TRAVERSE ACROSS THE TACONIAN OROGEN

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INTRODUCTION

In Early Ordovician time the rifted and submerged eastern edge of the North American continent (current coordinates) was located approximately at the present location of the Connecticut River in western New England (Figures 1A and 2). To the east, across a narrow ocean basin, lay an island arc. Subduction of oceanic crust beneath the arc allowed the arc to advance toward North America, colliding in Middle to Late Ordovician time (Figures 1B to 1F). The remnants of the island arc itself are present in western New England as a sequence of Ordovician sediments (e.g., Bradley and Kidd, 1991) and bimodal volcanic and plutonic rocks (e.g., Leo et al., 1984; Leo, 1985, 1991; Schumacher, 1988; Hollocher, 1993, 1994). The remnants of the island arc are found in four different forms: 1) unmetamorphosed sediments derived from the arc and forearc regions that were deposited west of the arc on North American crust; 2) variously metamorphosed continental shelf, continental slope, trench, and forearc rocks that became part of the arc's accretionary wedge and were thrust westward onto North America during subduction and collision; 3) interbedded sediments and volcanics associated with arc, and possibly forearc and back arc volcanics; and 4) the plutonic roots to the arc. This trip examines all four of these.

THE EARLY PALEOZOIC NORTH AMERICAN CONTINENTAL MARGIN

In the Late Precambrian and Early Cambrian much of eastern North America was emergent from the oceans, with Late Precambrian and Early Cambrian sediments accumulating on the continental shelf. Deeply eroded Precambrian metamorphic rocks, including those of Grenville age, were exposed over much of the surface of the continent. As the continental margin gradually subsided, the first unit deposited on the unconformity in many areas was quartz sandstone and quartz pebble conglomerate. This deposit is the Cheshire Quartzite in the Green Mountains and Berkshires of New England, and the Potsdam Sandstone in the area surrounding Precambrian rocks in the Adirondacks of New York State (Stanley and Ratcliff, 1985, Ratcliff et al., 1988). The unmetamorphosed Potsdam Formation is quite complex and includes fluvial, beach, dune, and shallow water offshore facies (Selleck, 1993). The basal Paleozoic sandstones are overlain by a variety of Cambrian and Lower Ordovician clastic and carbonate rocks that were deposited in shallow seas in near shore environments on the North American continental margin.

IGNEOUS ROCKS ASSOCIATED WITH THE TACONIAN ISLAND ARC

By Middle Ordovician time an island arc (the Taconic arc) began approaching North America because of subduction of the intervening oceanic crust beneath the arc. Large volumes of magma were emplaced into the arc. The remnants of the arc plutonic complex were metamorphosed during the Devonian Acadian orogeny, and are presently exposed as gneisses in eroded Acadian structural domes in the Bronson Hill anticlinorium (Figures 2, 3) and in a few outlying domes to the west. These Taconian arc plutonic rocks are predominantly felsic, metaluminous, and calc-alkaline, and range in composition from tonalite through granite (Leo et al., 1984; Leo, 1991; Hollocher, 1994). Small quantities of mafic, ultramafic, and anorthositic rocks also occur.

The compositions of the Taconian plutonic rocks in the Bronson Hill anticlinorium vary geographically (Figure 3). In the northern section of the Bronson Hill anticlinorium, Taconian felsic gneisses are predominantly granitic, rich in K_2O and Ba, poor in Sr, and have generally high Y concentrations. These rocks are generally strongly LREE-enriched, have flat MREE's and HREE's, and have moderate negative Eu anomalies. The rocks in the west-central part of the Bronson Hill anticlinorium are dominantly tonalitic. These rocks have less K_2O and Ba than those in the northern section, and tend to be somewhat less LREE-enriched. Rocks in the southeastern section are also dominantly tonalitic, but occur in two lithologically similar but geochemically distinct groups. The first group is identical to rocks of the west-central section, being largely tonalitic, having flat MREE and HREE patterns, and having

In Garver, J.I., and Smith, J.A. (editors). Field Trips for the 67th annual meeting of the New York State Geological Association. Union College, Schenectady NY, 1995, p. 145-161.

