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U.S. Geological Survey.
[Reports—Open file series]

Text to Accompany the

PRELIMINARY BEDROCK GEOLOGIC MAP OF THE GEORGETOWN QUADRANGLE, ESSEX COUNTY, MASSACHUSETTS

by K.G. Bell, A.F. Shride, and N.P. Cuppels

1977

Reproducible and map in Map Drawer.

Contents

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Bedrock geology of the Georgetown quadrangle, Massachusetts

Physiographic features

The Georgetown quadrangle, situated in the coastal region of northeastern Massachusetts, is within the Seaboard Lowland Section of the New England Physiographic Province as described by Fenneman (1938). This section is the partly submerged, sloping margin of the peneplaned New England Upland. The elevation of the bedrock surface in the Georgetown quadrangle ranges from below low tide level in the estuaries of the Mill and Parker Rivers in the northeast part of the quadrangle to 194 feet on Mt. Eleanor in the southwest corner. Maximum bedrock relief is about 150 feet, also in the southwest corner, and gradually decreases to about 50 feet near the river estuaries. The bedrock surface is rough and hummocky, the rougher parts being areas underlain by dioritic and gneissic rocks. The sluggish drainage system follows faults and major fracture zones with minor modification by glacial deposits.

Much of the topography of the Georgetown quadrangle is that of glacial deposits. Areas underlain by dioritic and gneissic rocks were preglacial hills, have abundant outcrops, and are partly covered by coarse boulder till derived from underlying and nearby bedrock. Areas underlain by other kinds of rocks have few outcrops and mostly are covered by kame deposits, eskers, and drumlin hills, seemingly reflecting deep sapropelization of readily weathered rock types. Several drumlin hills rise to elevations of more than 200 feet above the adjacent lowland. The low areas in the northeastern part of the quadrangle are partly covered by beach terraces and deposits of fine-grained wind-blown sand. The low relief and gradient of the bedrock surface and consequent sluggish drainage causes most of the low-lying ground, constituting about a third of the quadrangle, to be permanent or seasonal swampland.

Structural features

The Georgetown quadrangle is within the imbricate thrust fault zone of eastern Massachusetts. The dominant structures are large faults that disrupt all rock units and bound thrust sheets having different and unrelated lithologies (fig. 1). The lithologic areas are: Ia, Ib, Ic) a terrane of diorite and metavolcanic rocks in the western third of the quadrangle; IIa, IIb) unmetamorphosed volcanic and sedimentary rocks of the Newbury Complex in the northeast and central parts of the quadrangle; III) metamorphosed diorite, granodiorite, and mafic volcanic rocks in a northeast trending thrust sheet across the south-central part of the quadrangle; and IV) unmetamorphosed intrusive rocks of the Cape Ann Pluton in the southeast corner of the quadrangle. Displacements on the faults are not known but must be thousands of feet or even miles to bring various lithologies into juxtaposition.

The larger faults generally are not exposed. Their traces are topographic lineaments, in many places the sites of streams and swamps. Other criteria that were used to identify faults are gouge, cataclastic, and breccia zones, hydrothermal alteration of wall rock, truncated bedding, flow foliation, and metamorphic foliation, and abrupt changes of lithology at linear elements.

Minor faults that reflect internal adjustments of the thrust sheets are abundant and can be seen on most substantial bedrock exposures. Displacements range from inches to hundreds of feet. Throughout most of the quadrangle lack of outcrop precludes mapping of minor faults, but significant patterns can be demonstrated in localities of abundant outcrop. Many minor faults trend northwest, dip at high angles, and indicate northeastward movement that is consistent with the transport direction of the thrust sheets. Many minor faults trend east, dip at high angles and seem to indicate mainly vertical adjustments.

Estimated age of the faulting must be based on information from other areas. Faults of the imbricate zone displace stratified rocks of Pennsylvanian age in the Narragansett Basin of Rhode Island and stratified rocks of Triassic age in the Bay of Fundy area, New Brunswick, Canada. They are covered by undisturbed stratified rocks of Lower Cretaceous age on the Atlantic Coastal Plain. This faulting probably occurred either intermittently or more or less continuously from Permian to Jurassic time.

Folds are not significant structures within the Georgetown quadrangle. Stratified rocks mostly dip at high angles and within thrust plates are parts of homoclinal sequences.

Stratified or layered rocks

<u>Mafic metavolcanic deposits:</u>--The oldest rocks in the Georgetown quadrangle are mafic metavolcanic deposits tentatively correlated with the upper part of the Blackstone Series of Rhode Island as described by Shaler and others (1899) and Quinn and others (1949). They occur as a homoclinal sequence in the central and northern parts of thrust sheet III (fig. 1). These rocks are of possible Late Precambrian or Lower Cambrian age. Exposures of them are mostly small and scattered. They furnished large amounts of debris to the glacial drift, and this feature was used to determine the extent of their bedrock area.

