GUIDEBOOK *for Field Trips in the*
NORTHEAST KINGDOM *of* VERMONT
and Adjacent Regions

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Cover illustration generated in GIS by R. Coish using the USGS GIS-version of 1961 Centennial Map of Vermont (Doll et al., 1961). Belts after Stanley and Ratcliffe (1985) and Doolan (1996). See Figure 1, Trip B-2 for legend and caption.

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GEOCHEMISTRY AND EMPLACEMENT STYLE IN ACADIAN PLUTONS BETWEEN WOODBURY AND NORTHFIELD, VERMONT

by

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INTRODUCTION

One hundred years ago Dale (1909) published a comprehensive review of the granites of Vermont. Since then, and particularly in the current decade, understanding granite formation and magma emplacement has been a topic of considerable interest. A main achievement in this field has been the progressive replacement of the customary view of granitic magma slowly rising as diapirs, by the concept of felsic magma ascending rapidly via self-propagating dikes (Petford, 2000). The construction of plutons in the middle-upper crust by sequential emplacement of magma batches has been demonstrated with both amalgamation of subhorizontal sheets and as well as of vertical sheets (McNulty et al., 1996; Wiebe and Collins, 1998; Mahan et al., 2003; Coleman et al., 2004; Michel et al., 2008).

Another aspect of understanding emplacement is the role that various lithologic and tectonic structures serve in producing magma traps (Hogan et al., 1998).Variables influencing the transition (or lack thereof) from vertical flow to horizontal spreading of magma include vertical stress, horizontal stress, magma driving pressure, and integrated magma density (Hogan et al., 1998).

This field trip seeks to explore the lithologic and rheologic variations in some plutonic rocks in northeastern Vermont, with the goal of examining the relationship between emplacement style and pluton size. Each intrusion was trapped by a structure, and we intend to explore the role of the size of each magma batch, and the type and orientation of magma traps exploited.

GEOLOGIC SETTING

Vermont exposes basement, rift, platform, and arc sequences on the western side of the Appalachian orogen (Fig. 1). In eastern New York and western Vermont, Precambrian basement is exposed as the Adirondack massif and as inliers - the Green Mountain and Lincoln massifs. Cover units (west to east) include early Paleozoic carbonate platform, rift facies represented by the Green Mountain tectonic slices, oceanic accretionary prism rocks in the Stowe Formation, fore-arc and arc deposits in the Moretown Formation, Siluro-Devonian Waits River and Gile Mountain Formations in eastern Vermont, and finally portions of the Bronson Hill arc terranes (Doll et al., 1961; Stanley and Ratcliffe, 1985). Granitic plutons of purported Devonian age intrude the Waits River and Gile Mountain Formations (Fig. 1)

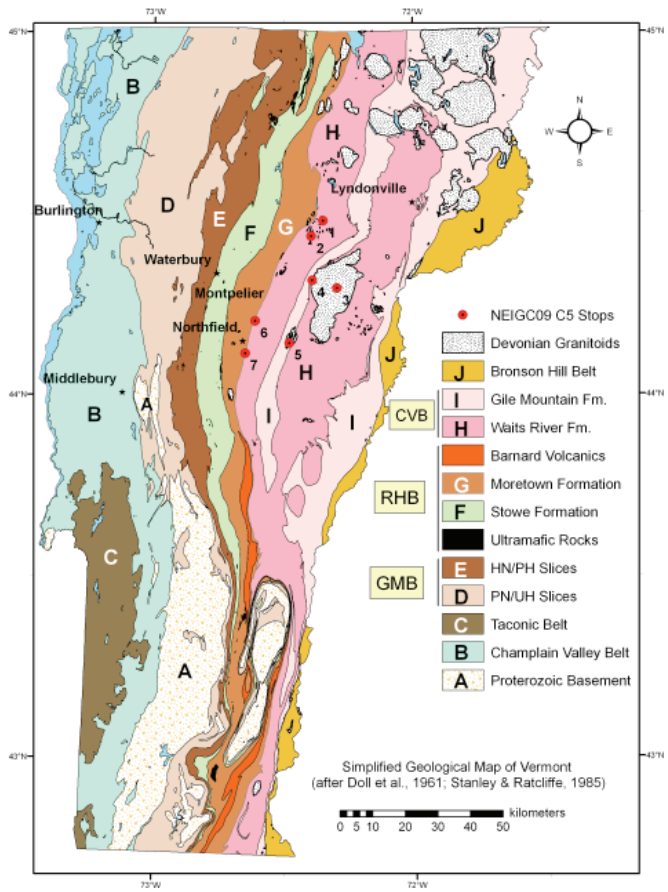


Figure 1: Geological provinces in Vermont showing locations of stops for this trip. HN – Hazens Notch; PN – Pinney Hollow; UH – Underhill; GMB – Green Mountain Belt; RHB – Rowe-Hawley Belt; CVB – Connecticut Valley Belt . (Geology after Doll et al., 1961).

Western and central Vermont record the evolution of the Laurentian continental margin from a late Precambrian rift valley to an early Paleozoic continental shelf sequence. The continental shelf bordered the western margin of the Iapetus Ocean. Eastward subduction in that ocean led to construction of either one long-lived volcanic arc (Stanley and Ratcliffe, 1985) or a short-lived arc followed by subduction flip and a second arc (Karabinos et al., 1998; Moench and Aleinikoff, 2002). In both cases the arc(s) collided with the Laurentian continent, and formations in western and central Vermont were assembled into westward-directed thrust slices (Green Mountain belt and Rowe-Hawley belt in Fig. 1) on the continental edge (Stanley and Ratcliffe, 1985).

In northeastern Vermont, the Connecticut Valley Trough (CVT) is occupied by mostly low-grade metamorphosed pelitic and quartzitic units of the Gile Mountain Formation that overlie calcareous quartzitic and pelitic units of the Waits River Formation. Siluro-Devonian ages are assigned based on Early Devonian plant fossils in the Gile Mountain Formation (Hueber et al., 1990) and a U-Pb zircon age of 423 Ma from a dike cutting the Standing Pond Volcanic member of the Waits River Formation (Aleinikoff and Karabinos, 1990). Ages may range regionally from 438 to 394 Ma (Tremblay and Pinet, 2005). All of eastern (and part of western) Vermont is thought to have been affected by the Acadian Orogeny beginning around 390 million years ago (Bradley et al., 2000), and perhaps continuing until at least 365 Ma (Ratcliffe et al., 2001).

