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Igneous Rocks of the Salem Area, Massachusetts

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TRIP E

IGNEOUS ROCKS OF THE SALEM AREA, MASSACHUSETTS[1]

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Igneous rocks of Essex County have been the subject of many detailed studies; publications covering more than local descriptions include those of Clapp (1921), Warren and McKinstry (1924), and Toulmin (1960, 1964). Among the important early descriptive works, the papers of Washington (1898-1899), Wright (1900), and Dale (1908, 1911) should also be mentioned.

The rocks to be examined on the present excursion fall into the following groups:

1) Gneisses and plagioclase amphibolites, tentatively referred to the Marlboro formation of probable Precambrian age;

2) Calcalkalic intrusive rocks (gabbro, diorite, quartz diorite, granodiorite) younger than the gneisses and older than the so-called "alkalic" igneous rocks (the calcalkalic rocks are divided into an older and a younger group according to their age relations with the fossiliferous Newbury formation of Late (?) Silurian or Early (?) Devonian age);

3) So-called "alkalic" igneous rocks younger than the preceding groups.

Most of the trip will be devoted to the last-named group, which includes rocks ranging in composition from granitic through syenitic to feldspathoidal and in texture from aphanitic through medium- and coarse-grained to pegmatitic.

In view of the recent publication of detailed descriptions of these rocks (Toulmin, 1964), their petrography will not be reviewed here. A brief statement of the history of emplacement and crystallization of the "alkalic" rock suite may, however, not be out of place. The following is quoted with minor modification from the author's unpublished thesis*.

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[1] Publication authorized by the Director, U.S. Geological Survey

* Toulmin, Priestley, III, 1958, Bedrock geology of the Salem area, Massachusetts: Ph.D. Thesis, Harvard University, Cambridge, Massachusetts.

Granitic magma, probably somewhat poorer in SiO_2 than the Peabody Granite and typical Cape Ann Granite, is believed to be the source magma of the leucocratic rocks of the "alkalic" series. The diversity of the leucocratic rocks is attributed to differentiation processes in essentially the same place where the rocks are now found, rather than in some hidden magmatic chamber at greater depth. The over-all form of the major intrusive body, the Cape Ann pluton, is not known, but at least local portions of its contact dip inward.

Crystallization of the magma began with the separation of alkali feldspar comparatively rich in Or (at least Or_{61}). In the interior of the pluton crystallization apparently continued uninterrupted and sufficiently slowly to allow more or less complete reaction between feldspar crystals and liquid, for zoned feldspar crystals are rare in the granites. During crystallization the feldspar became richer in Ab, but in none of the granites did the feldspar become less potassic than about Or_{44}. Quartz and ferrohornblende probably began to crystallize at about the same time; the order of their appearance may have differed from place to place within the crystallizing magma.

On the margin of the pluton a porphyritic facies was developed which grades continuously inward into granite both by increase in the proportion of phenocrysts and by appearance of phenocrysts of quartz and hornblende in addition to the feldspar phenocrysts present in the outermost shell.

Where volcanic activity occurred, the crystallization of the underlying magma was affected, principally by loss of H_2O. Rapid crystallization of feldspar ensued, and the feldspar so formed is nearly all between Or_{25} and Or_{40}, very much poorer in Or than the feldspars formed in the interior of the pluton. Where a "floor" of country rock existed under such a shower of sodic feldspar crystals, the crystals accumulated to form masses of syenite, passing upward into granite as "normal" crystallization resumed.

The many mafic dikes associated with the leucocratic rocks were formed at almost the same time as the leucocratic rocks; evidence of overlapping and almost contemporaneous intrusion is abundant. Some genetic relationship presumably exists between the mafic and granitic magmas, but whether they have differentiated from a common ancestor or are more or less independent products of the same general process of magma generation is unknown. At any rate, there is little doubt that both existed as mechanically separate magmas before they moved to the level of the crust now exposed in the Salem area.

