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Geology, petrology and origin of the Precambrian igneous rocks located in the area north of Boston

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GEOLOGY, PETROLOGY AND ORIGIN OF THE PRECAMBRIAN IGNEOUS ROCKS LOCATED IN THE AREA NORTH OF BOSTON

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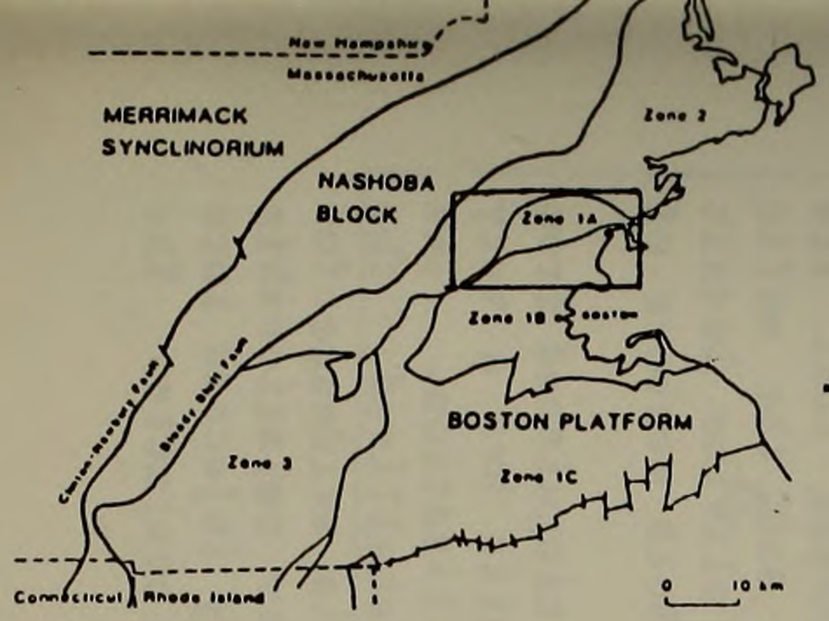
The terrane lying east of the Bloody Bluff Fault zone is variously identified as Dedham - Milford Zone (Zen, ed., 1983, Zartman and Naylor, 1984), Avalon Zone (O'Brien et al, 1983). The adopted designation here is after Hepburn, Hon and Hill (in review) who suggested the term Boston Platform in recognition that tis terrane is largely underlain by igneous and metamorphic rocks of pre-Appalacian age (>585 m.y.) with a thin veneer of the late Precambrian to Early Paleozoic sediments (Protorozoic Z to Cambrian). This field trip guide is designed to visit localities in a fault-bounded block north of Boston which show some of the complex relationships among various plutonic and volcanic units emplaced during the maximum igneous activity period (585 - 630 m.y.) and during the period immediately preceeding it.

Located north of Boston on the Boston Platform, this fault - bounded dominantly igneous Precambrian terrane (Fig. 1) abuts along its southern border against the Boston Basin and is seperated from the Boston Basin by the Northern Boundary Fault. The Walden Pond Fault seperates the block from the Salem Gabrodiorite and the Peabody Granite located to the north on the Boston Platform. The dominant rock type of this terrane is the Dedham Granodiorite, which is a fine to coarse grained calc-alkaline plutonic ranging from granodiorite to tonalite to diorite. Lying above as well as intruded by the Dedham are felsic volcanics. Current thinking (Zen, ed., 1983, Kaye, 1980) designates all these felsic volcanics as the Lynn Volcanic Complex with assigned ages ranging from Silurian to Precambrian (Protorozoic Z). Through detailed field mapping, we are able to show that there are actually two different felsic volcanic units. One of these units is in fact the Lynn Volcanic complex proper which through field criteria has been subdivided into four members, three extrusive and one intrusive. The other unit has a diffent structural setting, petrography and geochemistry than the Lynn. This unit is spatially related to the Middlesex Fells Volcanic complex and the Westboro Formation. It is pervasively intruded by the Dedham, is recrystallized and occurs in a rapidly changing sequence with the Middlesex Fells basalts. Because of this relationship, it is apparent that the Middlesex Fells Volcanic complex consists of two members, a previoulsy identified basaltic unit (here called the Middlesex Fells mafic member) and a felsic unit previously identified as the Lynn (here named the Middlesex Fells felsic member). The Middlesex Fells and the Westboro are pervasively intruded by the Dedham and sit essentially as large roof pendents in the Dedham. Through detailed field mapping, petrographic and geochemical studies, we have concluded that the Lynn and the Dedham form a co-magmatic volcano-plutonic complex.

FIELD AND PETROGRAPHIC STUDIES

The Dedham Granodiorite is a Precambrian, 600 - 630 m.y. old, granitic body that underlies most to the Boston Platform. North of Boston it occurs mostly as a granodiorite and diorite consisting of quartz, plagioclase, hornblende and small, varying amounts of microcline. Texturally the Dedham ranges from subvolcanic to coarsly crystalline varieties. The subvolcanic part contains a



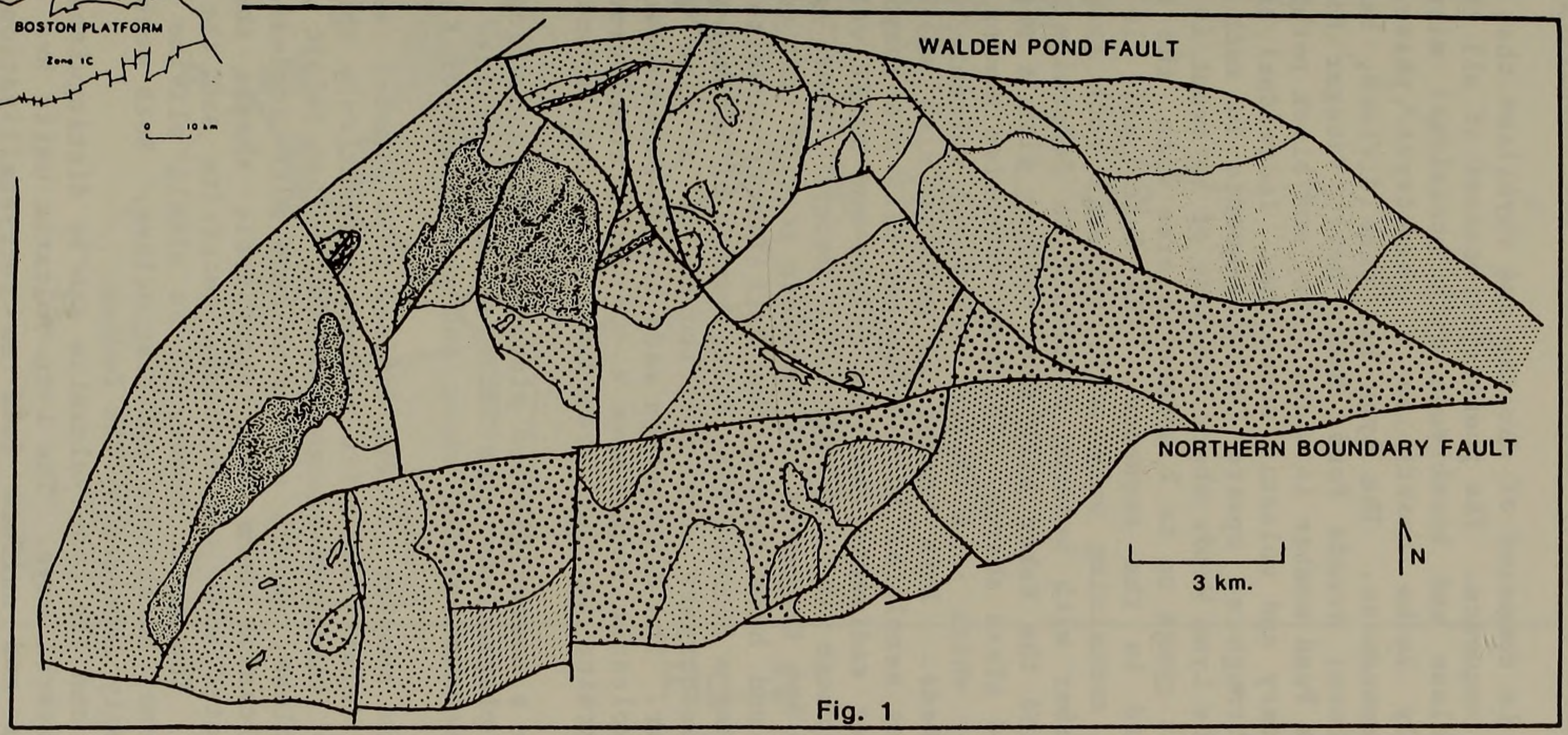


Fig. 1

DEDHAM GRANODIORITE

MIDDLESEX FELLS FELSIC MBR.

MIDDLESEX FELLS MAFIC MBR.

BALL QUARRY GRANITE

WESTBORO FMT.

LYNN VOLCANICS

BREEDS POND MBR.

BAKER HILL MBR.

VINEGAR HILL MBR.

SUBVOLCANIC MBR.

bimodal distribution of mineral sizes with large plagioclase and hornblende grains in a granophyric groundmass. The coarse crystalline phase consists of equal sized, euhedral grains of plagioclase and hornblende with quartz and microcline forming interstitial grains. In places the Dedham contains xenoliths of Westboro quartzite and basalt probably derived from the Middlesex Fells volcanics.