DEVONIAN GRANITOIDS

Overview

Granitoid plutons intruded both the deformed Waits River and Gile Mountain Formations (Fig. 1) near or following the end of the Acadian Orogeny (Ratcliffe et al., 2001). In northern Vermont, the plutons superimposed distinct contact aureoles on the regional deformational fabric, which may have been formed at around 390 Ma (Bradley et al., 2000). Many of these plutons have no tectonic fabric but some reveal foliations along faults that may be Acadian in age (Hannula et al., 1996). In general terms then, most of the granites are younger than 390 Ma.

The Devonian granitoids are mapped as 14 individual plutons, most of which are confined to 6000 km^2 in the Connecticut Valley Trough of northeastern Vermont (Fig. 1). Five of the plutons, collectively referred to as the Northeast Kingdom (NEK) batholith), were mapped, sampled and geochemically analyzed in the 1980's (Ayuso and Arth, 1985, 1992; Arth and Ayuso, 1997). Rock types range from hornblende gabbro, through hornblende-biotite quartz diorite and biotite granodiorite, to muscovite-garnet leucogranite. Rb/Sr whole-rock dating gives broadly defined dates from 390 Ma to 370 Ma, and the chemistry of the plutons shows good calc-alkaline trends. Thus, Ayuso and Arth (1992) concluded from the chemistry that the plutons were generated in a continental arc with mature crust.

Geochemistry

We present here (Figs. 2-4) preliminary data from the unpublished work of the PIs and their students (Applegate, 1996; Langer, 1996; Stout, 1998; Anderson, 1999; Filip, 2007a; Gleason, 2007; Miller, 2007), data from

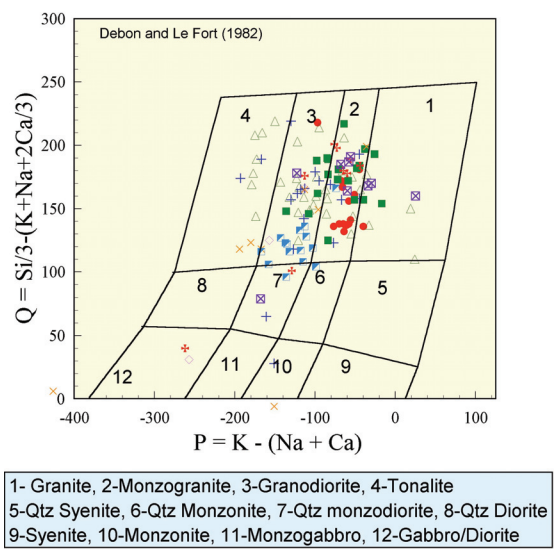


Figure 2: Chemical classification diagram showing the range of compositions of Devonian granitoids. Monzogranite and granodiorite are the most common.

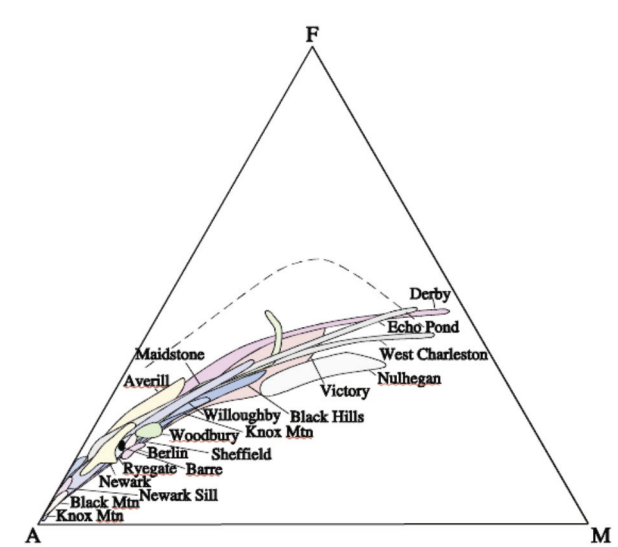


Figure 3: Preliminary data showing compositions for some northern Vermont plutons, plotted in an AFM diagram (Irvine and Baragar, 1971).

unpublished Masters theses (Griffin, 1982; Hengstenberg, 2000), and published data (Arth and Ayuso, 1997).

Data from preliminary research consist mostly of whole-rock major and trace element abundances, and some detailed mineral chemistry, on several plutons. Some plutons range from gabbro to granite while others are fairly homogeneous granodiorite or monzogranite (Fig. 2). They are meta-aluminous to peraluminous in composition and have an overall calc-alkaline trend (Fig. 3). Furthermore, trace element compositions show negative Nb-Ta anomalies (Fig. 4) consistent with derivation from either crustal sources or SCLM magmas contaminated by crust. Our working hypothesis is that these granitoid magmas were produced in the crust after the main collision event that produced the main phase of deformation of the Acadian Orogeny. Heat to generate the magmas may have been provided by hot asthenosphere that welled up following lithospheric delamination.

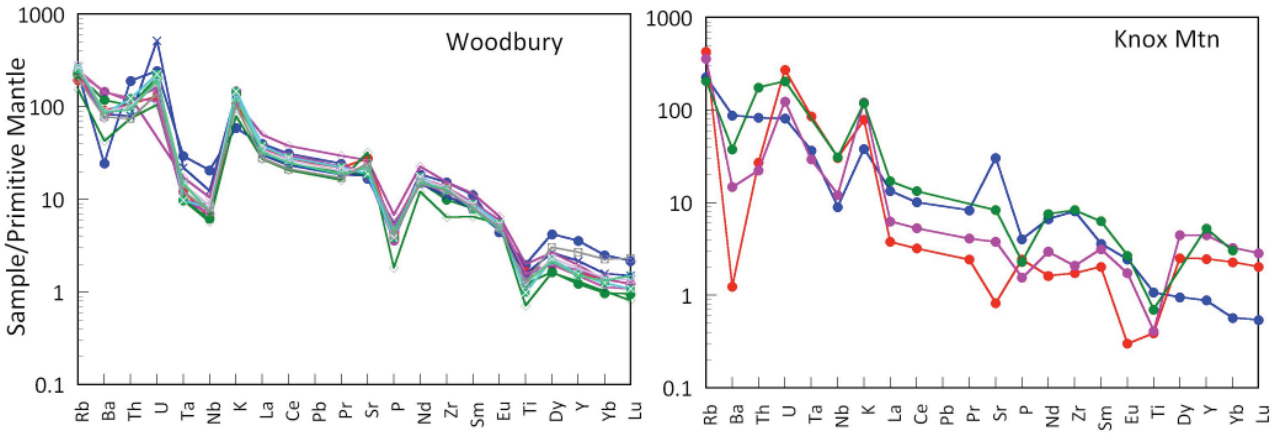


Figure 4: Elemental plots of Woodbury and Knox Mountain granitoid bodies, normalized to primitive mantle (Sun and McDonough, 1989).