The protoliths were fine, medium, and coarse pyroclastic deposits, ash-fall tuffs, and flow rocks. The lower part of the sequence consisted mostly of interlayered ash-fall tuffs and flow rocks, including a pillow lava zone near the base. A carbonate rock and calc-silicate zone existing in other localities is not exposed in the Georgetown quadrangle. The middle part consisted mainly of pyroclastic material interlayered with minor flow rock and ash fall tuff. The upper part was mainly ash fall tuff and fine pyroclastic deposits enclosing thin lenses of flow rock. The composition seems to have been predominantly basaltic although parts may have been andesitic. The upper part includes thin lenses of meta-andesite or metadacite. Both upper and lower parts of the sequence are cut out by intrusive rock and faults. Lack of exposures and dilation by intrusive rock prohibit accurate estimates of thickness, but probably 5,000 feet of the sequence of metavolcanic rocks exist in the Georgetown quadrangle.

These volcanic rocks have been regionally metamorphosed to amphibolite facies. Mafic constituents were converted mainly to hornblende, but in some beds or layers small quantities of biotite were formed. An early period of pervasive hydrothermal alteration, perhaps associated with emplacement of the diorite and granodiorite of the Rowley and Ox Pasture Brook localities, almost completely converted hornblende and biotite to chlorite and saussuritized feldspars with production of much epidote. During a later, post-faulting, hydrothermal episode carbonate minerals and specular hematite were deposited in fractures. The alterations almost eliminated bedding, foliate, and textural features, consequently attitudes on most outcrops are indeterminate. Most of the rock is now dark greenish-gray and has a seemingly fine-grained, massive appearance. Thin-section petrography reveals former textures, mineralogy and history.

Metavolcanoclastic rocks:--Two units of the thick metavolcanoclastic sequence of northeastern Massachusetts that is considered to be of Pre-Silurian age (Bell and Alvord, in press) are exposed in the Georgetown quadrangle. The Boxford Formation, named by Castle (1965) from outcrops in the town of Boxford, seemingly conformably overlies the Fish Brook Gneiss, named by Castle (1965) from outcrops near Fish Brook in Boxford. The lower part of the Fish Brook Gneiss as known from other localities to the southwest is cut out by faults and intrusive rock in the Georgetown quadrangle. Both units were deposited subaqueously in a presumably marine environment.

Fish Brook Gneiss:--The protolith of the Fish Brook Gneiss was partly degraded volcanoclastic detritus of rhyodacite or dacite composition. Much of this unit is conspicuously ripple bedded. Amplitudes of ripples range from a few inches in the lower part of the unit to an inch or less in the upper part, and some of the upper part is devoid of ripples. The Fish Brook Gneiss is generally leucocratic. The content of mafic constituents increases from the lower to the upper part, and the quartz content decreases toward the upper part. Thin beds and lenses of amphibolite, biotite-hornblende-feldspar gneiss, and feldspar-biotite schist formed from mafic tuff are interspersed throughout the unit but constitute less than 5 percent of its volume. About 5,000 feet of the formation is present in the Georgetown quadrangle.

Boxford Formation:--The Boxford Formation consists of conspicuously inlayered dark gray or black amphibolite and minor biotite-hornblende-feldspar and whitish to pale green calc-silicate rock. Layers range from a fraction of an inch to three feet thick but mostly are less than an inch thick. Intervals of this formation that are several hundred feet thick are pyritiferous, and weathering causes them to become heavily iron stained. The protolith of this formation was interlayered carbonate sediment and fine-grained mafic ash-fall tuff. The formation is about 5,000 feet thick in the Georgetown quadrangle.

Newbury Complex:--Rocks of the Newbury Complex comprise the entire surface of fault block II (fig. 1) which is a structural remnant of a volcanic terrane. In the Georgetown quadrangle an easterly trending fault divides this block into a northern segment (IIa) in which the strata strike northeasterly and dip moderately to steeply northwest and a southern segment (IIb) in which the strata strike northerly and dip steeply west. The stratigraphic and structural make-up of the terrane in the Georgetown quadrangle has been determined in part by extrapolation from exposures to the northeast in the Newburyport West and Newburyport East quadrangles and in part by examination of glacial debris. The complex consists of at least eight stratified members and one intrusive member. Neither the upper nor the lower parts of the complex are preserved, and the lower two members are not exposed in the Georgetown quadrangle. At a few localities cross-bedding, graded bedding, and conglomerates derived from earlier deposits show the strata to be generally overturned to the southeast or east, thus the rocks of the complex are progressively older in a westerly or northwesterly direction. As pieced together from several subsidiary fault blocks in the Georgetown, Newburyport West, and Newburyport East quadrangles the stratified members aggregate at least 12,000 feet and perhaps as much as 15,000 feet in thickness.

These rocks are petrographically little modified from the state in which they were laid down. Devitrification of the glassy rocks, local silicification, and pervasive propylitization of the mafic rocks are modifications that might have occurred mainly during lithification as plausibly as later. Epidote occurs generally along fractures in the more mafic rocks and quartz veins are locally abundant in all the stratified members. The Newbury Complex has not been affected by regional dynamic metamorphism as have all other stratified units within the quadrangle.