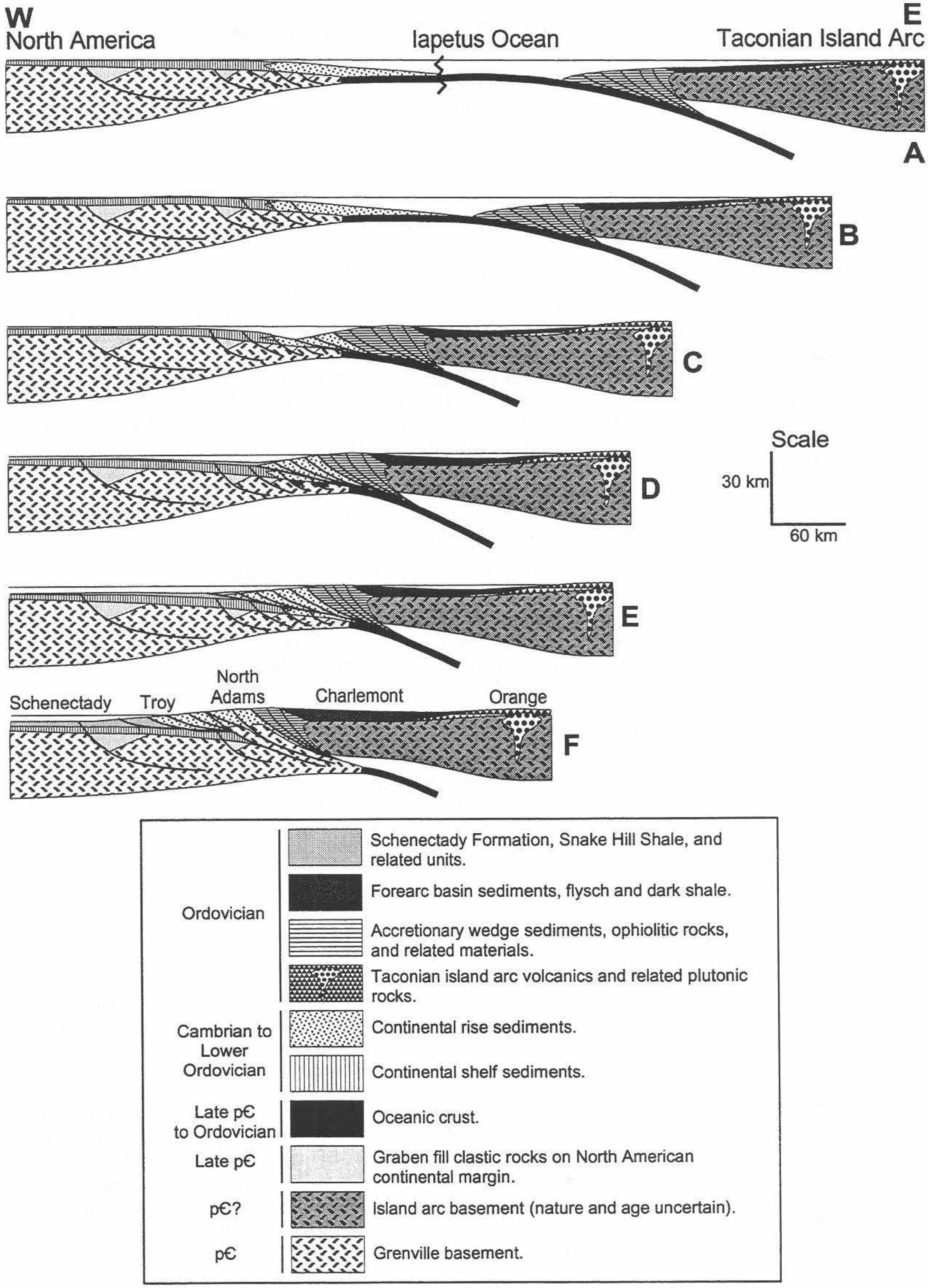

Figure 1. Schematic cross sections showing the tectonic development of the Taconic Orogen from Early Middle Ordovician (A) to Early Upper Ordovician (B). Adapted from Rowley and Kidd (1981).

marked negative Eu anomalies, low Sr, and generally high Y. In contrast, the second group has strongly depleted HREE's, no significant Eu anomaly, high Sr, and low Y.

The dominantly granitic Taconian arc plutonic rocks of the northern section are likely to have been derived from the melting of relatively K-rich intermediate or felsic igneous rocks (Roberts and Clemens, 1993) in the lower crust of the Taconian island arc. The preponderance of granitic rocks in the northern section of the Bronson Hill anticlinorium suggests that the basement to the Taconian arc in this area was composed of continental crust. The generally tonalitic Sr-poor rocks in the west-central and southeastern sections were probably derived from the melting of relatively K-poor mafic igneous rocks at moderate pressure in the stability field of plagioclase. Residual plagioclase during melting yielded the observed negative Eu anomalies and low Sr concentrations in the resulting liquids, because of the strong partitioning of these elements into plagioclase. The generally tonalitic high-Sr, low-Y, HREE-depleted rocks in the southeastern section were also probably derived from the melting of relatively K-poor mafic igneous rocks, but at a higher pressure in which garnet was abundant in the restite after melting rather than plagioclase. Garnet in the source area explains the observed lack of negative Eu anomalies, the strong HREE-depletion, the high Sr contents, and low Y contents of these rocks. The change across the strike of the Taconian arc from rocks having flat MREE and HREE element patterns to rocks having depleted HREE's is similar to variations in composition of plutonic rocks observed across strike in more recent subduction zone environments (e.g., the Peninsular Ranges batholith; Gromet and Silver, 1987).

The volcanic rocks that are associated with the Taconian island arc system are rather complex and somewhat problematic. The large volumes of volcanics that are usually associated with island arcs, and expected considering the large volumes of Ordovician plutonic rocks that are exposed, do not exist in the Bronson Hill anticlinorium, the presumed axis of the arc. The Taconian plutonic rocks in the Bronson Hill anticlinorium in southern New England are overlain by the Ordovician Ammonoosuc Volcanics and the Partridge Formation, which also contains metamorphosed volcanics. These rocks are relatively thin (generally only few hundred meters thick), and are in part mineralogically and chemically distinct from the Taconian plutonic rocks (Hollocher and Lent, 1987; Hollocher 1994). These and related volcanics have been interpreted, at least in part, to belong to a back-arc basin environment rather than to the arc itself (Hollocher, 1993; Stoll and Karabinos, 1993). It seems likely that large volumes of volcanics on the arc itself were eroded away during and after arc development in the Late Ordovician or Silurian. A variety of other metamorphosed volcanic and shallow intrusive rocks occur in units of probable Ordovician age between the Bronson Hill anticlinorium and the Green Mountain and Berkshire massifs. Some of these volcanics and related intrusives in the Hawley Formation (Kim and Jacobi, 1994, 1995 and in review; in part Stop 8) have recently been interpreted as an early set of basalts having variously island arc, mid-ocean ridge, and forearc boninitic affinities, and a later set having back-arc basin affinities. These suggest a complex evolution of the Taconian island arc, and perhaps even more than one arc.

EFFECT OF THE TACONIAN COLLISION ON NORTH AMERICA

Sediments that were scraped off the subducting plate accumulated on the trench side of the advancing island arc to form an accretionary wedge or thrust complex (Figure 1). Each package of accreted sediment was incorporated in the accretionary wedge along thrust faults. These faults stepped westward during collision of the arc with North America, forming a series of allochthonous, thrust-bounded packages of rock that now make up the Taconic Mountains and underlie much of the Hudson River Valley (Figures 1, 2, 4).

Just prior to subduction, the downgoing plate tends to bulge upward a little bit due to the strength of the subducting lithosphere. This strength transmits flexural stress oceanward from the downward-bending plate as it descends into the trench. As the Taconian island arc began to advance on the North American continent, this flexural stress caused up-bowing and emergence of parts of the North American margin. Emergence in the Middle Ordovician resulted in erosion of shallow marine sediments over much of New York State, forming the extensive Upper Middle Ordovician unconformity in this area (Bradley and Kidd, 1991; Isachsen et al., 1991). Flexural stresses during collision also caused extensive normal faulting due to downloading of the North American margin, some of which involved reactavation of older faults (Bradley and Kidd, 1991).

As the arc continued to advance, continued loading of the eastern margin of North America by the arc and the overriding accretionary wedge caused the region to submerge again, resulting in a deep-marine basin into which gray and black shales of the Snake Hill Shale accumulated. Gradually, sediments were shed westward off of the advancing arc and forearc region and were deposited into this basin as flysch of the Schenectady Formation. The Schenectady Formation, and its tectonized equivalents such as the Austin Glen Formation in the Hudson River Valley and the Pawlet Formation in the Taconics, consist of