Emplacement

Although large-scale structures in the CVT in Vermont are poorly understood in detail, the host rocks of the batholith are dominated at the formation scale by broad open structures such as low-angle recumbent nappes and associated thrusts (Thompson et al., 1968; Florence et al., 1993). Thus, the map pattern shows large wavelength repetition in parallel belts of both the older Waits River Formation and overlying Gile Mountain Formation, reflecting regional nappe structures (Hatch, 1988; Fig. 1).

Structures exhibited in outcrop rarely allow recumbent features to be seen, but instead are dominated by tight, upright isoclinal folds (Hatch, 1988; Locke and Larsen, 1997) and high-angle faults. An effort to understand the scale of the isoclinal structures is presented in Figure 5, in which 23 reversals of topping directions based on graded beds were measured along 370m of continuous outcrop along the north side of the VT Route 64 access road west of I-89. Figure 5a illustrates observed topping reversals with west-facing beds (dark) and east-facing beds (pale).

A simplistic approach was taken to approximate the structure of the section by making the assumption that bed thickness remained constant so that if 20m of east-facing beds on the west side of an anticline went up, then 20m came back down. If the next reversal to the east (a syncline) was less than 20m away, then the youngest rocks in that part of the section had to have reversed at a higher elevation and have since been eroded away. In this way, artificially created bedding units shown in Figure 5b illustrate that the section predominantly faces west and becomes progressively older toward the east. This is in keeping with the fact that more strongly calcareous and thicker-bedded rocks of the Waits River type dominate toward the east, while less-calcareous, thinner beds become more abundant toward the west approaching the Northfield Formation, which Hatch (1988) correlated as distal Gile Mountain equivalent.

The isoclinal folds illustrated on Figure 5 and seen in the field at Stop 7 have amplitudes measured in 100's to 1,000's of meters, but constitute wrinkles on the more sub-horizontal nappe structures that have amplitudes of 10's of kilometers.

MAGMA BATCH VARIATIONS AND MAP PATTERNS

Devonian intrusive bodies in Vermont range in size from the Averill and Knox Mountain plutons with exposed areas of 400 km^2, down to dikes with thickness less than a meter and lengths of a few 10's of meters. Sizes of more than 100 bodies have been examined, and the frequency of different sizes follows a typical logarithmic distribution with abundance increasing as size decreases. Additionally, the smaller the intrusion, the more elongated it tends to be, as seen in Figure 6 where aspect ratios and pluton areas are inversely correlated.

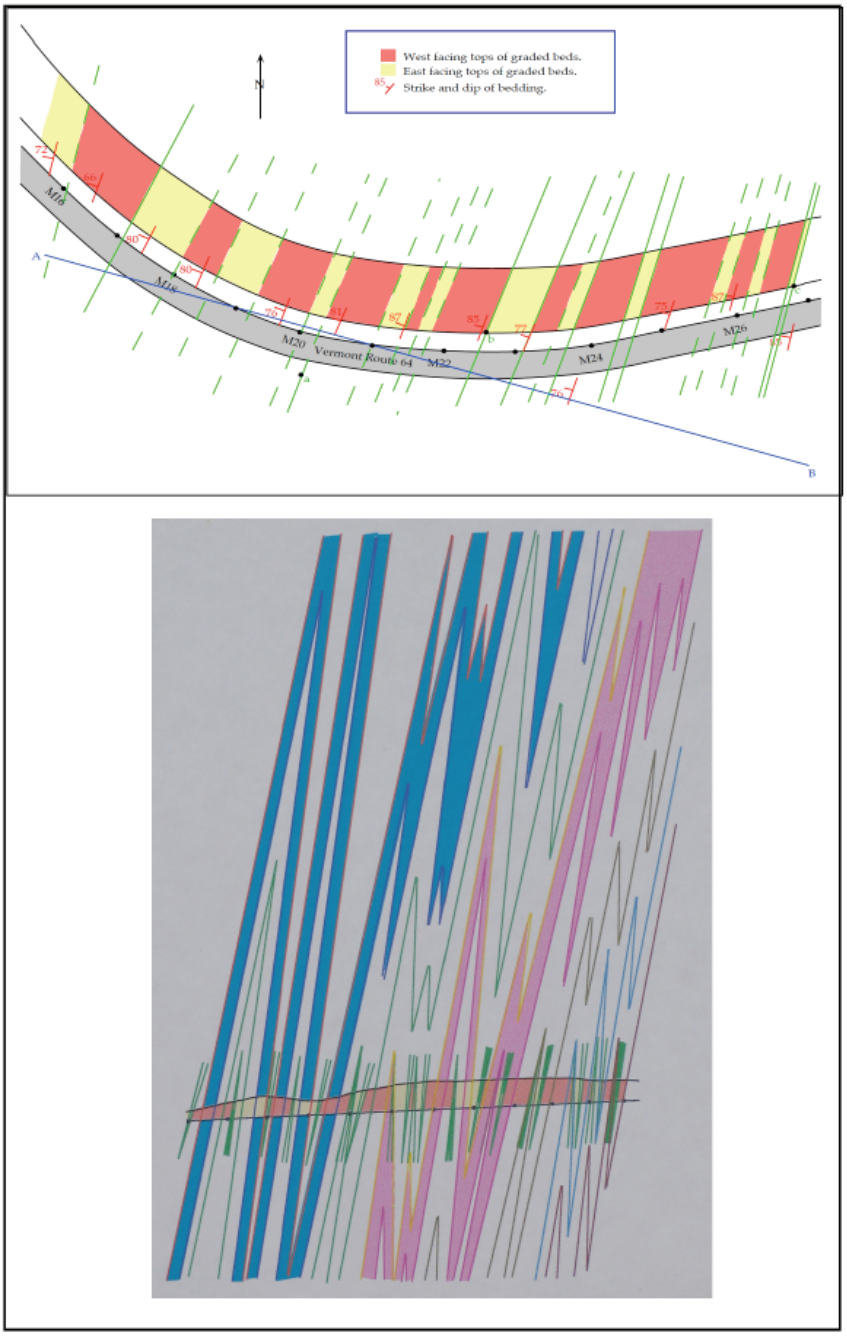


Figure 5: Upper figure: Map of bedding reversals in the 370m section exposed on the north side of VT Route 64 west of I-89 near Northfield, Vermont. Lower figure: Fold structures reconstructed to scale illustrating large amplitude, isoclinal structures (370m outcrop trace for scale).