The Lynn Volcanic complex is composed of dacites and rhyolites that form a thick extrusive and subvolcanic sequence. The phenocryst content of all the Lynn members is made up of plagioclase and hornblende with occasional microcline phenocrysts. The Lynn totally lacks quartz as a phenocryst phase. The phenocrysts lie in a glassy groundmass. The Lynn has been divided, based on field criteria, into four members; Breeds Pond, Baker Hill, Vinegar Hill and subvolcanic members. The Breeds Pond member is a red, gray and black porphyritic ash fall and tuff with sedimentary and volcanic xenoliths. Individual eruption events can be distinguished through an upward fining sequence in each event. This is especially evident in the Lynn Woods where the base of an event is marked by large volcanic xenoliths that range up to 2 meters in size with the size of the xenoliths decreasing upward in the sequence. The Baker Hill is a red porphyritic ash fall and tuff containing only small volcanic rock fragments. This is a very homogeneous member with bedding difficult to determine in the field. Both the Breeds Pond and the Baker Hill show bedding with a preferred alignment of the phenocrysts and glass shards. The most extensive member of the Lynn is the Vinegar Hill member which is a typical lahar and volcanic breccia containg crystal/lithic tuff beds. This member is massive with no bedding evident in the lahars. The many xenoliths in the Vinegar Hill are composed of the Westboro quartzite and other sediments, various felsic and mafic volcanics and granitic fragments which range in size up to 1 meter. These granite xenoliths are not of the Dedham but fragments of an older granite that outcrops in the Ball Quarry in Saugus and here termed the Ball Quarry Granite. The subvolcanic member of the Lynn has a bimodal size distribution of mineral grains. Plagioclase and hornblende phenocrysts are distributed in a fine grained groundmass of quartz and feldspar. The distinction made here between subvolcanic and extrusive is that the subvolcanic rocks have a coarser grained groundmass where the individual mineral grains in the groundmass are visible under the microscope.

The Ball Quarry Granite is a coarse grained plutonic rock containing large subhedral grains of kspar and plagioclase with anhedral quartz grains. It is distinguished from the Dedham because of the kspar and the excess of K_2O over Na_2O in the Ball Quarry.

The Middlesex Fells Volcanic complex as here defined is a bimodal suite of basalt and rhyolite. Both the felsic and mafic members are entirely thermally recrystallized and pervasively intruded by the Dedham. The felsic member contains phenocrysts of plagioclase, quartz and hornblende with inclusions of Westboro quartzite. These volcanics form thin pyroclastic sheets that are spatially related and intercalated with the Westboro quartzite and the mafic member of the Middlesex Fells. The mafic member is an alkali olivine basalt containing phenocrysts of pyroxene, hornblende and plagioclase. Both members of the Middlesex Fells are pervasively intruded by the Dedham.

The Middlesex Fells felsic and the Lynn Volcanics can be distinguished from one another in the field in several ways. The Lynn volcanic units hve a very fine grained glassy groundmass and suffers from no recrystallization. The Middlesex Fells, due to intrusion of the Dedham, is entirely recrystallized. The Lynn and the Dedham have a texturally gradational contact which is evidence for their co-genetic nature. The Middlesex Fells has a very complex relationship with the Dedham. Throughout the terrane, the Dedham is pervasively injected into the Middlesex Fells and in places becomes fine grained near the contacts. The

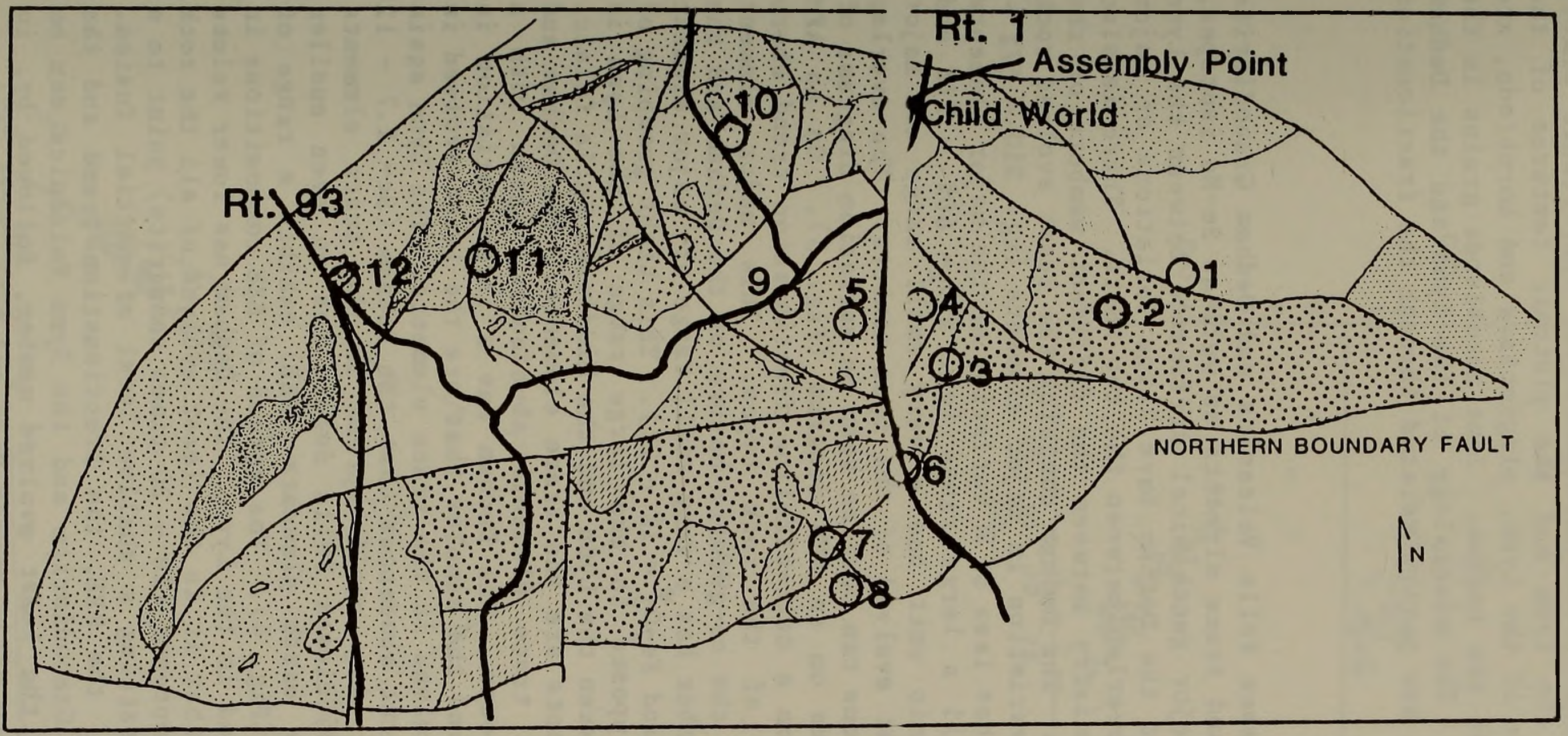


Fig. 2

	STOPS
LYNN VOLCANICS	1,2,3,5,7,8
DEDHAM PLUTONICS	4,5,7,9,10,11,12
BALL QUARRY GRANITE	2,3,5
MIDDLESEX FELLS FELSIC	10,12
MIDDLESEX FELLS MAFIC	10,11,12
WESTBORO FM.	4

Lynn contains no phenocrysts of quartz whereas the Middlesex Fells felsic member has quartz phenocrysts.

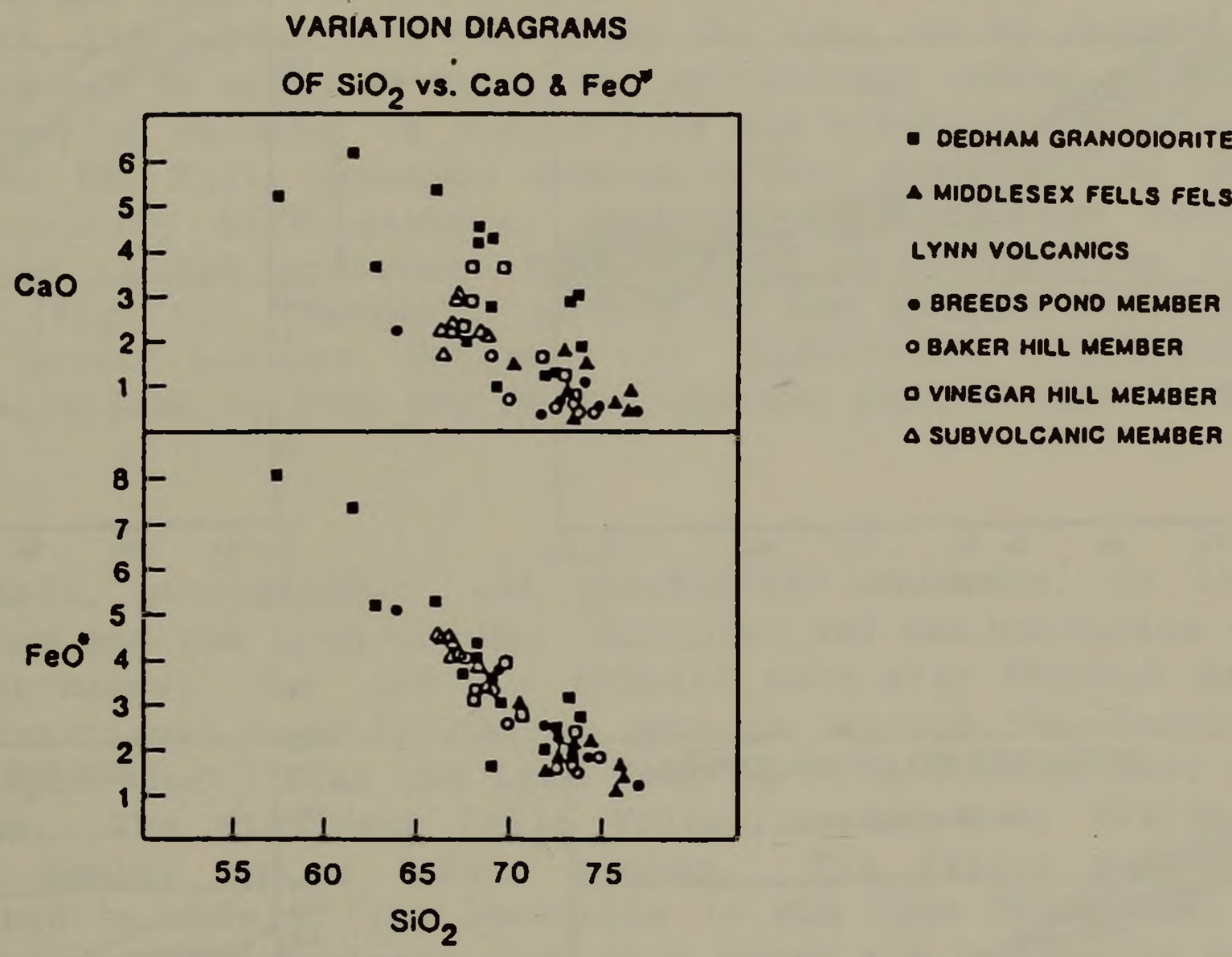
Another difference between the Lynn and the Middlesex Fells felsic member is that the Lynn is co-genetic with the Dedham. In the field this cogenetic nature is displayed through a gradual textural transition of the subvolcanic member between the volcanic textures of the Lynn and the plutonic textures of the Dedham. The major phenocryst phases of the Lynn, plagioclase and hornblede, are also the dominant mineral phases of the Dedham. Some hornblende grains in the Dedham exhibit cumulitic textures. The mineralogy of the Lynn and the Dedham sugest that the Lynn and the Dedham are partly related through the fractionation of plagioclase and hornblende.