The stratified members of the Newbury Complex exposed within the Georgetown quadrangle are, from oldest to youngest, 1) the upper part of a basaltic member composed mainly of massive flows having scoriaceous borders and separated by thin zones of basaltic tuff or fossil soil, 2) a rhyolite unit having a maximum thickness of about 2,200 feet and locally overlaid by poorly sorted conglomerate composed entirely of rhyolitic detritus, 3) an andesitic member composed of flows, tuffs, volcanoclastic breccias, and minor interspersed water laid conglomerate, sandstone, tuffaceous shale, and fossiliferous mudstone; the part of this member exposed within the quadrangle is at least 3,000 feet thick, 4) a siliceous siltstone unit, possibly 1,500 feet thick, that is poorly exposed within the quadrangle, being known mainly from glacial erratics, some being from 10 to 30 feet in long dimension, 5) a red mudstone member, perhaps 750 feet thick, known in the quadrangle only from slabby debris and friable boulders distributed to suggest bedrock underlies loose detritus, and 6) a limestone-shale member, exposed only in excavations, that may be about 300 feet thick, but which may be as much as 1,000 feet thick.

The intrusive member is fine-grained alaskite that is one of the most resistant rocks of the Newbury Complex, but outcrops lack continuity. They occur sporadically throughout an otherwise well ordered sequence of lithologic units which suggests they are near surface intrusive phases of the complex. These intrusions seem to be pod-form or sill-like bodies, ranging from a few feet to several hundred feet in thickness, emplaced about parallel to enclosing strata.

The Newbury Complex is the only unit in the Georgetown quadrangle dated by fossils. A collection of shelly marine fossils from an outcrop near the intersection of the Newburyport Turnpike and Central Street in the town of Rowley was first reported by LaForge (<u>in</u> Emerson, p. 163-164). A somewhat similar assemblage was found by N. P. Cuppels in an outcrop near the northeast edge of Wilson Pond, also in the town of Rowley. These fossils occur in thin calcareous mudstone zones that separate breccias and flows of the andesitic member. Remains of brachiopods, pelecypods, gastropods, ostracods, crinoids, and trilobites have been found. Cuppels also found ostracods to be locally abundant in the limestone-shale member. These fossils generally are considered to be of Late Silurian to Early Devonian age. Inasmuch as the Newbury Complex is everywhere in fault contact with surrounding formations and is not intruded by any of the plutonic units this knowledge provides no basis for dating other formations.

Latite porphyry:--Remnants of unmetamorphosed latite porphyry that lies unconformably on Fish Brook Gneiss and the type diorite of the Byfield locality are known only from exposures in excavations in the southwestern part of the Georgetown quadrangle and the southeast part of the South Groveland quadrangle. This latite is deeply sapropelized. It is iron- and sodium-rich and has about the same composition as the monzonite facies of the Cape Ann Plutonic Series exposed in the north part of the Salem quadrangle. It is tentatively considered to be an extrusive phase of the Cape Ann Plutonic Series.

Intrusive rocks

Intrusive rocks of possible Precambrian age:--Medium- to coarse-grained comagmatic diorite, quartz diorite, and granodiorite form most of thrust sheet III (fig. 1). These rocks are a gradational sequence in which the mafic facies grades into and is intruded by the salic facies. These rocks are considered to be of probable Precambrian age although no conclusive evidence confirms such an assignment. They intrude only the mafic metavolcanic rocks tentatively correlated with the Blackstone Series. These rocks have been altered and their appearance changed during a complex history of pervasive hydrothermal alteration. In their original state these rocks probably were whitish or light gray speckled with variable quantities of black mafic minerals. During an early episode of alteration mafic minerals were partly chloritized and feldspars were partly saussuritized causing the rocks to become somewhat greenish. This alteration is most noticeable in the north half of the thrust sheet III (fig. 1). During a post-faulting episode of alteration the feldspars became salmon-red by impregnation with iron oxide and small quantities of specular hematite were deposited in fractures. The later reddish alteration, which locally obliterated the earlier green alteration, is very conspicuous in the south half of thrust sheet III (fig. 1). The rocks of this series are characterized by blue-weathering quartz.

Mafic facies:--The mafic facies is best exposed in the town of Rowley. The rock in the central part of the outcrop area is slightly altered hornblende diorite. It is almost surrounded by an aureole of more salic rock that makes an intrusion breccia into the mafic metavolcanic rocks. Outlying small stocks and dikes of the diorite that intrude the metavolcanic rocks are generally highly chloritized. The diorite contains a small quantity, generally less than one percent, of blue weathering quartz.