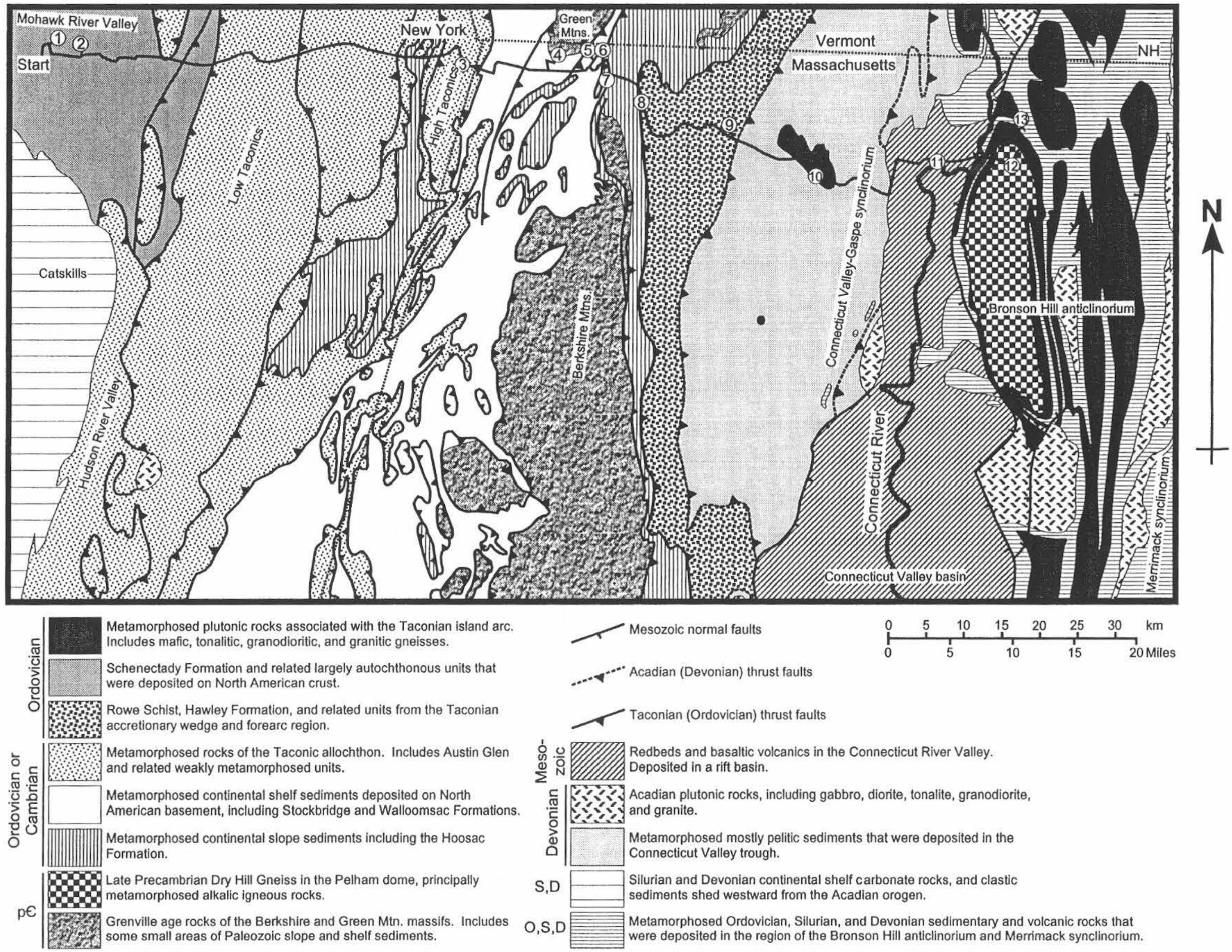

Figure 2. Generalized geologic map of eastern New York, western Massachusetts, and parts of adjoining states, showing the field trip route and trip stop locations (adapted from Stanley and Ratcliff, 1985; Zen, 1983; Rogers, 1990).

alternating gray shale and gray turbidite sandstones. The sandstones range in thickness from a few millimeters to over a meter, and in places have good internal grading, internal sedimentation features, and sole marks including superb flute and groove casts.

The collision of the arc with North America not only involved westward thrust transport of accretionary wedge and forearc sediments, but also involved transport Precambrian North American basement rock and overlying Lower Paleozoic sediments. These west-transported allochthonous blocks of metamorphic basement and cover rocks are resistant to erosion and hold up the Green Mountains and Berkshires of western New England (Figures 2 and 4).

METAMORPHISM

Figure 5 shows the realms of metamorphism in the area of this field trip. The trip starts in the Schenectady Formation, which is clearly unfoliated sedimentary rock (Stops 1 and 2). In the Schenectady area this rock contains coarse illite, chlorite, and kaolinite that, with other evidence, suggests diagenetic temperatures approaching 200°C (supported by work on units nearby, e.g., Friedman and Sanders, 1982; Conrad et al., 1983; Johnsson, 1986). These high diagenetic temperatures may have been the result of deep burial in the Devonian or Late Paleozoic. Rocks in the Taconic thrust slices, in and to the east of Troy, NY, are generally well-foliated and are of chlorite grade and higher. Ordovician metamorphic grade increases to chloritoid grade in the vicinity of the Taconic crest (Stop 3), to biotite grade in the Green Mountains-Mt. Graylock area (Stop 4), and to garnet grade in the eastern North Adams and the north-western Berkshires (Stops 5, 6, and 7). Ordovician metamorphic grades up to sillimanite grade are found in the central and southern Berkshires, south of the route of this trip. To the east of Stop 7, the effects of Ordovician metamorphism either never existed or have been overprinted by Acadian (Devonian) metamorphism, which ranges from the chlorite grade to the lower granulite facies (Figure 5). For an excellent discussion of Taconian and Acadian metamorphism, see Robinson (1986).