GEOCHEMISTRY

Samples of the Lynn and Middlesex Fells Volcanics and Dedham Granodiorite have been analyzed for both major and trace elements as well as Sm-Nd isotopes. Major and trace elements show no major geochemical difference between the Lynn and the Dedham. Both the Lynn and the Dedham have large variations of major element abundences with a complete overlap between the two units. There is also no difference in major element chemistry between the different members of the Lynn, all having a complete overlap. The Dedham contains the least evolved rock types in the area and has a large variation in major elements (eg. SiO_2= 57% - 74% and $Fe_2O_3^*$= 1% - 8%). The Lynn has less of a variation of the major elements than the Dedham, yet there is still a large range (eg. SiO_2= 66% - 77% and $Fe_2O_3^*$= 1.5% - 5%). The subvolcanic unit has a very small range of major elements and as a group are the least evolved of the Lynn members. The overlap and trend of major element compositions can best be seen on variation diagrams of SiO_2 vs. CaO and $Fe_2O_3^*$, as well as on an AFM diagram (Fig. 3). On an AFM diagram, the Dedham and Lynn plot on a calc-alkaline fractionation trend where the Dedham has the most evolved of the rock types. This major element similarity lends further support to the co-genetic nature of the Dedham and the Lynn. The Middlesex Fells felsic member has a very small range of major element concentrations (eg. SiO_2= 73% - 76% and $Fe_2O_3^*$ = 1% - 2%). This tight grouping of major element concentrations as opposed to the large range of the Lynn is another method of distinguishing between the Lynn and the Middlesex Fells felsic.

Consistant with the major elements are the trace elements. The Dedham and the Lynn have large variations in trace elements abundences, again with a complete overlap between the two groups. The Dedham has a large variation in trace elements (eg. Sc= 3 - 22 ppm) and the samples that are the least evolved in major elements are also the least evolved in the trace elements. The Lynn again shows a smaller spread in trace element abudences than the Dedham (Sc= 2.7 - 12 ppm). The subvolcanic Lynn has a very small spread in the trace elements abundences (Sc= 9 -12 ppm). The Middlesex Fells felsic has an even smaller spread (Sc= 4 - 6 ppm). The rare earth elements (REE) exhibit a range of compositions for all the rock types (Fig. 4). The spread of REE compositions in the Dedham is identical to the spread in the Lynn. The Dedham has lower values of the light REE (La-Sm) suggesting that it is the least evolved of all the rock types. The high heavy REE (Tb-Lu) contents (10 - 20 times chondrite) point to a lack of garnet in the residue suggestting a shallow level of partial fusion. From the trace elements, especially the REE, the fractionation trend and the evolutionary sequence of the Dedham Granodiorite and the Lynn Volcanics can be deduced. The subvolcanic member is the least evolved member, followed by, in order of least to most evolved, Vinegar Hill, Breeds Pond and Baker Hill members. The overlap of trace element abundences provides further support to the co-genetic nature of the Dedham and the Lynn.

As stated before, the Dedham and the Lynn may be related through the


VARIATION DIAGRAMS
OF SiO_2 vs. CaO & FeO^*
CaO
FeO^*
SiO_2
55
60
65
70
75
DEDHAM GRANODIORITE
MIDDLESEX FELLS FELSIC
LYNN VOLCANICS
BREEDS POND MEMBER
BAKER HILL MEMBER
VINEGAR HILL MEMBER
SUBVOLCANIC MEMBER