The textures of many of the trachytic syenite dikes imply that they have crystallized from a liquid of essentially the same composition as that of the rock. The most likely source of such a liquid is the fusion of massive syenite; the composition of the feldspar of the trachytic syenite is compatible with such an origin. The source of the heat required is uncertain, but mafic dikes in the area are known to have fused their syenitic wall rocks, and a larger body of mafic magma "at depth" presumably would be capable of fusing a larger body of syenite. Many of the rocks of the contact zone on Salem Neck and Great Misery Island may represent various stages of fusion and reaction of mafic and leucocratic rocks.

The intrusion of the granitic magma was probably not a simple single event. The rocks mapped as Cape Ann Granite in the Salem area are variable in composition and texture, but some areas in the interior of the Cape Ann pluton (mostly outside the Salem area) resemble the Peabody Granite both in compositional uniformity and in the rarity or absence of younger mafic dikes. These facts suggest that at some time after the intrusion (and differentiation?) of the Cape Ann pluton, granitic magma again invaded the area to form the Peabody stock and the areas of uniform granite within the Cape Ann pluton. Variations of the granites of the Cape Ann pluton have not been studied systematically in the present investigation; detailed study of the whole pluton should answer many of the questions left unanswered here.

ROAD LOG

Mileage	Notes
0.0	South Lynnfield Interchange (intersection of routes U.S. 1 and Mass. 128). Head east (toward Gloucester) on Route 128.
1.6	Peabody Industrial Development Commission on right.
2.0	The little quarry just off the road to the left is Stop 1, but it is necessary to continue a short distance and make a U turn to reach the quarry.
2.6	Make permitted U turn.
3.2	Stop 1.

STOP 1. This stop exhibits the typical aspect of the Peabody Granite. The rock is a medium-coarse-grained granite composed of quartz, microperthite, ferrohornblende, and accessories. As seen in this quarry and elsewhere throughout the Peabody stock, it is quite homogeneous both in composition and in structure. Xenoliths are fairly sparse in most outcrops, and widely spaced joints are characteristic. No flow structure is evident in the interior

of the stock, though some may be observed near the contacts. Aplite and porphyritic microgranite dikes are common, but trap dikes are very rare in the Peabody Granite.

Mileage	Notes
0.0	On leaving Stop 1, it is necessary to go west a short distance and then make another U turn across the center strip to go east on Mass. 128.
0.1	Make permitted U turn.
1.1	Stop light at Forest Street. Continue on Route 128.
1.4	Cross contact between Peabody Granite to SW and Salem Gabbro-Diorite to NE. The granite underlies the relatively higher area through which you have just come. The gabbro-diorite in general occupies a lower area ahead; possibly the ridge of gabbro-diorite directly ahead is held up because of increased resistance somehow related to the contact of the younger granite stock.
2.4	Take Exit 25N, Mass. Route 114 toward Middleton and North Andover.
2.9	Pass North Shore Shopping Center on left.
3.2	Continue straight on Route 114.
3.8	Danvers town line. The high ground to the left is underlain by Peabody Granite; the lowland to the right is underlain by Salem Gabbro-Diorite.
4.6	Railroad underpass.
5.0	Turn right onto U.S. 1, following signs for Newburyport, N.H., and Maine.
5.8	Turn right into interchange at Dayton Street, following sign for Danvers. Stop 2.