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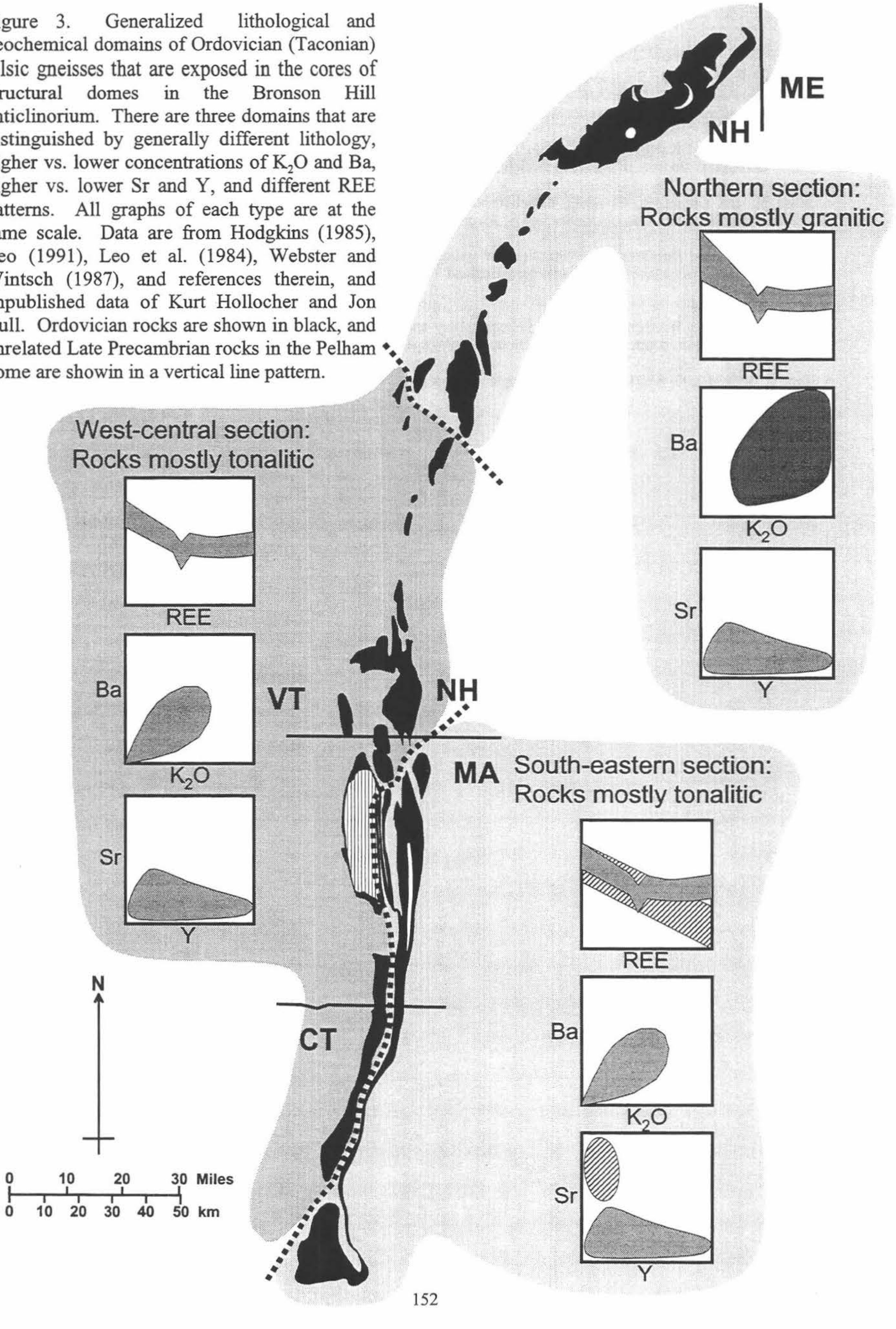
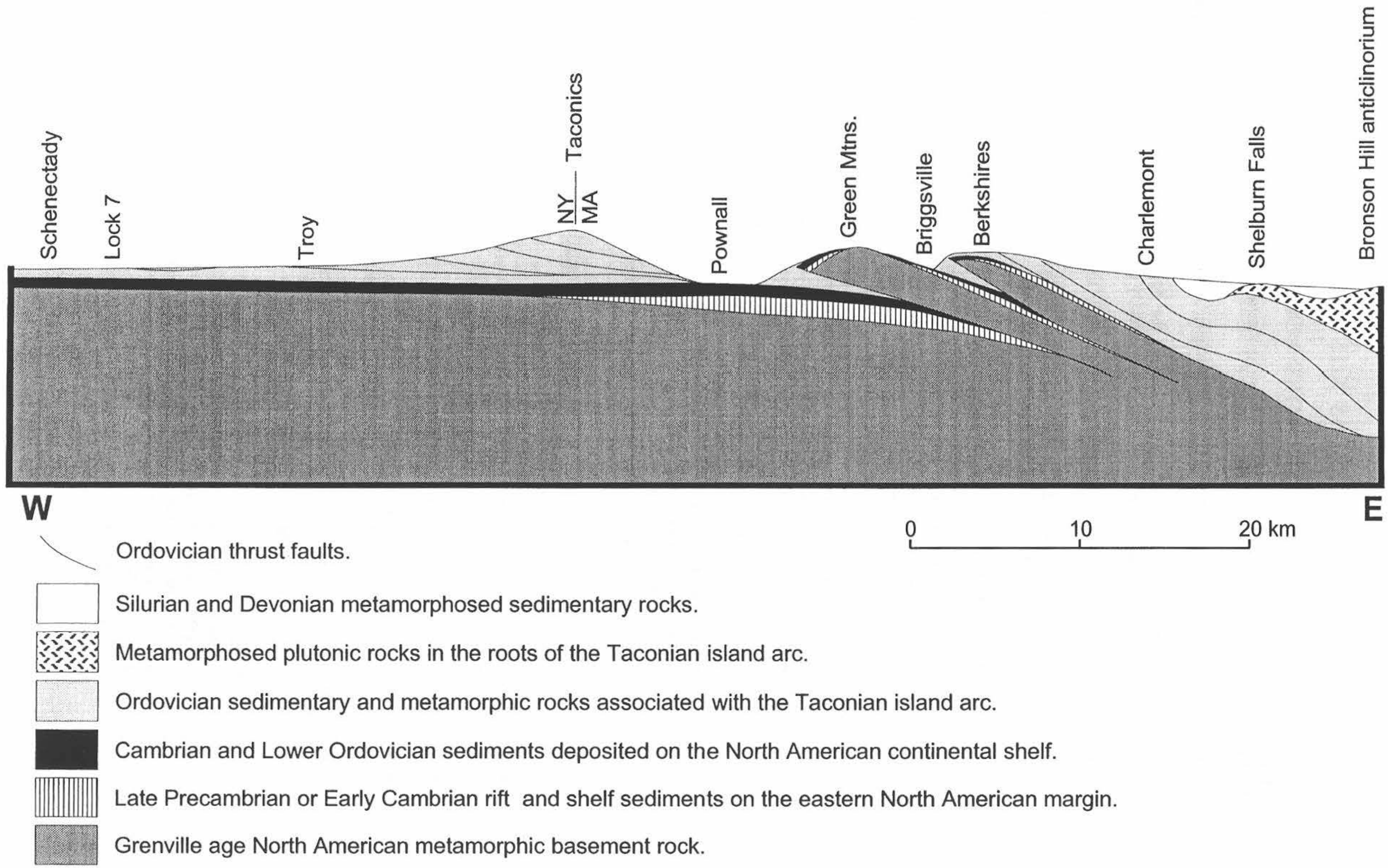


Figure 3. Generalized lithological and geochemical domains of Ordovician (Taconian) felsic gneisses that are exposed in the cores of structural domes in the Bronson Hill anticlinorium. There are three domains that are distinguished by generally different lithology, higher vs. lower concentrations of K_2O and Ba, higher vs. lower Sr and Y, and different REE patterns. All graphs of each type are at the same scale. Data are from Hodgkins (1985), Leo (1991), Leo et al. (1984), Webster and Wintsch (1987), and references therein, and unpublished data of Kurt Hollocher and Jon Bull. Ordovician rocks are shown in black, and unrelated Late Precambrian rocks in the Pelham dome are showin in a vertical line pattern.

Figure 4. Schematic cross section from Schenectady, NY, across the Taconics, the southern Green Mountains, the Berkshires, and the remnants of the Taconic island arc. High-angle Taconian faults and post-Ordovician deformation are not shown. Greatly modified after Stanley and Ratcliff (1985) and Zen (1983).



