1-1-1981

Felsic Volcanic Units in the Boston Area, Massachusetts

Naylor, Richard S.

FELSIC VOLCANIC UNITS IN THE BOSTON AREA, MASSACHUSETTS

Richard S. Naylor
Earth Sciences Department
Northeastern University

INTRODUCTION

Felsic volcanic rocks are widely exposed in the Boston, Massachusetts, area. The Middlesex Fells Volcanics and the Lynn Volcanics occur to the north. The Mattapan Volcanics are exposed in the western and southern parts of the Boston Basin. The Blue Hills Volcanics (sometimes mapped as Mattapan Volcanics) crop out in the Blue Hills highlands south of Boston. The rocks are highly compacted and pervasively recrystallized, but they display numerous primary volcanic structures and textures and are nowhere metamorphosed to higher than chlorite grade. The rock units are well described in the references cited. This paper is concerned chiefly with a discussion of the age relationships, and is based substantially on two Masters' theses, Sayer (1974) and Zarrow (1978), supervised by the author.

Kaye and Zartman (1980) report a zircon age of 570 m.yr. from the Mattapan Volcanics. They interpret this as indicating a Late Precambrian age for the Mattapan Volcanics, and suggest on the basis of field relationships that other felsic volcanics in the Boston area may be similarly old. Following Zarrow (1978) the author will argue that the Lynn Volcanics at Pine Hill (Stop 4) are Precambrian, and will suggest the same for the Blue Hills Volcanics. Before 1976 most geologists accepted the interpretation that the felsic volcanics were Carboniferous (Emerson, 1917; Billings 1929), although LaForge (1932) and Naylor and Sayer (1976) had suggested the volcanics might be as old as Silvro-Devonian.

BLUE HILLS AREA

Stops 1 through 3 will show relationships typical of those used to establish the relative ages of rock units south of the Boston Basin. The author believes the sequence of units is as follows:

Wamsutta Formation (Carboniferous)
Blue Hills Porphyry = Quincy Granite (Ordovician)
Braintree Argillite (Middle Cambrian)
Blue Hills Volcanics (?Late Precambrian).

The Wamsutta Formation and Braintree Argillite are reliably dated by well-preserved fossils. The Quincy Granite has been dated at 430 to 460 m.yr. by Zartman (1977; U-Th-Pb zircon data). (Naylor and Sayer (1976) argued that earlier zircon data could be consistent with a Silvro-Devonian age for the Quincy Granite. Zartman (1977) reports new analyses with improved precision, and the author agrees with his conclusion that the Quincy Granite is most probably an Ordovician intrusive.)

Warren (1913) demonstrated that the Quincy Granite and the Blue Hills Porphyry are closely similar in mineralogy and major element chemical composition. This is unlikely to be coincidental inasmuch as the chemistry of both is distinctively alkalic and the modes of both include distinctive minerals like riebeckite, fluorite, and astrophyllite. Sayer (1974) demonstrated that the two units also yielded distinctively similar rare earth element "fingerprints." The two units are almost certainly co-magmatic and for the most part, the Blue Hills Porphyry can be considered as a finely-crystalline border phase of the Quincy Granite. Bottino and others (1970) published an Rb/Sr whole-rock isochron for the Blue Hills Porphyry with an age of 282 $\pm$ 8 m.yr. Sayer (1974) and Naylor and Sayer (1976) argue that the isochron age is anomalously young, and does not comprise a strong argument for a Blue Hills Porphyry younger than the Quincy Granite.

The contact between the Carboniferous Wamsutta Formation and the Blue Hills Porphyry is best exposed at Stop 1. Following Sayer (1974) and Naylor and Sayer (1976) the author concludes that the Wamsutta Formation rests nonconformably on an older Blue Hills Porphyry. The contact is not a simple one, however, and has been variously interpreted in the past. (In a group visit it is instructive to see how many alternatives can be entertained!)

Stop 2 displays porphyritic rocks that are clearly intrusive into and younger than the Middle Cambrian Braintree Argillite. The locality is very close to the main body of the Quincy Granite, and although the dike rocks are not typical of the Quincy Granite, relationships such as these are widely accepted as demonstrating that the Quincy is younger than the Braintree Argillite. The relationships described in these two paragraphs are consistent with the present fossil and isotopic dates.