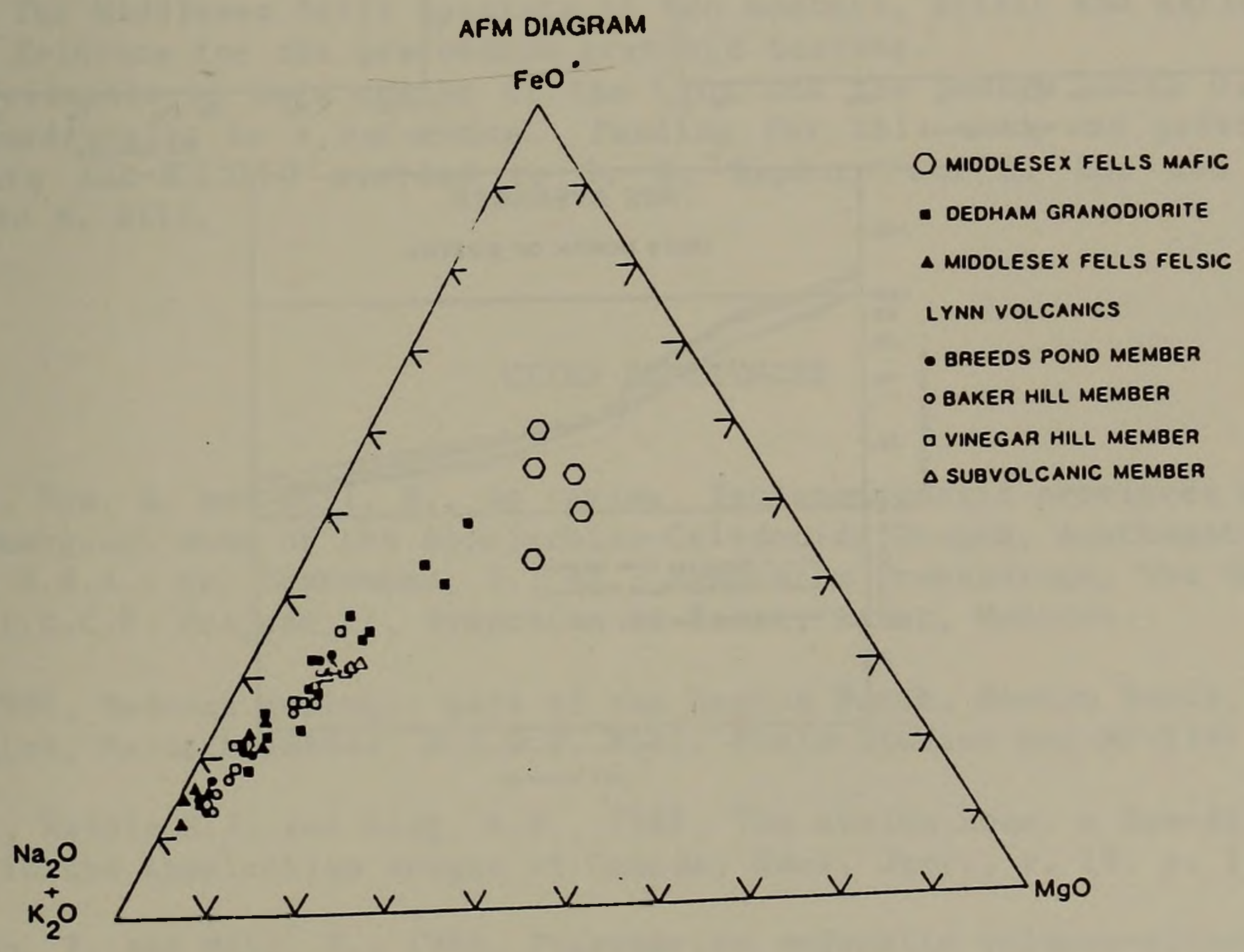
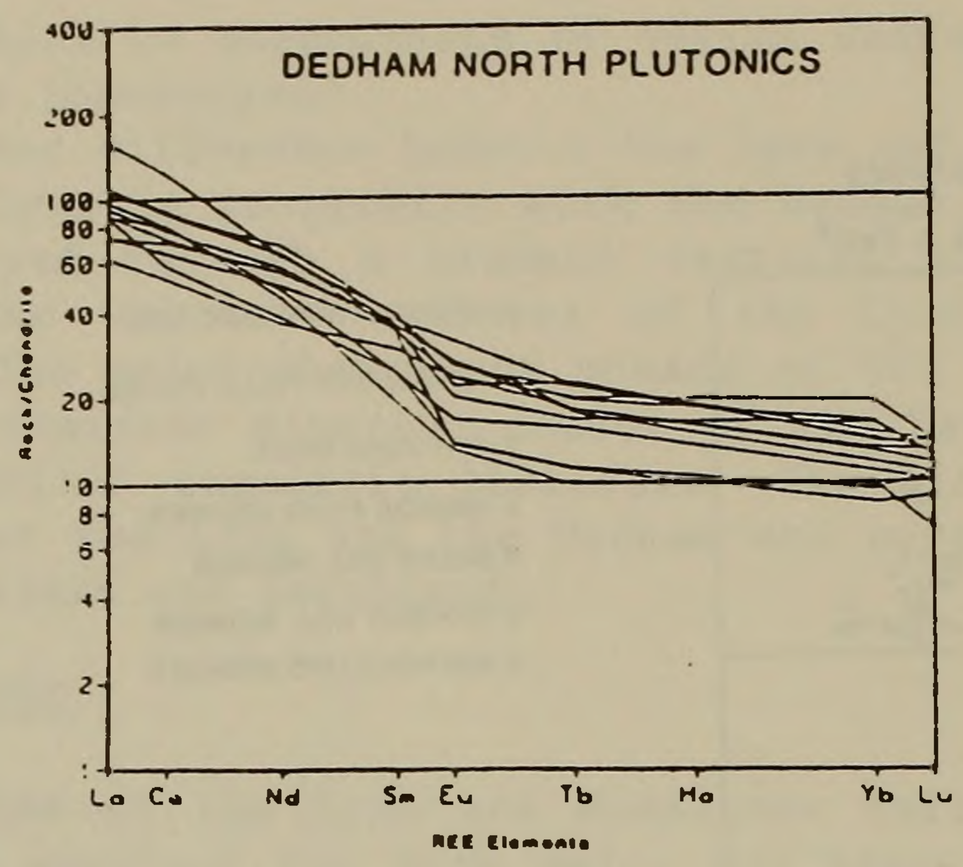
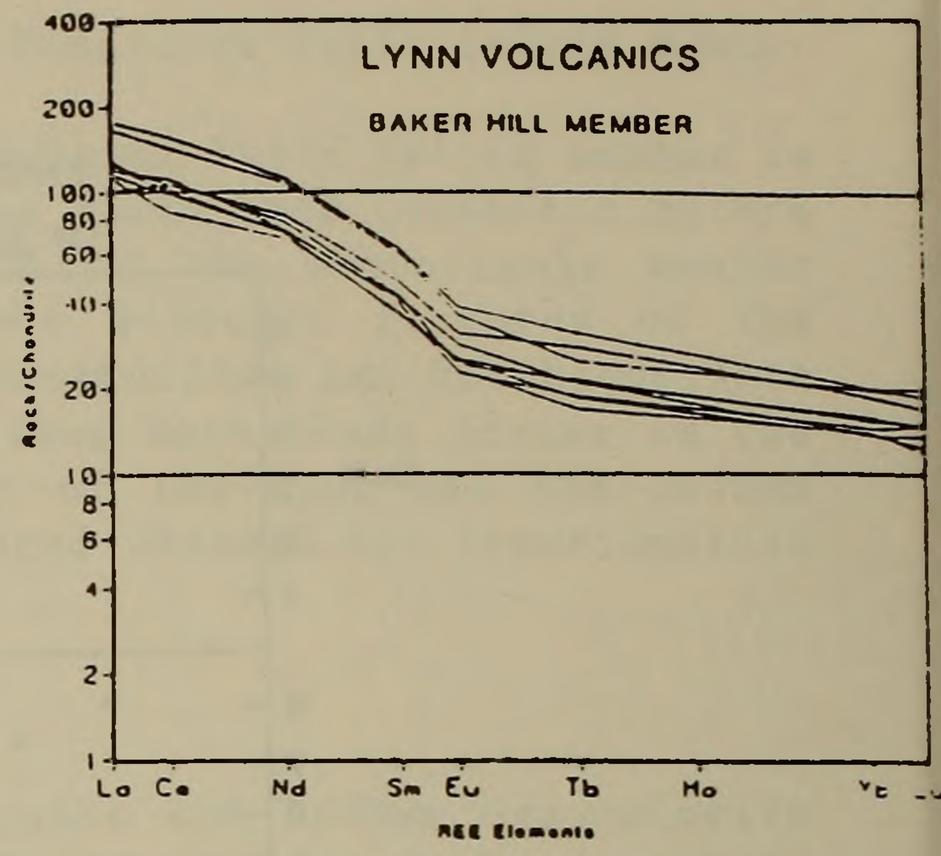
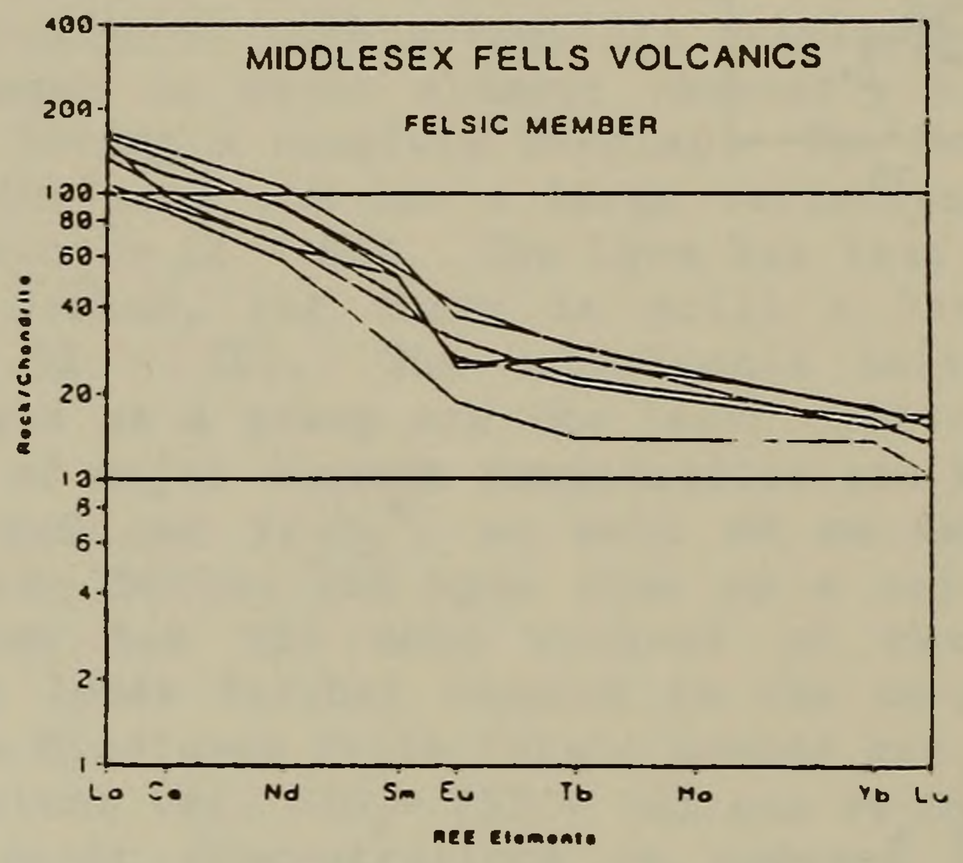
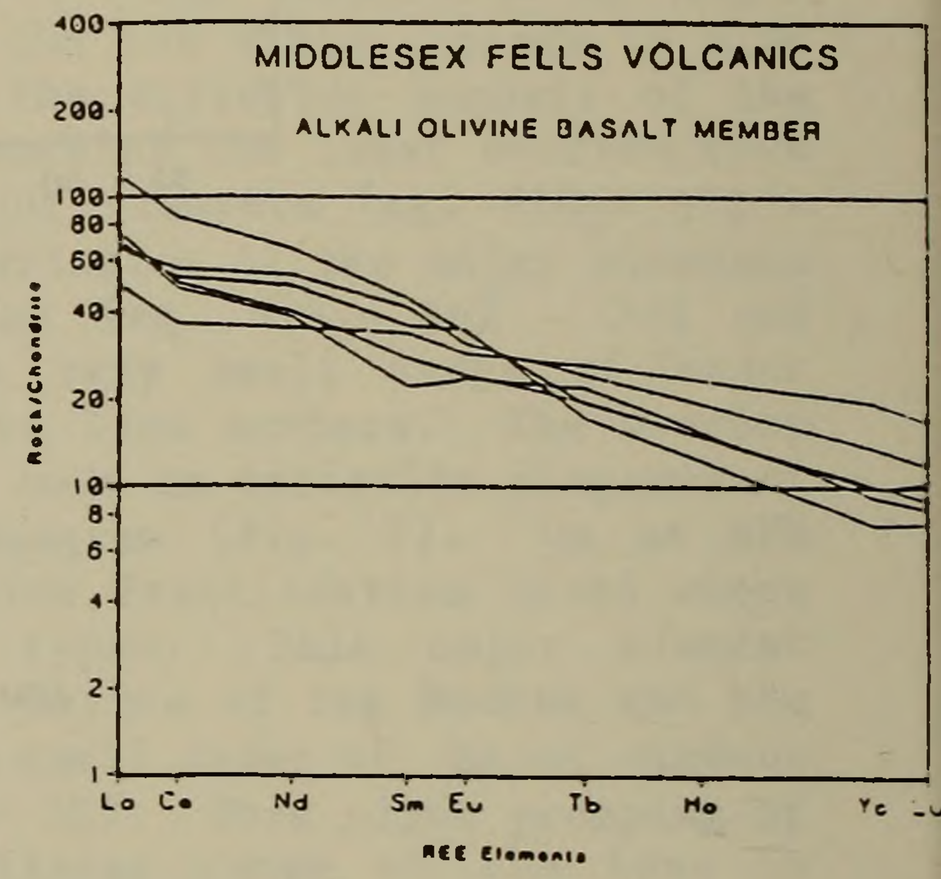