TRAVERSE ACROSS THE TACONIAN OROGEN

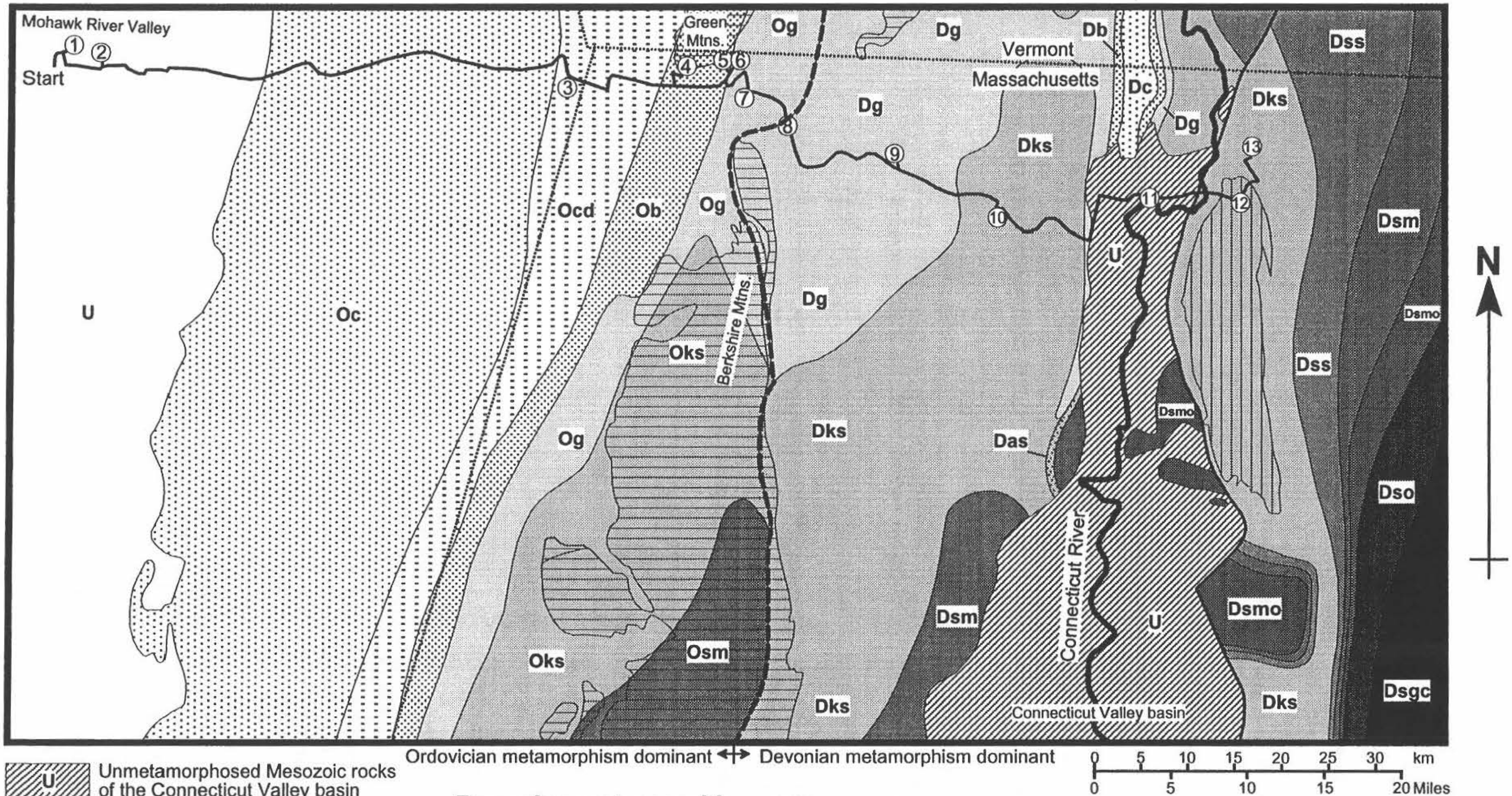
ROAD LOG

Miles from Start	Miles from last point	
0.0		Start at the parking lot near the power house, Union College, near the Geology Department.
0.1	0.1	Leave the Union College gate. Cross the intersection at Nott St. straight ahead (north) onto Van Vranken Ave. Van Vranken eventually turns into Aqueduct Rd.
2.9	2.8	Road crosses bicycle path and curves sharply to the right.
3.2	0.3	Cross Balltown Rd. (Rt. 146) and enter Williams St. Immediately turn left into small parking lot by bridge.

Stop 1. Rexford Bridge. **No hammers!** On the cliff across the Mohawk River you can see an excellent exposure of undeformed autochthonous Schenectady Formation, which is composed of interbedded gray shale and gray sandstone (graywacke). The sandstones are turbidite beds that are made of sediment derived from erosion of the Taconian island arc, and possibly associated emergent accretionary wedge and forearc material (see Kidd et al., this volume). Flute casts and other current indicators in eastern New York State indicate a generally northward turbidity current transport direction, suggesting deposition in a north-south trending, northward-deepening sedimentary basin. Garver et al. (in press) has shown that there is a dramatic increase in Cr and Ni concentrations part way up the stratigraphic section in these rocks in New York State and similar rocks in Quebec and Newfoundland. They interpret this increase as resulting from erosional unroofing of mafic and ultramafic ophiolitic rocks that were exposed in the forearc region during the arc-continent collision. Ophiolites are still exposed in western Newfoundland and eastern Quebec, but, except for small ultramafic pods, have been eroded away in western New England. Unstable mineral grains and rock fragments in these gray sandstones have decomposed to form illite, chlorite, and other diagenetic minerals. The mineralogy of these rocks is dominated by quartz, illite, chlorite, and kaolinite. Leave the parking lot and return to the traffic lights at Balltown Rd, and turn left.

4.7	1.5	At the next set of lights turn left (east) onto River Rd. On the skyline to the east you can see the high Taconics.
5.4	0.7	Enter the traffic circle near General Electric, go halfway around the circle and continue east on River Rd.
8.0	2.6	At T-intersection turn left onto Rosendale Rd.
8.4	0.4	As the road makes a sharp right at the bottom of the hill, turn left onto Waterplant Rd., with signs toward Lock 7. Watch out for traffic from the right!
9.0	0.6	Cross bike path at stop sign, continue to the left.
9.2	0.2	Pull off to right after small roadcuts on right.

Stop 2. Lock 7 access road. This small roadcut has allochthonous "Schenectady Formation" that has been deformed. The thrust zone along which these rocks have been transported extends approximately 500 m to the west. Notice that these are still sedimentary rocks and have not been metamorphosed significantly. Graded beds and sole marks in some sandstones indicate topping direction. Note that this outcrop is about 6 km west of a klippe of Austin Glen Formation, the westernmost mapped klippe in the Schenectady area (Figure 1). This and surrounding outcrops probably represent a poorly exposed thrust slice that was transported a relatively short distance. Continue straight ahead.



U	Unmetamorphosed Mesozoic rocks of the Connecticut Valley basin
U	Unmetamorphosed Paleozoic rocks
	Late pC rocks in the Pelham dome
	Middle Proterozoic rocks of Grenville age

Ordovician metamorphic zones

Oc	Chlorite zone
Ocd	Chloritoid zone
Ob	Biotite zone
Og	Garnet zone
Oks	Kyanite-staurolite zone
Osm	Sillimanite-muscovite zone

Devonian metamorphic zones

Dc	Chlorite zone
Db	Biotite zone
Dg	Garnet zone
Das	Andalusite-staurolite zone
Dks	Kyanite-staurolite zone
Dss	Sillimanite-staurolite zone
Dsm	Sillimanite-muscovite zone
Dsmo	Sillimanite-muscovite-orthoclase zone
Dso	Sillimanite-orthoclase zone
Dsgc	Sillimanite-garnet-cordierite zone

Figure 5. Generalized metamorphic map of eastern New York, western Massachusetts, and parts of adjoining states, showing the field trip route and trip stop locations (adapted from Zen, 1983; Ratcliffe et al., 1988). The metamorphic zones are based on common mineral assemblages in pelitic rocks. Sillimanite-muscovite grade rocks west of the Connecticut Valley Basin may include rocks of sillimanite-staurolite and sillimanite-muscovite-orthoclase grades. Ordovician metamorphic grade increases from west to east, up to the sillimanite-muscovite zone. Farther to the east, Devonian metamorphism partially or wholly overprints the earlier mineralogy and fabric. Devonian metamorphism reaches the lower granulite facies in the sillimanite-garnet-cordierite zone.