Salic facies:--The salic facies consists of coarse-grained granodiorite that encloses scattered small lenses and dike-like masses of generally more siliceous aplite. The granodiorite exposed in the vicinity of Ox Pasture Brook in the north part of the town of Rowley is moderately altered, mainly as a result of the early episode of hydrothermal alteration, but it is considered to be more nearly similar to the original appearance than any of this rock exposed elsewhere in the quadrangle. The granodiorite exposed in the town of Topsfield is altered to a rather dark salmon-red color and has a very different appearance.

Diorite of Byfield:--Diorite crops out abundantly in the low knobby hills of the western third of the Georgetown quadrangle (thrust sheet I, fig. 1). Roof, border, and intrusion breccia zones of a large pluton constitute most of the unit exposed in this quadrangle. Rock that probably is representative of the core of the pluton crops out in the vicinity of Byfield village in the southwestern part of the Newburyport West quadrangle. This diorite intrudes the Fish Brook Gneiss and Boxford Formation and is intruded by small masses and veins of white to pink granodiorite considered to be comagmatic with it.

The diorite of Byfield ranges from a hornblendic facies devoid of quartz to a biotitic facies containing about 15 percent quartz, 5 percent potassium feldspar, and no hornblende. The more mafic hornblendic facies is devoid of flow foliation and is thought to be representative of the core of the pluton. The biotitic facies forms the roof and border zones of the pluton. Within these zones there is considerable veining and diking of early biotitic facies by later facies, the older being most mafic and the younger most salic. Most outcrops show from two to eight cross-cutting facies. The more biotite-rich facies commonly have conspicuous flow foliation parallel to vein or dike walls. Rock in the chilled parts of the roof and border zones is mostly fine-grained, dark-colored, and biotite rich. Some of dioritic rock in the roof and border zones has a pseudo-foliation inherited from partly assimilated metamorphic wall rock.

Pink granodiorite

The pink granodiorite is a nonresistant rock that crops out very sparsely in areas having appreciable cover of glacial drift. It is seen in only a few outcrops between Wethersfield Street and the Parker River, and these might not have been recognized as indicators of significant bodies, except that they represent southerly extensions of a larger granodiorite mass that is more widely exposed just north of the quadrangle. The granodiorite is everywhere intruded into the diorite of Byfield, which commonly is intricately veined by the pinkish rock for some tens of feet adjacent to the larger masses of granodiorite. The recognition of these resistant veined diorites and the local dominance of granodiorite erratics over other glacial detritus are the main basis for outlining the granodiorite bodies as they are shown on this map. The bodies might be much more extensive in the areas shown, but are not likely less extensive.

Where the granodiorite is even moderately sheared the biotite has been obliterated, leaving an alaskitic-appearing rock that commonly forms rubble that is heavily rust-stained.

Cape Ann Plutonic Series:--The Cape Ann Granite and Salem Gabbro-diorite are comagmatic facies of the youngest plutonic series exposed in the Georgetown quadrangle (Bell and Dennen, 1972). These rocks together with many other facies forming the Cape Ann pluton of eastern Massachusetts, are unmetamorphosed and intrude regionally metamorphosed stratified rocks. Joint surfaces of all facies of this plutonic series have distinctive brown iron-rich coatings, and unweathered, unaltered feldspars are greenish and have a greasy luster. This plutonic series was emplaced prior to the regional faulting, possibly during a late stage of the Acadian orogeny or shortly thereafter. The maximum age for it seems to be Middle Devonian.

Cape Ann Granite:--The Cape Ann Granite forms most of thrust sheet IV (fig. 1) in the southeastern part of the Georgetown quadrangle. In this locality the bedrock surface is characterized by low northwest trending ridges and shallow valleys caused by differential weathering of quartz-rich and quartz-poor zones within the granite. Flow foliation parallels the zoning and is truncated by the fault bounding the northwest side of the thrust sheet. Quartz-rich granite underlies the valleys and has disintegrated to thick layers of gruss. Rock forming the ridges has a quartz content that is mostly less than 15 percent and may be as much as a third mafic constituents. Granite near the fault bounding the northwest side of the block has been subjected to weak pervasive hydrothermal alteration that slightly reddened feldspars, and it also shows incipient cataclasis.

Salem Gabbro-diorite:--Dioritic rock of the Cape Ann Plutonic Series that is similar to Salem Gabbro-diorite of the Salem quadrangle crops out in Palmer State Park. Its contact with surrounding granite is not exposed. Also, dioritic rock of the Cape Ann Plutonic Series may form dikes and intrusion breccia in the older diorite and metamorphosed stratified rocks along the east boundary of thrust sheet I (fig. 1), but the altered condition of these rocks makes identification uncertain. Salmon-red granodiorite, granite, and aplite veins that intrude the mafic and metamorphic rocks of the latter locality are similar to those known elsewhere only in the mafic border zone of the Cape Ann Pluton.

Mafic dikes

There are a few mafic dikes ranging from 2 to 30 feet in width in the northern part of the quadrangle. Their magmatic affiliation is unknown. Inasmuch as they intrude the Newbury Complex, their age is not older than Devonian and may be as young as Triassic.

