BEST KEPT GEOLOGIC SECRETS OF THE ADIRONDACKS AND CHAMPLAIN VALLEY

by
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INTRODUCTION

Finding clear, well-exposed field locations to help illustrate important aspects of petrology and structural geology to undergraduate students can be a challenge for a professor. In this field trip, we will visit the following four field stops in the Adirondack Mountains and Champlain Valley that are routinely used in my classes: the Cannon Point intrusive south of Essex; the Craig Harbor faultline scarp in Port Henry; the intrusion breccia in Roaring Brook on Giant Mt.; and Split Rock Falls crackle zone south of New Russia. In structural geology, the class works on field exercises that illustrate normal faulting at Craig Harbor and different orientations of joint sets at Split Rock Falls. Petrology students compare Proterozoic anorthosite containing xenoliths of metasedimentary rocks from the Roaring Brook intrusion breccia on Giant Mt. with a Cretaceous laccolith of trachyte porphyry on the shore of Lake Champlain. All of these outcrops are easily accessible and provide excellent opportunities for experiential learning.

REGIONAL GEOLOGY

Summary

The Adirondack Mountains are a regionally elevated exposure of Grenville age (ca. 1.0-1.35 Ga; McLelland et al., 1988; McLelland and Chiarenzelli, 1990; Mezger et al., 1991; McLelland et al., 1996) high-grade metamorphic rocks in northern New York state. This field trip will examine granulite-facies metaplutonic rocks (McLelland and Isachsen, 1986) in the Adirondack Highlands which comprise the central and eastern portions of the massif. An abrupt transition in topography occurs between the Adirondack Highlands and the Lake Champlain Valley between New York and Vermont with local relief along Lake Champlain varying from ~170 to 370 m. The flatter terrain of the Champlain Valley in New York is composed of Paleozoic sedimentary rocks ranging in age from Cambrian Potsdam Sandstone through Ordovician carbonates of the Trenton Group (Fisher, 1968; Isachsen and Fisher, 1970). Both the Proterozoic metamorphic rocks and Paleozoic sediments are intruded by Early Cretaceous (105-146 Ma) alkalic plutons and dikes throughout northeastern New York, northern New England and southern Quebec (McHone and McHone, 1999). In this field trip, outcrops of Precambrian anorthosite, gneiss, metagabbro and marble, Paleozoic carbonates and a Cretaceous trachyte porphyry will be visited (Figure 1).

Proterozoic Metamorphic and Paleozoic Carbonate Rocks

Roaring Brook Intrusion Breccia. Giant Mt. is composed dominantly of Proterozoic anorthosite and gabbroic anorthosite (Jaffee and Jaffee, 1986; Whitney et al., 1989). Apatite fission-track (AFT) ages of 168-83 Ma (standard error of ~± 10 % of AFT age) for Proterozoic crystalline rocks from the Adirondack Mountains indicate unroofing in this region occurred from Late Jurassic to Early Cretaceous. The High Peaks region of the Adirondacks yielded the oldest AFT ages ranging from ~140-170 Ma. This indicates that the High Peaks area was the first part of the Adirondacks to become unroofed in the Late Jurassic. An anorthosite sample from the southeast side of Giant Mt. at 2800 ft. elevation yielded an AFT age of 135 Ma (Roden-Tice et al., 2000).

From Roaring Brook Falls on the southwest side of the Giant Mt., a stop on the trail to the intrusion breccia, a beautiful view of the Great Range in the High Peaks of the Adirondacks can be obtained. Several varieties of anorthosite, anorthositic gabbro, and leuconorite showing mutually cross-cutting relationships suggesting multiple intrusions outcrop within and near the brook (Whitney et al., 1989).

Farther up Roaring Brook trail and after bushwhacking up Roaring Brook to a few hundred feet above the 2260 ft. level, a spectacular intrusion breccia is exposed (Kemp, 1920; deWaard, 1970; Jaffee and Jaffee, 1986; Whitney et al., 1989). The intrusion breccia crops out in large pavement outcrops in the stream bed. Jaffee and Jaffee (1986) describe the exposure as containing numerous blocks of angular, dark gray, fine-grained rocks that are completely embayed and surrounded by coarse-grained pink rock composed of mainly blue plagioclase and abundant garnet.