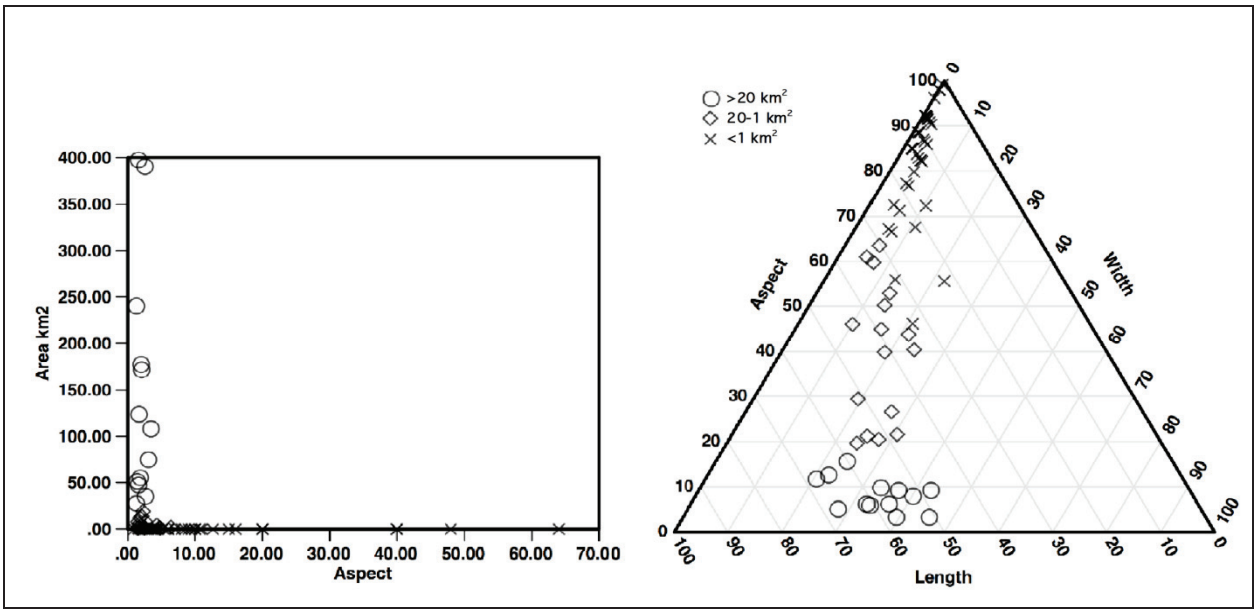


Figure 6: Dimensional patterns of intrusive units of the Northeast Kingdom Batholith, based primarily on Doll et al. (1961) for plutons greater than 20 km^2 in area, and on all bedrock maps referenced therein for small units.

Another characteristic of the pluton dimensions in northeastern Vermont is exhibited when their alignment is compared with the orientation of the local structure as seen by the trend of bedding and cleavage fabric (Fig. 7); the greater the pluton's aspect ratio (length divided by width), the better it's alignment with the regional foliation of the host country rock.

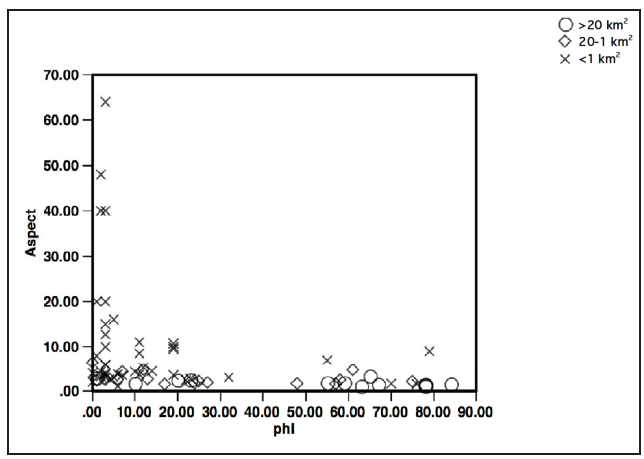


Figure 7: Illustration of increasing parallelism (low phi angle) for small intrusions with large aspect ratios.

Chang et al. (2007) have recently shown that in the Yellowstone region, magma replenishment has produced a 1,200 km^2 sill at 10 km depth, and is currently lifting the roof at 7 cm/year. Hornblende geobarometry indicates that three Vermont plutons were emplaced at similar depths, between 8 and 14 km (Anderson and Coish, 1999).

While the size discrepancy of Vermont's largest plutons (400 km^2 surface area) and the Yellowstone laccolith is significant, it appears that high driving pressures associated with large magma batches has the potential to create space along sub-horizontal magma traps by lifting the roof. Taken together, these relationships suggest that small magma batches exploit small structures, i.e. those related to upright isoclinal folds and high-angle faults, while large magma batches exploit large structures, i.e. recumbent structures related to nappes and thrust faults (Fig. 8).

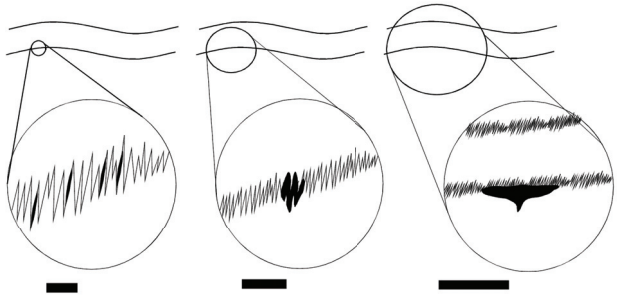


Figure 8: Three scales of emplacement. Left represents small magma batches exploiting small structures such as isoclinal folds along the base of a large sub-horizontal nappe structure. Center represents intermediate style of emplacement resulting from intermediate batch size. Right represents a large intrusion exploiting a large-scale magma trap.

ROAD LOG

Mileage

0.0 Meet in town parking lot near Village Restaurant in Harwick, Vermont. Enter parking lot from Wolcott street. Turn left out of parking lot onto Wolcott Street, then right onto South Main Street (Route 14 south)

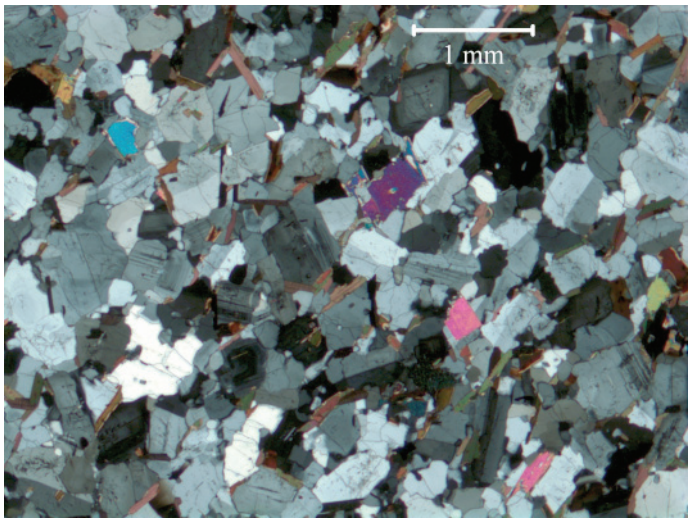
0.4 Turn left onto Winter Street, becomes Mackville Road