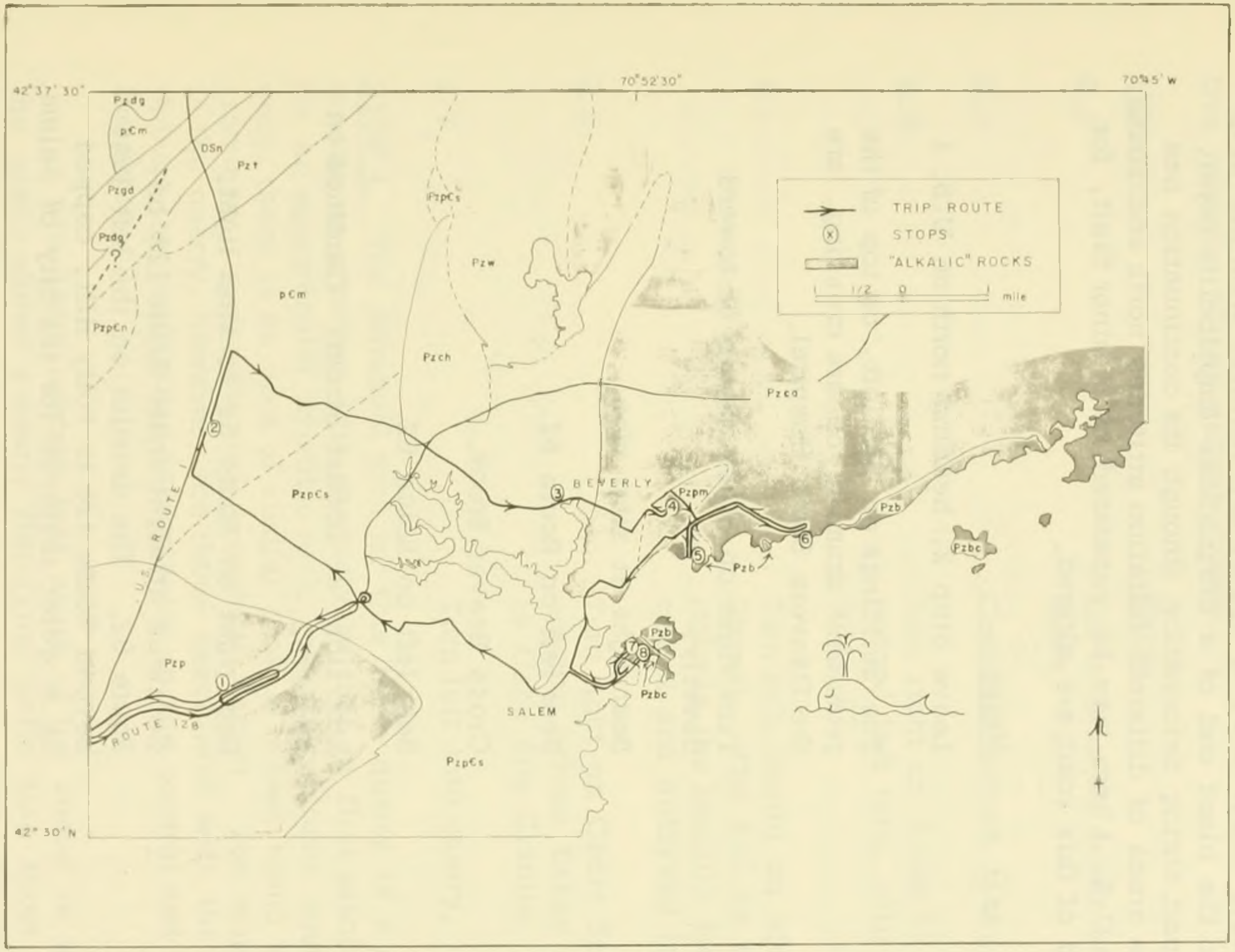

Figure 1. Sketch map of route of trip Sat. E. Rock units: Pzb, Beverly Syenite; Pzbc, Beverly Syenite contact zone; Pzw, Wenham Monzonite; Pzpm, porphyritic microgranite; Pzch, Cherry Hill Granite; Pzca, Cape Ann Granite; Pzp, Peabody Granite; Pzt, Topsfield Granodiorite; Pzgd, medium-grained granodiorite; Pzdg, diorite and gabbro, undifferentiated; DSn, Newbury Formation; PzpGn, Newburyport(?) Quartz Diorite; PzpGs, Salem Gabbro-Diorite; pGm, Marlboro(?) Formation. Geology after Toulmin (1958, 1960, 1964).

