FIELD GUIDE TO CRETACEOUS INTRUSIONS IN THE NORTHERN TACONIC MOUNTAINS REGION, VERMONT

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INTRODUCTION

Northern New England and adjacent Canada were host to a great spread of mid-plate, non-orogenic alkalic igneous intrusions during Early Cretaceous times. In several stages from 130 to 100 million years ago, groups of plutons, dike swarms, and individual complexes combined to form an igneous province that stretches 400 km from the central Adirondack Highlands of New York eastward through southern Maine, and 350 km from the Monteregian Hills of southern Quebec southeastward through New Hampshire (Fig. 1). Including its subprovince groups, we have been calling this the New England-Quebec ("NEQ") igneous province (McHone and Butler, 1984). Still more of the these intrusions are found in the continental shelf (Puffer, 1989), and they continue across the western North Atlantic as the New England seamount chain.

If an "eogeologist" could do field work in the Vermont of 110 million years ago, some members of the NEQ province would be mapped as volcanic mountains, in a tectonic setting perhaps not too different from that of East Africa today. Our present topography of valley basins and mountain ranges was far from finished, and "terrible lizards" walked upon stratigraphic formations that were several kilometers above the present surface. Those formations may well have included Mesozoic clastic and volcanic rocks, especially within the structural basins that flank Vermont (McHone, 1982). One proven area of volcanism in eastern Vermont is the great monadnock of Ascutney Mountain, which has blocks of volcanic rocks preserved within plutonic rocks near its peak. Others, such as the Cuttingsville complex and Barber Hill stock of western Vermont, have no evidence left for associated extrusive rocks. We have no sure idea of whether dikes of hypabyssal magmas, such as are visited on this trip, ever reached the surface anywhere in the region.

Differential erosion controlled by faulting, uplift, downdrop, and weathering has removed the stratigraphic evidence of Vermont's Mesozoic volcanic and sedimentary rocks, and has provided excavations of several kilometers into some of the plutonic chambers that once lay beneath Cretaceous volcanoes. Erosion has also exposed thousands of dikes across the NEQ province, some of which we describe in this paper, and others of which are described in works listed in the bibliography. High-angle faults, mostly normal, are also exposed and may be relicts of Mesozoic tectonism in the region (McHone, 1987).

NEQ dikes display a bimodal range of mafic and felsic types in overlapping sets and swarms, each with somewhat distinctive ages and physical characteristics. Given that they cooled in contact with rocks only a few kilometers below today's surface, the dikes are naturally intermediate in crystal character between phaneritic plutons and aphanitic volcanic rocks. Good eyesight and a handlens are required to make out the minerals and textures of the dikes, but with care and experience, most can be classified in the field. Unlike the great quartz tholeiite intrusions of southern and eastern New England, most NEQ dikes are too small to have produced flood basalts or large volcanic edifices. Yet, as shown by xenoliths of spinel peridotites and other mantle rocks (N. W. McHone, 1986), these magmas, in dikes with just a few meters of exposed width, ascended from mantle depths.

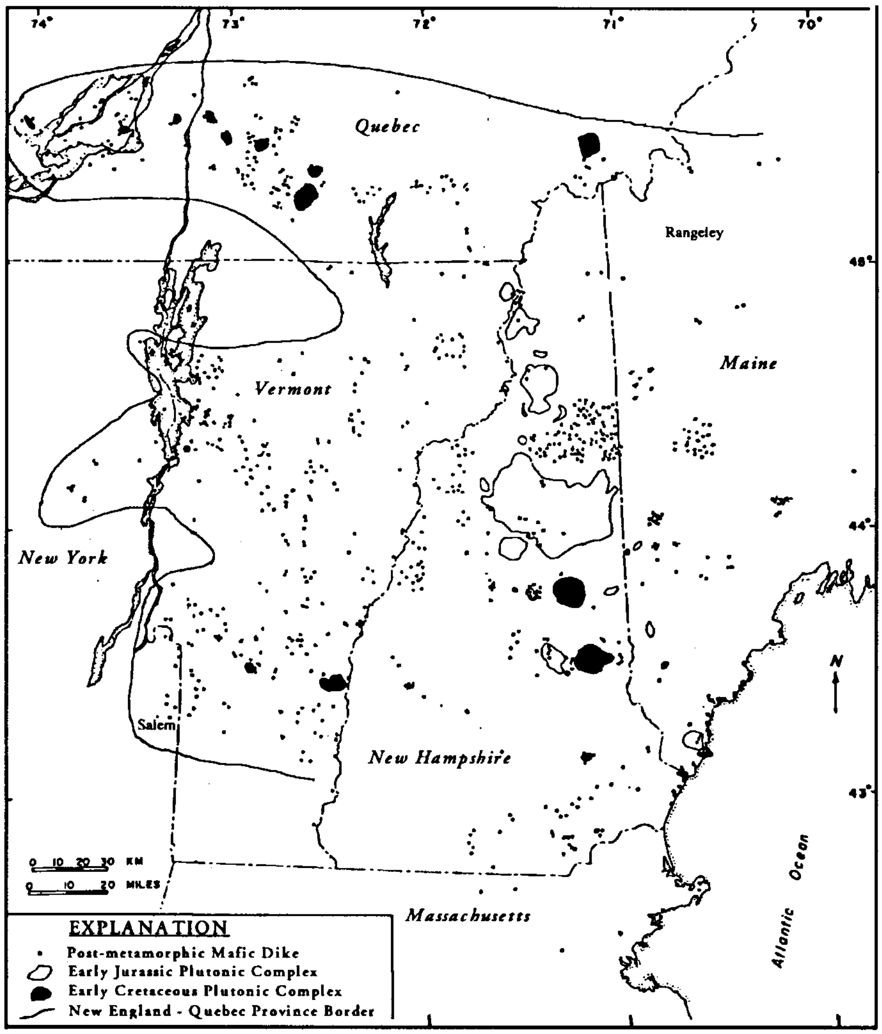

Figure 1. Distribution of post-metamorphic dikes in northern New England.

This field excursion presents work that characterizes the little-known northern Taconics (NT) subprovince of the New England-Quebec igneous province. We have barely outlined the properties of only a few of the NT intrusions, which are worthy of a thesis or other efforts (let us know if you are interested). As in other regions, relatively few of the geologists who produced the quadrangle bedrock maps for the area have paid much attention to these intrusions. Some older papers contain very useful information, such as those by Marsters (1889), Dale (1899), Eggleston (1918), and Fowler (1950). More recent work centers on the pluton at Cuttingsville, including papers by Laurent and Pierson (1973) and Robinson (1990), and studies by Wood (1984) and Eby (1992).