1.1 Fork left to stay on Mackville Road

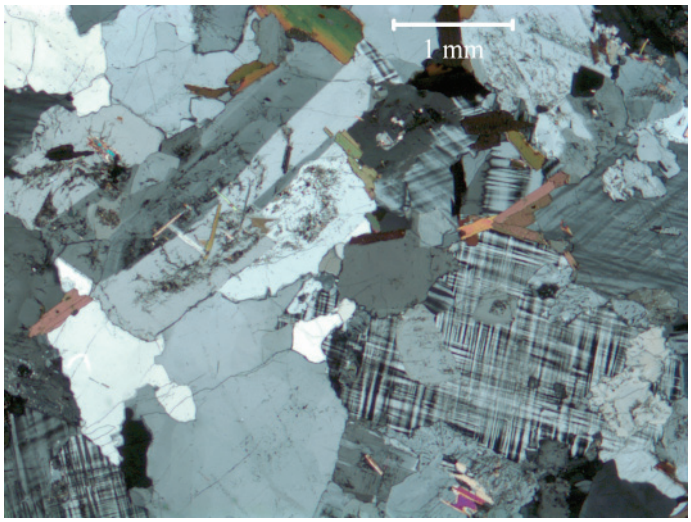
2.1 Stop at pull off on left side of road. Walk about 300m along track to abandoned quarry

STOP 1: **MACKVILLE QUARRY** (UTM NAD83 18T 0710883 4928893). At this stop, one of numerous mapped exposures of the Woodbury granitic body has been quarried here. The body is predominantly medium-grained, grey granodiorite. However, there is considerable variation in grain size and composition. Finer-grained biotite-rich phases, thin kspar-rich veins and dikes cut the dominant body. Numerous xenoliths of the Waits River Formation occur in outcrop and in quarried blocks, perhaps reflecting the proximity of the pluton roof.

	RM0701	RM0703
SiO2	71.44	71.60
TiO2	0.43	0.25
Al2O3	15.81	15.10
Fe2O3(t)	2.63	1.48
MnO	0.06	0.04
MgO	1.21	0.70
CaO	2.83	1.90
Na2O	5.02	4.08
K2O	1.77	4.24
P2O5	0.10	0.06
Total	101.30	99.45
Sc	7	4
V	52	28
Cr	29	17
Co	7	3
Ni	19	13
Cu	6	<1
Zn	89	88
Rb	148	
Sr	354	253
Y	16	9
Zr	170	81
Nb	15	
Ba	170	405
La	27.2	
Ce	55.20	
Pr	6.69	
Nd	25.10	
Sm	4.94	
Eu	0.74	
Gd	4.27	
Tb	0.60	
Dy	3.10	
Ho	0.56	
Er	1.5	
Tm	0.2	
Yb	1.2	
Lu	0.2	



Fine-grained phase (tonalite) at Mackville Quarry (RM0701)



Typical coarse granodiorite at Mackville Quarry (RM07003)

Typical medium to coarse grey phases are classified as granodiorite; they consist of 25-30% quartz, 30-45% plagioclase, 10-20% k-feldspar (microcline), 6-10% biotite, and 2-3% muscovite. Fine-grained darker phases consist of approximately 30% quartz, 60% plagioclase, 2% k-feldspar, 15% biotite and 1% muscovite – these samples plot as tonalite in a QAP modal diagram.

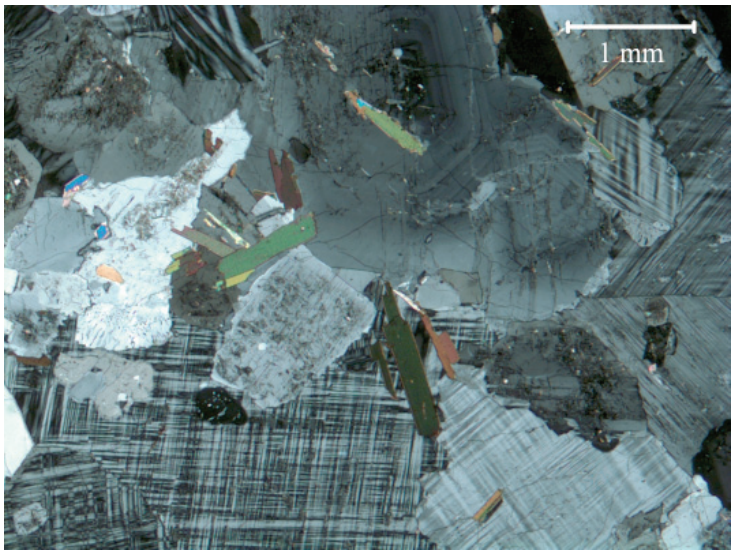
Return to cars. Retrace route on Mackville Road back to Route 14.

3.7 Turn left (south) onto Route 14 toward Woodbury
8.7 Turn left onto Cabot Road in Woodbury
9.5 Turn left at Fletcher Quarry Road
10.2 Take sharp right to continue towards quarry
11.0 Arrive at active quarry, whose early operation was described by Dale (1909).

STOP 2: **FLETCHER QUARRY** (UTM NAD83 18T 0707405 4924017). Here homogenous Woodbury granodiorite is quarried. Uniformity in grain size and composition make this an excellent building stone. Mineralogy of the homogeneous granodiorite consists of approximately 30% quartz, 35% plagioclase, 20% k-feldspar, 12% biotite, 3% muscovite. Occasional biotite-rich bands occur to break up the uniformity. Scattered late veins of quartz, feldspar, tourmaline and garnet cut across the body.

Exposures of hornfelsed country rock roof pendant material are seen at the quarry entrance where a granite dike is well exposed. Similar country rock exposures occur along the quarry road before granite occurs again at the surface.