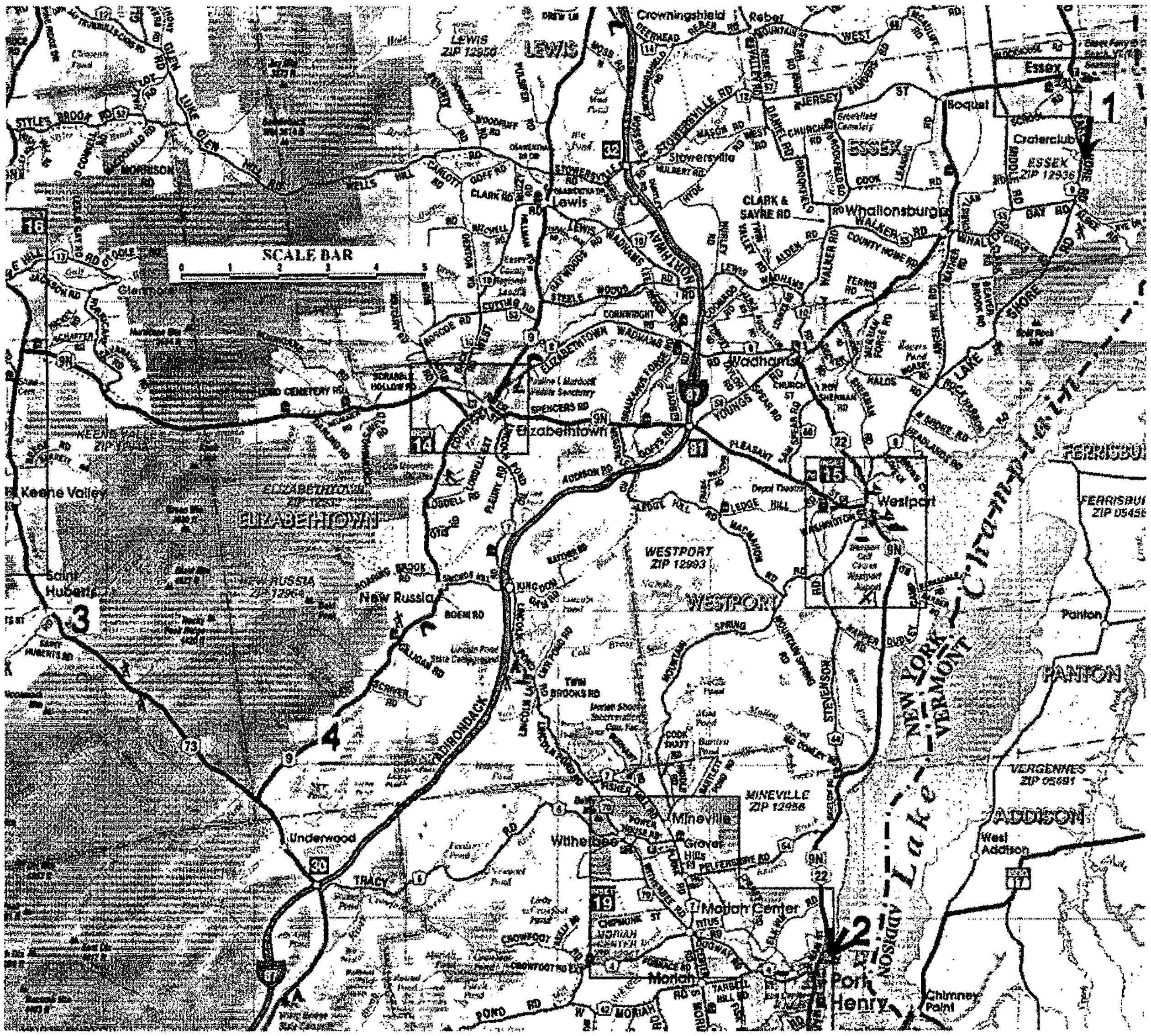

Figure 1. Field trip route map showing the locations of stops 1-4.

The blocks are xenoliths of Grenville rock that has been previously deformed and rotated and is compositionally metasedimentary and mafic granulite (Figure 2; Whitney et al., 1989).