Dikes at Stops 1, 2, 3, and 5 were first shown to J.G.M. by E. Stanley Corneille, who shared these geological interests at the University of Vermont during graduate work in the early 1970's. Other field visits were made with J. Robert Butler during and after Ph.D.

work at the University of North Carolina at Chapel Hill (1974-1978), and other field work was conducted with Chiasma Consultants, Inc. for the National Uranium Resource Evaluation (1978-1980). We made a field tour in September of 1992 for this log.

THE NORTHERN TACONIC NEQ SUBPROVINCE

The western margin of the NEQ province is formed with three lobes, or subprovinces, that extend westward from northern New England (Fig. 1). On the northern side, the Monteregian Hills subprovince of southern Quebec is well known for its carbonatites and ultramafic stocks, as well as for alkali lamprophyre dikes (Eby, 1992). Most radiometric dates are near 110 (+/-5) Ma, although a greater age spread has been suggested.

Igneous rocks are unknown in the northernmost Lake Champlain Valley, but north and south of Burlington, Vermont there are several hundred lamprophyre and trachyte dikes exposed along shorelines, roadcuts, streams, and hillsides. Lamprophyre dikes of this subprovince are distributed westward into the central Adirondack Highlands of New York, and eastward into north-central Vermont (McHone and Corneille, 1980). Champlain dikes are identical to Monteregian dikes, including carbonate-rich types, but associated plutonic complexes are fewer and smaller in the Lake Champlain region than in Quebec. Radiometric dates indicate ages near 135 Ma for monchiquites, 125 Ma for trachytes and syenites, and 115 Ma for camptonites (McHone, 1987), but this very neat division needs better confirmation.

TABLE 1. RADIOMETRIC DATES, NORTHERN TACONIC IGNEOUS ROCKS

Site	Description	Date (Ma)	Ref.
Stop 3 (PO-1)	Rte. 4 roadcut Poultney quadrangle lat 43o32'05"N lon 73o10'35"W	113 +/-4	(1)
Stop 6 (WR-3)	hbl spessartite, Rt.4 roadcut West Rutland quadrangle lat 43o30'49"N on 73o03'20"W	108 +/-4	(2)
Stop 9 (RT-7)	andesitic breccia, Shrewsbury Rutland quad lat 43o30'57"N on 72o53'56"W	101 +/-4	(1)
Stop 10	biotite syenite, Cuttingsville	102 +/-2	(3)
	essexite	98.8 +/-2	(3)
	essexite	103 +/-4	(4)
	quartz syenite	108 +/-1	(5)
	quartz syenite	100 +/-3	(6)

Note: all dates are by K-Ar analysis of whole-rock and mineral samples, except for Cuttingsville date by ref. 5, which is by Rb/Sr isochron. Dates have been revised, where appropriate, to newer IUGS decay constants.
References: (1) this paper; dates courtesy of H. Kreuger, Geochron Labs; (2) Zen, 1972; (3) Armstrong and Stump, 1971; (4) Stone & Webster unpub. date, ref. Kanteng (1976); (5) Eby, 1992; (6) G. N Eby, pers. comm., 1992

In the southern, upper Champlain Valley (the lake flows northward), there is a "virtual" gap in igneous rocks, with only a few stray dikes known at Vergennes, Middlebury, Westport (New York), and Orwell. The third lobe (herein labeled "NT", for Northern Taconics) has around 70 known dike localities, some of which are probably exposures of the same dike, distributed along the northern Taconic region between Proctor and Dorset, westward a few kilometers into eastern New York, and eastward across the Vermont Valley into the Green Mountains southeast of Rutland (Fig. 2). Many of the intrusions have petrologic characteristics that are distinct from the northern NEQ dikes, but there are also some very similar examples. Except for a few trachytes near Rutland, all of the dikes so far studied are lamprophyres. Dates are mostly 100-110 Ma (Table 1).

Little detailed work has been accomplished for the dike rocks, but the Cuttingsville plutonic complex southwest of Rutland has received attention since the 1970's from mineral companies as well as by research geologists. We consider the Cuttingsville intrusions to connect with the Taconic subprovince on the basis of age and petrology, although the distribution of dikes does show fewer examples towards Cuttingsville (Fig. 2). Eastward from Cuttingsville, dikes remain fairly common (2 to 6 examples have been sampled per 15' quadrangle), and they merge into the regional camptonite swarms of eastern Vermont, New Hampshire, and Maine (McHone, 1984).

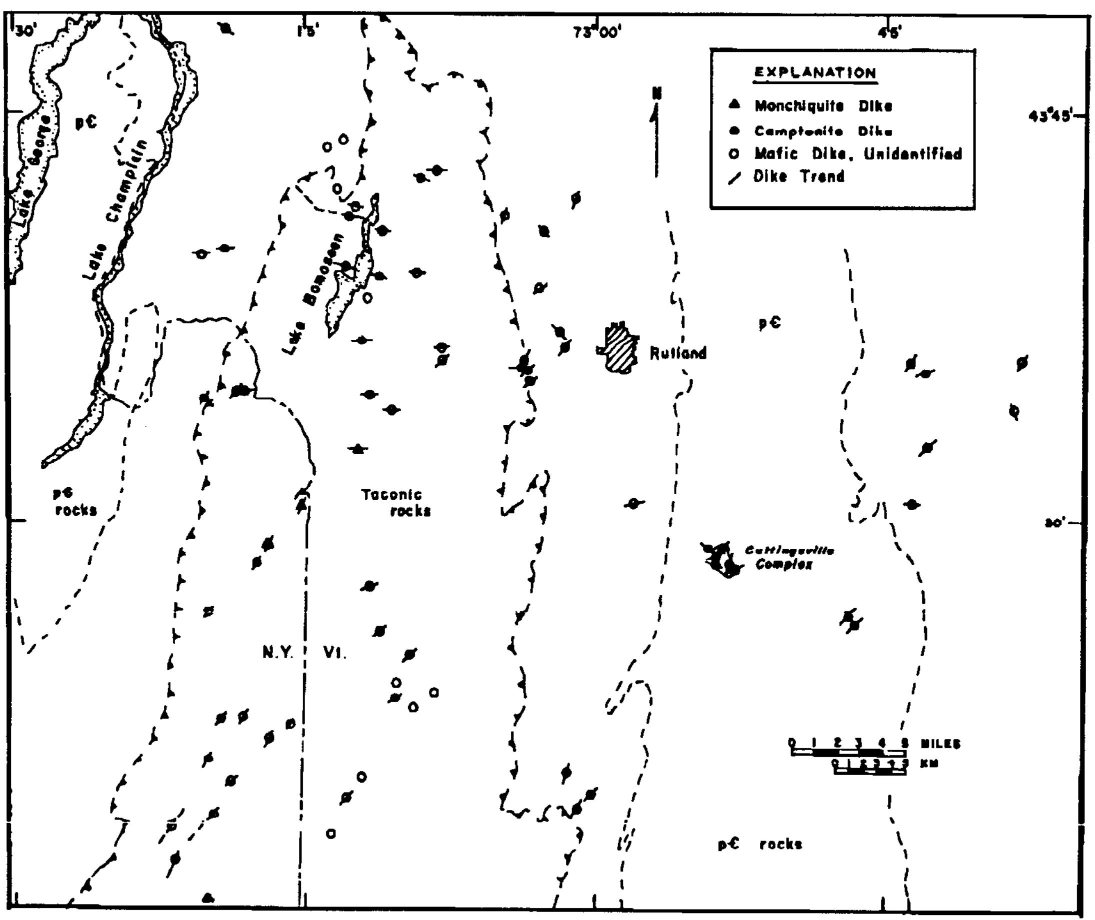

Figure 2. Dike locations in the northern Taconics region, Vermont and New York.