The relationship of the Blue Hills Volcanics to the other units is less reliably established. Warren (1913) and most subsequent geologists have concluded that the Blue Hills Volcanics are older than the Blue Hills Porphyry and Quincy Granite. Stop 3, where the volcanics can be interpreted as screens enclosed in the porphyry, shows relationships typical of those on which this conclusion is based. Most workers have tacitly assumed that the volcanics are closely related to the granite and porphyry -- all three units comprising the "Blue Hills Igneous Complex."

If other felsic volcanics in the Boston area are as old as Precambrian, the author knows of no reason why the Blue Hills Volcanics cannot also be Precambrian. Chute (1969), who is responsible for the primary mapping of the Blue Hills could find no distinction between the Mattapan and Blue Hills Volcanics and mapped both as Mattapan. The Blue Hills Volcanics do not have the distinctive mineralogy or alkalic chemistry of the Quincy Granite and Blue Hills Porphyry, hence there is no proof of correlation with those units. The direct relationships demonstrate that the Braintree Argillite and the Blue Hills Volcanics are both older than the Quincy Granite, but do not prove which of the two is the older. It seems entirely possible that the Blue Hills Volcanics are Precambrian country rock intruded by, but genetically unrelated to, the Quincy Granite.

PINE HILL AREA

The Fells Upland is separated from the Boston Basin to the south by the Northern Border Fault. The fault dips to the north. Along it older, mostly igneous rocks of the Fells Upland have thrust upward and southward over the predominantly sedimentary rocks of the Boston Basin. The major rock units of the Fells Upland are the Dedham Granodiorite, the Middlesex Fells Volcanics, and the Westboro Quartzite. The Dedham Granodiorite has been dated as Late Precambrian (Kovach, and others, 1977; Zartman and Naylor, in press), and intrudes the Middlesex Fells Volcanics and Westboro Quartzite.

The Pine Hill area, Stop 4, lies in the Fells Upland immediately north of the border fualt. The Dedham Granodiorite is well exposed there, but the main body of the Middlesex Fells Volcanics lies further north. A dismembered screen of Westboro Quartzite is exposed in a string of xenoliths within the Dedham Granodiorite at Pine Hill. From Pine Hill eastward, a unit of felsic volcanics, the Lynn Volcanics, crops out between the Precambrian terraine described above and the border fault. The age of the Lynn Volcanics has been a subject of controversy, and is discussed in the remainder of this section.

Most geologists have adhered to the conclusion of Emerson (1917) and Billings (1929) that the Lynn Volcanics are Carboniferous. Others, including LaForge (1932) and Naylor and Sayer (1976) have suggested that the Lynn Volcanics correlate with intermediate and felsic volcanics of Silurian and Early Devonian age that are widespread to the northeast (Newbury Volcanics and the Coastal Volcanic Belt in Maine). In either case, the contact between the Dedham Granodiorite and the Lynn Volcanics from Pine Hill eastwards was interpreted as an unconformity with the younger volcanics resting on an eroded surface on the older plutonic rokcs. Zarrow (1978) remapped the Pine Hill area and concluded that the Lynn Volcanics there are intruded by the Dedham Granodiorite and are therefore also part of the Precambrian terraine. Her arguments are discussed below and may be demonstrated at Stop 4.

Internal Stratigraphy.

Zarrow (1978) was able to distinguish three local members within the Lynn Volcanics at Pine Hill (Figure 1). From east to west they are:

Pine Flow Member: pale grey-red to grey-green, uniform aphanitic matrix with abundant phenocrysts of quartz, K-feldspar, and plagioclase. Mafic minerals comprise about 2% of the rock and are conspicuous in hand specimens. The rock is locally brecciated, but xenoliths of other rocks are lacking.

Tower Member: dark grey aphanitic matrix with quartz and feldspar phenocrysts locally abundant. Xenoliths are locally abundant and are a distinguishing feature of the member. Some are probably altered, flattened pumice fragments; others appear to be xenoliths of volcanic material and of orthoquartzite. Banding is prominant around some of the xenoliths.

Mud Road Member: dark grey to dark grey-brown aphanitic matrix with phenocrysts of plagioclase, K-feldspar, and quartz. Near the granodiorite the matrix is strongly recrystallized and on some weathered surfaces the rock is hard to distinguish in hand specimen from the Dedham.