The metasedimentary xenoliths are in general fine-grained, equigranular, diopside-K-feldspar-plagioclase-quartz rocks which show fine-scale (mm) laminations that may represent sedimentary layering or perhaps, foliation (Whitney et al., 1989). The host rock is anorthositic metagabbro ranging in composition to mafic mangerite and jotunite and is stained pink as a result of oxidation of abundant iron-rich pyroxenes (Whitney et al., 1989; Jaffee and Jaffee, 1986). It contains plagioclase, two pyroxenes, Fe-Ti oxides, garnet (as discrete grains and as garnet-plagioclase symplectites around oxides), hornblende, and K-feldspar, with minor quartz and apatite (Whitney et al., 1989). Jaffee and Jaffee (1986) describe clots and veins of black to blue-green pyroxenes and pearly white K-feldspar that occur throughout the anorthositic gabbro. The intrusion breccia is reported to extend intermittently to nearly the summit of Giant Mountain (Kemp, 1920; deWaard, 1970; Jaffee and Jaffee, 1986).

The intrusion breccia is an excellent locality for petrology students to interpret intrusive and cross-cutting relationships. It also underscores the complexity of Adirondack geology and structure. From the vantage point of

Roaring Brook Falls, the Mesozoic unroofing history of the Adirondacks (Roden-Tice et al., 2000) can be discussed and evidence for ongoing Adirondack uplift (Isachsen, 1975; 1981) presented.

Figure 2. Metasedimentary xenolith in gabbroic anorthosite at Roaring Brook intrusion breccia.

Split Rock Falls: Zero-Displacement Crackle Zone. Split Rock Falls is located on the Boquet River lineament which is one of a major set of NNE-trending faults and linear valleys that dominate the topography of the southeastern Adirondacks (Figure 3; Isachsen et al., 1983). The lineaments have been interpreted to be the result of two kinds of brittle deformation: 1) high-angle normal faults and 2) "zero-displacement crackle zones" (ZDCZs) (Isachsen et al., 1983). ZDCZs are defined as intensely fractured rocks that differ from faults because they lack throughgoing shear planes or visible offsets and from joints in having an extremely diverse array of fracture directions (Isachsen et al., 1983; Whitney et al., 1989).

An anorthosite sample from the upper falls yielded an AFT age of 102 Ma (Gaudette et al., 2001) indicating the unroofing in this area occurred significantly later than in the High Peaks region of the Adirondacks. A trend of Early to Late Cretaceous AFT ages (~120-80 Ma) exists for all of the southeastern Adirondacks and across the Lake Champlain Valley into western Vermont (Gaudette et al., 2001; Roden-Tice et al., 2001).

The outcrop on the west side of Rt. 9 across from Split Rock Falls shows strongly foliated gabbroic anorthosite containing inclusions of unfoliated coarse-grained anorthosite and plagioclase megacrysts and is cross-cut by two thin basaltic dikes. A large slickensided surface is exposed at the southwestern end of the outcrop.

Whitney et al. (1989) describe the Boquet River lineament at Split Rock Falls as a NE-trending zone of right-stepping, en echelon segments measuring about 200 m in length. The segments are stepped 20-80 m apart along N30W and N60W connecting segments that are usually unexposed. The crackle zone segments are 5 to 15 m wide and occur in a 45-100 m zone of fracturing. The segments trend N30E and dips vary from 80°NW to 80°SE. Whitney et al. (1989) also state that late faults, striking N50E to N80E, cross the crackle zone but do not show any topographic expression.

Wiener and Isachsen (1987) measured attitudes and spacings of all fractures longer than 10 cm along two-meter wide traverses spaced 200 m apart. When plotted on stereonet diagrams, variations in fracture geometry across the crackle zone from anastomosing, to planar-parallel, and planar-intersecting types can be seen. Closely-spaced, steeply-dipping fractures within the crackle zone increase in diversity of strikes, dips and curvature towards the center of the zone. Whitney et al. (1989) state that because the fractures parallel the regional joint system that the aligned microcracks formed during regional jointing. Isachsen et al. (1983) suggest that these crackle zones are tension features that form at shallow depths resulting from crustal extension over a rising elongate dome. Crackle zones may form at shallow crustal levels while tensional fractures form at the surface.

Split Rock Falls ZDCZ provides an opportunity for structural geology students to collect attitude measurements on the different planar orientations present in the crackle zone (Figure 4) and make a density plot of the data. Each student takes 20 measurements from different parts of the upper and lower falls and shares their data with the rest of the class. From this complied data, each student makes a density plot of all the data on a Schmidt stereonet as poles to planes. This density plot is then used to make a contour diagram of the fracture orientations with a Kalsbeek counting grid. The exercise combines field skills with statistical presentation of data. It also allows the students to interpret the dominant paleostress directions in the crackle zone.