Each of the three western NEQ lobes has different orientation maxima for dikes (Fig. 3). The Monteregian subgroup has a WNW-ESE maxima for dikes, examples for which are found the entire distance from Montreal to northwestern Maine (McHone, 1978a). Dikes of the Champlain Valley subprovince have a very distinct E-W preference (McHone and Corneille, 1980). When plotted together, the dikes of the northern Taconics region indicate a NE-SW maxima. But when the map of the area is examined (Fig.2), it can be seen that while most of the dikes on the southern and eastern portions of the subprovince show this NE-SW trend, there are also several dikes in the northern portions that trend between E-W and NW-SE.

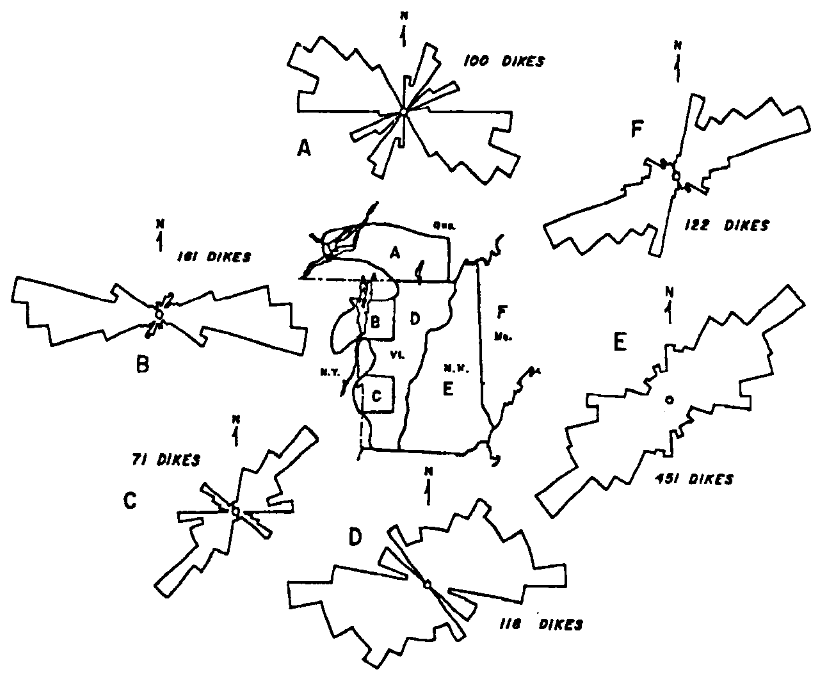

Figure 3. Dike trends (rose diagrams) in northern New England. Rose diagram labels refer to areas shown in the central figure, with rose C representing northern Taconic dikes.

We believe that most dike magmas intrude along directions of simple extension, widening fractures against the direction of minimum compression within the upper crust (McHone, 1988). But how can dikes of (presumably) the same generation have different trends across such a small area? Possibilities include (1) that the dikes radiate from a plutonic center or chamber, analogous to the exposed Spanish Peaks (New Mexico) volcanic center. Such a hidden pluton would have to exist somewhere near Rutland to be roughly at the intersection of local dike trends. Or perhaps (2) the dikes have originated at different times in different areas, responding to a changing stress field as they formed. Perhaps (3) some dikes have filled "shear" fractures in addition to extensional fractures during the same event. Finally, (4) we are intrigued by the notion of a major lithospheric break that acted as a tectonic boundary to stress (and strain) fields in the region.

McHone and Shake (1992) suggested that the shift of the Cretaceous NEQ dikes as seen in Figure 3, from E-W and WNW-ESE in northern areas to a NE-SW trend toward southeastern New England, is controlled by a lithospheric cross-structure that is partly expressed by major topographic lineaments (Shake and McHone, 1987). The proposed structure acted as an active boundary for stress fields in New England as indicated by the NEQ dike orientations, along a lineament that runs across the region in a northesterly direction from the vicinity of Salem, New York at least to Rangeley, Maine (Fig. 1). The Salem-Rangeley zone is contiguous with the Alabama-New York lineament of King and Zietz (1978), which they proposed to be due to a major high-angle structure. We have no direct field evidence for such a major "basement break", however.

NORTHERN TACONIC IGNEOUS ROCK TYPES

The NT dike types include monchiquite (nephelinite), camptonite (basanite), bostonite (trachyte), and spessartite (andesite), all of which will be examined during this trip. The quartz syenite member of the Cuttingsville complex is visited on the final stop, depending on field conditions. All of these igneous types are presumed to be related through some mantle-to crustal event of fractional melting, differentiation, and crystallization, but it is unlikely that they were at one time all co-magmatic.

Monchiquite is a very mafic, granular, analcite-bearing, olivine-bearing, augite-rich alkali basalt, often also with appreciable calcite (in spheroidal bodies), phlogopitic mica, and kaersutitic hornblende. Feldspar (Ca-plagioclase) is poorly developed or lacking. Monchiquite is commonly dark gray in color.

Camptonite can look much like monchiquite, except that olivine is rare or absent, kaersutite is common to abundant, and plagioclase is more abundant than analcite. Phenocrysts are only mafic (augite and/or kersutite), rather than felsic. Camptonite dikes usually have a brownish to medium gray range of colors.

Spessartite dikes lack olivine and analcite, but plagioclase (intermediate Ca) is well developed and present as phenocrysts as well as intergrown with augite in the groundmass. Phenocrysts (or megacrysts) of kaersutite serve to distinquish spessartite from tholeiitic dolerite (diabase) dikes that are common in other parts of New England. Spessartite often shows a distinctly greenish or purplish cast as well as gray colors.

