PRELIMINARY BEDROCK GEOLOGIC MAP OF THE IPSWICH QUADRANGLE, MASSACHUSETTS

by William H. Dennen

1975

U.S. Geological Survey
OPEN FILE MAP 75-544

This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

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Contents

BEDROCK GEOLOGY OF THE IPSWICH QUADRANGLE, MASSACHUSETTS

Introduction

Rocks of the Ipswich quadrangle have previously been described by Sears (1905), Emerson (1917), and Clapp (1910, 1921). Surficial deposits were mapped by Sammel (1963), and surficial coastal geology described by Chute and Nichols (1941). Geophysical Investigations Map GP-719 (1970) provides contours of total magnetic intensity for most of the quadrangle. The bedrock is Precambrian (?) and Paleozoic intrusive and extrusive igneous rocks; granite and gabbro-diorite of the Cape Ann Pluton underlie the southeastern two-thirds of the quadrangle and a series of northeasterly trending bands of extrusive and intrusive rocks underlies its northwestern third. Outcrop of quartzose plutonic rocks is generally good, but mafic intrusive and extrusive rocks provide scanty outcrop.

Physiographic Features

The Ipswich quadrangle is situated on the northeastern Massachusetts coast within the Seaboard Lowland section of the New England Physiographic Province (Fenneman, 1938).

The present shoreline results from late Tertiary (?) submergence of a stream-dissected topography having 15-50 meters of relief,

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which was later over-ridden by Pleistocene glaciation. The ice sheet, moving approximately S40°E, [redacted] smoothed the surface by planation and deposition of ground moraine and outwash deposits forming a smooth and gently sloping surface. Complex shifting of ocean level through Pleistocene time stabilized in a stand slightly below the present level, and in the past few thousand years a rise of perhaps 30 meters has taken place. Holocene deposition has formed a seaward barrier beach [redacted] of beach and dune sands on Plum Island and Castle Neck backed by a wide area of salt marsh.

The veneer of glacial deposits over dissected bedrock consists of ground moraine which may range upward of 15 meters in thickness, a variety of outwash deposits including kames, kame terraces and fine sediments of glaciofluvial and glaciomarine origin, and numerous drumlins of roughly oval plan rising to 65 meters or more. Holocene deposits cover the glacial material and bedrock from the inner edge of the salt marsh seaward, except for partially drowned drumlins such as North Ridge and Tilton Hill.

Hilltops and high areas on the dissected bedrock surface provide most of the present bedrock outcrop. The elevation on the bedrock surface ranges from +49 meters on Fifteen Mile Hill in the Town of Essex to -11 meters under the salt marsh at Six Goose Creek to more than -20 meters in the northeastern quadrangle corner. Bedrock relief generally decreases to the north and west to 15 meters or less in the Town of Rowley.

The topography of the quadrangle is divisible into three

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north-south zones dominated from west to east by (1) irregular and hummocky ground interspersed with level, often swampy areas, (2) an extensive area of salt water marsh crossed by numerous tidal channels, and (3) beach and dune deposits.

Most of the rivers within the quadrangle are completely tidal; the Ipswich and Essex Rivers are tidal inland to "falls" above which they provide sluggish drainage from the west.

Structural Features

The bedrock of the Ipswich quadrangle is divided along northeasterly lines into alternately metamorphosed and unmetamorphosed terrains by two major faults of the imbricate thrust zone of eastern Massachusetts (Bell, 1967). Unmetamorphosed volcanic rocks of the Newbury Complex occupy the extreme northwest corner of the quadrangle, metamorphosed mafic volcanic rocks, granodiorite, and diorite the northwest one-third, and unmetamorphosed intrusive rocks of the Cape Ann Pluton underlie the southeastern two-thirds of the quadrangle.

These faults are high-angle right-lateral thrusts of unknown, but possibly large, displacement. A minor fault of this set follows the general course of the Ipswich River from the western boundary of the quadrangle east and northeast through the town of Ipswich where it is lost in the marsh. Although none of these faults is exposed, their position is inferred from linear topographic lows, zones of cataclasis in the rocks, hydrothermal effects in some places, magnetic lineaments, and juxtaposition of metamorphosed and unmetamorphosed rocks. Minor normal faulting along north-

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westerly trends is common throughout the area as evidenced by offset boundaries, local cataclasis, and development of foliation and slickensides.