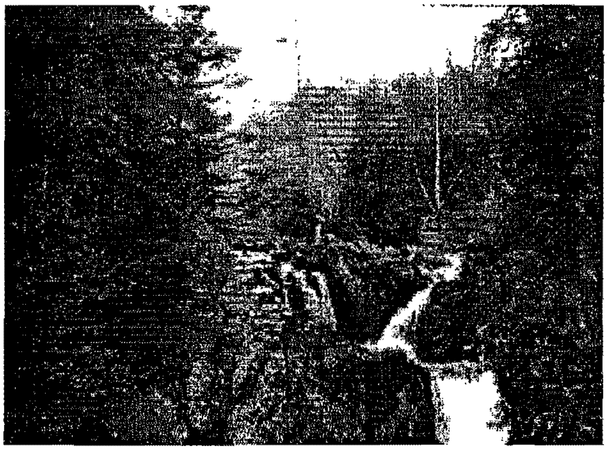

Figure 3. Split Rock Falls: Zero displacement crackle zone.

Figure 4. Measuring fracture attitudes at Split Rock Falls.

Craig Harbor Faultline Scarp. McHone (1987) provides an excellent description of the Craig Harbor locality on Lake Champlain in Port Henry, New York. The exposures include complicated field relations of Proterozoic marbles and calc-silicates, older basement granitic gneisses, lenses of metagabbro, a magnetite ore body, part of the Paleozoic carbonate shelf sequence and a large-scale normal fault that juxtaposes Paleozoic and Precambrian rocks.

The northern wall of Craig Harbor, a small embayment now cut off from Lake Champlain by the Delaware and Hudson Railroad, is a 165-ft.-high fault scarp at the north end of the Port Henry fault block which separates the Proterozoic and Paleozoic sections (McHone, 1987). The upper west cliff face, composed of Proterozoic marble, contains amazingly contorted, folded and disrupted lenses of gneiss and calc-silicate (Figure 5). This marble with its inclusions, and high-temperature minerals was first noticed by Emmons (1842) and suggested to be of igneous origin. The marbles have been suggested to be either part of the Paradox Lake Formation (Walton and deWaard, 1963) or above the biotite-quartz-plagioclase Eagle Lake Gneiss (Wiener et al., 1984; McHone, 1987).

Figure 5. Deformed gneiss lens in Proterozoic marble in Craig Harbor faultline scarp.

Below the marble in the cliff face, an orange-weathering hornblende-rich granite gneiss outcrops showing west dipping layers of foliation and a magnetite horizon (Emmons, 1842; Kemp and Ruedemann, 1910; McHone, 1987). A sample of this gneiss yielded an AFT age of 123 Ma which is slightly higher than but within analytical error of AFT age of the Split Rock Falls sample (102 Ma) but significantly lower than AFT ages from the High Peaks region which range from ~140-170 Ma (Roden-Tice et al., 2000).

North along the railroad tracks, the contact between dark, fine-grained granular metagabbro composed of altered plagioclase, brown hornblende, and augite, and the overlying gneiss containing hypersthene, augite, hornblende, microcline and plagioclase is exposed (McHone, 1987). Farther north, the metagabbro becomes coarser with an ophitic texture and contains coronas of garnet, brown hornblende, biotite, and clear plagioclase surrounding cores of magnetite, augite or hypersthene (Kemp, 1894, 1920; Gillson et al., 1928; McHone, 1987). P-T conditions of 8 kb and 800°C (granulite facies) were estimated for similar corona textures from other Adirondack metagabbros by Whitney and McLelland (1975) and McLelland and Whitney (1980).

A small magnetite prospect is located in the gneiss above the metagabbro. The deposit was known before the 1840s but was not worked because the ore is unusually high in sulfur and especially titanium which made it difficult to work with in the early forges (McHone, 1987).

South of Craig Harbor along the railroad tracks, the Cambrian Ticonderoga Dolostone and Ordovician Whitehall Dolostone are well-exposed and have an estimated thickness of 800 ft. (McHone, 1987). The uniform, "dove-colored", Ordovician Whitehall Dolostone is the first unit exposed in the cliffs south along Lake Champlain. It is a lower unit of the Beekmantown Group and is about 300 ft. thick with dips to the northeast (Welby, 1961). An inferred fault through a swale separates the Whitehall Dolostone outcrops from those of the Cambrian Ticonderoga Dolostone (Kemp and Ruedemann, 1910). The Ticonderoga Dolostone is sandy, characterized by crossbedding, channel depressions and blue-black chert layers and nodules and shows low easterly dips in its layers (McHone, 1987). The swale once contained a crushing mill and a quarry that once produced carbonate flux material for the local iron industry (McHone, 1987).