Bostonite is a name that in a strict sense applies only to felsic (anorthoclase-rich) dikes that have a "felty" clumped-grain texture, which is not always present. Trachyte, although used for volcanic rocks as well, is a better general term. Minor minerals include oxidized biotite, quartz, and clay products. Some examples show well-formed alkali feldspar and/or quartz phenocrysts. Trachyte dikes may be iron-stained, but they are generally light brown to cream-colored on fresh surfaces. The quartz syenite of Cuttingsville is chemically like trachyte (Table 2), but at stop 10 the syenite has been enriched by sulfides.

SITE LOCATIONS

The region is generally rural, and famous for its scenery. Motels and other amenities are most abundant in Rutland, but that city also has the most unpleasant traffic flow of the area. An excellent campground (in season) is Bomoseen State Park, on the west side of Lake Bomoseen a few miles north of Rte. 4. Some of the ten sites of this field guide may be difficult to visit during bad weather (snow, ice) or high stream flow...judge for yourself from the stop descriptions.

U.S.G.S. topographic maps are all available at 1:24,000 scale for the area. The route traverses six 7 1/2' quad maps in the order of: Proctor (dated 1944, Rte. 3 no longer as shown), West Rutland (1972), Poultney (1972), Bomoseen (1944), Poultney again, West Rutland again, Rutland (1980), and Wallingford (1986). We have found The Vermont Atlas and Gazeteer (DeLorme Mapping Co.) to be generally useful, and widely available. The U.S.G.S. Planimetric Maps for Ticonderoga (Fig. 4) and Rutland include the sites.

Directions to start: From Burlington, drive south on Route 7 to Pittsford, then follow Route 3 southwest to Proctor. From southern/eastern/western approaches, turn north onto Rte. 3 off Business Route 4 between Rutland and West Rutland, then north to Proctor. The Vermont Marble Company is just across the bridge in the western part of the village. We have permission to assemble in their lot near the information kiosk.

Along the way, a lunch break can be made in the village of Castleton, which is crossed before and after Stop 5. Gasoline is available in Castleton, but not in many other places along the trip route. Restaurants and gas stations can also be found along Rte. 7 in Rutland before or after the trip. The total travel distance from stops 1-10 is less than 60 miles.

TABLE 2. CHEMICAL ANALYSES OF ROCKS AND MINERALS, NORTHERN TACONICS REGIONAL INTRUSIONS

OXIDE	WR-4B	PO-1	MPMB	QTZSY	PO-1k	PO-1a	PO-1p	PO-1i
SiO2	45.09	50.85	69.00	65.86	41.32	50.77	55.32	6.61
TiO2	2.89	1.71	0.24	1.03	4.84	1.08	0.15	55.62
Al2O3	13.58	16.66	16.50	17.19	11.60	4.43	28.08	2.56
FeO*	10.97	6.71	2.25	2.88	12.03	5.45	0.70	18.15
MnO	0.19	0.22	0.20	0.17	0.28	0.17	0.01	0.84
MgO	7.02	3.86	0.06	0.06	12.09	15.83	0.06	2.58
CaO	10.38	7.32	0.50	0.84	11.86	21.35	10.48	1.58
Na2O	2.94	5.15	4.30	6.78	2.82	0.80	4.66	0.51
K2O	1.25	2.63	4.00	5.24	1.09	n.a.	0.38	0.18
P2O5	0.71	0.35	0.10	0.03	n.a.	n.a.	n.a.	n.a.
H2O+	1.10	1.49	3.00	n.a.	n.a.	n.a.	n.a.	n.a.
CO2	3.28	2.85	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
H2O-	0.30	0.39	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total	99.70	100.19	100.15	100.08	97.75	99.88	99.84	88.63
TRACE ELEMENTS								
Rb	25.9	58.3	43.0	111				
Sr	805	843	205	29.0				
Y	28.7	27.5	n.a.	n.a.				
Zr	279	261	532	469				
V	234	144	n.a.	5.0				
Cr	267	179	n.a.	50.9				
Ni	142	51.0	n.a.	12.8				
Ba	609	1120	n.a.	181				

Note: FeO* = total Fe as FeO
n.a. = not analyzed
oxides are weight percent
trace elements are ppm

WR-4B = camptonite near stop 6, ref. McHone, 1978b
PO-1 = spessartite at stop 3, ref. McHone, 1978b
MPMB = Champlain Valley trachyte dike at Charlotte, ref. McHone and Corneille, 1980
QTZSY = average of 5 Cuttingsville quartz syenite analyses, ref. Wood, 1984b
PO-1k = kaersutite phenocryst from dike PO-1, ref. McHone, 1978b
PO-1a = augite phenocryst from dike PO-1, ref. McHone, 1978b
PO-1p = plagioclase phenocryst from dike PO-1, ref. McHone, 1978b
PO-1i = ilmenite phenocryst from dike PO-1, ref. McHone, 1978b