The age of the faulting cannot be determined from observations within the quadrangle except that it is younger than the youngest rocks exposed. Evidence from the adjoining Georgetown quadrangle (K.G.Bell and others, *Personal Communication, 1974*) suggests an age of late Paleozoic through early Mesozoic.

Although no genetic relationship is implied, the foliation and bedding within some of the fault blocks emphasized the general NE-SW grain of the bedrock. Northeasterly-trending mineral foliation and oriented inclusions characterize the granodioritic rocks of possible Precambrian age in the northwest third of the quadrangle and is also well developed in those Precambrian (?) metavolcanic rocks which have escaped retrograde metamorphism. The few bedded outcrops which may be seen are characterized by northwesterly dips and northeasterly strikes generally parallel with the northeasterly trend of the principal formations. Evidence of folding is absent.

Other rocks are massive except that foliation or banding is very locally but in some places strongly developed in them by magmatic motions or by post-consolidation shearing, often accompanied by evidence of hydrothermal activity and sometimes resulting in chloritized mylonite zones.

Stratified or Layered Rocks

Mafic Metavolcanic Rocks: These rocks comprise most of the bedrock between the Roger Island and Eagle Hill Rivers and were originally deposited as fine- to medium-grained interlayered basaltic pyroclastic and flow rocks

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which were later regionally metamorphosed to foliated amphibolites. Hydrothermal alteration, possibly related to the emplacement of the adjacent granodiorite, converted hornblende to biotite and chlorite, saussuritized the feldspars, and generated large amounts of epidote. During a later hydrothermal episode specular hematite, pyrite, and minor calcite were deposited in joints and fractures.

In consequence of this hydrothermal activity, these rocks today are typically hard, flinty, dark-colored metavolcanic rocks that have closely spaced polyhedral jointing and whose primary features have largely been erased in the most extensive outcrop areas along Bull Brook and east of the Boston and Maine Railroad one kilometer south of its crossing of the Rowley River, as well as in the smaller outcrop area on Ipswich Common and vicinity where mafic metavolcanic clasts are incorporated in the igneous breccia on the boundary between Salem Gabbro-diorite and Cape Ann Granite.

A few occurrences of strongly foliated biotitic amphibolite are preserved without significant hydrothermal alteration farther away from the granodiorite intrusive. Foliated amphibolite supports the navigational spindle at the southern end of Plum Island Sound, comprises a minor portion of the Salem Gabbro-diorite pendant in the Cape Ann Granite, and is sparsely distributed in the granite as small inclusions.

These mafic metavolcanic deposits are the oldest rocks in the Ipswich quadrangle and have been correlated by R.G. Bell (written communication, 1973) with the upper part of the Blackstone Series of Rhode Island of

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Precambrian age as described by Quinn (1971).

Newbury Complex: Rocks of the Newbury Complex underlie the extreme northwestern corner of the Ipswich quadrangle [illegible] north of the major fault which separates the Newbury basin from older rocks to the south. Rocks of the Newbury Complex are remnants of a volcanic terrain including a number of extrusive and at least one intrusive member. In this quadrangle, the complex is represented only by poorly exposed andesitic extrusive rocks including both flow and agglomeratic material, and pod-like bodies of white to flesh-colored rhyolite. These rocks have suffered little petrographic change since their formation, principally some devitrification and local silicification of the rhyolitic member and saussuritization of the andesites.

These volcanic rocks have been placed at the Siluro-Devonian boundary on fossil evidence by LaForge (in Emerson, 1917) and this age is supported by additional fossil assemblages collected by N.P. Cuppels (written communication).