As shown in Figure 1, the contacts between the units are irregular. They do not appear to be conformable to the contact with the granodiorite. Rather, it seems more likely that they strike into the Dedham Granodiorite and were truncated by its intrusion.

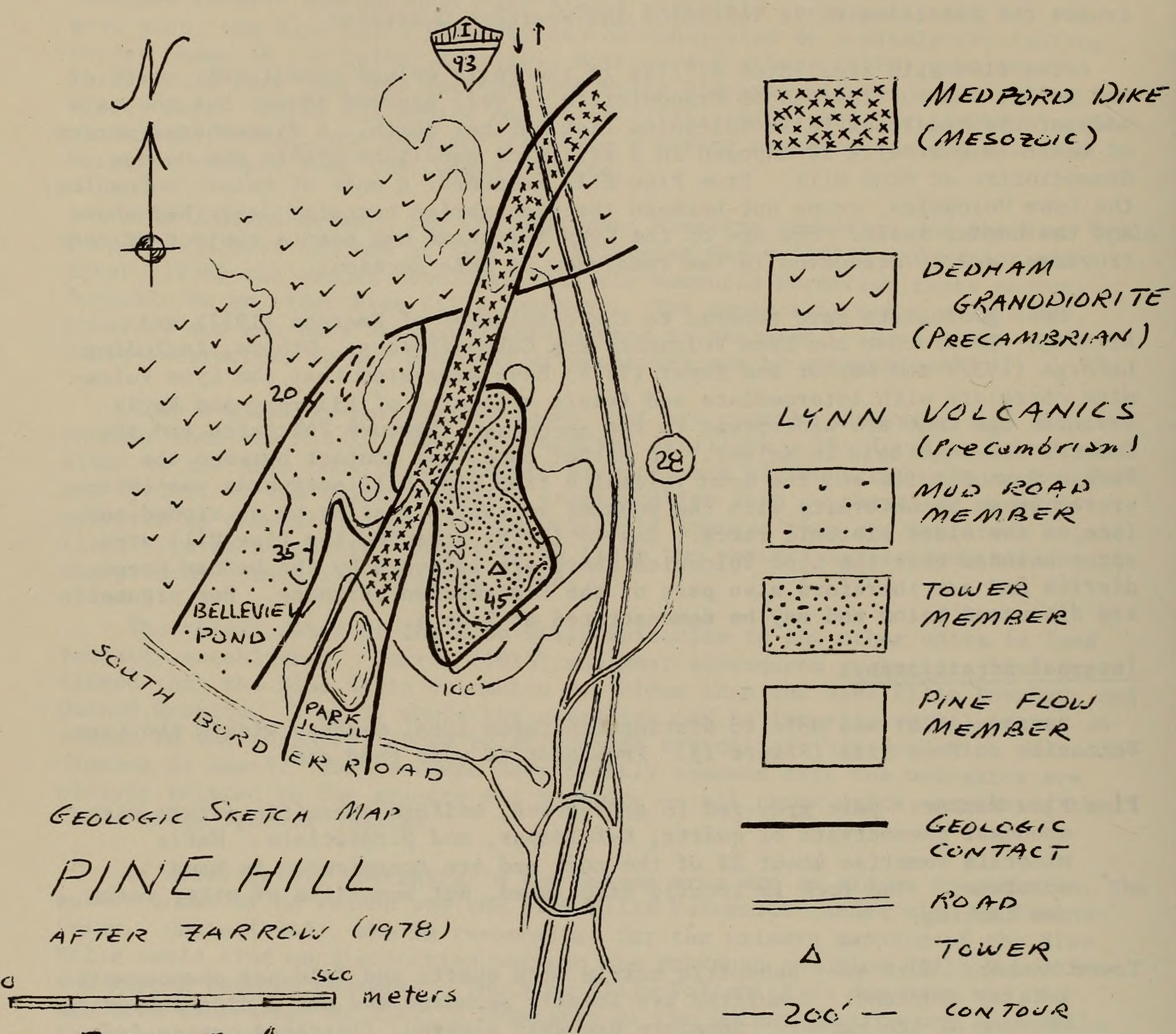

FIGURE 1

Xenoliths in the Dedham Granodiorite

Xenoliths, ranging up to several meters across are common in the Dedham Granodiorite at Pine Hill. Most of the xenoliths are very fine-grained and most contain quartz as a very conspicuous mineral. Many of the xenoliths are of orthoquartzite. A string of these xenoliths north of Pine Hill may be a dismemebered screen of Westboro Quartzite. Thin section study shows that about half of the xenoliths are of felsite -- slightly more recrystallized, but otherwise similar to the Lynn Volcanics. Since most of the felsites contain abundant quartz in both matrix and phenocrysts, quartz is very conspicuous in the felsic xenoliths. When viewed as lichen-covered outcrops in the dark woods it is very hard to distinguish the xenoliths of felsite from those of orthoquartzite, but the eye can be trained to do this by practicing on xenoliths that have been identified in thin section. No clasts of granodiorite have been identified in the Lynn Volcanics.

Zarrow (1978) and the author interpret the felsic xenoliths as xenoliths of older Lynn Volcanics in a younger, intrusive Dedham Granodiorite.

Contact Relationships

The contact between the granodiorite and the volcanics dips 20 to 40 degrees NW. It would thus have to be strongly overturned if the Lynn Volcanics were interpreted as a younger unit resting unconformably on the Dedham. As the contact is approached, the Dedham Granodiorite becomes locally more finely crystalline (chilling?) and the Lynn Volcanics become more coarsely crystalline (contact metamorphism?). Northwest of Pine Hill is a possible dike of fine-grained granite penetrating the Lynn Volcanics.

All of these relationships seem more plausible if the Lynn Volcanics at Pine Hill are an older unit intruded by a younger Dedham Granodiorite. Given the age of the Dedham, the Lynn Volcanics at Pine Hill must be no younger than Late Precambrian.

Trace Element Studies

Zarrow (1978) studied the trace element distribution in samples of the Lynn Volcanics and Dedham Granodiorite at Pine Hill. Samples were analyzed for comparison from the Middlesex Fells Volcanics, the Mattapan Volcanics, and the Newburg (Silurian) Volcanics. Among her conclusions are the following:

1) All but one of the samples show "normal" granitic rare earth element (REE) distributions -- enrichment by 100 to 200 in La dropping with increasing atomic number but leveling off at 10 to 20 for the heavy REE (Tb to Lu).

   The exception was the Middlesex Fells sample which showed a flat (little fractionated) enrichment of about 25 across the REE spectrum. This sample, with a color index of 20, is more mafic than the others.

2) Using both major and trace element data it is possible to construct "liquid descent" models relating the Lynn Volcanics and the Dedham Granodiorite.

3) Three samples from the Pine Flow Member showed REE "fingerprints" that were identical within experimental error. The Mud Road Member shows distinctly greater enrichments and more variability between samples but has an REE pattern similar in shape to the Pine Flow samples. Differences in the REE data correlate with the criteria used to distinguish the two units in the field.

4) One felsic xenolith from the Dedham Granodiorite at Pine Hill was analyzed. It yielded an REE "fingerprint" identical to that of one of the Mud Road samples and identical to the Pine Flow samples except for slightly less depletion of Eu.

5) Of the comparison samples, the Mattapan Volcanics showed an REE pattern identical to the Pine Flow Member. The Newbury Volcanic sample was similar but showed much greater Eu depletion.

6) The REE pattern for the Lynn and Mattapan samples are very different from the pattern determined for the Quincy Granite (Buma and others, 1971) and the Blue Hills Porphyry (Sayer, 1974).

AGE OF THE BOSTON BAY GROUP

The Roxbury Conglomerate and Cambridge Argillite are the major formations in the Boston Bay Group. To the south, the Cambridge overlies the Roxbury and the two units are separated by the Squantum "Tillite". To the north, the Cambridge appears to interfinger with the Roxbury. Some volcanics (mostly mafic) interfinger with basal Roxbury Conglomerate. At most localities where the base of the Roxbury is exposed, the Roxbury rests unconformably on felsic volcanics or on Dedham Granodiorite. Following the determination by Bailey and Newman (1978) that the "Roxbury tree trunk fossils" are most probably sandstone dikes, no fossils are recognized from the Boston Bay Group. This means that the age must be determined indirectly.