The timing of faulting is not well established but at Craig Harbor has to postdate the Lower Ordovician Whitehall Dolostone. Comparable high-angle faults occur throughout the southeastern Adirondack Mountains, Lake Champlain Valley of New York and Vermont, and the St. Lawrence River Valley of Quebec (McHone, 1987; Quinn, 1933; Welby, 1961; Stanley, 1980). Reactivation of Adirondack border faults, such as the McGregor fault system located about 80 km south of Craig Harbor near Wilton, New York, has been suggested in the Late Precambrian, Paleozoic and possibly Holocene (McHone, 1987; Willems et al., 1983; Isachsen et al., 1983). Evidence for Late Mesozoic reactivation of faulting in the Champlain Valley has been shown by cross-cutting relationships with Early Cretaceous alkalic intrusions in Vermont (McHone, 1978; Stanley, 1980). Early to Late Cretaceous igneous activity and fault reactivation in the Champlain Valley and perhaps along Adirondack border faults may help explain the younger (80-120 Ma) AFT ages in the southeastern Adirondacks and Champlain Valley indicating more recent unroofing than those determined for the High Peaks region of the Adirondacks (140-170 Ma; Roden-Tice et al., 2000; Roden-Tice et al., 2001).

Craig Harbor is a superb field location for an undergraduate structural geology exercise. First, the students describe and make attitude measurements on the Paleozoic carbonates along the railroad tracks south of Craig Harbor. They learn to distinguish the two dolomite formations based on their sedimentary characterisitics and infer the normal fault that juxtaposes the formations. Then, the students examine the gneisses and metagabbro north of Craig Harbor and interpret the normal fault that brings these Proterozoic metamorphics in contact with the Paleozoic carbonates. Finally, the students are confronted with the marble containing deformed inclusions of gneiss, metagabbro and calc-silicates in the cliff along the faultline scarp (Figure 6). They are often awestruck by the deformation shown by the inclusions and spend a great deal of time in discussion on how this outcrop could have formed. Craig Harbor provides a great backdrop for a thought-provoking field lab on the P-T conditions and depths necessary in the Precambrian to produce the deformation now seen at the Earth's surface.

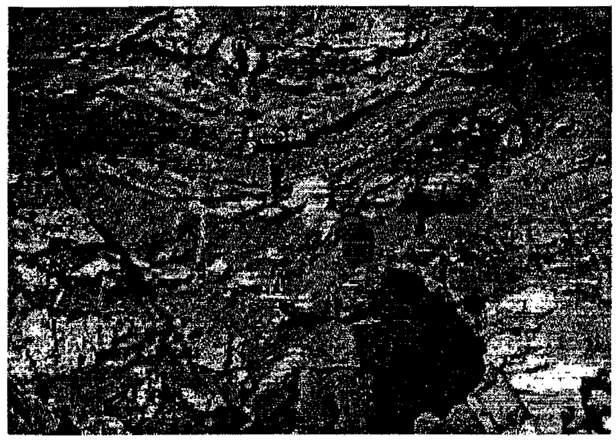

Figure 6. Variety of deformed inclusions in Proterozoic marble at Craig Harbor faultline scarp.

Mesozoic Intrusive Rocks

Cannon Point Intrusive. At Cannon Point on Lake Champlain, a laccolith trachyte porphyry sheet with interlayers of shale outcrops along the lake shore for ~.75 mi. and extends ~.5 mi eastward underneath a private camp known as the Crater Club (Figure 7; Buddington and Whitcomb, 1941). The laccolith intrudes upper Middle Ordovician Canajoharie Shale and is conformable with the bedding. The trachytic rocks were classified as bostonite (trachyte having felty clumps of alkali feldspar apparent only in thin section; McHone and Mc Hone, 1999) by Kemp and Marsters (1893) based on occurrence, trachytic texture and leucocratic characteristics.