Intrusive Rocks

Intrusive Rocks of possible Precambrian age: Medium- to coarse-grained plutonic rocks ranging from quartzose granodiorite to diorite form a comagmatic suite which, together with mafic metavolcanic rocks, make up the fault block bounded by the two major northeasterly faults crossing the Ipswich quadrangle. These rocks have undergone extensive post-depositional hydrothermal modification resulting in chloritization of ferromagnesian minerals and saussuritization of feldspars. A later

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hydrothermal episode introduced iron which locally obliterated the earlier greenish colors of the feldspars and gave them a salmon-red tinge. The granodiorite is coextensive with identical rocks in the Georgetown quadrangle at Ox Pasture Brook Hill thought by Bell and others (personal communication, 1974) to be possibly Precambrian in age. It appears to be the same rock as the Topsfield Granodiorite of Toulmin (1964) to which he assigned a Mid-Paleozoic age.

Diorite of Rowley: This rock is represented in the Ipswich quadrangle by a single outcrop of massive hornblende diorite 0.65 kilometers S30°E from the Pine Grove School. It is petrographically identical with a mafic facies of intrusive rocks of possible Precambrian age in the Georgetown quadrangle, as described by Bell and others (personal communication, 1974) who consider it to be a mafic phase of the Precambrian (?) granodiorite.

Granodiorite: The salic facies is a quartzose granodiorite found in numerous small outcroppings especially common in the marshes east of the Boston and Maine Railroad and north of the Rowley River. Foliation is well developed trending N60°E and dipping 60-70°NW. Compositional variation within the mass leads to border areas enriched in mafic minerals, now principally chlorite, which together with its pink feldspar give the rock a distinctive pink-green mottled appearance. The central portion of the body is less chloritic and a fresh surface is pink and gray. Ovoids of quartz, often bluish, are prominent. Dikes of this granodiorite cut the mafic metavolcanic rocks to the south at outcrops near the head of Metcalf Brook and in a drillhole at Six Goose Creek,

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and inclusions of the mafic metavolcanic rocks are occasionally found in the granodiorite. A poorly exposed pluton of this granodiorite is located in the vicinity of Paradise Road, Ipswich.

Cape Ann Plutonic Series: The Cape Ann Granite and Salem Gabbro-diorite (Clapp, 1910, 1921) encompass a number of identifiable facies which range from medium- to very coarse-grained and contain a characteristic alkali-iron-rich suite of mafic minerals, greenish feldspars with a greasy luster, and glassy quartz. Chemically, optically, and morphologically identical principal and accessory minerals are present in all phases but in different proportions.

These rocks have been ascribed widely different ages by previous workers because of their intrusive relations; the gabbro-diorite generally being called Precambrian or Lower Paleozoic and the granite, Upper Paleozoic in age. Petrographic study (Bell and Dennen, 1972) and spectrochemical analysis of a number of the same mineral species from the two rocks and geochemical studies (Survant, Personal Communication 1975 Norton, 1974), however, indicate that these rocks are comagmatic facies emplaced in rapid succession, gabbro-diorite first. An absolute age of 450 $\pm$ 25 m.y. for the Cape Ann Granite and 460 $\pm$ 15 m.y. for the Salem Gabbro-diorite is given by Zartman and Marvin (1971). Early separation of the mafic phase at depth reduced the calcium and magnesium content of the rest magma to negligible levels, and settling of microcline microperthite concomitant with the emplacement of the granitic material resulted in a highly variable quartz content.

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Salem Gabbro-diorite: Hornblende diorite with a variable but usually well oriented fabric and typically veined with pink felsic stringers similar to that in the Salem quadrangle (Toulmin, 1964), borders the Cape Ann Granite along the general line of the Ipswich River and makes up most of a large pendant within the granitic portion of the pluton. Good outcrop may be seen between Pine Swamp Road and Kimball Brook at the western quadrangle boundary in the town of Ipswich and on the west bank of the Ipswich River southeast of East Street. Scattered small outcrops in the pendant are found from the junction of Argilla and Northgate Roads to Fellows Road 0.7 kilometer south of its junction with Lakeman Lane.

The anomalously high total magnetic intensity and gravity values measured over the Cape Ann Pluton (Joyner, 1963; Kane and others, 1972) may probably be ascribed to the presence of this rock at shallow depths beneath the Cape Ann Granite.