Given the unconformities at its base, the Boston Bay Group cannot be older than the felsic volcanics and the Dedham Granodiorite. Emerson's (1917) assignment of an Acadian age to the Dedham is a major reason why the Boston Bay Group has conventionally been dated as Carboniferous. Proximity to the well-dated Norfolk and Narraganset Basins of Carboniferous age has also been a factor in this assignment, as were attempts to date the now-discredited "Roxbury tree-trunk fossils," but the sedimentary facies of the Boston Basin are not notably similar to those of the other basins. Billings (1929) lowered the age of the Dedham Granodiorite to Precambrian (eventually confirmed by isotopic dates), but did not regard this as cause to question the age of the overlying units. Naylor and Sayer (1976) suggested that the felsic volcanics might be Siluro-Devonian (correlation with the Newbury Volcanics and with the volcanics of the Maine Coastal Belt), and noted this would allow the Boston Bay Group to be as old as Devonian.

At present, the author knows of no proof that any of the felsic volcanics underlying the Boston Bay Group are younger than Late Precambrian. Given the lack of fossils (despite 150 years of geologic study) there appears no reason why the Boston Bay Group itself (at least in part) might not be Late Precambrian as proposed by Kaye & Zartman (1980).

On field trips to Newfoundland, the author has been impressed by lithologic similarities of the Cambridge Argillite and the Conception Group, the

Roxbury Conglomerate (plus underlying felsites) and the Harbour Main Volcanics, and the Dedham Granodiorite and the Holyrood Granite. Although designated "volcanics," the Harbour Main consists of both porphyritic felsites and polymict red conglomerates with clasts of granodiorite, felsite, and orthoquartzite. The stratigraphic sequence for the Avalon Peninsula, Newfoundland (King, 1980), seems remarkably similar to that of the Boston Basin, including the presence of tillite between the Harbour Main and the Conception group. The author was particularly impressed by relationships he was shown at Bacon Cove near Colliers, Newfoundland. There, banded argillites of the Conception Group are thrown into gently undulating folds and lie unconformably beneath Hyalithes bearing, red, silty limestone of Early Cambrian age. If correlations with the Avalon are precisely valid, this would suggest a Late Precambrian age for the bulk of the Cambridge Argillite.

It has by no means been demonstrated that all felsic volcanic rocks in the Boston Area are older than the Dedham Granodiorite. The literature contains numerous references to felsic volcanics lying unconformably above the Dedham or interbedded with sediments that contain Dedham clasts. It seems very likely that some felsites postdate the Dedham Granodiorite, but even these could be Precambrian. Siluro-Devonian intermediate and felsic volcanics are widespread along the southeast coast of Maine in a belt that includes the Newbury Volcanics of northeastern Massachusetts. It is at least possible that some felsic volcanics in the Boston area correlate with these, although all the known Siluro-Devonian volcanics appear to lie west of faults that connect with the Bloody Bluff Fault west of Boston.

AKCNOWLEDGEMENTS

Clifford Kaye first suggested to the author the possibility that the Boston Bay group and underlying felsites might be Cambrian or older. He and David Roy introduced the author and students to the geology of the Pine Hill area.

REFERENCES

Bailey, R.H. and W.A. Newman (1978), Origin and significance of Cylindrical Sedimentary Structures from the Boston Bay Group, Massachusetts: Amer Jour. Sci., v. 278, pp. 703-714.

Billings, M.P. (1929) Structural Geology of the eastern part of the Boston Basin: Amer. Jour. Sci. 5th Ser., v. 18, pp. 97-137.

Bottino, M.L., P.D. Fullagar, H.W. Fairbairn, W.H. Pinson, and P.M. Hurley (1970) The Blue Hills Igneous Complex, Massachusetts, whole-rock Rb-Sr open systems: Geol. Soc. Amer. Bull. v. 81, pp. 3739-3746.

Buma, G., F.A. Frey, and D.W. Wones (1971) New England Granites: trace element evidence regarding their origin and differentiation: Contr. Mineral. and Petrol. v. 31, pp. 300-320.

Chute, N.E. (1969) Bedrock Geologic map of the Blue Hills Quadrangle, Norfolk Suffolk, and Plymouth Counties, Mass.: U.S. Geol. Survey Quad. Map GQ-796.

Emerson, B.K. (1917) Geology of Massachusetts and Rhode Island: U.S. Geol. Survey Bull. 597, 289 p.