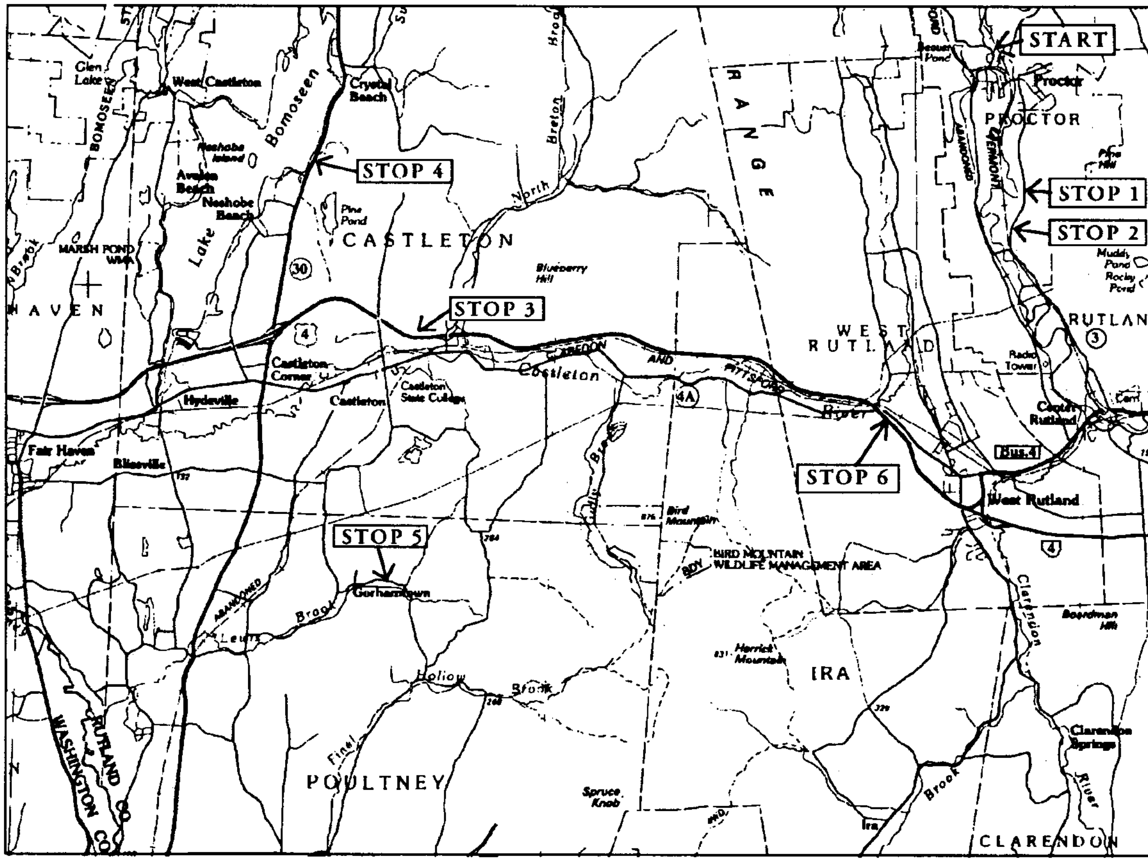

Figure 4. Roads and locations of stops 1-6, northern Taconics region.

ROAD LOG AND SITE DESCRIPTIONS

0.0 miles. START.

Meet at the Vermont Information kiosk in the parking lot of the Vermont Marble Company, Proctor, Vermont. The marble industry in Vermont is nearly 200 years old, and this is the only remaining large-scale operation out of many former businesses. If you have time, take a tour of their showcase museum. Some bargains of polished stone seconds can be had at the adjoining sales yard, and we can personally recommend their handsome stone table tops from the store inside.

Head south on Rte. 3.

1.7 miles. STOP 1. PROCTOR TRACHYTE DIKES.

Roadcut on eastern (left) side of the the highway. Watch for the traffic as you pull onto the wide shoulder on the eastern side, about 3/4 of the way down the cut.

There are two trachyte dikes towards either ends of the cut about 40 m apart, our samples PR-1 to the north and PR-2 to the south. PR-2 is oriented Azimuth 264,55 (when looking 6 degrees south of west, dip is 55 degrees to the right, or north), and 42 cm wide (measured at chest height). PR-1 is AZ 236,71; 91 cm wide. These two are fairly typical of "bostonite" dikes with their tan color, rhythmic weathering stains, and brittle fracture patterns. Their mineralogy is dominated by anorthoclase, with minor Na- plagioclase, quartz, oxi-biotite, and iron sulfides.

The dikes cross a thick quartzite bed that dips steeply to the east, and which shows much fracturing along the intrusion margins. There are some small faults apparent as well, and small syn-intrusional steps in the dike walls that produced curving flow lines. Trachyte was much more viscous as a magma than the mafic types we will see, and they generally appear in the vicinity of larger, syenitic plutons or differentiated plutonic complexes. As discussed for Champlain Valley dikes (McHone and Corneille, 1980), we infer that trachyte dikes are offshoots of such magma chambers, while the widespread lamprophyres are not. Here we are about 25 km northwest of the Cuttingsville complex, and so these trachytes are rather isolated...unless there is another pluton.

During the uranium evaluation (NURE) work of the late 1970's, it was noted that trachyte dikes have gamma radiation levels that are 5 to 10 times higher than surrounding rocks. An analysis of the PR-1 dike shows 9 ppm U3O8 and 60 ppm eTh (McHone and Wagener, 1980). These values are high but within the range of 1 to 15 ppm U3O8, and up to 105 ppm eTh measured for syenitoids and granitoids of the Cuttingsville and Ascutney plutons. U-enriched trachytes have been mined in Europe, which explains the interest.

Continue south on Rte. 3.

2.1 miles. STOP 2. PROCTOR MONCHIQUITE DIKE.

This is another good roadcut on the eastern side of Rte. 3, with dike WR-2 toward the southern end. This dark gray monchiquite shows "typical" features such as a zone of small pink-white ocelli towards the center, some development of pebbly alteration-texture, and even schistose weathering zones. Note the lack of obvious feldspar and the fine, granular texture of mafic minerals (augite and olivine). The blocky, cobblestone fracturing is also common among lamprophyres. During this trip, observe the different colors for mafic and felsic dikes types. Our measure is AZ 132,85 (a rare NW-SE orientation), and 148 cm of width. There is similar dike west of Orwell village, on strike with WR-2 and also with a NW orientation, but almost 30 km away.

Being basaltic rocks, lamprophyres are not very radioactive. However, two Vermont lamprophyre dikes to the north have 2.2 and 2.5 ppm U and 9.7 - 10.5 ppm Th (McHone, 1978b), which is several times higher than the average tholeiite or oceanic basalt. Lamprophyres are relatively rich in other "incompatible" elements as well, probably because they are small melts of an "enriched" mantle source.

Continue south on Rte. 3

3.9 miles. Not a stop, but there is another lamprophyre dike (WR-1) hidden behind brush along this cut. It has a northeasterly strike like others to the south and east.

4.6 miles. Intersection of Rte. 3 with Business Rte. 4. Turn right, head west on Business Rte 4.

6.2 miles. Turn right into the interchange with Rte. 4, heading west (bear right where the road splits).

7.5 miles. For the next mile, there is good exposure along the other lane. Stop 5 is near the northwestern end on the way back.

13.6 miles. Continue past Exit 5.

14.4 miles. STOP 3. CASTLETON DIKE.

This handsome intrusion (PO-1), near the western end of the cut, has a purplish color that contrasts with the surrounding green Mettawee Slate. This is an example of spessartite, not like most of the the "alkali lamprophyres" in the Champlain Valley to the north, which are camptonite or monchiquite. The date (Table 1) and chemistry (Table 2) make this one of the best-characterized of the northern Taconics dikes. Oriented AZ 076,81; 281 cm. Notice how the northern contact is stepped 10-20 cm outward in places upward in the dike, and that despite its size, thermal metamorphism is not apparent in the Mettawee slate at the margins.

The dike contains phenocrysts of plagioclase, and large (up to 1 cm) rounded megacrysts of kaersutite (brown Ti-hornblende). There are also small xenoliths of dark quartzite and gneiss, presumably derived from the Grenvillian basement beneath the Taconic and Champlain Valley lithologic sequences. In keeping with its feldspar-rich nature, the chemistry of the rock shows much Si, Al, and Na relative to alkali lamprophyres (Table 2). The kaersutite in PO-1 is not different from kaersutite in the type camptonite and in other lamprophyres, however. Similar kaersutite is known from harzburgites and other mantle lithologies that are found as xenoliths in dikes at North Hartland, Vermont and Ayres Cliff, Quebec (Williams, 1987).

Continue west on Rte. 4.