Cape Ann Granite: The Cape Ann Granite underlies all of the quadrangle southeast of the Ipswich River. Outcrop is generally good, and extensive outcrop areas are found on Appleton Farm, along Choate and Belcher Streets, and in both Essex and South Essex. Rocks of the Cape Ann Pluton in this area are generally unfoliated, medium coarse-grained, and compositionally variable from alkali-feldspar granite through alkali-feldspar quartz-syenite to alkali-feldspar syenite. The compositional variation is most easily seen in the modal quartz content of the rock as measured on outcrop, and

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mapping shows the different phases to occur in bands, probably reflecting rude primary layering within the mass. Cumulate textures are occasionally present and suggest that settling of microcline microperthite is the mechanism of differentiation.

The Cape Ann Granite intrudes the Salem Gabbro-diorite and contains dioritic inclusions. Inclusions of mafic metavolcanic rocks identical with those exposed at Bull Brook, etc. and fine-grained, fine-banded metasedimentary rocks of unknown provenance are also present. Fine-grained granite is found as widely scattered inclusions and is especially abundant in outcrops north of Heartbreak Hill and between Craft and Fifteen Tree Hills. This granite is an early phase of the Cape Ann Granite and is equivalent to the diorite of Shaler (1889) and Squam Granite of Clapp (1910). Granophyric apophyses from the Cape Ann Granite cut mafic metavolcanic rocks along the Ipswich River, and Cape Ann differentiates form the matrix of the intrusion breccia outcropping on Meeting Green 0.35 kilometer southeast of Winthrop School, Ipswich.

Mafic Dikes

Scattered mafic dikes ranging from a few inches to over ten feet in width and including basaltic and diabasic types were encountered in mapping. Age assignment has not been possible but similar dikes elsewhere in eastern Massachusetts are Triassic in age, while on Cape Ann some are genetically related to the emplacement of that pluton; others may be older.

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Metamorphism

Metamorphic effects within the quadrangle are sharply delimited by the major faults. Metamorphic effects in the block occupied by the rocks of the Newbury Complex are very slight and are probably essentially deuteric. In the block occupied by the Cape Ann Pluton, effects are restricted to the thermal metamorphism of sedimentary rock inclusions to garnet grade and the development of porphyritic textures in the granite adjacent to inclusions.

In contrast to this modest metamorphism of the younger rocks, the older mafic volcanic rocks and granodiorite of the central block bear profound metamorphic effects. The granodiorite of the Ox Pasture Brook locality in the Georgetown quadrangle and its easterly extension in the Ipswich quadrangle has a strong foliation and pervasive cataclasis of its quartz grains, and has undergone a considerable degree of hydrothermal alteration. The mafic volcanic rocks were regionally metamorphosed to amphibolite facies and then underwent retrograde changes which obliterated their distinctive earlier fabrics. A single episode of regional metamorphism, possibly Acadian, followed by two episodes of hydrothermal activity which may be related to the intrusion of the granodiorite and to the regional faulting, adequately explains the observed effects.

Economic Geology

The only geologic materials of value which have been produced from the Ipswich quadrangle are sand and gravel. Most deposits are of poor quality, but good sand is being exploited at several sites in the Town of Ipswich.

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Minor sulfides are found within the mafic metavolcanic rocks at Bull Brook Reservoir and were encountered in drill holes along Paradise Road, Ipswich, and near Six Goose Creek. The occurrences are mainly of scattered pyrite and have no economic potential.

Cape Ann Granite that has 15-25% modal quartz has been extensively quarried in the Gloucester and Rockport quadrangles, and rock of equivalent quality underlies parts of the Ipswich quadrangle, particularly the southwestern portion. Exploitation would be difficult because of heavy cover, high water table, and costly transportation.