Kaye, C.A. and R.E. Zartman (1980) A Late Precambrian to Cambrian Age for the Stratified Rocks of the Boston Basin, Massachusetts: in D.R. Wones, ed., Proceedings of the "Caledonides in the U.S.A.," I.G.C.P. Project 27: Virginia Polytechnic Institute and State University Memoir 2, pp. 257-262.

King, A.F. (1980) The Birth of the Caledonides: Upper Precambrian Rocks of the Avalon Peninsula, Newfoundland, and their correlatives in the Appalachian Orogen: in D.R. Wones, ed., Proceedings of the "Caledonides in the U.S.A.," I.G.C.P. Project 27: Virginia Polytechnic Institute and State University Memoir 2.

Kovach, A., P.M. Hurley, and H.W. Fairbairn (1977) Rb-Sr Whole-rock Age Determinations of the Dedham Granodiorite, Eastern Massachusetts: Amer. Jour. Sci. v. 277, p. 905-912.

LaForge, L. (1932) Geology of the Boston Area, Massachusetts: U.S.G.S. Bull. 839, 105 p.

Naylor, R.S. and S. Sayer (1976) The Blue Hills Igneous Complex, Boston Area, Massachusetts: in B. Cameron, ed. Geology of Southeastern New England, N.E.I.G.C. Guidebook 68 lh. Ann. Mtg., pp. 135-146.

Sayer, S. (1974) An Integrated Study of the Blue Hills Porphyry and Related Units: Mass. Inst. Tech. unpubl. M.S. Thesis., 146 p.

Warren C.H. (1913) Petrology of the alkali-granites and porphyries of Quincy and the Blue Hills, Mass.: Proc. Amer. Academy of Arts and Sciences, v. 49, n. 5, pp. 203-332.

Zarrow, L. (1978) Structural Relationships and Geochemical Investigation of the Lynn Volcanic Complex, Pine Hill, Boston North Quadrangle, Massachusetts: Mass. Inst. Tech. unpubl. M.S. Thesis, 184 p.

Zartman, R.E. (1977) Geochronology of some Alkalic Rock Provinces in Eastern and Central United States: Ann. Rev. Earth Planet. Sci. v. 5, pp. 257-86.

Zartman, R.E. and R.S. Naylor (in press) Structural Implications of Some Radiometric Ages of Igneous Rocks in Southeastern New England: Geol. Soc. Amer. Bull.

ROAD LOG

The official trip will assemble at the University of Rhode Island, Kingston. Drive towards Boston on I-95 then turn eastbound (South Shore) on Route 128. Persons starting the trip from Boston may drive south on the Southeast Expressway and turn westbound on Route 128. (The exit to the first stop can be made from either direction off 128).

Junction Routes 28 and 128; exit to Route 28 northbound. A few hundred yards north of the interchange turn right into a small parking area in the woods alongside the road.

0.0 STOP 1 CONTACT BETWEEN THE BLUE HILLS PORPHYRY AND THE PONDVILLE CONGLOMERATE MEMBER OF THE WAMSUTTA FORMATION.

Walk back along the west side of Rt 28 and up the access ramp to the NW clover leaf of the Rt 28-128 Interchange. The cut which exposes the contact was built after Chute (1969) had completed most of his field mapping; it is one of the more controversial exposures in the Boston area.

Briefly examine the Blue Hills Porphyry, then work your way fairly quickly along the outcrop until you are well up into the Pondville Conglomerate. Now decide where you would put the contact between the two units (in a group it is instructive to put this to a vote).

The PONDVILLE CONGLOMERATE is the basal unit of the Norfolk Basin sequence, the higher members of which contain Carboniferous fossils. The conglomerate (here called the Giant-Pebble Conglomerate) contains clasts of Blue Hills Porphyry, felsite (presumably Aporhyolite), quartzite, and argillite. Clasts of normal Quincy Granite have not been reported, although clasts of fine-grained hornblende granite can be found. At the top of the section the clasts are well-differentiated from the matrix, and lower in the section one can find an irregular but discrete surface below which the clasts no longer "pop out" from the matrix. Most workers, ourselves included, regard this surface as a non-conformity separating the Carboniferous Pondville Conglomerate from an older Blue Hills Porphyry.