Metamorphism

The older rocks of the Georgetown quadrangle have been subjected to regional metamorphism. The mafic metavolcanic rocks tentatively correlated with the Blackstone Series were raised to amphibolite facies, possibly by thermal metamorphism during intrusion of the diorite and granodiorite of the Rowley and Ox Pasture Brook localities. If so, the effects of later regional metamorphism have been obscured or obliterated by post-faulting pervasive hydrothermal alteration. Regional metamorphism of the diorite and granodiorite is indicated by generally pervasive minor cataclasis of quartz and feldspar. The Fish Brook Gneiss and Boxford Formation were regionally metamorphosed to amphibolite-biotite facies. These rocks are only locally down-graded. The regional metamorphism generally is considered to have occurred during the Acadian orogeny. There is no feature within the quadrangle that conclusively demonstrates two episodes of regional metamorphism.

Hydrothermal alteration

A post-faulting episode of hydrothermal alteration has locally affected all rocks of the Georgetown quadrangle. The conspicuous effects are reddening of feldspars by introduction of iron oxide, deposition of specular hematite in joints, and partial chloritization of mafic constituents. This alteration is most conspicuous in the south half of thrust sheet III (fig. 1) and adjacent to northeast trending faults.

Economic geology

Sand and gravel are the only materials that have been produced from the Georgetown quadrangle. Most of the deposits are small, are partly depleted, and are mixed with variable quantities of clay. The principal use made of these material is for common fill. Hydrothermally altered gouge zones of some minor faults are slightly mineralized with copper, lead, and zinc, but the probability that significant deposits of these metals exist seems small. Most of the diorite, granodiorite, granite, and gneiss can be used as fill or ballast.

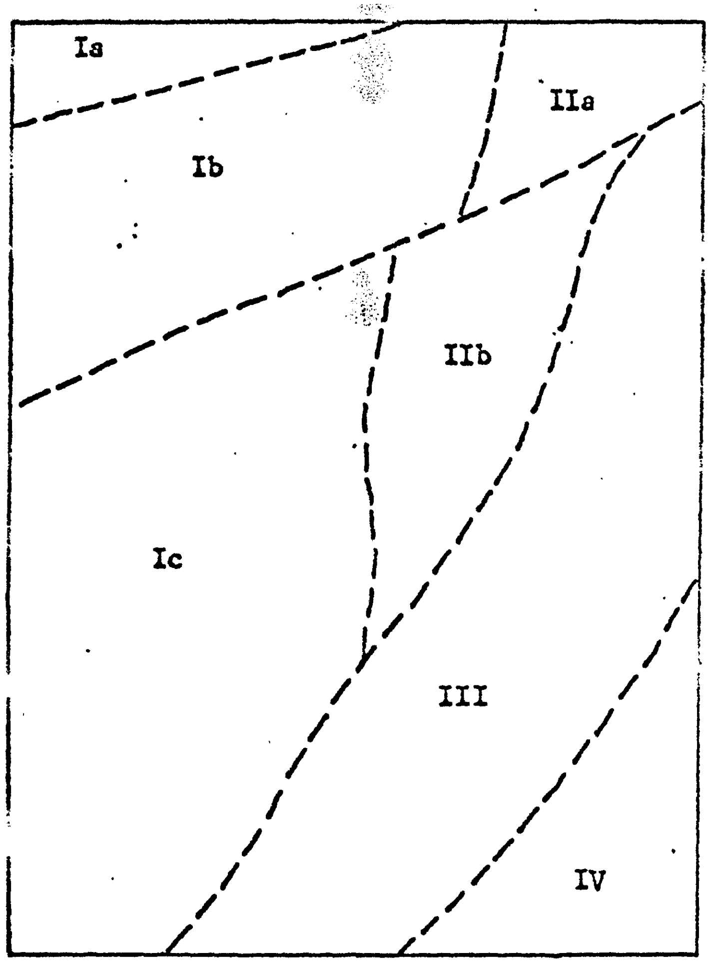

Figure 1. Major structural and lithologic divisions of the Georgetown quadrangle.

Analyses

	1	2	3	4
SiO_2	53.5	75.1	60.4	55.5
Al_2O_3	18.6	13.4	17.9	18.9
Fe_2O_3	3.1	.68	3.7	1.8
FeO	6.4	.48	.84	5.1
MgO	4.2	.06	.60	2.7
CaO	7.9	.35	2.2	8.1
Na_2O	2.4	2.4	6.1	4.0
K_2O	.52	6.7	4.4	.64
H_2O+	1.7	.47	.90	1.0
H_2O-	.10	.03	.73	.11
TiO_2	1.4	.22	.89	1.2
P_2O_5	.25	.06	.31	.37
MnO	.14	.00	.15	.11
CO_2	.04	.02	1.0	.06
Sum	100	100	100	100

1) Diorite of Rowley. Outcrop 1,950 feet S40E from junction of Weathersfield Road and Bennett St., Rowley. (Analysts: P. Elmore, J. Glenn, J. Kelsey, H. Smith).