	RM0706		
SiO2	71.83	Sc	4
TiO2	0.32	V	37
Al2O3	14.78	Cr	22
Fe2O3t	1.94	Co	5
MnO	0.03	Ni	17
MgO	0.95	Cu	<1
CaO	1.89	Zn	24
Na2O	3.77	Rb	150
K2O	4.43	Sr	380
P2O5	0.08	Y	8
LOI		Zr	118
Total	100.02	Nb	5
		Ba	1016
		La	25.7
		Ce	51.00
		Pr	6.22
		Nd	23.70
		Sm	4.05
		Eu	0.90
		Gd	2.79
		Tb	0.34
		Dy	1.51
		Ho	0.25
		Er	0.72
		Tm	0.09
		Yb	0.68
		Lu	0.09
		Hf	4.1
		Ta	0.4
		Th	9.8



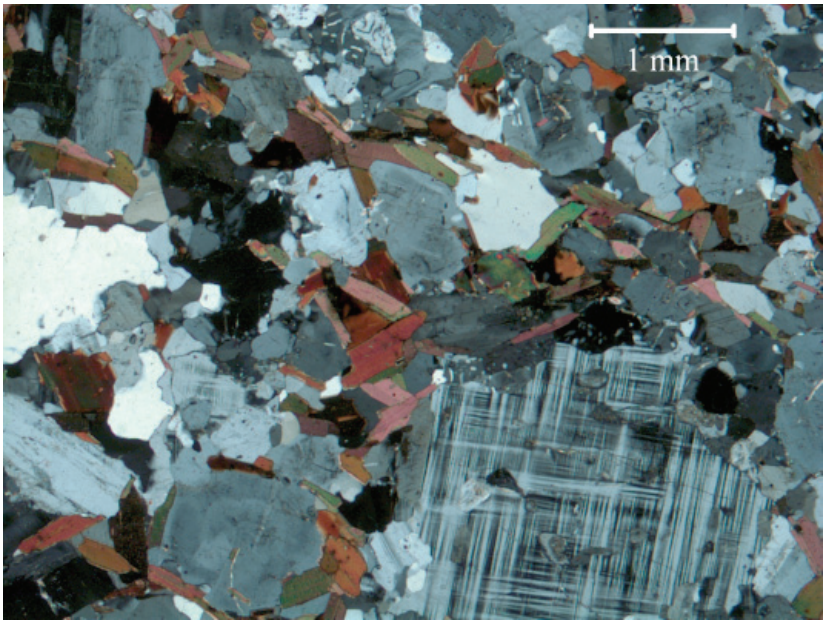
Homogeneous granodiorite at Fletcher Quarry (RM0706)

Return to cars and retrace route to Cabot Road

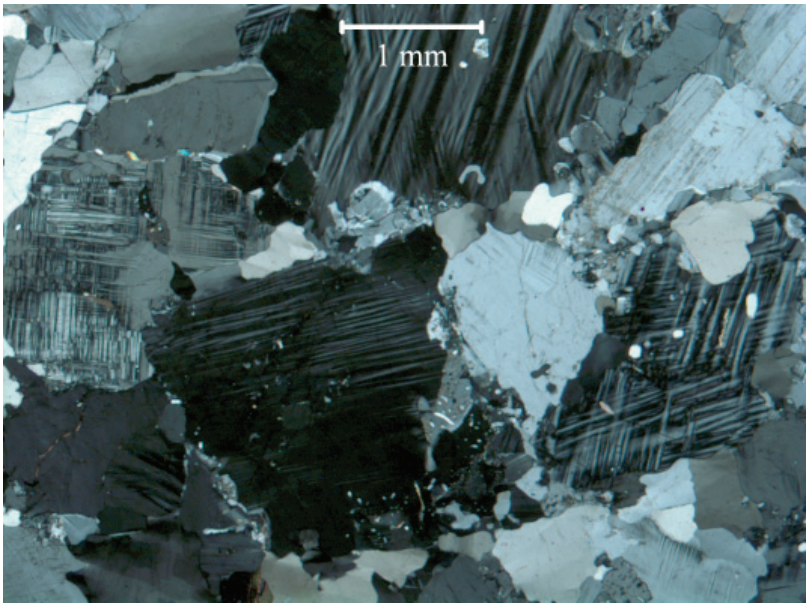
12.5 Turn left onto Cabot Road
16.1 Turn right onto WestHill Road
17.9 Turn right onto Route 215 South
21.0 Turn right on Route 2 West
24.3 Turn right at sign for Bickford Quarry
24.5 Stop at lower Bickford Quarry (UTM NAD83 18T 0708099 4910517)

STOP 3: **BICKFORD QUARRY.** The western contact of the Knox Mountain granitic body with Waits River Formation is exposed here. The NW side of the quarry is mostly hornfelsed Waits River whereas the SE side exposes Knox Mountain rocks with numerous large xenoliths of Waits River Fm. Uphill and NW from the quarry, thick sills of the granitoid body are interlayered with Waits River. Numerous dikes (aplitic and pegmatitic) cut the main grey granitoid body.

	7690	7691
SiO2	70.10	72.31
TiO2	0.43	0.12
Al2O3	16.01	15.96
Fe2O3(t)	2.35	0.49
MnO	0.07	0.02
MgO	1.26	0.23
CaO	2.27	1.27
Na2O	4.04	3.26
K2O	3.38	6.29
P2O5	0.10	0.04
Sc	6	2
V	47	7
Cr	26	5
Co	24	34
Ni	15	3
Cu	8	5
Zn	55	13
Rb	184	208
Sr	337	251
Y	10	8
Zr	142	35
Nb	10.4	3.3
Ba	607	411
La	26.0	16.7
Ce	54.70	37.20
Pr	6.20	4.65
Nd	23.70	18.30
Sm	3.80	4.20
Eu	0.79	0.60
Gd	2.72	3.06
Tb	0.43	0.47
Dy	2.03	1.91
Ho	0.31	0.28
Er	0.8	0.7
Tm	0.1	0.1
Yb	0.8	0.6
Lu	0.1	0.1
Hf	4.3	1.7
Ta	1.0	0.8
Th	12.1	16.0
Pb	4.6	6.9
U	4.3	28.7



Biotite granite, Bickford quarry (sample 7690)



Leucocratic dike, Bickford quarry (sample 7691)

Return to US Route 2, turn left (east), and proceed through Marshfield
29.1 Turn right (south) on VT Route 232
34.5.1 Turn left (east) on Owl's Head Road
35.4 Park in the turnaround and hike 0.2 miles to summit of Owl's Head.

STOP 4 LUNCH: A homogeneous biotite-rich grandiorite facies of the Knox Mountain pluton is well-exposed here with crosscutting felsic granite dikes, in turn cut by late pegmatite dikes.