AFM DIAGRAM
FeO^*
Na_2O
K_2O
MgO
MIDDLESEX FELLS MAFIC
DEDHAM GRANODIORITE
MIDDLESEX FELLS FELSIC
LYNN VOLCANICS
BREEDS POND MEMBER
BAKER HILL MEMBER
VINEGAR HILL MEMBER
SUBVOLCANIC MEMBER

Fig. 3


DEDHAM NORTH PLUTONICS
400
200
100
80
60
40
20
10
8
6
4
2
1
La Ce Nd Sm Eu Tb Ho Yb Lu
REE Elements


LYNN VOLCANICS
BAKER HILL MEMBER
400
200
100
80
60
40
20
10
8
6
4
2
1
La Ce Nd Sm Eu Tb Ho Yb
REE Elements


MIDDLESEX FELLS VOLCANICS
FELSIC MEMBER
400
200
100
80
60
40
20
10
8
6
4
2
1
La Ce Nd Sm Eu Tb Ho Yb Lu
REE Elements


MIDDLESEX FELLS VOLCANICS
ALKALI OLIVINE BASALT MEMBER
400
200
100
80
60
40
20
10
8
6
4
2
1
La Ce Nd Sm Eu Tb Ho Yb
REE Elements

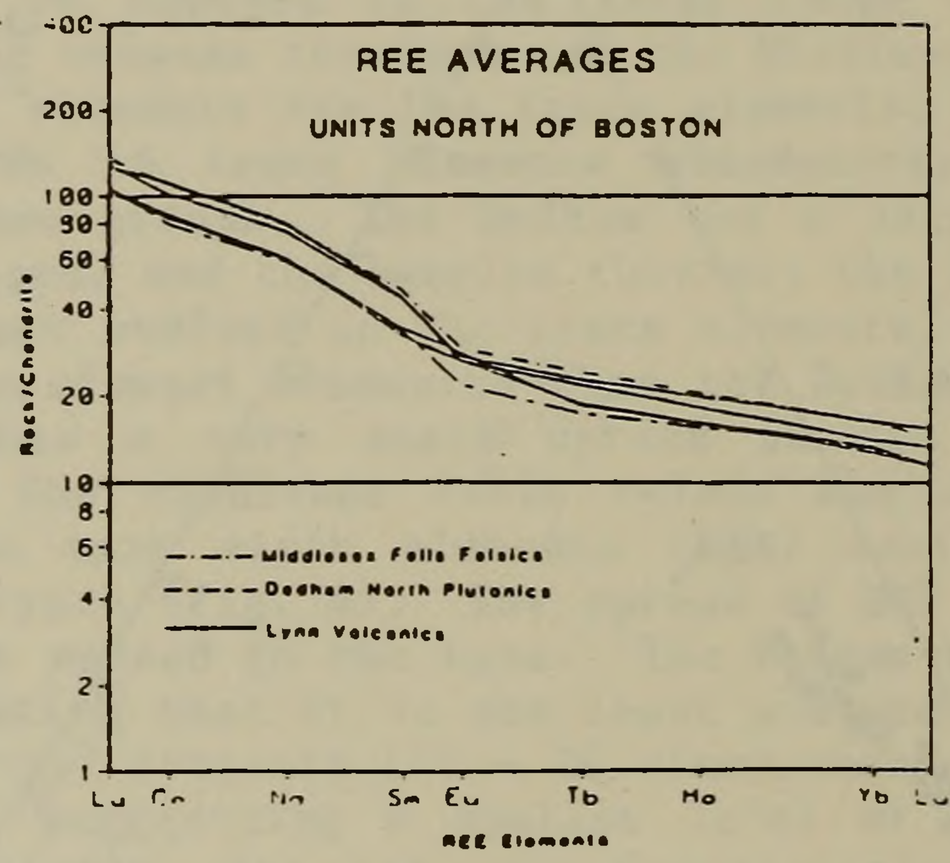

REE AVERAGES
UNITS NORTH OF BOSTON
400
200
100
90
60
40
20
10
8
6
4
2
1
Middlesex Fells Felsics
Dedham North Plutonics
Lynn Volcanics
La Ce Nd Sm Eu Tb Ho Yb Lu
REE Elements

Fig. 4

fractionation of plagioclase and hornblende. Smith et al (1984) applied crystal fractionation models to explain the chemical differences between the REE of the various members of the Lynn and the Dedham (Fig. 5). Using the Dedham as the most primitive rock, the subvolcanic member of the Lynn can be derived. The rest of the Lynn members can be modelled using the subvolcanic member as the parent by fractionation of varying amounts of plagioclase and hornblende phenocrysts.

The Sm-Nd data (M. Hill, personal communication) suggets that the Lynn and Dedham were isotopically heterogeneous, inplying heterogeneous sources. This data is interpreted as two processes that worked in conjunction to form the Dedham/Lynn magma (Fig. 6). Variable mixing of two shallow sources, basaltic and continental crust sources followed by fractional crystallization of hornblende and plagioclase to form the Dedham and the various Lynn members.

SUMMARY

From the field, petrographic and geochemical evidence, it is concluded here that the Dedham and the Lynn are the intrusive and the extrusive equivalents of the same parent magma. The two are related partially through magma mixing but mostly by a fractional crystallization process through the fractionation of hornblende and plagioclase. Thus the Lynn must be of a similar Late Precambrian age as the Dedham. The Middlesex Fells Volcanics are here divided into two members, a mafic member and a felsic member. The felsic member had been previously undefined because of its inclusion in the Lynn Volcanics. The field and geochemical evidence conclusively show that there are two felsic volcanics in the area. The Middlesex Fells forms an earlies volcanic pulse in the magmatic episode that formed the Dedham and the Lynn.

This field trip is designed to visit localities which show relationships dealing with one of the following points (Fig. 2):

1. Textural variations within the Lynn Volcanic complex are evidence for the gradational textural changes from the Lynn into the Dedham granodiorite
2. The Middlesex Fells consists of two members, felsic and mafic
3. Evidence for the pre-Dedham granitic terrane.

It is adviseable to have copies of the Lynn and the Dedham North U.S.G.S 7 1/2 minute quadrangles as a reference. Funding for this work was provided through NSF grants EAR-8212760 awarded to J. C. Hepburn and R. Hon and EAR-8212761 awarded to M. Hill.

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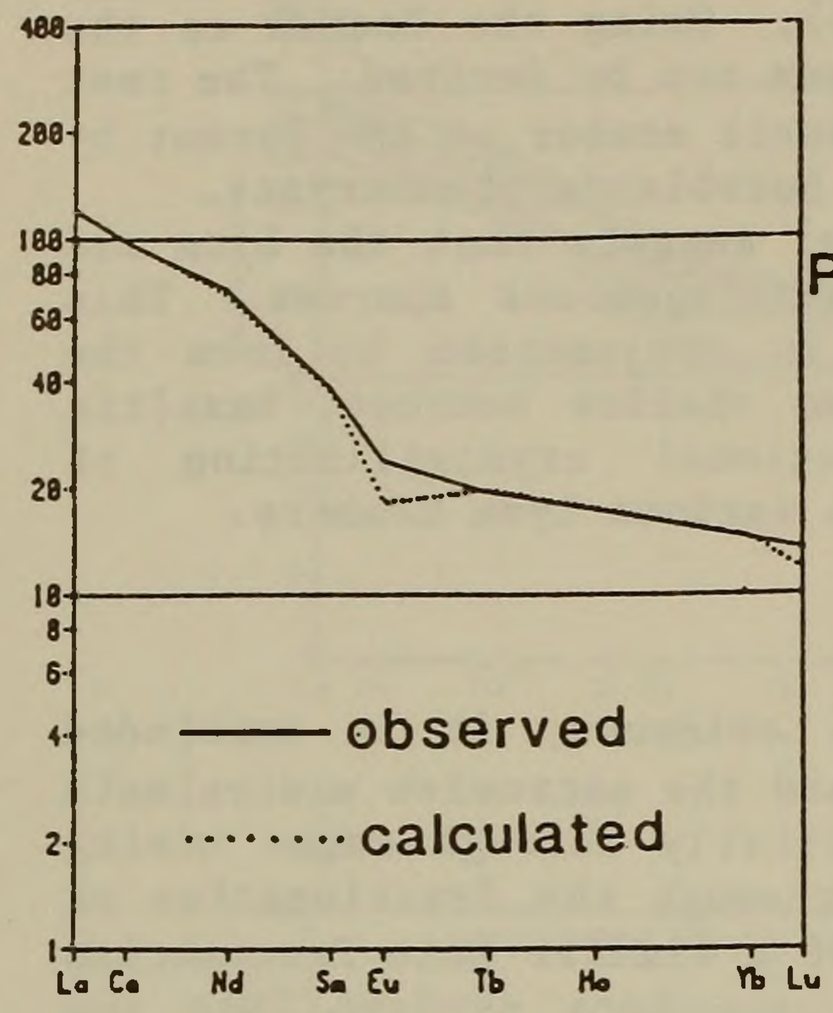
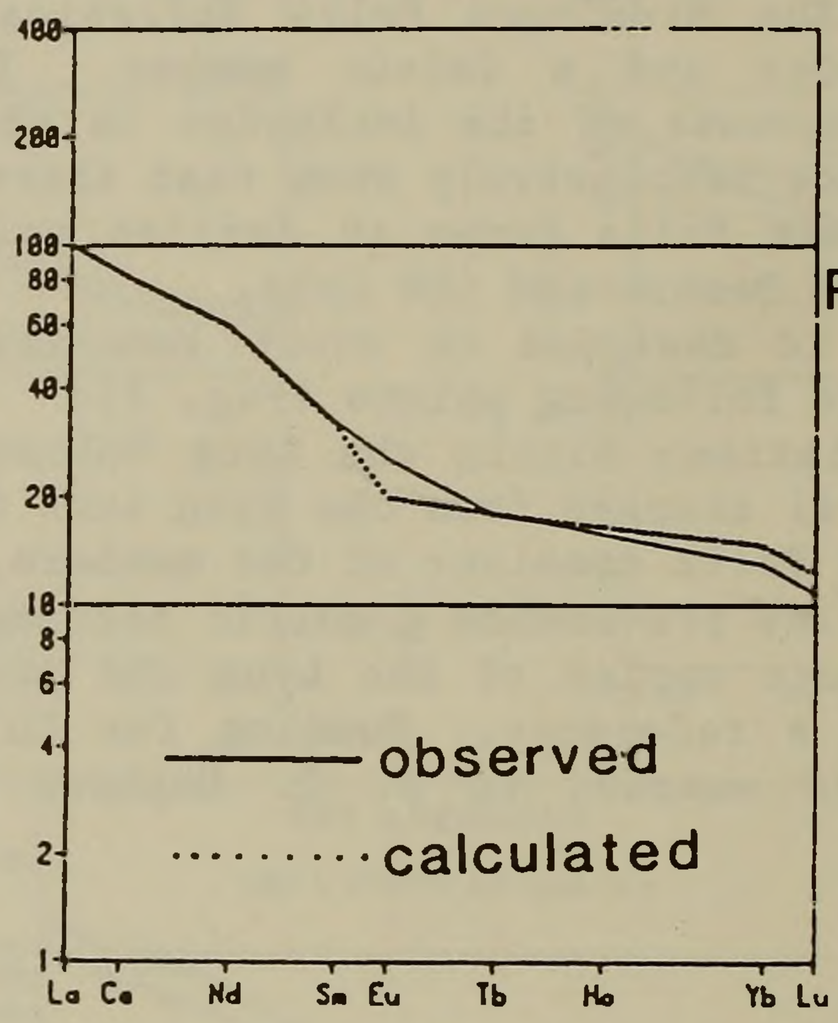
MODEL REE DIAGRAM
FOR
BAKER HILL MEMBER