2) Granodiorite vein in diorite. Cut on east side of Interstate Hwy. 95, 500 feet south of Fuller Road-River Road overpass, Boxford. (Analysts: P. Elmore, J. Glenn, J. Kelsey, H. Smith)

3) Latite porphyry. Outcrop 2,400 feet N67W from junction of Haverhill St. and Rowley Road, Topsfield. (Analyst: S. D. Botts)

4) Diorite of Byfield. Cut on west side of Middleton Road, 1,200 feet south of junction with Fuller Road-River Road (RJ64),

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PRELIMINARY BEDROCK GEOLOGIC MAP OF THE GEORGETOWN QUADRANGLE, ESSEX COUNTY, MASSACHUSETTS

by K.G. Bell, A.F. Shride, and N.P. Cuppels 1977

Explanation

The petrographic descriptions apply to the rocks as they exist in the Georgetown quadrangle. Descriptions of some of the units as they exist in adjacent or nearby quadrangles may differ somewhat because of metamorphism, cataclasis, and facies changes.

Intrusive rocks

Rocks of the Cape Ann pluton

Devonian(?)

cag

Cape Ann granite

Medium- to coarse-grained leucocratic granite. Quartz ranges from 5 to 35 percent, feldspars from 60 to 90 percent, and mafic minerals from 1/2 to 5 percent of the rock. Feldspars in unaltered, unweathered rock a pale gray to pale green, have a greasy luster, and weather to pale pinkish brown. Quartz is glassy. In thin section rock shows an uneven granitic fabric. Clusters of medium- to coarse-grained anhedral quartz and feldspar grains are partly to completely surrounded by interstitial clots and zones of fine-grained quartz and feldspars. Mafic minerals occur as ragged clots and feathery wisps. Quartz shows weak to moderate strain shadows, and most of it contains dust-like inclusions, some in trains and some randomly distributed. The most abundant feldspar is microcline-microperthite, some as elongate Carlsbad twins. Less than 25 percent of the feldspar is microcline, and minor quantities are albite and oligoclase. Mafic constituents vary from place to place. Some specimens contain only ragged clots of reddish brown biotite. Other specimens contain clots showing a reaction series from pyroxene to biotite; cores are colorless or very pale green augite partly or completely surrounded by pale green hornblende, darker green iron- and sodium rich hornblende, and reddish-brown biotite. Magnetite granules are dispersed among the mafic constituents. Apatite and zircon are accessory constituents. There are two groups of zircons, one of minute euhedral crystals, the other of larger rounded grains, some of which are embayed or fractured. Zircon within or in contact with biotite has formed very weak pleochroic haloes.

Sgd

Salem gabbro-diorite

Medium-grained, mottled black and greenish-white subporphyritic diorite. In thin section the rock shows a very uneven, irregular fabric. Grain size of major constituents ranges from 3 mm diameter to fine interstitial. Mafic constituents form clots showing a reaction series from pyroxene to biotite, and there are abundant irregularly shaped biotite flakes. All mafic constituents are somewhat poikilitic. The composition is about 1 percent quartz, 15 percent twinned plagioclase, some as zoned crystals, $Ab_{80}An_{20}$ to $Ab_{65}An_{35}$, 35 percent untwinned feldspars, mostly albite and oligoclase, and some showing incipient development of microperthite, 5 percent untwinned potassium feldspar, 10 percent pale green augite, 15 percent green, iron-rich hornblende, 15 percent dark reddish-brown biotite, 3 percent magnetite as small granules, 1 percent apatite, accessory zircon.

Stratified and layered rocks

Devonian(?)

lp

Latite porphyry

Holocrystalline rock consisting of 10-15 percent subhedral to euhedral whitish or pale gray phenocrysts, maximum dimension about 1/4 inch, and smaller books of reddish-brown biotite in a very fine-grained pale brown, reddish, or lavender ground mass. Rock has well-developed flow structure. Some of the phenocrysts seem to have been white, some glassy, but all are now clouded by alteration products. About half of the phenocrysts are twinned oligoclase, some as zoned crystals, and half are sanidine, some as Carlsbad twins. The groundmass is composed of minute feldspar microlites clouded by a clay-like alteration product and by dusty iron oxide and interstitial iron oxide granules. The rock is 85-90 percent feldspar, 2-7 percent biotite, 2-3 percent iron oxide, 0.5-2 percent quartz, and accessory zircon(?).