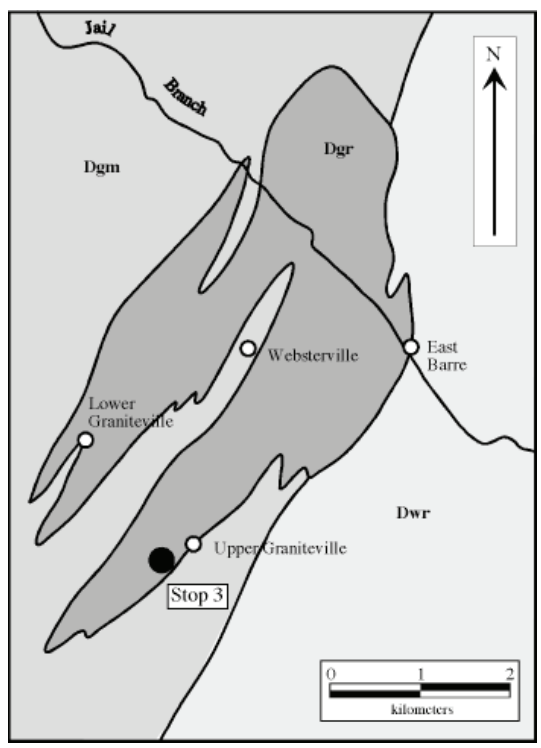
Return to vehicles and retrace Owl's Head Road

36.2 Turn left (south) on VT Route 232
44.2 Turn right on Route 302 East
59.3 Use the traffic circle to turn south) on VT Route 110
59.5 Turn right and then immediately left onto Waterman Street
60.2 Waterman Street turns into Donahue Road; continue south
61.3 Turn right (east) onto Drury Hill Road that becomes Graniteville Road
61.8 Stop in the parking lot on the left at the old Visitor's Center

STOP 5: BARRE GRANITE QUARRY (UTM NAD83 18T 0701477 4891184). Dimension stone quarrying of this fine-grained, homogeneous body began in the 1830's to provide material for construction of the Vermont State House (see Dale, 1909). The Barre Granite district continues as one of the major granite producers in the US, quarrying almost 1 million cubic feet of granite annually and contributing greatly to making Vermont one of the top two granite producing states. Naylor dated several of these bodies, with ages clustering around 380 Ma (Naylor, 1971); a younger age of 368 ±4 has recently been reported (Ratcliffe et al., 2001).

General descriptions of the granite and quarries are available in the literature (Richter, 1987; Richter et al., 1997). The pluton is elongated parallel to the regional fabric, and several septa of country rock penetrate the body. Contacts are transgressive and a well-developed contact aureole is superimposed on the regional staurolite grade rocks. Additionally, exceptionally low percentages of iron oxides and sulfides as accessories produces a stone that tends to hold its color without staining.

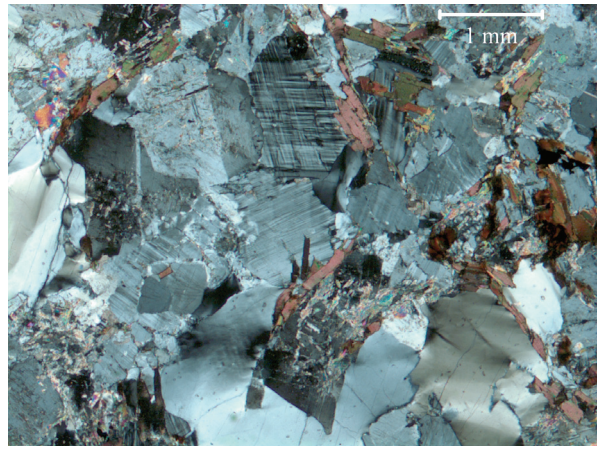
Proceed around the quarry side of the building past the old locomotive and out to the quarry overlook. Note the polished block at the end of the trail illustrating the sharp contact between "Barre light" and "Barre dark", two of the three facies sold by the Rock of Ages Corporation. Modal percentages of this two-mica, two feldspar granite body are amazingly consistent despite grain size and color variations (Chayes, 1952), and the lack of dikes, veins, pegmatites and inclusions result an a remarkably homogeneous pluton. Primary igneous flow patterns dipping gently southwest are faintly visible at many locations, but the most prominent structures in the pluton are the intersecting widely-spaced, high-angle joints and sheeting joints (Richter, 1987). Mesozoic basalt dikes that occur scattered throughout Vermont can be seen in the north wall of the quarry and in the roadcut along Websterville Road. Return to the road and walk east to the upper outcrop to examine the Mesozoic dike and the main facies of the granite.

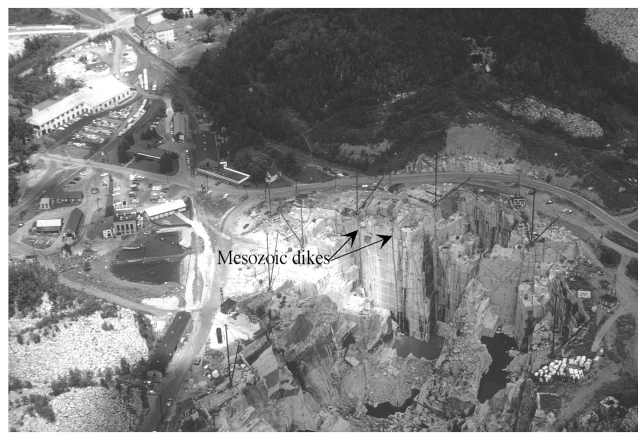


Generalized geologic map of the Barre granite area. Abbr. Dgm = Gile Mountain Formation; Dwr = Waits River Formation; Dgr = Barre granite. Geology after Murthy (1957) and Doll and others (1991).

These Barre quarries are located at around 1,500 feet elevation, well above former shorelines of glacial lakes that occupied the dammed river valleys, and as a result, the area is covered with glacial till. Cobbles and boulders are abundant at the east end of the outcrop, dominated by the local hornfelsed bedrock. Also notable are easily recognized fragments from the ophiolite complex exposed NNW of the area. Material having the most distant source is Precambrian gneiss from the Grenville terrane NE of Montreal, Canada.