15.9 miles. Exit 4, turn north onto Rte. 30.

18.6 miles. STOP 4. BOMOSEEN DIKE.

Park in the small lot across from the restaurant. Note: because of limited parking and no road shoulder, this stop can only be made safely with a small group, and few vehicles. Walk back (south) about 200 m, past the driveway of a fairly new, contemporary-style house. Exposures are along the east side of the road. NARROW SHOULDER.... WATCH FOR CARS.

This dike (our BO-1) was mapped by Fowler (1950, Plate II), who shows it as extending in a WNW direction across the lake for about 4 km. When we first visited it in 1981, there was an exposure of the dike about 12 meters wide, on both sides of the road, with an orientation of AZ 293,89 along its southwestern contact. More recent construction has since masked much of its northern side, but the remarkably coarse texture of what is left will attest to the great mass of this intrusion. The dike runs across the lake just to the north of the slate quarry, visible from here.

Thin sections from this site show a hornblende-bearing plagioclase-rich rock that we are calling spessartite. Groundmass augite is greatly altered to brown minerals. The rock is rather stained and weathered in hand sample, but still looks nothing like the narrower mafic dikes of the NEQ province. Because of its relatively slower cooling, the Bomoseen dike has taken on plutonic aspects of an alkali diorite such as may been seen at Ascutney or in the Monteregian Hills. There is another "great dike" parallel to BO-1 on the western side of the lake farther north, which we have not visited. Fowler (1950, p. 58) reports that dikes in the Castleton 15' quadrangle have no preferred orientation. We note above that dikes farther south and east are predominantly NE-SW trending, while there are several WNW-ESE trends among dikes in this area.

Continue north on Rte. 30 to turn around.

19.1 miles. Crystal Beach; turn around in the parking area to the left, head south on Rte. 30.

22.4 miles. Cross under Rte. 4.

22.9 miles. Cross Rte. 4A.

Continue south on Rte. 30, unless a lunch stop or break is needed. Castleton village is nearby to the east on Rte. 4A.

24.0 miles. Turn left (E) at crossroad, off Rte. 30.

24.6 miles. Pass under old RR bridge, now a foot/bike path.

24.8 miles. Pond Hill Farm, turn right (S) onto gravel road.

26.1 miles. Left (E) at intersection, past restored farmhouse.

26.9 miles. STOP 5. LEWIS BROOK FLUME DIKE.

Park at the small pulloff along the south side of the road. Note: this stop depends on low stream flow and no ice. As at stop 4, only a small group can be accomodated. The site requires an athletic scramble down and back up a steep stream bank. Walk towards the west (downstream) to find a place to scramble down. Be careful along this bank.

Figure 5. View downstream within the Lewis Brook flume. The dike fills the canyon floor and forms the streambed. Bob Butler is looking south.

The Lewis Brook flume is controlled by erosion along a very large, spessartite dike, PO-2, AZ 092,90; 480 cm width (Fig. 5). This gorge is a little larger than The Flume at Franconia Notch, New Hampshire, but much smaller than Quechee Gorge of Vermont, both of which are also formed by stream erosion along dikes. Such flumes develop both because the mafic dike rock erodes faster than the country rock, and because fractures along the dike path are more abundant than in other areas. Often a stream will be "captured" by the dike for a portion of its length, usually starting with a waterfall into the flume and continuing to a less-steep point where the stream can escape. The Lewis Brook dike is well exposed for several hundred meters, depending partly upon boulders moved by each spring flood. Maps show a very linear stream segment of more than 1 km along and below the flume, but dike exposure is poor downstream because of road fill.

Fowler's (1950) map of the Castleton 15' quad shows several dikes nearby, but misses this one. We found it only because of a sketch in a 19th century reference that describes the wonders of this site (reference since lost to us). It is very rare for a dike to have such a great horizontal exposure; most are only known in vertical segments at roadcuts or waterlines. This site has a peaceful if eerie ambience, like being in a large cave.

At the eastern end of the flume, the dike is faulted about 4.5 m in a left lateral sense, so that it disappears not far into the stream bank along the northern side. The fault is partially exposed, and clearly truncates the dike along AZ 140. Lewis Brook follows this fault from upstream, so that it turns at this point into the east-west flume not far downstream from a series of falls. The fault must have had lateral or oblique movement, because pure dip-slip would not produce offset on this near-vertical dike. The fault is not mapped by Fowler (1950) or Zen (1964). The country rock is Mettawee slate.

Retrace path back to Rte. 30 and then north.

30.9 miles. Cross Rte. 4A.

31.4 miles. Turn right onto Rte. 4 East.

31.6 miles. Pass the Castleton uranium occurrence in the slates on your left, a small vein with 150 ppm U3O8. Slates and black shales in this region are two to three times more radioactive than are most other rocks, but U concentrations are small.

39.1 miles. STOP 6. ZEN'S DIKE.

Pull well off the pavement on the right shoulder of Rte. 4, about a hundred meters past the start of the roadcut. Dike WR-3 (faulted) should be close by (Fig. 6).

This dike attracted attention because of its displacement by a prominant normal fault, first described and date of 108 Ma (Table 1) given by E-an Zen (1972). It is another spessartite, with augite altered but still showing abundant brown hornblende (kaersutite) and plagioclase, and approaching camptonite in its petography. Our sample code is WR-3, measured AZ 015,83; width 160 cm. The fault is about AZ 019,66, displacement about 80 cm. We are very close to the Bird Mountain thrust fault of Zen (1964), which here divides the allochthonous Mettawee slate from autochthonous Ira phyllite below. The fault zone has fairly thick gouge especially near the dike, no doubt due to mechanical rock properties. The fault has not been traced.

(photo reversed)

Figure 6. Faulted dike WR-3, east lane of Rte. 4. View is to the ~~south~~west.

This roadcut extends 1.5 km (0.9 miles) to the southeast and shows at least four more dikes, all of which are similar to WR-3 in type and trend. The next dike (WR-4) is about 100 m to the south, and was chemically analyzed (Table 2). As is evident in Table 2, camptonite has less silica and sodium than does spessartite, reflecting its Na-rich plagioclase content. There are few such continuous outcrops in the area, and the smaller roadcuts happen to show only one or two dikes as a rule. But it appears that dikes generally do occur together in small parallel groups, as shown by this cut and as observed in several other area of the NEQ province.

Continue east on Rte. 4 to Rte. 7.

44.7 miles. Turn right onto Rte. 7, heading south.

47.4 miles. Pass turnoff to Rte. 103.

49.8 miles. Roadcut on west (right) side of Rte. 7. Pull off near southern end of cut.