STOP 2. The rocks exposed in the road cuts of the interchange here are fairly typical of the dominant lithologies in the Marlboro (?) Formation in the Salem quadrangle. The plagioclase amphibolite ranges from a distinctly foliated to an apparently isotropic fabric. The augen gneiss displays a considerable range in megacryst content and in degree of foliation.

The structural details of the locality are complex. A small fold in the augen gneiss (in the cut on the west side of the first ramp east of U.S. 1 and north of the road passing under U.S. 1) apparently resulted from the wrapping of the gneiss around the blunt end of a plagioclase-amphibolite layer, which may have pulled apart during deformation (though its continuation has not been identified). The areas of different foliation attitudes north and south of the road passing under U.S. 1 here may be separated by a minor fault, for the rocks at the west end of this road are altered.

Mileage	Notes
0.0	Leave Stop 2, heading north on U.S. 1
0.7	The buildings on the left, on top of the prominent drumlin you are crossing, are the Danvers State Hospital.
1.0	Turn right on Mass. Route 62 toward Beverly.
1.3	Bear right at stop sign.
2.1	Bear left on Route 62.
2.4	Cross Beaver Brook.
2.8	Bear left on Route 62.
3.0	Stop light at Locust Street. Continue on Route 62.
3.6	Bear right on Route 62 at stop light.
3.9	Continue straight under Route 128 on Route 62. The drumlin on the left just beyond Route 128 is Folly Hill, capped by a water reservoir for the city of Salem.
4.8	Bear left on Route 62 at fork in road.

5.7	Stop 3. Park by store right of road.

STOP 3. The rocks along the left side of the road here are more or less typical of the Salem Gabbro-Diorite near its contact with younger intrusives of the "alkalic" igneous complex. The rock has been somewhat recrystallized locally, and is shot through with veins or small dikes of more salic materials, which may be either highly contaminated alkalic rock or the product of selective refusion of the gabbro-diorite.

Mileage	Notes
0.0	Leave Stop 3, going east (toward Beverly) on Mass. 62.
0.7	Continue across Mass. Route 1-A on Route 62.
0.8	Turn right on Route 62 at Cabot Street; take second left turn, still following signs for Route 62.
1.1	Turn left (north) on Mass. Route 22 (Essex Street). The hill on the playground to the right is the locality for the amazonite described and analyzed by J.W. Webster in 1824.
1.5	Turn right on Cedar Street (unpaved). The outcrop across Essex Street from Cedar Street is Cape Ann Granite.
1.7	Turn left into quarry. Stop 4.

STOP 4. The principal rock of this little quarry is a porphyritic microgranite so crowded with phenocrysts that at first glance it could be mistaken for an equigranular syenitic rock. At the extreme southeast end of the outcrop, there is an area of similar rock in which round quartz phenocrysts are prominent, giving the rock a granitic aspect. The most interesting features in the quarry, however, are those associated with the mafic dikes that cut through the porphyritic microgranite in the central and northwestern part of the quarry.

The large outcrop just south of the center of the northeast edge of the quarry shows a nearly flat-lying mafic dike about 8-10 inches thick that extends along almost the entire outcrop. Near the center of the outcrop, this dike is offset both perpendicular and parallel to its walls, in such a way as to suggest irresistibly that the dike has been broken and pulled apart and that the surrounding rock must have been able to flow easily enough to fill in the resulting potential void. Careful scruntiny fails to reveal fractures that could have served as faults to produce the observed relations. Although the heat-supply problem is admittedly a difficult one, no better solution has occurred to the writer than to suggest that a still warm vitrophyre might fracture, allowing the intrusion of an andesitic magma with a liquidus temperature sufficiently higher than that of the vitrophyre so that the observable chilled borders of the dike could result; the vitrophyre, though brittle enough to fracture under short-term stresses, might react viscously to more slowly applied, long-continued forces, so that the flowage required to explain the separation of the two parts of the dike could have taken place. The chilled margins of the dike are clearly transected by the ends of the two segments of the dike, so the relations cannot be explained as the result of an originally branched intrusion.