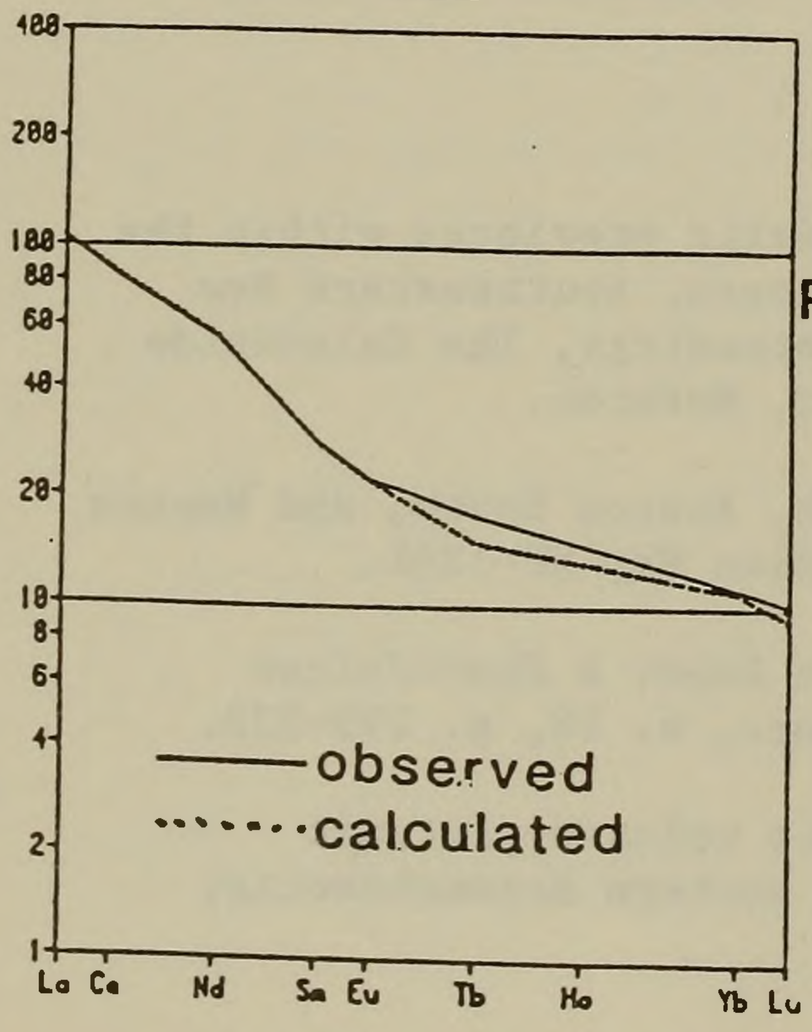
PARENT:
AVG. SUBVOLCANIC LYNN
24% CRYSTAL REMOVAL
85% PLAGIOCLASE
15% HORNBLENDE

MODEL REE DIAGRAM
FOR
SUBVOLCANIC MEMBER



PARENT:
AVG. DEDHAM NORTH
22% CRYSTAL REMOV
75% PLAGIOCLASE
25% HORNBLENDE

MODEL REE DIAGRAM
FOR
VINEGAR HILL MEMBER



PARENT:
AVG. SUBVOLCANIC LYNN
6% CRYSTAL REMOVAL
25% PLAGIOCLASE
75% HORNBLENDE

Fig. 5

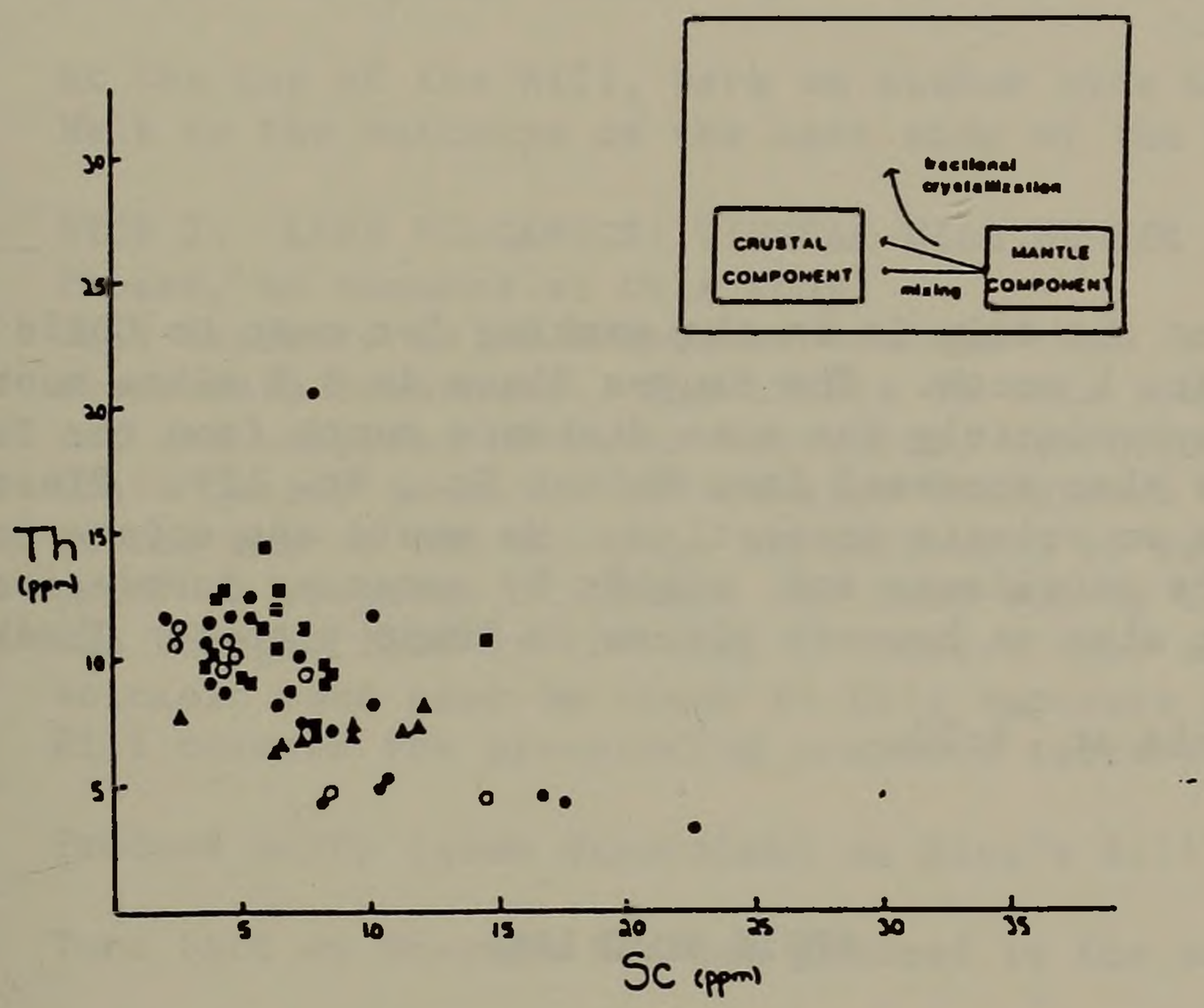

fractional crystallization
CRUSTAL COMPONENT
MANTLE COMPONENT
mixing
Th (ppm)
Sc (ppm)
Dedham North Plutonics
Lynn Extrusives
Lynn Intrusives
Middlesex Fells Felsics
(open symbols: data from Zarrow, 1978)
La (ppm)
Th
ϵ_{Nd} (t=600my)

Figure 6.

Zartman, R.E. and Naylor, R.S., 1984, Structural implications of some radiometric ages of igneous rocks in southeastern New England; Bull. Geol. Soc. Amer., v. 95, p. 522-539.