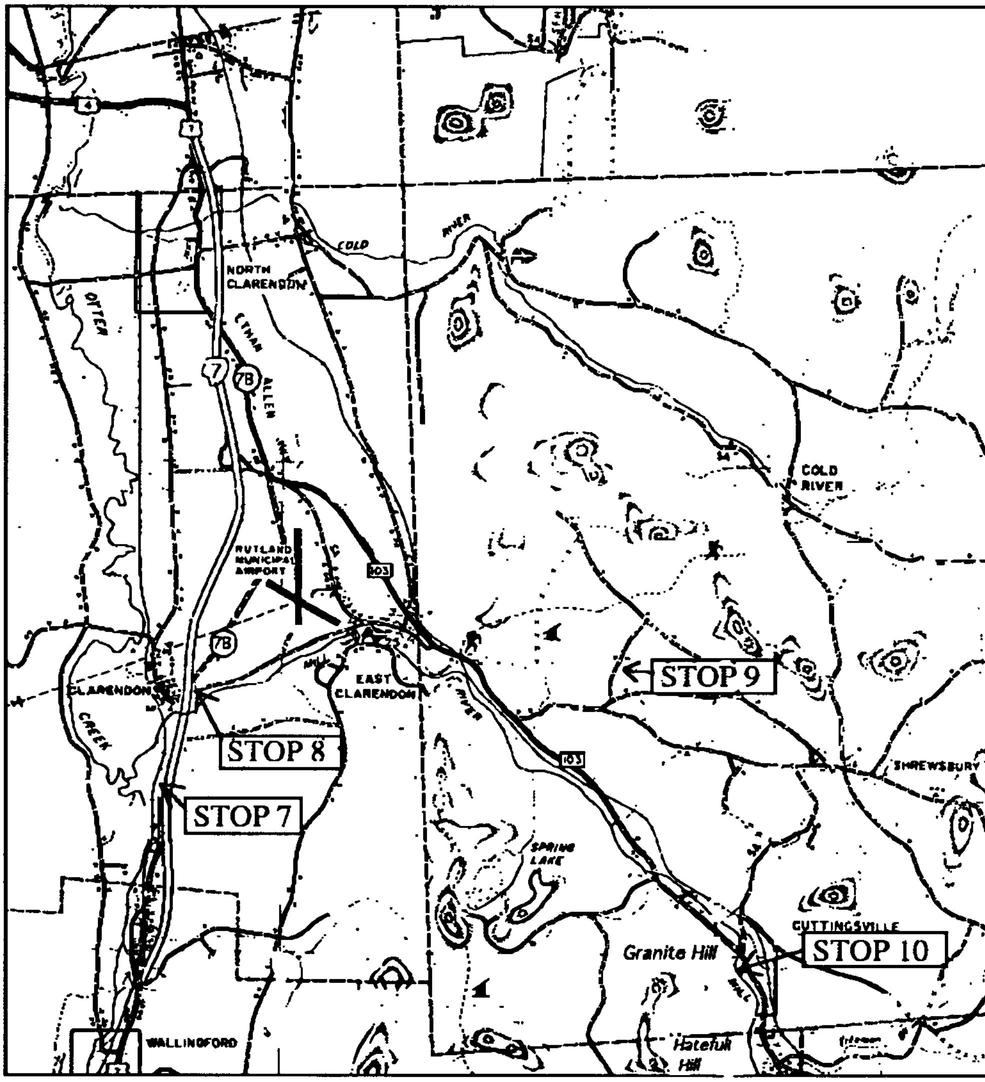

Figure 7. Locations of stops 7-10, southeast of Rutland. Map adapted from The Vermont Atlas, DeLorme Mapping, 1988.

STOP 7. SOUTH CLARENDON TRACHYTE DIKES.

This very fractured dike (RT-4; AZ300,86; 230 cm) is hardly recognizable as an igneous intrusion until you examine the rock fragments. As also seen in Figure 8, there is a very "shaley cleavage" developed parallel to the dike walls, which must have a tectonic cause. The dolostone country rock shows both faults and hydrothermal alteration at other outcrops.

On the northern end of the cut there is a smaller, dark-weathering trachyte (RT-1; AZ 060,75; 14 cm) exposed. Small fingers of this dike have a green color, which we have seen in other very thin trachytes that intrude dolostone (McHone, 1987). Perhaps a chemical reaction with the Mg-rich country rock has produced a fine-grained green mineral that is diluted in thicker dikes.

McHone and Wagener (1982) report 6 ppm U3O8 and 44 ppm eTh for dike RT-4, in line with other trachytes.

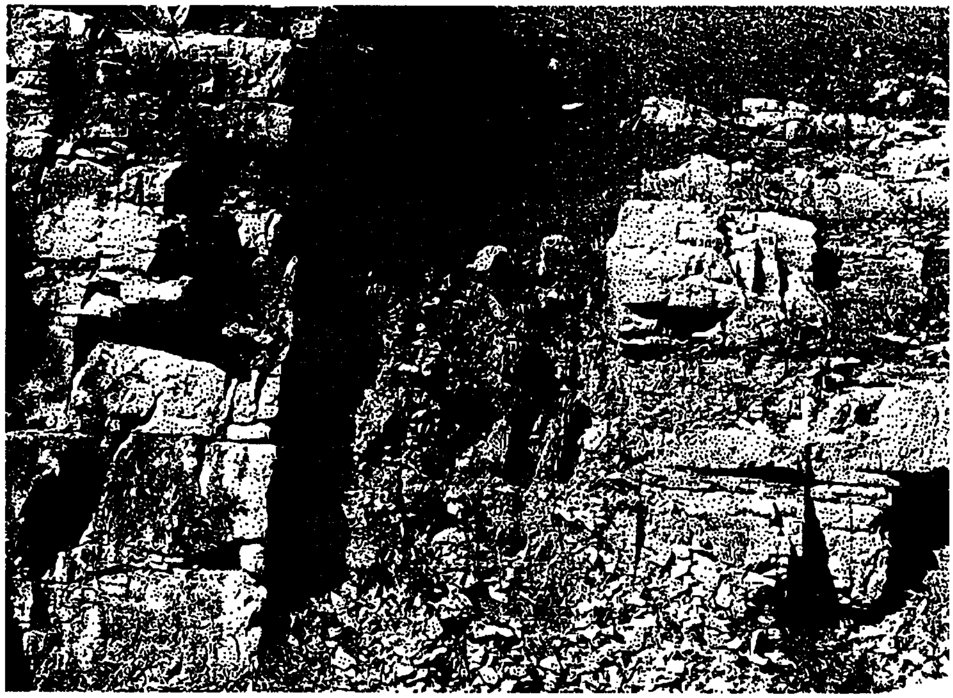

Figure 8. South Clarendon trachyte dike (RT-4), Rte. 7 roadcut. View is to the west. The dike has a very shaley fracture, but offset is not apparent.