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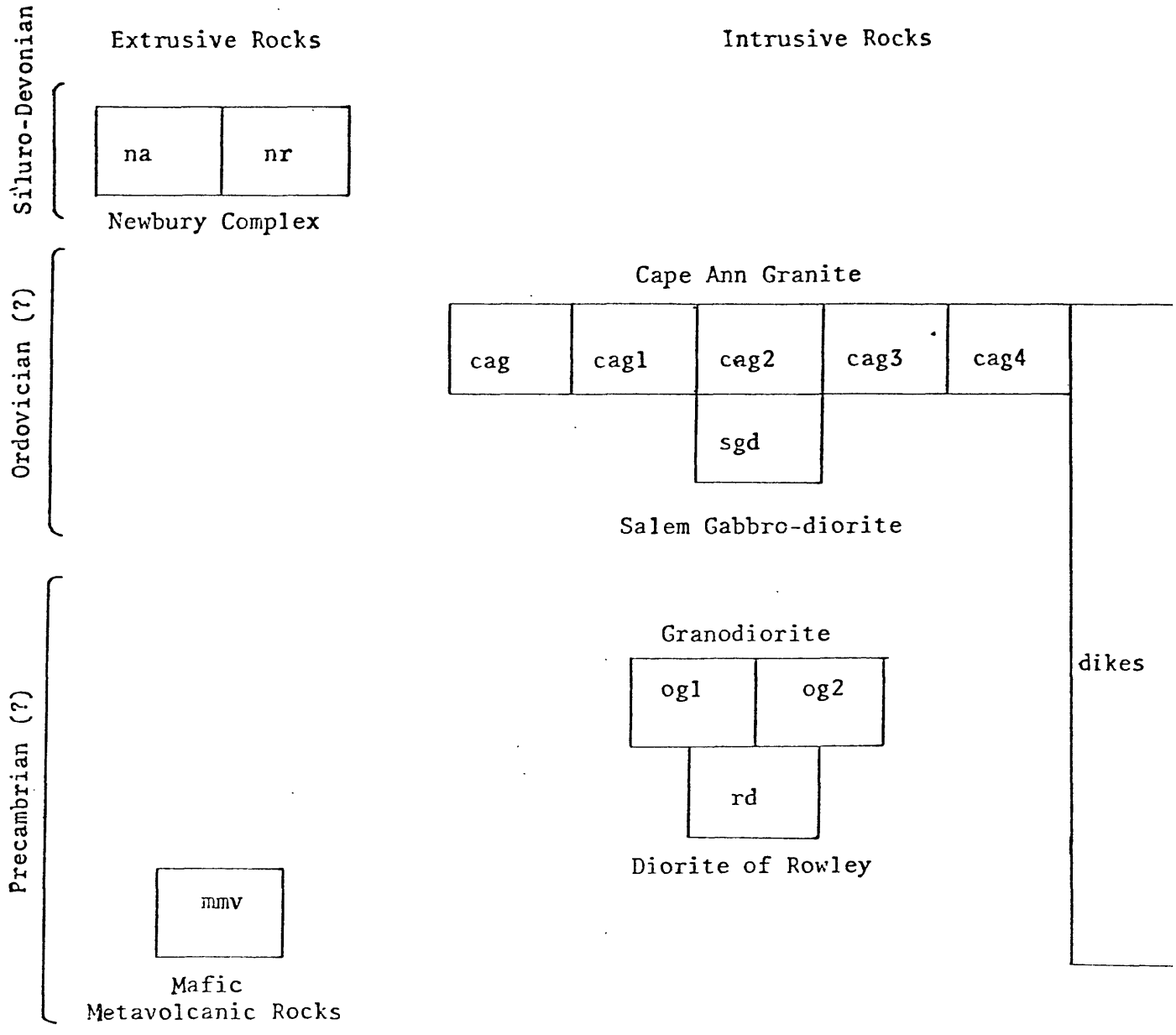
Correlation of Map Units



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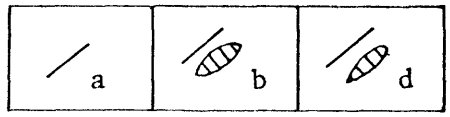
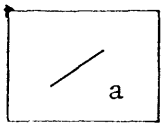
na — Newbury Complex: Grayish-green to red-purple, flow-banded or agglomeratic, occasionally amygdaloidal, extrusive andesitic rocks. Propylitization is pervasive. In flow rocks, phenocrysts principally altered subhedral plagioclase (An_{30-40}) and rare quartz; groundmass is very fine devitrified material charged with hematitic dust and granular blebs. Agglomerate clasts include lithic volcanic fragments, plagioclase, and rare quartz grains; interstitial pleonaste and sparry calcite common.

nr — Newbury Complex: Massive white to flesh-colored dense rhyolite vitrophyre intrusives. Xenomorphic intergrowths of quartz and potash feldspar containing sparse plagioclase, minor muscovite, and iron oxides. Spherulitic micrographic intergrowths of quartz and potash feldspar common.