The Cannon Point trachyte porphyry has a distinctive pinkish-brown color in outcrop and is porphyritic containing large K-feldspar phenocrysts approximately 2-5 mm in length (Buddington and Whitcomb, 1941). In thin section, the euhedral K-feldspar phenocrysts and laths in the groundmass show a crude trachytic flow texture. Plagioclase phenocrysts are present but rare (Buddington and Whitcomb, 1941). Kemp and Marsters (1893) determined the K-feldspar to be primarily anorthoclase which makes the Cannon Point trachyte porphyry similar in composition to Early Cretaceous trachytes in Vermont. They also found approximately 10% interstitial quartz in the groundmass, some of which was in micrographic intergrowth with K-feldspar, trace amounts of zircon, magnetite, and apatite but no other primary mafics.

In outcrop, the Cannon Point laccolith shows conformable relations with the Canajoharie Shale and locally contains thin included layers of shale and injected apophyses up to 2 ft. in length into the shale (Figures 8 and 9). The intrusive weathers with a platy structure that is parallel to the bedding and flow structure (Buddington and Whitcomb, 1941). The laccolith sheet strikes N60W and dips gently to the north (Buddington and Whitcomb, 1941). The lowest section of the intrusive is exposed ~0.4 mi. south of Cannon Point and contains rounded inclusions of Paleozoic limestone and Potsdam sandstone. To the west beyond the outcrops in the Crater Club, the laccolith is covered by overburden. Buddington and Whitcomb (1941) speculated that a lack of surface float from the laccolith in this vicinity suggested that the intrusive either pinches out or is cut off by faulting. The upper part of the intrusive at ~0.3 mi. north of Cannon Point is 5 ft. thick and weathers to a pale buff color. It has a dense texture and the phenocrysts are small and sparse (Figure 7).

Figure 7. Northern end of the Cannon Point trachyte porphyry laccolith on Lake Champlain.

Figure 8. Cannon Point laccolith with Canajoharie shale layer included.

An estimate of the crystallization age of the Cannon Point laccolith can be obtained from partial Rb-Sr data collected by Fisher (1968) which suggests an age of "less than 140 Ma" (McHone and McHone, 1999). This data fits a whole-rock Rb-Sr isochron of 125 ± 5 Ma detemined for seven trachyte dikes from the Burlington area (McHone and Corneille, 1980). No AFT age was determined for the Cannon Point intrusive. However, an Early Cretaceous camptonite dike located about 10 miles north of Cannon Point on Willsboro Point on Lake Champlain yielded an AFT age of 116 Ma (Roden-Tice et al., 2000). This is consistent with K-Ar ages of 113, 123, 127 Ma for camptonite dikes from the eastern Adirondacks determined by Isachsen and Seiderman (1985). The similarity between the K-Ar crystallization ages and AFT ages suggests that the Early Cretaceous intrusives in the Champlain Valley and eastern Adirondacks were emplaced at shallow levels (~3-4 km depth) and temperatures < 100°C (closure temperature for fission-track retention in apatite). Eby (1984) concluded a similar shallow intrusion depth for the Monteregian Hills in southern Quebec because their AFT ages were comparable to their Rb-Sr crystallization ages (~120 Ma).

The Cannon Point laccolith shows excellent examples of contact relationships between a conformable intrusive and the shale country rock such as baked zones, apophyses, and included layers of shale (Figures 8 and 9). Its large size (~1 square mi in area) is also impressive to petrology students who are used to seeing small dikes that are only a few feet wide at most. Standing on the shore of Lake Champlain, the instructor can point across the lake to the Early Cretaceous Barber Hill syenite stock at Charlotte, Vermont which forms a low hill in the foreground. The Barber Hill stock has been dated by K-Ar as 111 ± 2 Ma on a biotite separate by Armstrong and Stump (1971) and is considered to be cogenetic with trachyte dikes in the Charlotte area (McHone and McHone, 1999). The comparable position of these two large contemporaneous igneous intrusives on opposite sides of the lake plus the abundance of both trachyte and lamprophyre (camptonite and monchiquite) dikes along the lake in both New York and Vermont provides for an interesting discussion on Mesozoic tectonics in this region.

Figure 9. Cannon Point laccolith apophysis in Canajoharie shale country rock.