Similar tearing apart of trap dikes seems to have taken place in the porphyritic microgranite of the northwestern outcrop in the quarry, but apparently at a time when the wall rocks were at least slightly cooler and less yielding. Here the spaces between the matching dike segments are occupied by quartz-rich pegmatite or pods of quartz. These were presumably sweated out of the country rocks.

Both phenomena strongly suggest that the mafic dikes were emplaced quite shortly after the emplacement of the porphyritic microgranite, which implies the simultaneous presence in near proximity of magmas of strongly contrasting composition.

Mileage	Notes
	Leave Stop 4 and retrace route to intersection of Cedar and Essex Streets.
0.0	Intersection of Cedar and Essex Streets. Turn right (north) on Route 22 (Essex St.).
0.4	Turn right on Corning Street, just past Plummer's Store.
0.9	Stop sign. Continue straight.
1.1	Turn right on Hale Street (Mass. Route 127) at stop sign.
1.2	Turn left on Woodbury Street.
1.5	Stop at dead-end at water. Stop 5.

STOP 5. The outcrops on the shore here are fairly typical of the Beverly Syenite. The feautres to be noted particularly are the range in grain size and the large size of some of the microperthite crystals. The outcrop should be visited at low tide.

Mileage	Notes
0.0	Leave Stop 5, retracing route along Woodbury Street.
0.3	Turn right on Mass. 127 (Hale Street).
0.4	Cross Corning Street. Church In The Cove on right. Continue on Hale Street (Mass. 127).
1.0	Make sharp right turn at blinking yellow light, still following Mass. 127.
1.6	Main entrance to Endicott Junior College on left (College Hall and others). Continue on Route 127.
1.9	Mingo (Endicott) Beach on right. Stop 6. Please remember that we are on College property here.

STOP 6. The outcrops at water's edge on the east side of the point in the middle of Mingo Beach show a portion of the contact between Beverly Syenite and Peabody Granite. The relations are, unfortunately, not so clear-cut here as in some other localities, which are not accessible to a group the size of this one, but the generally continuous, or abruptly transitional, character of the contact can be seen. In some localities in West Manchester, the contact is practically unmarked structurally, but consists simply of a surface across which the quartz content of the rock increases abruptly in an otherwise continuous mesh of crystals of the other minerals, chiefly feldspar. At the present stop, an aplite dike follows much of the contact, but the general relations may be discerned.

Syenite, which makes up most of the seaside exposures on the headland, acquires minor amounts of quartz over an interval of about 20 feet toward the contact with granite in the easternmost outcrop (next to the beach). Granite underlies the northwestern part of the point and the hilly area across Hale Street to the north; the syenite on the point is one of several remnants of a body that probably once was a continuous band of syenite south of the granite.

Mileage	Notes
0.0	Leave Stop 6, heading west (toward Beverly and Salem) on Mass. 127.
0.9	Turn sharp left at blinking yellow light; stay on Mass. 127.
1.5	Cross Corning Street (Church In The Cove on left); continue straight on Mass. 127.
1.9	Bear left on Route 127.
2.0	Intersection with Route 62; turn left on Route 127.
2.8	Turn right, following Route 127.
3.1	Turn left, following Route 127, which here merges with Mass. 22; at mile 3.2, these merge with Mass. 1-A. Follow any and/or all of these toward Salem.
3.4	Turn left across bridge on Mass. 1-A.
3.7	South end of Danvers River Bridge. Continue south on Route 1-A.
4.3	Turn left on Webb Street (watch closely for this turn).
4.5	Bear right; follow road along end of Collins Cove.
4.7	Cross Essex Street; bear left around traffic island shortly thereafter.
5.0	Intersection with Derby Street, Fort Avenue, and Memorial Drive, by fire house and power plant. Turn left on Memorial Drive (left of fire house) and continue on Memorial Drive.
5.4	Stop at power line. Stop 7 is outcrop behind house at 64 Memorial Drive (on right).