Zen, E-an, ed., 1983a, Bedrock Geologic Map of Massachusetts; U.S.G.S., scale 1/250,000.

The starting point for the trip is in the parking lot next to Child World in the Saugus Plaza off of Rt. 1 south. The Saugus Plaza is 6.5 miles south from the Inn at Danvers and approximately the same distance north from the Tobin Bridge in Boston. The Plaza is also accessed from Walnut St., Rt. 129. Please note that many of the stops are on private properties. We would appreciate courtesy in respecting the owner's privilages and rights by securing permission before viewing the outcrops; also no hammers please in these places. Thank you.

Assemble at Child World at 8:30.

BEGIN ROAD LOG

0.0	0.0	Exit the Saugus Plaza and turn right onto Walnut St. and proceed over Rt. 1.
0.6	0.6	Keep left at the traffic lights.
0.4	1.0	Birch Pond on the left.
2.5	1.5	Park on the left (north) side of the road in the designated parking spaces. From the parking lot, walk straight across the ballfields toward the spillway for Breeds Pond. Continue northwest along the shore for 750 feet. Meet at an abandoned quarry.

STOP 1. LYNN VOLCANICS: BREEDS POND MEMBER

The abandoned quarry displays a rapid change in a variety of rock types with irregular contacts and possible dome-like intrusions. There are four rock types here; welded tuffs, crystal tuffs, breccias and intrusive dome facies. The volcanics are typical of the Breeds Pond with phenocrysts composed of plagioclase and hornblende with the plagioclase dominant. The matrix is glassy and exhibits flow textures. The inclusions in the breccia are composed of fragments of other members of the Lynn. The dome facies here intrudes the volcanics in many places with a very irregular contact between the two facies. This intrusive style is common in the Lynn terrane where domes of Lynn magma intrude into its own volcanic pile. Proceed back to the park and examine the exposure just beside the spillway. Note: there are no granitic inclusions found in this member.

Turn around and proceed west on Walnut St.

0.3 2.8 At the blinking traffic light turn left onto O'Callahan Way.

0.3 3.1 Turn right into the King's Lynne apartments on King's Hill Dr. and proceed up the hill.

0.6 3.7 At the top of the hill, park on either side in parking areas. Walk to the outcrops on the east side of the road.

STOP 2. LYNN VOLCANICS: VINEGAR HILL MEMBER
Please, no hammers at this stop!
This exposure is of a boulder breccia that is massive with no observable structure. The clasts in this rock weather in relief and are composed of other volcanics, Westboro quartzite, granite (Ball Quarry Granite) and basalts (Middlesex Fells mafic). Note at the top of the outcrop, an inclusion of basalt that had, prior to eruption, intruded the Ball Quarry Granite. Chemically the Vinegar Hill is the most primitive unit of the Lynn. The volcanic vent must be close to this exposure and the Vinegar Hill covered the preexisting granitic terrane.

Proceed north (same direction) on King's Hill Dr.

0.2 3.9 Turn left on Sherman St. and proceed to the end of the street.

0.1 4.0 Turn left on Fairmount St. and proceed south.

0.2 4.2 Turn right into Forest Highlands development. Turn immediately right and drive to the end of the street.

0.1 4.3 Park and walk to the freshly blasted outcrops.

STOP 2A. LYNN VOLCANICS: VINEGAR HILL MEMBER
These outcrops are exactlly identical to stop 2 but contain a greater amount of granite xenoliths. Note: these outcrops are temporary and possibly may not be accessible in the future.

0.3 4.6 Leave Forest Highlands and turn right on Fairmount St. and continue to the end of the street.

0.5 5.1 Turn right (at Pvt. J. W. Pace Square) onto Pace Rd. and proceed west.

0.2 5.3 Join (toward right) onto Hamilton St. and proceed west.

0.6 5.9 Cross the Saugus River.

0.3 6.2 Continue straight through Saugus Center on Main St.

0.5 6.7 At the traffic lights, turn left onto Vine St.

0.1 6.8 Turn left onto Talbot St. and continue to the end of the road.

0.3 7.1 Park at the Waybright School. Walk across the ballfield toward the railroad tracks. Walk south along the railroad tracks to outcrops along the tracks.

STOP 3. SUBVOLCANIC LYNN AND BALL QUARRY GRANITE
Along the railroad tracks is the subvolcanic facies of the Lynn. This is a shallow intrusion of Lynn magma containing phenocrysts of plagioclase and hornblede. The matrix is slightly coarser grained than the volcanic units. Walk around the north wall toward the abandoned quarry. Exposed along the north wall is a largely brecciated Ball Quarry Granite (BQG) cemented by matrix identical to the Vinegar Hill. Note: The BQG is also the one which is identified in the numerous inclusions in the Vinegar Hill. As you proceed from the railroad tracks, the brecciated facies is gradually replaced by massive BQG. This granite is coarse grained having large euhedral kspar and plagioclase grains. This granite is the only rock in this terrane with K_2O in excess of Na_2O. We interpret this quarry as a volcanic vent in which the Vinegar Hill extruded and covered an older granitic terrane of the BQG. Return to the parking lot by proceeding over the walls of the quarry. Note again the increasing occurance of the brecciated facies.

Return to Main St.

0.3	7.4	At the traffic lights, turn right onto Main St.
0.1	7.5	Turn left into Saugus Common.
0.2	7.7	Park here on the right.

STOP 4. DEDHAM NORTH GRANODIORITE AND INCLUSIONS OF WESTBORO FORMATION
Outcrops in the middle of the loop exposes Dedham containing numerous inclusions of the Westboro Formation. This is an example of the typical granodiorite phase of the Dedham with coarse euhedral plagioclase and hornblende grains surrounded by quartz and minor kspar. These outcrops show how the Westboro sits in the Dedham as a roof pendant.

Continue on the road and complete the loop and return to Main St.

0.5	8.2	Turn right on Main St. and proceed west.
0.4	8.6	Cross over Rt. 1 and continue on Main St. for approximately 1000 feet.
0.2	8.8	Turn left into entrance of K-Mart Shopping area and continue to the rear of K-Mart.
0.1	8.9	Park here at outcrops behind K-Mart and Stop & Shop.

STOP 5. DEDHAM NORTH GRANODIORITE
Typical outcrops of the Dedham. This is a coarse grained rock containing hornblende, biotite, plagioclase, quartz and kspar. The Dedham is a typical calc-alkaline granodiorite with normative diopside up to 8%. There are two rhyolite dikes that intrude through the Dedham. Note the contorted contacts between

the dikes and the Dedham. These "soft" contacts imply that the Dedham was not wholly crystalline but partly plastic when the dikes intruded. On the south side of the exposure in the middle is a 2 - 3 feet large granitic inclusion mineralogically and chemically identical to the BQG, which serves as additional evidence that the BQG is a pre-Dedham granite. Note the numerous mafic dikes of unknown age that intrude the Dedham.

Return to Rt. 1 south.

0.4 9.3 Turn right on Rt. 1 and proceed south.

0.6 9.9 Bear right onto Rt. 99 south.

0.3 10.2 Turn left into parking lot of Vogue restaurant. Walk north approximately 300 feet along Rt. 99 to exposures on southeast side of the road.

STOP 6. SUBVOLCANIC LYNN MEMBER
A typical red-green outcrop of the subvolcanic member of the Lynn. This outcrop is very homogeneous containing phenocrysts of plagioclase and hornblende in a ground mass of quartz and feldspar in which the individual mineral grains are visible in thin section. This unit is geochemically very homogeneous with a very limited range in both major and trace element compositions. This unit acted as the shallow magma chamber from which the other members fractionated and which also grades texturally into the Dedham.

Return to Rt. 99 south by turning left out of the parking lot.

0.8 11.0 At the traffic light, turn right onto Elwell St.

0.1 11.1 Turn left into the Malden Moose and park by the large exposure behind the building.

STOP 7. SUBVOLCANIC DEDHAM WITH RHYOLITIC DIKES
Here the fine grained facies of the Dedham is intruded by rhyolitic dikes of the same age. The subvolcanic facies of the Dedham contains phenocrysts of hornblende and plagioclase in a granophyric groundmass of hornblende, plagioclase, biotite, kspar and quartz. The rhyolitic dikes are of the Lynn and are of a similar age as the granite due to the "soft" contacts between the dikes and the granite, similar to the dikes at stop 5. Here the dikes show flow lineations and contain phenocrysts of plagioclase. This was a very shallow area quite near a volcanic opening. The dikes may have acted as feeder dikes to a volcanic vent.

0.2 11.3 Return to Elwell St. and proceed straight across Rt. 99 onto Central Ave. Continue up the hill.

0.2 11.5 Turn left on Kennedy Dr. across from the Granada Apartments entrance.

0.1 11.6 Park on the left side at the red roadcuts.

STOP 8. LYNN VOLCANICS: BAKER HILL MEMBER
These exposures of the Baker Hill are homogeneous and massive red and green volcanics. This unit is an ash fall and welded tuff that contains plagioclase and minor hornblende phenocrysts, lacking or containing very small xenoliths. Note the dike at the end of the northern exposure which contains an inclusion of gray Lynn. This member contains some of the most evolved (least primitive) units of all the members.

0.1 11.7 Turn left at the stop sign onto Salem St.

0.3 12.0 Turn left at the stop sign. Go under Rt. 1 and turn left onto the entrance ramp for Rt. 1 north. Proceed north on Rt. 1.

2.3 14.3 Exit Rt. 1 immediatly after the overpass onto Main St. Proceed west on Main St.

0.9 15.2 At the traffic lights and the Village Park Shopping Plaza, turn left onto the Lynn Fells Parkway and proceed west.

0.3 15.5 Turn left into the Sheffield Heights Condominiums.

0.2 15.7 Park on the right by the roadcut.