Silurian - Devonian

Newbury Complex

- ni: massive, fine-grained, even-textured, holocrystalline, micrographic alaskite, light-colored in hues of red to brown, commonly weathering to buff or dark colors; devoid of internal structures other than joints; composed almost wholly of quartz and feldspars; microcline, microcline-microperthite, and an incipient form of microperthite are abundant; twinned oligoclase generally is present in quantities of less than two percent, opaque minerals less than one percent; micas are uncommon accessory constituents.
- nl: medium to dark-gray aphanitic limestone and limy shale; weathers olive gray; thin bedded or thinly laminated; locally contains abundant ostracods.
- nm: mudstone, grayish red to dull dark red; soft and friable; much of it contains very fine-grained detrital mica; bedding features generally are obscure, but some parts of the unit are very thinnly and rather conspicuously bedded.
- ns: siliceous siltstone; dusky yellowish-green or dark greenish-gray to very dusky purple, in thin beds apparent only on weathered exposures; includes minor thin interlayered whitish, pinkish, or greenish chert-like bands and lenses, and thin beds or zones including calcite and calc-silicate minerals.
- na: grayish-red or grayish-green to dark gray, mostly porphyritic andesite, mainly as massive layers of breccia and tuff breccia intercalated with andesite flows and minor units of water-laid conglomerate, sandstone, and mudstone composed of andesitic detritus, tuffaceous shale, and rare thin layer of fossiliferous calcareous mudstone also containing much andesitic detritus; propylization is pervasive.
- nr: dense grayish-red to dusky red-purple minutely laminated (flow-banded) rhyolite vitrophyre, sporadically porphyritic; now wholly devitrified; zones of conspicuously spherulitic rhyolite common near mid-section.
- nb: fine-grained, greenish gray basalt as flows 100 feet or more thick; thoroughly propylitized; scoriaceous, non-resistant flow borders; tuffaceous and fossil soil zones a few feet thick between flows are non-resistant and crop out only sporadically in swales.

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Approximate contact

Fault

Fault, approximately located

Thrust fault, approximately located

Probable fault, approximately located

Strike and dip of overturned beds

Strike and dip, metamorphic foliation parallel to bedding

Strike and vertical dip, metamorphic foliation parallel to bedding

Strike and vertical dip of flow foliation

Outcrop

Area of abundant outcrop

Localities in which glacial deposits were examined

pg

Pink granodiorite

Pinkish-gray to orange-pink, rusty weathering, medium- to coarse-grained inequigranular rock, dominantly granodiorite, characterized by grayish-orange pink translucent poikilitic microcline of very irregular outline, clear gray quartz, and minute (<1 mm) ragged leaves of biotite. Milky white oligoclase and quartz each comprise about one-third of rock, microcline somewhat less, and biotite about 5 percent. Distinctive inequigranular texture varies with size of microcline grains; as microclines progressively increase in size texture becomes, first subtly porphyritic, then distinctly porphyritic; with phenocrysts as much as 20 mm in length. Parts most nearly equigranular commonly are quartz monzonites.

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Silurian(?) or Devonian(?)

bd

Diorite of Byfield

Mostly medium- to fine-grained diorite and quartz-diorite but grades locally into minor granodiorite and granite facies. The most mafic facies is medium-grained, equigranular, speckled black and white diorite. It is composed of 40-60 percent plagioclase, about $Ab_{65}AN_{35}$, 40-55 percent hornblende, commonly poikilitic, having plagioclase inclusions, 1-3 percent magnetite, and accessory biotite, quartz, sphene, and apatite. This rock grades to a biotite facies composed of 5-15 percent quartz, 40-60 percent plagioclase, $Ab_{75}An_{25}$ to $Ab_{65}An_{35}$, 0-10 percent potassium feldspar, 5-25 percent biotite, 0.5-2 percent magnetite, and accessory sphene, apatite, and zircon. Border facies are biotitic, fine-grained, and commonly altered; mafic minerals have been chloritized, and feldspars show extremely fine-grained micaceous alteration. All of these rocks are speckled black and white or are dark gray except chloritized parts which may be dark greenish gray.

Pre-Silurian

b

Boxford Formation

Fine-grained, interbedded amphibolite, mafic gneiss, and calc-silicate rock. Generally beds are an inch or less thick but in some parts of the formation they may be a few feet thick. Mafic beds show moderate to strong metamorphic foliation, are dark gray or black but locally may be dark greenish gray because of chloritization of hornblende and biotite. Calc-silicate beds are whitish or pale green, tend to be devoid of foliate features. Much of the formation is pyritiferous, causing weathered rock to become strongly iron-stained. Compositions of both mafic and calc-silicate beds are variable throughout the formation. Amphibolite beds are composed of 40-85 percent hornblende, 10-50 percent oligoclase, 0-10 percent quartz, 3 percent or less of opaque minerals, mostly pyrite but minor secondary iron oxide, and minor epidote and chorite; hornblende generally exceeds plagioclase, and many beds contain no quartz. Calc-silicate beds are composed of 30-65 percent oligoclase, 25-60 percent epidote and clinozoisite, 0-20 percent quartz, and accessory opaque minerals and sphene. Amphibolite grades to biotite-hornblende-oligoclase gneiss; maximum biotite contents are about 20 percent.