This leaves a curious zone with pseudo-cobbles (greenish spheroids of microperthite, quartz porphyry in a matrix of generally finer-grained reddish porphyry) separating the Pondville from the normal, massive variety of the Blue Hills Porphyry. Chute interpreted this as a zone of spheroidal weathering and residual soil below the non-conformity.

D.R. Wones drew our attention to features suggesting a certain amount of transport of the pseudo-cobbles. They differ from each other and from the matrix in the details of phenocryst abundance and composition, in such a way that it appears unlikely that all the differences could be caused by weathering. He raised the possibility that the porphyry at this locality might be a Carboniferous volcanic unit grading upwards into the true conglomerate through a zone containing volcanic clasts in a welded volcanic matrix, the outcrop possibly having formed as a lahar.

If time and interest permit, one may see the overlying Wamsutta Formation on the opposite side of Route 128. Return to Route 28 and walk through the underpass, skirt the fence then backtrack to walk along the canal to the Wamsutta roadcut in the exit loop. Note the cross-beds, channel-fill, and other sedimentary features, and study the oxidation-reduction reactions represented in the red and green coloration. Can you decide if the reduced zones (green) are localized around carbon-rich plant-fragments?

RETURN to cars and drive NORTH on Rt 28 (Randolph Ave)

1.1 Jct. Randolph Ave and Chickatawbut Road, CONTINUE north on Randolph Ave. past golf course.

2.3 PARK on right at gravel road (don't block) opposite yellow & white house on left. Walk about 200 meters (yards) SE on the gravel road then up hill (north) on a poorly marked trail. The hill is overgrown with brambles, making it worthwhile to locate the trail. Look for ledges off the trail just below the brow of the hill and for adjacent outcrops on the flat summit.

STOP 2 RHOMB PORPHYRY AND BRAINTREE ARGILLITE

The outcrops along the slope of the hill are hornfels representing the Middle Cambrian BRAINTREE ARGILLITE. This unit has yielded some of the largest trilobites known, Paradoxides harlani. These are Acado-Baltic fossils whose faunal-province relationships are part of the evidence for the closing of the Iapetus ("proto-Atlantic") Ocean during the evolution of the Appalachian Mountains. It is generally agreed that the Braintree Argillite occurs as xenoliths and roof-pendants in the Blue Hills Igneous Complex, which is thus younger than Middle Cambrian. At this locality the Braintree Argillite is cut by diabase dikes that appear to be older than the Quincy Granite. Further uphill is a 30 m wide apophysis of fine-grained Quincy Granite with abundant inclusions of rhomb-porphyry and argillite, and at the top of the hill is the main body of the Quincy Granite marked by abudnant inclusions and an intrusion breccia.

2.3 RETURN to cars. U-TURN and return south on Randolph Ave.

3.5 Jct Randolph Ave and Chickatawbut Road. TURN LEFT on Chickatawbut Road. Pavement outcrops at the SE corner of the jct. are Blue Hills Porphyry and were described as Stop 5 of Naylor and Sayer (1976).

4.8 Blue Hills Reservoir on right.

5.0 PARK on RIGHT or LEFT in small parking areas.

STOP 3 BLUE HILLS PORPHYRY AND BLUE HILLS VOLCANICS
(APORHYOLITE is a local synonym for the Blue Hills Volcanics)

STOP 3A Walk back to the junction of Wampatuck and Chickatawbut Roads, then south on trail (old road) about 100 meters (yards). To the left is a rock-knob with a vertical face on the south side; examine the face. The knob is mostly Blue Hills Porphyry but the face shows a fine-grained rock that is probably a screen or large inclusion of APORHYOLITE. Examine the porphyry on the top of the knob; the aphanitic matrix characteristic of the porphyry is more evident here than at the previous stop. The porphyry appears chilled against the Aporhyolite.

STOP 3B Return to cars and follow trail south to summit of rock-knob. On the way up you cross a thin screen of Aporhyolite in the porphyry and one can closely approach a contact on the south side of the screen. The porphyry on the summit of the knob contains digested xenoliths of the Aporhyolite.