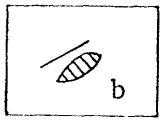
Description of Map Units



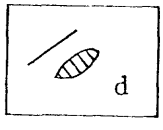
Dike Rocks: a = syenite; b = basalt or gabbro; d = diabase. Where appropriate, rock type symbols are combined with p (= porphyritic) and/or s (= dike is separated into isolated angular blocks surrounded by unfoliated country rock).



Syenite and feldspathoidal syenite dikes. Texture variable including trachytic, massive, and pegmatitic types. Potash feldspar dominant, 0-10 percent nepheline and sodalite, 5-15 percent mafic minerals. Occasionally well crystallized magnetite.



Fine to medium-grained mafic rocks with granular and porphyritic textures. Texturally and mineralogically variable. Plagioclase altered, commonly labradorite. Hornblende is the dominant mafic mineral; there is also pinkish pigeonite, pale green augite, and biotite, and rare olivine. Accessory minerals are apatite, sphene, magnetite, and pyrite. Often separated and cut by unfoliated granite. Chilled margins typical but fractured ends of separated blocks not chilled.



Medium-grained mafic rock with diabasic texture; otherwise the same as b.

cag

Cape Ann Granite: Predominantly unfoliated fine-, medium- to coarse-grained (0.3 to 1.5 cm) leucocratic alkali granite to alkali syenite. Ranges and medians of the principal minerals are: potash feldspar, 58-85 (63) percent; plagioclase (An_{6-12}), 0-22.5 (2.8) percent; quartz, 0-41 (24) percent; ferrohornblende, 0.1-17 (4.5) percent; biotite, 0-3.2 (0.8) percent; and opaques 0.2-7.5 (1.0) percent. Augite occasionally present. Accessory minerals include sphene, zircon, apatite, fluorite, allanite, magnetite, and ilmenite. Feldspars in unaltered rock are pale green-gray, have a greasy luster, and weather to a faintly pinkish tan or white. Potash feldspar is the dominant mineral--usually microcline microperthite but sometimes homogeneous microcline; albite or oligoclase is present in minor quantities. Quartz is glassy, shows weak strain shadows, and contains dust-size inclusions. Feldspar and quartz as large single grains and grain clusters partly to completely surrounded by finer grained interstitial quartz and feldspar. Ferromagnesian minerals, variable in amount and appearance, occur as ragged clots, wisps, single subhedral crystals and zonally arranged reaction aggregates. Augite is colorless to pale green as a core partly or completely surrounded by pale-green amphibole, darker-green soda-iron amphibole, and reddish-brown biotite with magnetite granules scattered throughout the reaction aggregate. Isolated crystals and clots of soda-iron amphibole, biotite, or both. Rock fabric is principally uneven granitoid, but varies to subporphyritic and is locally an accumulate.

cag1	Beverly Syenite Facies, Cape Ann Granite: Predominantly unfoliated medium- to coarse-grained, texturally variable alkali syenite. Textural extremes include very coarse-grained (2-5 cm) massive and coarse-grained trachytic phases whose mineral composition, except for lack of quartz and common presence of nepheline and sodalite, is identical with Cape Ann Granite. Modal quartz content measured on outcrop less than 5 percent.
cag2	Cape Ann Granite: Modal quartz content measured on outcrop 5-15 percent.
cag3	Cape Ann Granite: Modal quartz content measured on outcrop 15-25 percent.
cag4	Cape Ann Granite: Modal Quartz content measured on outcrop greater than 25 percent.