9.4 0.2 Bear left at the 'Y' intersection and turn around in the parking lot. Backtrack to Rosendale Rd.

10.3 0.9 Stop sign at Rosendale Rd. Turn left to continue east on Rosendale Rd.

12.1 1.8 Turn left onto Old River Rd. Watch out for cars from the right! Rosendale Rd. continues right up a steep hill. If you encounter Rt. 7, backtrack down the hill and take the correct turn.

14.3 2.2 Old River Rd. meets a T-intersection. Turn right (southeast) onto Forts Ferry Rd.

15.3 1.0 Turn left (north) onto Sparrowbush Rd. Watch out for approaching traffic! Immediately bear right (east) at the 'Y' intersection to continue on Sparrowbush Rd.

16.4 1.1 Cross the I-87 overpass.

16.7 0.3 Traffic lights at intersection with Rt. 9. Go straight across the intersection to take Rt. 7 east toward Troy.

17.4 0.7 Outcrops to left and right are Ordovician Austin Glen Formation. These weakly metamorphosed rocks have a strong east-dipping foliation, contain numerous small thrust faults, and is quite inhomogeneous, giving the outcrop a mélange-like appearance.

18.0 0.6 Low Taconics visible in the distance ahead.

20.7 2.7 Cross the Hudson River. Get in the left-most lane. After the traffic lights enter the middle lane and continue straight up the hill on Rt. 7 east, Hoosic St.

24.8 4.1 Junction of Rt. 142 with Rt. 7. Continue straight on Rt. 7 east.

25.8 1.0 Turn right (southeast) off Rt. 7 onto Rt. 278, toward Rt. 2.

27.4 1.6 Rt. 278 ends at a T-intersection, junction with Rt. 2. Turn left (east) onto Rt. 2.

35.1 7.7 Town center of Grafton, NY.

37.3 2.2 High Taconics visible on the skyline ahead.

41.2 3.9 Town center of Petersburgh, NY.

46.5 5.3 Taconic crest, Petersburg Pass. Turn right into the dirt parking lot.

Stop 3. Taconic crest. These highly deformed rocks of the Nassau Formation had a shaley deep water facies protolith. Now they are chloritoid-grade phyllites with abundant deformed quartz veins (I have not found chloritoid in this outcrop). The quartz veins occur in several generations, as can be discerned by different degrees of deformation and crosscutting relationships. The phyllites contain the mineral assemblage quartz-white mica (muscovite and paragonite)-chlorite-carbonate (probably ankerite). The large rusty cavities in the quartz veins are weathered carbonate. Although two or three fold generations are apparent in the outcrop, the general dip of the schistosity is east, typical of the entire Taconian accretionary wedge system. Shear sense indicators suggest a top-to-the-west transport direction. Notice that the dominant foliation has been folded by a steeply east-dipping crenulation cleavage. Leave the parking lot and turn right, continuing east on Rt. 2 into Massachusetts.

50.7 4.2 At bottom of the valley you encounter a T-intersection with Massachusetts State Rt. 7. Turn left (north) to continue on Rt. 2.

52.0 **1.3** Enter Williamstown. Follow signs around a small square to continue on Rt. 2 east into town.

53.7 **1.7** At the first set of traffic lights since the Taconic crest turn left (north) onto Cole Rd.

54.4 **0.7** Cross the Hoosic River.

54.5 **0.1** At the T-intersection, turn right (east) onto Bridge Rd.

54.9 **0.4** Turn left onto Pine Cobble Rd.

55.1 **0.2** Turn left into little the parking lot and park. This hike will be to Pine Cobble on the Long Trail. The hike is 3.2 miles round trip and 800' of climbing. It will take about 2.5 hours. Bring water, a snack, and appropriate clothing.

<u>**Stop 4.**</u> Pine Cobble. **No hammers!** This outcrop of Cheshire Quartzite is located on the southern tip of the Green Mountains, and is equivalent to the Potsdam Formation in New York State. This is the basal Cambrian clastic unit that overlies older rocks, including Grenville age metamorphic basement rocks, of the Green Mountains and Berkshires. The quartzite has a weak foliation defined by muscovite that dips gently east. A set of steeply east-dipping joints may be a fracture cleavage, because the joints have an orientation similar to the crenulation cleavage evident in the more ductile rocks at Stops 3 and 7, and are approximately parallel to the antiformal axial surface of the Green Mountains. The Taconic Mountains are visible to the west, Mt. Graylock to the south, and the Berkshires to the east. The mountains are held up by allochthonous metamorphic rocks that were thrust-transported westward in the Taconian accretionary wedge. The valley is floored by Cambrian and Lower Ordovician carbonate and clastic continental shelf rocks that stratigraphically overly the Cheshire Quartzite of this stop. The Cheshire and underlying rocks, which is part of a broad anticlinal structure that makes up the Green Mountains, plunges southward beneath the valley. The rocks in the valley floor are also allochthonous, having been transported piggyback-style on the Precambrian-based block of the Green Mountains. Hike back down, leave the parking lot and backtrack down Pine Cobble Rd.

55.2 **0.1** At the stop sign turn right (west) onto Bridge Rd.

55.6 **0.4** Turn left (south) back onto Cole Rd.

56.4 **0.8** At the traffic lights, turn left to continue on Rt. 2 east. Continue through Williamstown and North Adams on Rt. 2. Highlands to the left (north) are the southern end of the Green Mtns.

62.2 **5.8** Rt. 2 goes up a hill while sharply turning right. On the turn take the left onto Rt. 8 north toward Clarkesville and Stanford Vt.

62.7 **0.5** Turn left (west) onto McCaully Rd. to Natural Bridge State Park.

62.8 **0.1** Cross stream and take the dirt road to the right. Park in small parking lot on left before the gate, if possible. Otherwise continue up road to park and pay the $2.00 parking fee.

<u>**Stop 5.**</u> Natural Bridge State Park. **No hammers!** These are rocks of the Cambrian to Ordovician Stockbridge Formation. This unit represents North American Cambrian or Lower Ordovician continental shelf carbonate rocks that were deformed and transported westward along Taconian thrusts. These have themselves been overridden by Taconian thrust sheets, including the Berkshire block immediately to the east. Backtrack to Rt. 8.

63.1 **0.3** At the intersection with Rt. 8, turn left (north), continuing on Rt. 8.