STOP 7. The rock at this stop is an exceptionally fine example of a type that is quite widespread in the area of Salem Neck mapped as "Beverly Syenite contact zone" in USGS Bull. 1163-A; the rock consists of a mixture of mafic porphyry and leucocratic syenite, arranged in a fashion at least geometrically similar to the basalt and palagonite of pillow lava. Both rocks show evidence of contamination -- labradorite phenocrysts of the dark porphyry have albitic centers, and crystals of the minerals of the dark porphyry are strewn through the syenite. The ellipsoidal structure is widespread but is particularly well displayed in this outcrop, where it also shows the unusual feature of apparently having been deformed more or less synchronously with its formation. The crudely synclinal structure in the outcrop is obvious; if the near-vertical fractures in the axial region are tension fractures related to the deformation that produced the syncline, then the fact that syenite fills them implies that the syenite is either younger than, or more or less synchronous with the folding. Inasmuch as the ellipsoidal structure has not been seen without the syenite stringers between the ellipsoids, it seems reasonable to assume that the origin of this structure and the syenite are closely related; hence the syenite must be essentially contemporaneous with the folding.

Mileage	Notes
0.0	Leaving Stop 7, retrace route along Memorial Drive.
0.2	Continue straight: do not bear right past hospital, but go left of Bentley School.
0.4	Intersection at fire house and power plant; turn left on Fort Avenue.
0.8	Park on right at gate at near (SW) end of stone wall. Go through gate and follow path to shore of Cat Cove. This is Stop 8.

STOP 8. This stop displays both the wide variety of rock types in the Beverly Syenite contact zone and several interesting igneous structures. Dikes of many varieties of porphyry cut one another in considerable confusion. The youngest dike rock is the nepheline-sodalite syenite, a blue-gray rock in which a greasy-looking feldspathoid is apparent in hand specimen. What looks like a single mineral is actually both nepheline and a sodalite that fluoresces bright orange in long-wavelength ultraviolet light; it is virtually identical to the mineral described from the nepheline-sodalite syenite of Red Hill, N.H. (Quinn, 1935, 1937). At various places along the shore of the cove, one can see good examples of ellipsoidal structure

and discontinuous dikes that may result either from an initial branching of the fracture along which the dike was emplaced or from later deformation. At the extreme western end of the outcrop, by the masonry wall near the wire fence that surrounds the sewage plant, is an outcrop of coarse-grained fresh gabbro; this rock which was referred to by Washington (1898-1899) as the "hyperitic variety" of essexite, is composed of fresh labradorite, olivine, augite, hornblende, and biotite, for the most part without any textural indication of a reaction relationship. Alkali feldspar is very rare, and nepheline absent, as noted by Washington.

Mileage	Notes
0.0	Leaving Stop 8, retrace route along Fort Avenue.
0.4	Bear right at fire house and power plant (do not make sharp right turn into Memorial Drive).
0.7	Continue straight across Essex Street on Webb Street.
0.9	Bear slightly left at McManus Square.
1.0	Turn left on Routes 107 and 114.
1.1	Bear slightly right at flashing yellow light, following signs for Mass. 107, <u>not</u> for Mass. 1-A.
1.5	Go right around rotary, then branch right, following signs for Mass. 114.
2.0	Bear slightly left, following Route 114.
2.5	Cemetery entrance on right.
3.0	Route 114 turns left; follow it.
3.5	Stop light. Turn left, following Route 114.
3.6	Take second right, following signs for Route 114.
4.3	Pass over Route 128; turn right on ramp to Route 128 toward U.S. 1, following signs for S. Lynnfield and Boston.

5.9	Forest Street stop light.
6.7	Quarry of Stop 1 on right.
7.9	Turnoff to U.S. 1 and South Lynnfield Interchange.

TRIP E

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