STOP 9. DEDHAM NORTH GRANODIORITE
Here exposed is the quartz dioritic facies of the Dedham. This rock is slightly darker than the exposures at stop 5, somewhat finer grained and more homogeneous. The plagioclase and hornblende grains are euhedral and make up greater than 70% of the rock. Many of the hornblende grains exhibit cumulitic textures. Sphene is a very common phase and occurs as euhedral prisms that are evident in hand sample. The Sheffield area contains some of the most primitive rocks in the area with low SiO_2 (61% - 66%), high FeO^* (5% - 7%) and high Sc (10.5 - 17 ppm) compositions. The rocks in this area were some of the first to form, being where some fractionation occured causing cumulate and "quenched" textures.

Exit Sheffield condominiums by turning right onto the Lynn Fells Parkway.

0.4 16.1 Turn left on Main St. at the traffic lights and Village Park Shopping Plaza and proceed north on Main St.

0.9 17.0 Pull off the right side of the road by the exposures on the northeast.

STOP 10A. MIDDLESEX FELLS BASALT AND DEDHAM NORTH GRANODIORITE
At the south end of the outcrop is a fine grained dioritic phase of the Dedham. Further north on the outcrop, this Dedham intrudes into the Middlesex Fells basalt. This basalt has been thermally metamorphosed and recrystallized. Intercalated with this basalt is a small bed of the Middlesex Fells felsic member. The Dedham is quenched, fine grained and dark containing plag-

ioclase and hornblende grains and small pods of coarser material. The basalts were originally fine grained containing plagioclase phenocrysts. It has since been recrystallized due to the injection of the Dedham. The small felsic bed is very fine grained and also recrystallized.

Either walk or drive north along Main St.

0.3 17.3 Stop at the outcrops along the right of the road.

STOP 10B. MIDDLESEX FELLS FELSIC MEMBER.
Outcropping here is a light, somewhat pinkish, recrystallized, porphyritic rhyolite that is intruded by a dioritic dike possibly related to the Dedham magma source. Time permitting, a walk up Castle Hill is possible to further view the variety of types of the felsic member. This is a good exposure to contrast the Lynn and the felsic Middlesex Fells. The rocks here have a lower phenocryst content than the Lynn although the visible phenocryst phases are the same, plagioclase and hornblende. While the Lynn has a very fine grained glassy grounmass, the rock here is totally recrystallized. The different structural setting between the two volcanics is also evident where the Dedham is injected into the Middlesex Fells. Chemically, the Middlesex Fells felsic member has overall higher SiO_2 (74% - 76%) than the Lynn (67% - 75%) and a much narrower range of compositions. These series of outcrops show the rapidly changing nature of the Middlesex Fells where the basalts and rhyolites are intercalated and are closely related to the Westboro quartzite just south along Main St. This whole sequence is then pervasively intruded by the Dedham. (Good exposures showing the pervasive intrusive character of the Dedham can be seen under the power line about one half mile from the road in both directions.)

Proceed north on Main St. Upon entering Wakefield, Main St. changes to Farm St.

1.1 18.4 Turn left onto Water St. and continue west to Wakefield Center.

0.9 19.3 Railroad crossing

0.2 19.5 Turn left onto Main St. (in Wakefield) and proceed south on Main St.

1.4 20.9 Continue on Main St. through the traffic lights.

1.1 22.0 Turn left at the traffic light onto Franklin St. (in Melrose) and proceed northwest on Franklin St.

0.4 22.4 Railroad crossing.

0.3 22.7 Note small outcrop of the Middlesex Fells felsic to the right. This is a typical, rapidly changing sequence of different units. The rock types here are similar to the types at stop 10B.

0.9 23.6 Turn left on Franklin Place into Stoneham Jr. High.

0.2 23.8 Proceed and park at the tennis courts and walk to the outcrops behind the tennis courts.

STOP 11. MIDDLESEX FELLS BASALT
At the extreme south end of the outcrop, the dioritic facies of the Dedham is intruding the Middlesex Fells basalt. Further behind the tennis courts, there are aplitic dikes intruding the basalts. The basalts are thermally recrystallized due to the Dedham, Strike is N 30° E which is evident from the rapid succession of differing basalt flows. In the northeast corner, a porphyritic rhyolite dike or volcanic of the Middlesex Fells felsic member is exposed in the basalt. On the north face of the outcrop, there are structures that are interpreted to be pillows. The lack of full development of the pillows is due to the low viscosity of alkaline olivine basalts. Observed pillow structures are rare in the Middlesex Fells. The basalts are nepheline normative alkali olivine basalts that sit as roof pendants in the Dedham.

0.2 24.0 Return to Franklin St. and turn left. Proceed left.

0.7 24.7 At the traffic light, turn left onto Rt. 28. Proceed south.

0.4 25.1 At the traffic light, turn right onto Marble St. and go west .

0.3 25.4 At the lights, turn left onto Park St. and go south.

0.2 25.6 Turn left into Mosely Park Townhouse Condominiums and park. Assemble at southern outcrops along Park St.

STOP 12. MIDDLESEX FELLS VOCANICS AND DEDHAM GRANODIORITE
Walk south along Park St. to Orchard St. Walk north examining outcrops of Dedham North diorite - granodiorite. These are sheared medium grained grading northward to fine grained. The Dedham then intrudes the mafic Middlesex Fells. These basalts are recrystallized to greenschist facies having the original structures totally obliterated due to intrusion of the Dedham. Carefully cross Park St. and walk up the northern entrance ramp of Rt. 93 to the outcrops on the right. Here the Middlesex Fells felsic member is also intruded by the Dedham. These exposures nicely exhibit the the rapidly changing sequence in the Middlesex Fells and the intrusive nature of the Dedham. New foundation construction exposed a marble lens 15 feet wide in the Middlesex Fells mafic member. We attach a particular importance to the lens since the observed lithologies make it comparable to the Blackstone Series in Rhode Island or possibly the Greenhead Group in New Brunswick.

END OF TRIP

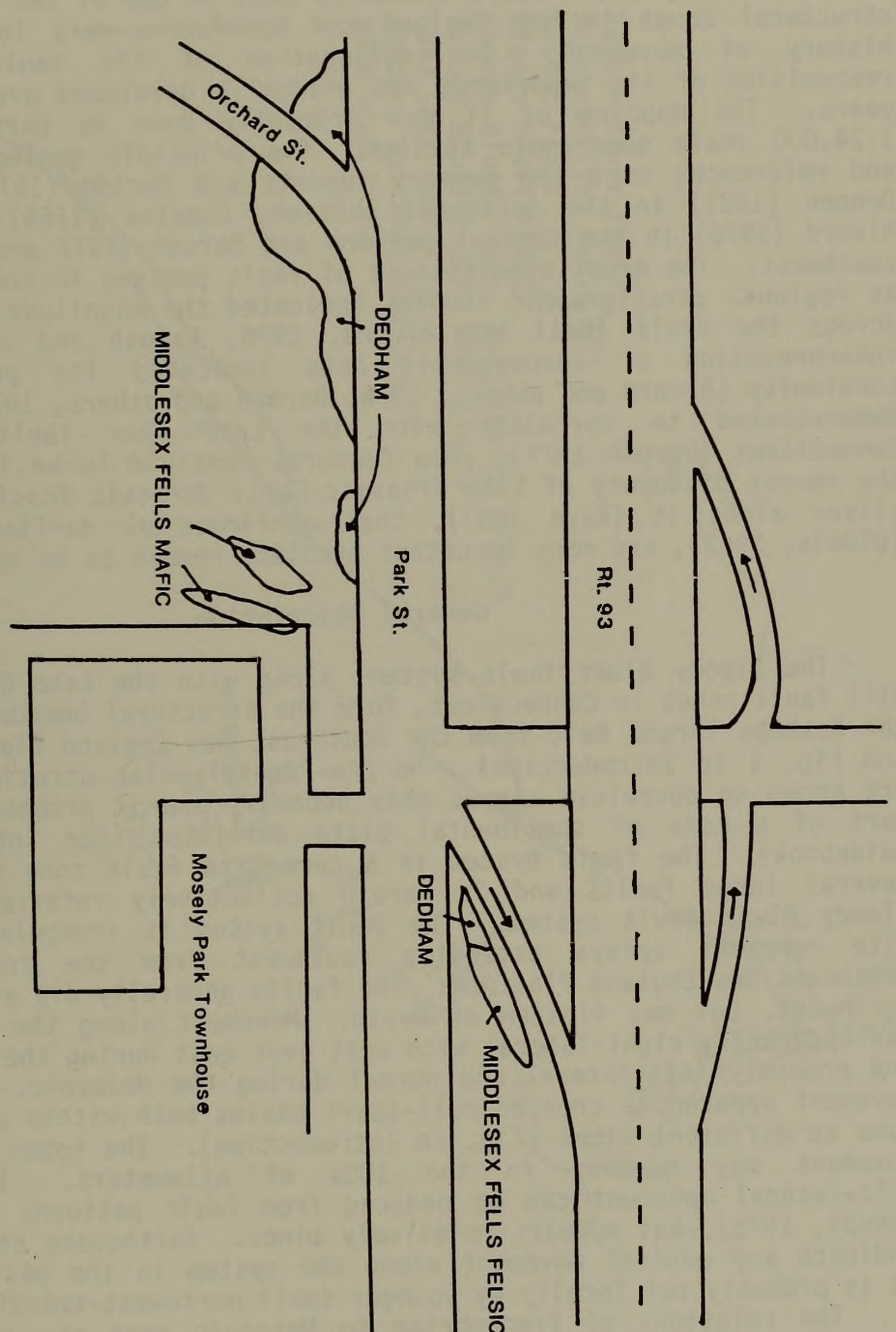


Fig. 7

Map of STOP 12