ROAD LOG

Mileage

Total	by Point	
0	0	Start trip from the parking lot of the Comfort Inn in Plattsburgh. Exit parking lot and turn left (west) on Cornelia St. (Rt. 3)
0.2	0.2	Intersection of Cornelia St. (Rt. 3) and Interstate 87. Turn left onto Interstate 87 south.
18.7	18.5	Take Exit 33 - Willsboro/Essex Ferry. Turn left (east) at end of exit ramp and proceed across overpass and straight through blinking red light on Rt. 22 south to Willsboro.
28.5	10.0	Remain on Rt. 22 through town of Willsboro (cross bridge and turn right).
32.9	4.4	Stop sign/light. Continue straight south through the village of Essex on Essex County Rt. 80.
34.7	1.8	Park along County Rt. 80 where possible. The road is very narrow and winding and has little shoulder. Outcrop is down stairs behind picnic table along Lake Champlain shore opposite large brown house set far back from road (44°15.507, 73°20.924).

STOP 1. CANNON POINT LACCOLITH. (45 Minutes).

This is the north end of the intrusion which is located on private property owned by the Crater Club. We will be walking south along beach at the low water mark. The intrusion is exposed along the shore and beneath private homes. If visiting this outcrop during May through October, permission to access the intrusion should be obtained from the Crater Club and homeowners. We will walk south along the lakeshore through the exposure of the Cannon Point intrusion and observe its contact relationships with the host Canajoharie Shale.

Return to cars and continue south on County Rt. 80 (Lake Shore Rd.).

44.0	9.3	Lake Shore Rd. intersects with Rt. 22. Turn left onto Rt. 22 south into Westport.
44.05	0.05	Turn left again on Rt. 22 and Rt. 9N.
53.4	9.3	Entering Port Henry. Turn left at Craig Harbor Campground sign and proceed down steep hill to the end of the road at the lakeshore (44°3.482', 73°27.227').

STOP 2. CRAIG HARBOR FAULTLINE SCARP. (1.5 Hours).

This is private property but permission to visit the site is easily obtained. The name and address of the owner are given on the posted sign at the entrance. We will begin by walking south along Lake Champlain and the railroad tracks to examine the Paleozoic carbonates. These tracks are used several times a day by both Amtrack passenger and freight trains. Caution and listening for trains is strongly advised. There is generally room to stand safely on the side of the tracks.

After studying the Paleozoic dolostones, we will proceed north along the tracks across Craig Harbor to see the faultline scarp, Proterozoic marble, gneiss, and metagabbro. The faultline scarp is visible just north of Craig Harbor. From the tracks, one can determine that the marble in the cliff has an unusual structure. We will get to look at the marble up close later. Orange-stained, strongly foliated, Proterozoic gneiss is the first rock type encountered along the railroad tracks north of Craig Harbor. A few feet further north, the fault contact between the gneiss and coarse-grained, iron-oxide stained, metagabbro is visible. Further north across from a small railroad cut on the lakeside of the tracks, a rough path disappears uphill into the woods. We will scramble up it and view the magnetite prospect. Be careful of the poison ivy!

After returning to the cars, we will drive a short distance within the campground to one of the campsites that borders the faultline scarp. At this location, there are fantastic exposures of Proterozoic marble with abundant and diverse deformed inclusions. A contact between the Proterozoic marble and the Ordovician Whitehall Dolostone can be seen along the faultline at the west end of the outcrop.

If permission to visit the campsite cannot be obtained, similar spectacular outcrops of marble with deformed inclusions can be seen along the lakeshore by walking north along the railroad tracks from the magnetite mine for about 0.5 mi. The entire site can be accessed from the south by walking along the railroad tracks from the marina south of the dolostone outcrops. Parking is available at the public boat launch in Port Henry. McHone (1987) gives a good description of this route to Craig Harbor.

Return to Rt. 22, turn left (south) and continue south into the village of Port Henry.

54.2	0.8	Stop at Stewart's on left side of road in Port Henry for lunch, drinks or snacks. Return to cars and retrace route north on Rt. 22 (Main St.) down steep hill to Beach Rd. We will have lunch in a village park near the marina on Lake Champlain. After lunch, take Rt. 22 back up steep hill and turn right on Broad St. (Essex County Rt. 4). Proceed west up hill to Moriah.
56.0	1.8	Intersection of County Rts. 4 and 42. Turn right (northwest) and continue on County Rt. 4.
57.4	1.4	Stop sign in Moriah Center at the intersection of County Rt. 4 and Center Rd. (County Rt. 7). Turn right (north) at Old Mine Saloon, cross bridge and then immediately bear left on Essex County Rt. 70 to Witherbee.