Travel 0.2 miles farther south to turn around.

50.0 miles. Turn around by pulling into road on right, then crossing Rte. 7 to head north.

50.7 miles. Roadcut with dikes on the east (right) side. Turn right onto old Rte. 7, then right uphill behind the roadcut, park (dead end road).

STOP 8. SOUTH CLARENDON DIABASE DIKES.

Diabase, as a term used by us, is essentially a basaltic rock that is appreciably altered, generally by hydrothermal solutions or weathering rather than by burial metamorphism (although the term has been used for low-grade metamorphosed rocks as well, for which we prefer "meta-diabase"). As at this site, it can be difficult to see much original texture and primary mineralogy. This dike (RT-2) and its small neighbor (RT-3) on the southern end of the cut may have originally been camptonite, but the mafic minerals are so changed that it is difficult to classify.

This E-W dike (AZ 084,86; 124 cm wide) has a small but distinct positive magnetic anomaly, which we measured with a portable proton precession magnetometer (Fig. 9), along with the trachyte dike of stop 7. We traced its magnetic expression through the field to the east for several hundred meters, as far as the Mill River. The dike is exposed in the river gorge on this magnetic line, and could possibly be traced much farther. We are interested in discovering whether datable dikes are offset by faults along the Green Mountain front.

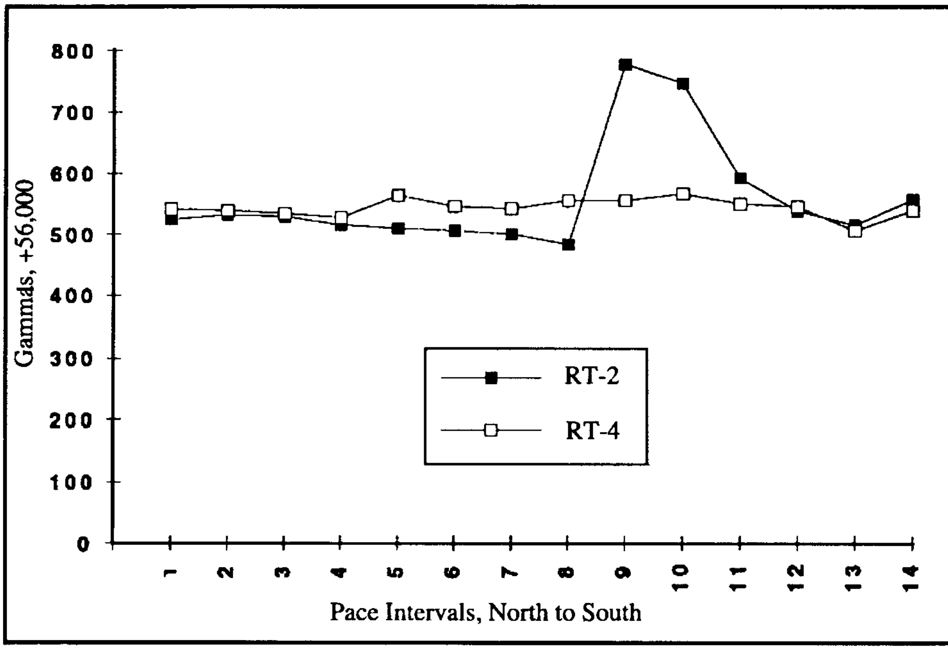

Figure 9. Magnetic anomaly across diabase dike RT-2, traversed along the road ditch . A similar traverse across trachyte dike RT-4 reveals no anomaly.

Turn right, away from Rte.7 to follow gravel road along the Mill River, to East Clarendon.

52.3 miles. Turn right at stop sign.

52.8 miles. Turn right (southeast) onto Rte. 103.

53.9 miles. Turn left onto Maplecrest Farm Road. Go uphill, eastward.

54.6 miles. Bear left at intersection.

54.7 miles. Bear right at intersection.

54.8 miles. Stop along road near edge of woods to your right (east). Outcrops are low rock mounds in the woods.

STOP 9. SHREWSBURY INTRUSIVE BRECCIA.

This site is on private property of Mr. Arthur Pierce, whose residence is at the last intersection. Please do not damage the fence or other property.

The map by Brace (1953) shows this breccia and a few others to the southeast in vague ovals, because exposure is poor. It was certainly a violent intrusion, full of clasts of local metamorphic rocks of the Grenvillian Mt. Holly complex, and there may be several "pipes" as the true forms of the intrusions. This site provided samples for Paul Doss (1986), who cataloged many of the lithologies within the breccia. Doss (1986) looked especially for sedimentary clasts of the Champlain Valley sequence, which would prove an overthrust relationship of the western Green Mountains, but none were identified.

The dike matrix is fairly fresh in a few places between xenoliths, and has a very volcanic, andesitic look in thin section. The date of 101 Ma (Table 1) is reasonable and indicates little contamination by K or Ar from the country rocks.

Turn around, head back to Rte. 103.

55.8 miles. Turn left (southeast) onto Rte. 103.

59.3 miles. Pull into Ford dealer lot on right, park in the back, away from dealer stock. We will walk south about 150 meters along the Mill River, if conditions permit (low water is helpful).

STOP 10. CUTTINGSVILLE QUARTZ SYENITE.

Observe the good exposures of biotite quartz syenite of the Cuttingsville complex. The Mill River cuts about 2 km southward from here through the complex, also exposing members and contacts of essexite, non-quartz syenite, and petrographical varieties. The juxtoposition of nepheline syenite with quartz syenite is an interesting problem in several plutons of New England. Probably, the quartz-bearing magmas were formed by interaction with crustal rocks, while the Si-poor magmas are closer to differentiates of mantle magmas. We see a similarity with the quartz-bearing trachytes, which are chemically like the Cuttingsville quartz syenite (Table 2), keeping company with analcite-bearing lamprophyres. Although no grabbroic analog of lamprophyre is exposed at Cuttingsville, there is a strong magnetic anomaly over the stock which indicates a mass of gabbro beneath the felsic phanerites.

McHone and Wagener (1982) report 15.5 ppm U3O8 and 105 ppm eTh for syenite in this area. This is higher than most "primary" values even for alkalic rocks, and may be effected by the hydrothermal enrichment of ore minerals that is evident here. The sulfide enrichment of the syenite is evident in the streambank, and a large mass of iron-copper sulfides ("copperas") was once mined on the hillside to the northeast. A tunnel is still present on the hillside above the river, no doubt a prospect for metals. Good crystals of pyrite and quartz are easy to find along this stop, at least during low water. Even more interesting may be the native gold that Robinson (1990) has described from this area.

End of trip. Return to Burlington via Rte. 7, or if you have lots of time, we suggest continuing southeast on Rte. 103 to intersect Rte. 100 and other scenic roadways.

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