STOP 3C Return to parking area and follow trail north of raod to summit of Wampatuck Hill. (Take LUNCH to eat on summit with good views over Boston.) The trail uphill is mostly in Blue Hills Porphyry then crosses a contact into the APORHYOLITE, which crops out on the top of the hill. The volcanics (Aporhyolite) here were designated by Kaktins (1976) as the Wampatuck Hill Ash Flow, which he subdivided into the following units: a basal clastic-rich eutaxitic zone; a densely-welded zone with few phenocrysts and few spherulites; a eutaxitic zone with abundant flattened pumice; and an upper phenocryst-rich zone with minor, but relatively uncompressed pumice. The uppermost unit is the one in contact with the porphyry, the probable top of the flow having been cut out here; down-section is to the north at this locality. (Kaktins, 1976; Geol. Soc. Amer Memoir 146)

5.0 RETURN to cars. CONTINUE EAST on Chickatawbut Road.

5.1 TURN LEFT (north) onto Wampatuck Road

5.6 Small quarry in woods on left exposes the contact between the BLUE HILLS PORPHYRY and the QUINCY GRANITE. Warren (1913) designated this the type locality for the porphyry and the locality is described as Stop 2 of Naylor and Sayer (1976).

6.2 Merge (straight) onto Willard St.

6.3 Jct. with Southeast expressway. Continue (more or less straight ahead) under the expressway then turn LEFT onto ramp and enter Expressway NORTHBOUND (towards Boston).

(Mileages beyond this point have not been logged.)

STAY on Expressway north past jcts. with Mass Ave. and the Mass Pike through the South Station Tunnel and downtown Boston. After leaving the tunnel, drive in the middle-left lane and follow signs for I-93 northbound. About ½ mile north of North Station/Boston Garden, CONTINUE STRAIGHT from the left or center lanes to pick up I-93 while much of the traffic veers right onto I-95 and the Mystic (Tobin) Bridge. (Just before this jct. traffic enters from the left and many of these cars want to cross to the right; don't let them push you so far to the right that you can't get onto I-93!)

A mile or two north of the jct watch on your left for Somerville Lumber, then a church, then the Somerville Housing Project. A low quarry wall back of the project is the best surface exposure of the Cambridge Argillite. From here, Pine Hill (woods with stone tower) should be visible ahead on the left.

The exit to Pine Hill is shown on Figure 1; it is just before the base of the hill. The exit from I-93 should have signs to Rt 28 north. Cross over the interstate and exit the rotary onto South Border Road. Turn RIGHT into the small parking area at Belleview Pond. Lock cars.

STOP 4 DEDHAM GRANODIORITE AND LYNN VOLCANICS AT PINE HILL

Figure 1 is a sketch map after Zarrow (1978) by the geology at Pine Hill. Participants on the trip will be given a more detailed base-map showing contours, trails, etc. (Pine Hill is popular as a mapping exercise for colleges in the Boston Area, and the author is reluctant to publish a "solution" showing contacts on the detailed base-map.) The descriptions ignore the Medford and other mafic dikes which are described elsewhere in this guidebook by M.E. Ross.

a. Follow the trail E from Pond skirting base of Pine Hill to large cuts along I-93. The first cut exposes the homogeneous Pine Flow Member of the Lynn Volcanics cut by mafic dikes and by a few dikes of felsite breccia. The further, lower cut exposes the contact between the Lynn and the Dedham. Adjacent to the contact is a finely crystalline granite (chilled Dedham?). The Dedham contains numerous xenoliths, mostly of quartzite. A further, small cut shows interesting interactions between the Dedham and the mafic Medford Dike. From here, scramble up to see the Dedham-Lynn contact and the xenoliths from the top of the second cut.

b. Worm under the fence and follow the contact west about 100 yards, crossing the Medford Dike. Outcrops accessible from the trails to the north expose numerous xenoliths of felsite and quartzite. (See text for significance of the felsite xenoliths and the problem of identifying them in the field.)

c. Follow broad trail SE to summit of Pine Hill. Familiarize yourself with the characteristics of the Tower Member of the Lynn Volcanics (see text), then attempt to trace contact with Pine Flow Member on the south side of the hill. Look for stratification. Return to Pond.

d. Trails NW from the Pond cross the Mud Road Member of the Lynn Volcanics (see text). Try to identify and follow the contact with the Dedham Granodiorite. (As discussed in the text, the two units are distinct in thin section, but many weathered surfaces on the volcanics are easily confused with those of the granodiorite.)