fg

Fish Brook gneiss

Fine- to medium-grained, generally equigranular, biotite-quartz-feldspar gneiss. A weak metamorphic foliation is defined by alignment of biotite flakes. Unweathered, unaltered rock is pale gray finely streaked or intermittently pin-striped with biotite. Weathered rock becomes pale yellowish-brown from oxidation of a minute quantity of pyrite. Hydrothermally altered rock is somewhat greenish because of alteration of biotite to chlorite and development of minor epidote or is reddish-brown because of partial replacement by calcite and iron oxides and bleaching of biotite. Biotite content ranges from 2 to 10 percent, quartz from 20 to 50 percent, plagioclase of composition $Ab_{75}An_{25}$ to $Ab_{70}An_{30}$ from 40 to 65 percent, and potassium feldspars are generally less than 5 percent. Hornblende is an uncommon minor constituent. Finely granular pyrite is dispersed throughout the gneiss. Zircon is an accessory constituent in some layers.

Precambrian(?)

og

Granodiorite of Ox Pasture Brook locality

Medium- to coarse-grained, non-foliated, generally equigranular, granitic-textured granodiorite. It locally grades to subporphyritic phases, feldspars forming the larger grains. The color is dependent on the locally predominant process of alteration; in the northern part of the Georgetown quadrangle it is light-gray or whitish spotted by variable amounts of pinkish feldspars and tinted or streaked by greenish alteration products; in the southern part of the quadrangle it is salmon-red. This granodiorite is composed of about equal proportions of plagioclase, potassium feldspars, and quartz and 10 percent or less mafic constituents. Feldspar grains are mostly subhedral to euhedral. Most plagioclase is partly saussuritized. All feldspar shows some micaceous (sericitic?) alteration. Many plagioclase grains are zoned; compositions range from $Ab_{70}An_{30}$ to $Ab_{85}An_{15}$. Potassium feldspars are mostly untwinned, but some grains show partial microcline twinning. Quartz shows intense strain shadows, is mostly clouded by randomly distributed dust-like particles; it is grayish or smoky on freshly broken surfaces and becomes blue when exposed to weathering or possibly light. In some parts of this granodiorite quartz occurs as ellipsoidal aggregates, the greatest dimension ranging from 1/8- to 1/2-inch. Mafic constituents tend to occur as small, fine-grained clots and wisps. Hornblende is less altered than biotite and products. Less than a half percent opaque minerals, mostly magnetite, some pyrite occur as tiny granules within and adjacent to mafic constituents. Apatite and zircon are very minor accessory constituents.

rd

Diorite of Rowley

Medium grained, equigranular, non-foliated mottled pale green and black diorite. Feldspars are moderately to intensely saussuritized causing them to be greenish. In thin section the rock shows an equigranular, blocky granitic texture. There is 60-75 percent plagioclase, mostly as subhedral grains and ranging from anhedral to euhedral forms; its average composition is $Ab_{65}An_{35}$. There is less than 5 percent untwinned potassium feldspar as anhedral grains. Quartz is less than 5 percent, shows intense strain shadows, and is clouded by randomly distributed dust-like particles; it is grayish or smoky on freshly broken surfaces and becomes bluish when exposed to weathering or possibly light. Hornblende ranges from 15 to 25 percent, is somewhat poikilitic, and partly chloritized. Opaque granules, mostly magnetite, some pyrite, tend to be concentrated within or adjacent to hornblende. Apatite and zircon are sparsely distributed accessories. Locally the diorite grades into a quartz diorite facies by increase of quartz, potassium feldspar, and albite constituent of the plagioclase. Dikes and stocks of the diorite that intrude the mafic metavolcanic rocks of the Blackstone Series are mostly intensely saussuritized and chloritized.

Precambrian(?)

mmv

Mafic metavolcanic rocks (tentatively correlated with the upper part of the Blackstone Series of Rhode Island)

Dark greenish-gray, chloritized and epidotized mafic metavolcanic rocks. Protoliths of the sequence were amygdaloidal and massive flows, pillow lavas, pyroclastic deposits, and ash-fall tuffs. These rocks were metamorphosed to amphibolite facies and subsequently hydrothermally down-graded. Bedding, foliate, and textural features generally are obscure or have been obliterated but locally are preserved in the least altered rock. Much of the rock has a seemingly massive, fine-grained, featureless appearance. Former mineralogy and textures generally are recognizable in thin section. The metamorphosed phase, prior to alteration, consisted mainly of hornblende and plagioclase and minor quantities of magnetite and pyrite. Small quantities of biotite occur in parts of the sequence. Fragmental or pyroclastic deposits seem to have consisted entirely of mafic volcanoclastic detritus. Amygdules were composed of epidote, chlorite, and calcite. The altered rock, in its present state, consists mainly of commonly pseudomorphic after hornblende and biotite, saussuritized plagioclase, and epidote. Remnants of hornblende and biotite occur locally. Secondary or introduced calcite and hematite are common minor constituents. In the south part of the outcrop area joint surfaces are commonly coated with hematite.

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