Barre granite*	Barre (B1)
	wt%
SiO2	70.70
TiO2	0.33
Al2O3	14.60
Fe2O3(t)	2.19
MnO	0.03
MgO	0.77
CaO	1.45
Na2O	4.15
K2O	4.64
P2O5	0.09
	ppm
Cr	0.03
Rb	149
Sr	458
Y	11
Zr	123
Nb	10
Ba	692
La	11.7
Ce	24
Nd	9.2
Sm	2.2
Eu	0.68
Gd	0.06
Yb	0.4
Th	5.7
U	3.3





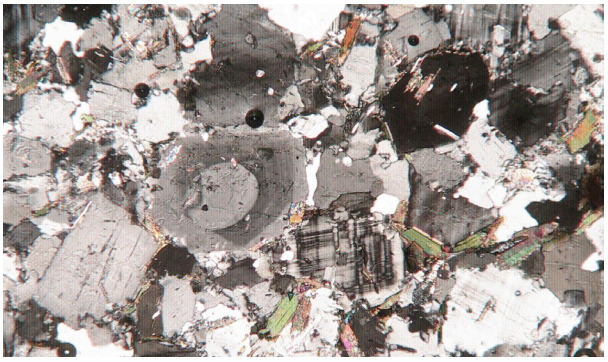
Photomicrograph of Barre granite above. Areal photo of the quarry at Stop 7 prior to flooding (photo by F.D. Larsen). Whole-rock analysis from Hengstenberg, 2000.

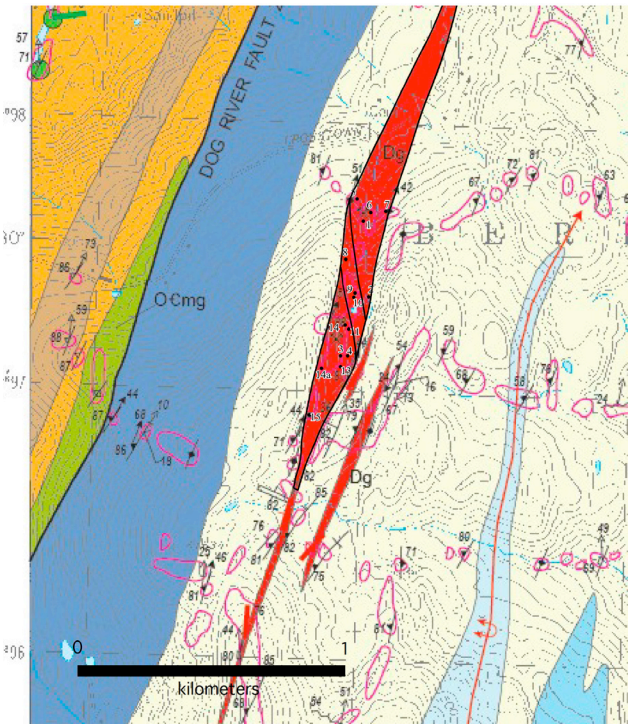
Turn left (west) out of the Old Visitor's Center parking lot and continue on Graniteville Road.
62.8 Continue straight on Middle Road near the new Visitor's Center
64.2 Cross Route 14 and proceed west on Route 63 to I89
67.9 Turn north onto I89
71.1 Exit I89 onto Route 62 E
71.6 Turn right (south) on Paine Turnpike North
71.9 Turn right (west) on Crosstown Road, pass under I89
71.6 Bend left (south) continuing on Crosstown Road
73.0 Park along the right side of the road (UTM NAD83 18T 0690967, 4898151) and hike southward on the old quarry haul road for 350m to the main quarry of the Berlin granite

SAMPLE	BL-10	BL-3	BL-6
UNIT	Berlin Dk	Berlin Int	Berlin Lgt
wt%			
SiO2	70.19	70.60	71.42
TiO2	0.38	0.31	0.28
Al2O3	16.12	15.87	15.71
Fe2O3(t)	2.26	1.95	1.74
MnO	0.03	0.03	0.03
MgO	1.05	0.90	0.81
CaO	2.52	2.32	2.09
Na2O	4.39	4.47	4.35
K2O	2.95	3.36	3.56
P2O5	0.12	0.20	0.00
ppm			
Sc	4	5	4
V	41	36	28
Cr	30	21	19
Co	22	24	16
Ni	7	7	11
Cu	16	13	10
Zn	60	56	42
Rb	130	149	114
Sr	596	536	407
Y	7	7	7
Zr	135	121	102
Nb	5	11	2
Ba	579	512	419

STOP 6: **BERLIN GRANODIORITE**. The Berlin granodiorite is exposed here in an abandoned quarry that operated in the 1800's (see Walsh et al. this volume (Stop 7) for more information). The main body consists of early, zoned plagioclase (average 2mm diameter), with microcline and quartz, and late green-brown biotite, minor muscovite, and epidote. Minor accessory sphene occurs as euhedral, diamond-shaped crystals. Deuteric epidote and muscovite forming at the expense of the plagioclase. A porphyritic chill border facies occurs locally, characterized by equidimensional zoned plagioclase phenocrysts.

Recent geochemical study of these rocks (Filip, 2007b) suggests a zonation as shown on the map that accompanies this description, with N-S trending zones of slightly variable compositions. Least-evolved rocks (richer in refractory elements and poorer in silica) occupy the northern end of the intrusion, with slightly more-evolved rocks to the south, and most-evolved rocks separate the other two units. *In situ* fractionation is unlikely given the spatial distribution of variations, supporting the idea of emplacement as sheets drawn from an evolving source. Contacts between magma batches are not seen in the field, so the sequence of emplacement is unconstrained.





Geologic map above after Walsh et al. (in press), with zonation of the Berlin granite added after Filip (2007b). Border facies photomicrograph shows well- rounded 0.4mm plagioclase cores .

Continue west on Crosstown Road

74.7 Turn left (south) on VT Route 12
78.8 Pass through Northfield, VT
79.1 Continue straight on VT Route 12
80.2 Turn left (east) onto VT Route 64 toward I-89
80.7 Park well off the road at the east end of the outcrop section

STOP 7: ISOCLINALLY FOLDED SILURO-DEVONIAN SECTION (UTM NAD83 18T 0688269 4887456). This stop examines the section described in the guidebook article above (text and Fig. 5) where 23 reversals of topping directions have been identified in the 370m section on the north side of the road. These Siluro-Devonian turbiditic rocks occur along the western margin of the Connecticut Valley – Gaspé Trough and make up what has been mapped as a transition zone between the thicker-bedded, carbonate-rich rocks of the Waits River Formation to the east and the carbonate-poor slaty rocks of the Northfield Formation to the west. Bedding is well preserved throughout although zones of shear, with or without massive quartz veins, disrupt the section. Tops are recognized by triplet bedding patterns with gray sandy bases grading into darker phyllite, capped by brown-weathering calcareous silts. A number of Mesozoic dikes are exposed throughout this section.

It is interesting to note that this section shows a predominance of west-facing beds that continue westward across Route 12 to the last outcrops of Northfield Formation which is everywhere bound on it's western margin by the Dog River fault zone (Westerman, 1987). This relationship was critical to Hatch's (1988) revision of the Siluro-Devonian section in which outcrop scale high-angle structures are superimposed on more nearly sub-horizontal structures on a much larger scale.

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