63.3 **0.2** Pull off the road to right after roadcut.

__Stop 6.__ Road cut on Rt. 8. This rock is composed of relatively low-grade metamorphosed calcareous sandstone in the Ordovician Walloomsack Formation. This unit was also deposited on the North American continental margin. Although the rock is folded, sedimentary structures such as cross bedding can still be found in some places. The folds are best outlined by carbonate-rich layers in which the carbonate weathers out to form rusty pits. Turn vehicles around and backtrack south on Rt. 8 toward Rt. 2.

64.1 **0.8** Intersection of Rt. 8 with Rt. 2. Turn left to continue on Rt. 2 east.

64.7 **0.6** Climb up the Berkshire front.

67.0 **2.3** Hairpin turn. Continue up the hill.

67.9 **0.9** At the top of the hill turn right into the Wigwam and Western Summit Gift Shop parking lot. Excellent views of the Williamstown-North Adams valley with the Taconics, Mt. Graylock massif, Green Mtns., and the carbonate-floored valley.

__Stop 7.__ Berkshires "western summit". This outcrop of Hoosac Formation contains biotite grade metamorphosed clastic sediments similar in composition to those seen at the Taconic crest. At these higher grades, biotite is the dominant mafic mineral rather than chlorite. Gray albite porphyroblasts up to 3 mm across are very common, and have grown to replace paragonite as the principal Na-bearing phase. Although the foliation generally dips east, there are numerous folds visible. Most are late, broad, open, folds having a prominent steeply east-dipping crenulation cleavage similar to that at Stop 3. More rare are isoclinal folds that indicate a top-to-the-west shear sense in the plane of the dominant foliation. This rock overlies Precambrian rocks in the Berkshire massif, and so it is part of a block of North American basement that has been transported westward over the shelf sediments seen at Stops 5 and 6. Leave parking lot and turn right (east) to continue on Rt. 2.

70.5 **2.6** Pass by the Witcomb Summit Resort Inn. Rt. 2 starts descending the eastern slope of the Berkshires.

71.7 **1.2** Turn left into the Eastern Summit Gift Shop parking lot. Excellent view of the eastern slope of the Berkshires, and the Bear Swamp pumped storage hydroelectric reservoir.

__Stop 8.__ Eastern Summit Gift Shop. **No hammers!** This glacially striated pavement outcrop of Rowe Formation contains garnet grade phyllite (but no garnets) that has a composition richer in Fe and Mg and poorer in K, Na, and Si than the schists and phyllites of Stops 3 and 6. This more mafic composition is probably caused by a large volcanoclastic component in the sediments, presumably derived from erosion of volcanics from the Taconian island arc. The dominant minerals are chlorite, white mica, quartz, and octahedral crystals of magnetite. The patchy appearance of the outcrop is caused by mechanical mixing of a variety of slightly different sedimentary lithologies, probably when the rock was a soft sediment. On a large scale, the Rowe Formation has been characterized as a mélange, and includes basaltic and ultramafic rocks. Leave the parking lot and turn left (south) down the hill on Rt. 2 east. Units passed on the steep, winding descent of the Berkshires include the Rowe and Hoosac Formations.

79.3 **7.6** Cross bridge over railroad tracks.

80.0 **0.7** Cross bridge over the Deerfield River.

80.1 **0.1** Take left immediately after the bridge, following the sign toward Rowe and Monroe.

80.3 **0.2** Outcrops on right are Hawley Formation.

80.4 **0.1** Turn vehicles around in small pulloff on the right. Backtrack toward Rt. 2 about 100 m.

80.5 **0.1** Pull off onto the shoulder to the right.

Stop 9. Hawley Formation. The Hawley Formation contains large quantities of volcanic and intrusive rocks along with the volcanoclastic sediments. The igneous rocks include mafic and felsic varieties. The mafic rocks have compositions similar to basalts, and seem to include mid-ocean ridge, back-arc basin, and boninitic, and calc-alkaline varieties. These metamorphosed igneous rocks are related to the Taconian island arc, but their diverse lithology, compositions, and ages indicate a complex history for the island arc system in which they were emplaced. The rocks at this outcrop are amphibolite grade carbonate- and hornblende-bearing chlorite-muscovite schists. They contain abundant acicular hornblende up to 20 cm long in some areas, although they are typically 1 to 3 cm long in this outcrop. Euhedral carbonate rhombs (ankerite?) can be seen weathering out on outcrop surfaces to form rhombohedral pits. On the steep slope on the river side of the road there are some nice exposures of coticule (fine-grained pink garnet quartzite). This unusual rock type is thought to represent metamorphosed Mn- or Fe-rich chert that formed from silica derived from the weathering or hydrothermal alteration of volcanic rocks. Continue down the hill toward Rt. 2.

80.8 **0.3** Stop sign at the intersection with Rt. 2. Turn left (east) onto Rt. 2 east toward Charlemont.

82.8 **2.0** Town center of Charlemont, MA.

85.7 **2.9** Good outcrops of garnet-rich Devonian Goshen Formation schist on the north shore of the Deerfield River to the right (south).

89.6 **3.9** Outcrops are calc-alkaline felsic gneisses and related amphibolites in core rocks of the Shelburn Falls dome (roots of the Taconian island arc).

90.4 **0.8** Turn right (south) onto Rt. 2A toward Shelburn Falls.

91.2 **0.8** In the center of Shelburn Falls turn left (east) onto the steel bridge across the Deerfield River.

91.3 **0.1** Small access road to the right (south) soon after the bridge. Do not drive down this road, but find a place to park after the bridge. On foot, follow signs on the small access road to "glacial potholes". Find the steps going down to the river behind the gift shop. Do not go down to the rocks if the gate is locked, or if water is flowing strongly over the rocks.

Stop 10. Shelburn Falls. **No hammers!** This exposure is an excellent example of the core gneisses of the Shelburn Falls dome. This is an Acadian (Devonian) structural dome that exposes a variety of plutonic-looking calc-alkaline gneisses and amphibolites. These rocks have generally been interpreted to be part of the plutonic roots to the Taconian island arc. Igneous features that can be seen in this outcrop include crosscutting relationships, dikes, xenoliths, intrusion breccia, and late-stage quartz veins and faults. These rocks are similar to, but less deformed than, the Ordovician gneisses exposed in the cores of domes in the Bronson Hill anticlinorium, farther to the east. The precise relationship of the Shelburn Falls rocks to those in the Bronson Hill anticlinorium is somewhat problematic. Although the two are lithologically and chemically similar, a preliminary age date on the Shelburn Falls rocks is substantially older (Paul Karabinos, oral communication, 1993) than the 443-453 MY age of the calc-alkaline gneisses in the Bronson Hill anticlinorium (Tucker and Robinson, 1990). Other features that can be seen here include wonderful large potholes that were formed by the Deerfield River when it was swollen with glacial melt water. Continue in the same direction away from the bridge (east on Rt. 2A). Do not backtrack across the bridge.

91.7 **0.4** Turn right (southeast) following sign for Rt. 2A toward Greenfield and Boston.