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sgd

Salem Gabbro-diorite: Medium- to medium coarse-grained texturally variable mottled black and greenish-white ferrohornblende-biotite diorite containing variable amounts of augite, pigeonite, and quartz. The rock consists of 55-65% plagioclase as twinned andesine (zoned crystals An_{20} to An_{35}) and untwinned albite or oligoclase, 5% potash feldspar, 1-5% quartz, 0-25% pale-green augite, 0-10% pinkish titaniferous pigeonite, 10-30% green pleochroic iron-rich hornblende, 0-10% reddish-brown biotite, and 1-5% opaques as scattered granules and exsolved blades in pyroxenes. Accessory apatite, zircon, and sphene are also present as grains and as rims on opaque granules. Chlorite, iron oxides, and calcite are present as alteration products. Mafic minerals are always somewhat poikilitic and commonly occur in zonally arranged aggregates that represent a reaction series from augite to biotite with magnetite granules dispersed throughout the aggregate. Biotite occurs as irregularly shaped and scattered flakes. The feldspars are pale gray-green with a greasy luster. The fabric is irregular and uneven. The rock is commonly brecciated and cut by salmon-pink felsic stringers.

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Granodiorite: Medium- to coarse-grained unfoliated to well-foliated granitoid to subporphyritic granodiorite. Feldspars are sericitized or saussuritized subhedral to euhedral grains, often zoned, and are colored pink by hydrothermal addition of ferric iron. Microcline 3-15 percent, plagioclase (An_{30}) 35-45 percent. Quartz (30-50 percent) occurs as elongate grains, large equant grains, and as ellipsoidal grain aggregates having sutured internal boundaries, and fine intergranular material; large grains show intense strain shadows; it is faintly smokey on freshly broken surfaces and becomes bluish after exposure. Muscovite (2-5 percent) is dispersed as shreddy grains. Mafic constitutents aggregate less than 10 percent. Hornblende and the less common biotite are altered to chlorite. Accessories include magnetite, pyrite, sphene, apatite, and zircon.

og1

Granodiorite (Central Zone): Sparse ferromagnesian minerals. Fresh surfaces are mottled pink and gray.

og2

Granodiorite (Border Zone): Enriched in ferromagnesian minerals whose alteration to chlorite produces a pink-green mottled rock.

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rd

Diorite of Rowley: Medium-grained, equigranular, massive, mottled pale-green and black, hornblende diorite. Intensely saussuritized plagioclase (An_{35}) occurs as subhedral grains that make up 70 percent of the rock. Anhedral untwinned potash feldspar makes up less than 5 percent of the rock; quartz with strong strain shadows, less than 5 percent; and poikilitic, partially chloritized, hornblende, 20 percent. Accessories include magnetite, apatite, and sphene.

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mmv

Mafic Metavolcanic Rocks: Dark- to light-gray, greenish-gray, and dark-green fine-grained altered mafic volcanic rocks. Relict fabrics include diabasic, ophitic. agglomeratic, amygdaloidal and prophyritic. Originally mafic lava flows, pyroclastic deposits and minor felsic lava flows; metamorphosed to amphibolites and subsequently hydrothermally altered. Much of the rock has closely spaced blocky joints and a massive featureless appearance. Former mineralogy principally hornblende, calcic plagioclase, some pyroxene, and small amounts of biotite, magnetite, and pyrite. Alteration has saussuritized the feldspars and generated abundant chlorite, epidote, and some quartz and calcite. Much local variability in original mineralogy, fabric, and degree of alteration.

SYMBOLS

Lithologic contact of principal formations. Approximately located

Lithotypic contact of rock types within principal formations. Approximately located

Strike and dip of beds

Inclined
Vertical

Strike and dip of vertical schistocity

Strike and dip of foliation in igneous rocks

Inclined
Vertical

Strike and dip of shearing

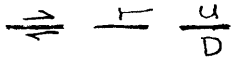
Inclined
Vertical

Strike and dip of joints

Inclined
Vertical

Dikes

More than 5 feet wide
Less than 5 feet wide



Probable fault. Approximately located; dotted where concealed. U, upthrown side; D, downthrown side. Arrows show direction of relative movement; ⊢ on upper plate of thrust faults.

Lineament, possible fault. Approximately located. U, upthrown side; D, downtrown side.

Diamond drill hole

Individual outcrops

Area of abundant outcrop

Cataclased rocks