary School on west side of Rd.

115.3 STOP 11. Hornblende amphibolite and gneiss in Wilmington antiform and discussion of Ar/Ar results.

Hornblende and biotite from this outcrop (GM28, fig. 11) yielded 40Ar/39Ar ages of 376 and 377 Ma respectively. Although originally mapped as the Turkey Mountain Member of the Hoosac Formation by Skehan (1961) this rock may actually be basement gneiss. In this general area strong subhorizontal mylonitic foliation is prevalent in rocks above the Wilmington fault. Crosscutting pink pegmatoids as veins and pods are common. These granitic pods are non-deformed and suggest that post-thrusting high grade metamorphism affected these gneisses. The Ar/Ar data suggest that hornblende and biotite passed through their effective blocking temperatures nearly simultaneously, thus suggesting quick cooling from an Acadian high temperature event. Textures and mineralogy in nearby rocks suggest widespread post-foliation recrystallization consistent with Acadian thermal overprinting of Taconian fabric.

Fieldtrip ends - return south on 100 Wilmington, take Rt. 9 east to Brattleboro and 5 and 9 north to cross Connecticut River. Follow Rt. 9 to Keene.

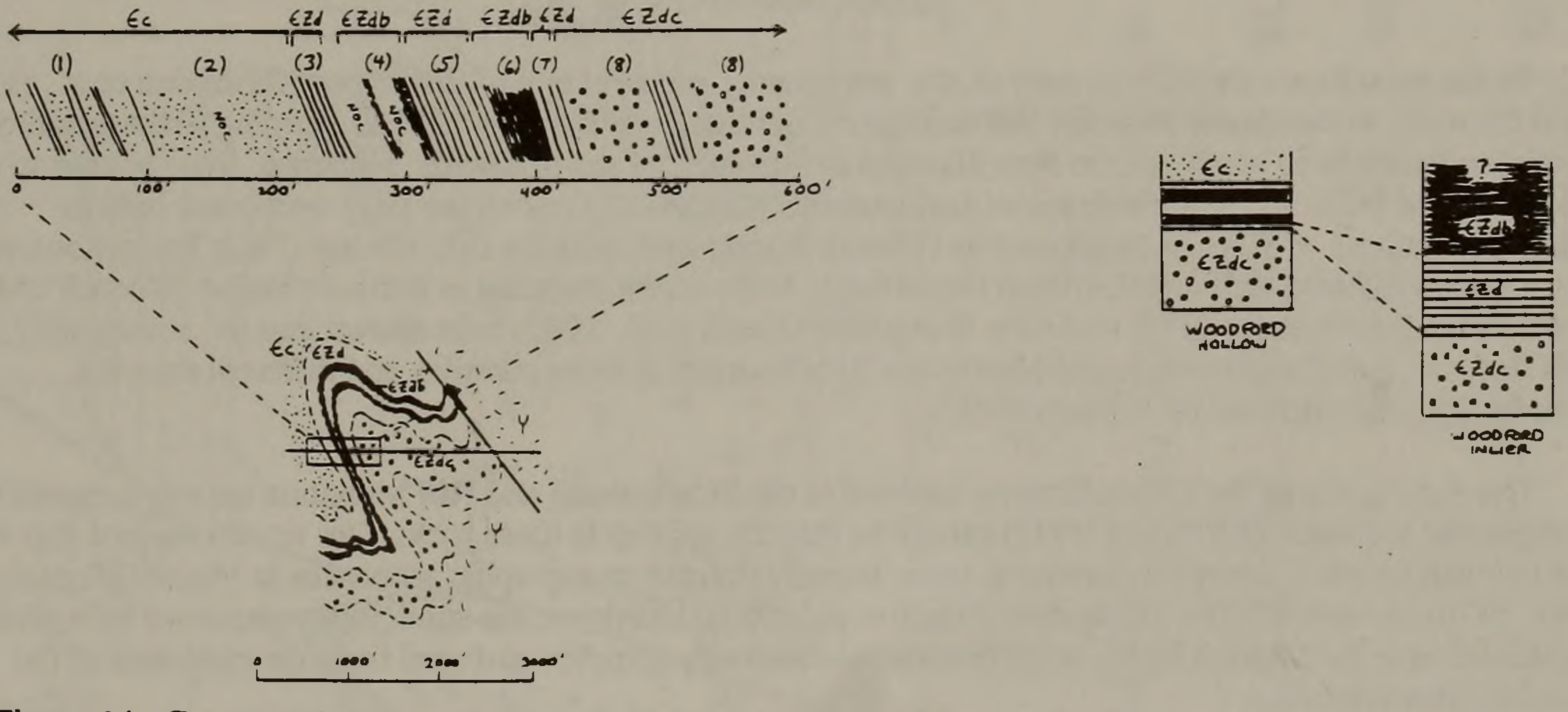

Figure 14. Cross section through Cheshire Quartzite and Dalton Formation on east side of Woodford Hollow cover sequence, Stop A-8 and comparison of cover sequence in Woodford Hollow and Woodford synform.