91.9 **0.2** Intersection with Rt. 2. Turn right (east) onto Rt. 2.

94.3 **2.4** Road climbs out of the topographic depression of the Shelburn Falls dome. Hills bounding the dome here are kyanite-staurolite grade Goshen Formation schists that are more resistant to erosion than the calc-alkaline gneisses in the dome interior.

99.4 **5.1** Excellent view of the Deerfield basin, the northernmost sizable portion of the Mesozoic rocks of the Connecticut River Valley. The N-S trending ridge in the middle of the basin is held up by the Deerfield Diabase, probably correlative with the Holyoke Basalt farther south. The large mountain to the southeast is Mt. Toby.

100.5 **1.1** Enter the traffic rotary in Greenfield, which circles underneath I-91. Continue 3/4 of the way around the rotary.

100.7 **0.2** Enter the on ramp for I-91 north, which is also Rt. 2 east.

102.5 **1.8** Excellent exposures of fluvial facies of the Mesozoic red beds of the Connecticut Valley basin.

103.1 **0.6** Take Exit 27 (the first exit) to continue on Rt. 2 east.

105.3 **2.2** At the next traffic lights, bear left to continue on Rt. 2 east.

106.0 **0.7** At the bottom of the hill, cross the Falls River. Immediately after the river turn right into the parking lot.

Stop 11. Turner's Falls. Although it has little to do with the Taconian orogen, this wonderful set of outcrops has excellent exposures of Mesozoic basaltic lava and terrestrial sediments that formed in a rift valley. The outcrops near the parking lot are of tholeiitic Deerfield basalt. The flow base, in contact with red beds, is accessible on the south side of the road to the west of the parking lot. The flow base has pillow lavas that formed as the lava flowed into a saline rift valley lake. The flow top and overlying red beds are visible in the roadcut across the road from the eastern end of the parking lot. Several faint, coarse-grained layers sub-parallel to the flow top are visible in the central part of the roadcut. These are sill-like segregations of residual magmatic liquid that separated from the crystal mush of the compacting, solidifying flow (described for a different locality by McHone and Philpotts, 1995; Philpotts et al., 1995). The outcrops near the river, accessible by foot path from the parking lot, have excellent exposures of the vesicular lava flow top, and one of the coarse-grained sill-like layers. The flow is overlain by fluvial conglomerate, arkose, siltstone, and shale. The fluvial sediments have excellent depositional and soft sediment features including bed forms, mud cracks, trace fossils, raindrop imprints, shale rip up clasts, and filled channels. Near the dam the sediments grade into finer-grained gray and black lake sediments in which fish and plant fossils can be found. Leave the parking lot and turn right to continue on Rt. 2 east. For excellent introductions to the geology of the Connecticut Valley basin, see Hubert et al. (1978) and Horne et al. (1995).

108.5 **2.5** Small road cuts on both sides of the road are composed of very coarse-grained matrix-supported conglomerate. This outcrop represents the alluvial fan facies of the Mesozoic red beds of the Connecticut River Valley. The alluvial fans were principally built on the east side of the basin, below the mountains on the east side of the border fault along which the basin subsided.

109.4 **0.9** Cross the French King Bridge over the Connecticut River. This is the approximate location of the normal fault that forms the eastern margin to the Connecticut River Valley rift basin.

111.6 2.2 Large road cuts on either side of the road. Pull off road to right and stop.

Stop 12. Millers Falls. This large roadcut is in the biotite member of the Dry Hill Gneiss, a Late Precambrian (Tucker and Robinson, 1990) unit exposed in the core of the Pelham dome, one of the structural domes in the Bronson Hill anticlinorium. This unit is interpreted to be a thick series of metamorphosed alkalic volcanics that probably erupted in a continental rifting environment (Hodgkins, 1985). The relationship of these rocks to surrounding rocks is unclear, but they are unrelated to the Taconian island arc except to the extent that they are exposed in this dome in the Bronson Hill anticlinorium. The Dry Hill Gneiss is overlain, perhaps along a fault, by felsic Fourmile Gneiss, which is part of the Taconian igneous suite. The Dry Hill Gneiss is a moderately well foliated, layered granitic gneiss that contains the assemblage quartz-plagioclase-microcline-biotite±amphibole (hornblende or hastingsite), with accessory sphene, magnetite, apatite, zircon, and allanite. The allanite crystals are large and are visible as dull tan-colored crystals in hand specimen. The large K-feldspar megacrysts in the gneiss were probably derived from severely deformed and dismembered pegmatites. This texture indicates the great strength of feldspar compared to the quartz- and biotite-rich matrix during extreme solid-state deformation. Continue east on Rt. 2.

116.1 4.5 Turn left onto Mountain Rd., in Erving, at the cemetery on the side of the hill to the left.

119.0 2.9 Intersection with South Mountain Rd. Turn right up the hill.

119.3 0.3 Pull off to the right at the top of the hill and park. Follow white blazes along the private driveway. At the double blaze, turn right into the woods. Follow the trail to the quartzite ledges after about 1/4 mile.

Stop 13. Crag Mountain. **No hammers!** This prominence is composed of thickened (by folding) Silurian Clough Quartzite. In this locality it is a quartz pebble and cobble conglomerate metamorphosed to kyanite-staurolite grade. Pelitic schists in the area can contain the assemblage quartz-plagioclase-garnet-biotite-muscovite-staurolite-kyanite. The Clough Quartzite was deposited on an extensive Silurian erosion surface in western New England, and it rests on a variety of Ordovician and older rocks. The quartzite has been deformed so that quartz cobbles and pebbles have been flattened and extended to different degrees, visible in outcrop. The milky quartz is full of fluid inclusions, suggesting that it was originally metamorphic vein quartz. Silurian erosion of Taconian low- and medium-grade metamorphic rocks in the Taconics, Green Mountains, and Berkshires may have been the source for the necessary large quantities of high-purity vein quartz. End of trip!

TO RETURN

Turn around and head down the hill (west) down South Mountain Rd..
Turn left (east) onto Mountain Rd.
Stop sign at the intersection of Mountain Rd. with Rt. 2. Turn right (west) onto Rt. 2.
Follow Rt. 2 back into New York State. Continue on Rt. 2 through Troy and into Latham. Don't take Rt. 278 and 7 into Troy.
Cross the Hudson River. Continue straight on Rt. 2 west.
In Latham, NY, Rt. 2 enters a traffic circle where the road crosses over Rt. 9. Continue halfway around the circle to continue west on Rt. 2 toward Schenectady.
Rt. 2 turns into Rt. 7. Continue straight on Rt. 7 (west) toward Schenectady.
In Niskayuna, Rt. 7 bears left. Bear right (west) onto Union St. toward downtown Schenectady and Union College.
Traffic lights at Union Ave. Union College visible on the right.
Traffic lights at Nott St. Stay in the right hand lane.
Traffic lights at Seward Place. Turn right (north) onto Seward Place.
Traffic lights at Nott St. Turn right (east) onto Nott St.
Entrance right to main (Van Vranken Ave.) Union College parking lot.