PRELIMINARY BEDROCK GEOLOGIC MAP OF THE MYSTIC QUADRANGLE, NEW LONDON COUNTY, CONNECTICUT; SOUTHOLD COUNTY, NEW YORK; AND WASHINGTON COUNTY, RHODE ISLAND

by

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Geologic Notes

The bedrock of the Mystic quadrangle is covered by a discontinuous mantle of unconsolidated deposits of glacial origin. Information on the bedrock was obtained from rock exposed at the surface and from rock debris that was derived from bedrock at shallow depth. Fishers Island, Wicopesett Island, Napatree Point, and Sandy Point are composed of thick unconsolidated deposits of glacial origin and no bedrock information is obtainable from these areas. The surficial geology of the Mystic quadrangle has been mapped by J. E. Upson (1971).

The bedrock consists of plutonic, volcanic, and subordinate sedimentary rocks of Paleozoic or older age metamorphosed to the upper amphibolite facies and cut by unmetamorphosed dikes of granite and pegmatite of Pennsylvanian or younger age. The pre-Pennsylvanian rocks are continuous with an extensive area of granitic gneisses and subordinate metasedimentary and metavolcanic rocks that underlies most of western Rhode Island and extends westward in a belt north of Long Island Sound to the vicinity of New Haven, Connecticut. No fossils have been found in these rocks and their age is largely inferred from continuity and comparisons with sequences of similar but poorly-dated rocks in Rhode Island and eastern Massachusetts and in the western part of eastern Connecticut and central Massachusetts. The metamorphosed rocks are probably pre-Silurian and range from Ordovician to late Precambrian in age. The Narragansett Pier Granite cuts strata of Pennsylvania age in the Narragansett Basin that unconformably overlie the granitic gneiss terrain of Rhode Island (Quinn, 1971, p. 43). Although no Narragansett Pier Granite has been recognized as such in the Mystic quadrangle dikes of aplite and pegmatite probably related to the Narragansett Pier and dikes of the related Westerly Granite cut the metamorphic rocks of the Mystic quadrangle, thus giving an upper limit to their age.

The rocks of the quadrangle lie within the sillimanite metamorphic zone and possibly partly above the sillimanite-orthoclase isograd. Diagnostic rocks are scarce. Metamorphic textures and structures indicate that at least two periods of regional dynamo-thermal metamorphism have affected the rocks; an earlier phase during which the rocks were tightly-folded, the primary foliation formed, and granite intrusion took place; and a later period or periods during which the earlier foliation and the intrusive rocks were folded. All these episodes occurred at elevated temperatures. The Narragansett Pier and Westerly Granites were emplaced during a late period of plutonism at a time of crustal distension.

Bedrock in the quadrangle consists primarily of the Mamacoke Formation and small amounts of Plainfield Formation and Hope Valley Alaskite Gneiss. These units have been described and their stratigraphic position discussed elsewhere (Goldsmith, 1966) and need not be repeated here. The Mamacoke Formation in the Mystic quadrangle is apparently much thicker than it is in the quadrangles to the west and is less clearly layered. The bulk of the formation in the quadrangle consists of a hornblende-biotite-plagioclase gneiss that superficially resembles the Granodiorite of the New London Gneiss except that the latter contains no hornblende. It is more akin mineralogically to rock mapped as Monson Gneiss in the New London, Niantic, and Montville quadrangles to the west (Goldsmith, 1967a, b, c). In the ~~new~~ adjacent New London quadrangle, the clear distinctions between the Monson Gneiss, New London Gneiss, and the Mamacoke Formation evident in the quadrangles still further west, become less clear. In the Mystic quadrangle the only recognizable unit is the Mamacoke Formation. The Mamacoke Formation is equivalent to the unit mapped as Metavolcanic rocks by Moore (1967) in the Watch Hill quadrangle to the east.

The gneisses of the Mystic quadrangle lie on the south limb of a large complexly folded overturned to recumbent anticline whose axis lies north of the quadrangle and trends in a more or less east-west direction. In the Mystic quadrangle, the dominant structural feature is a secondary assymetric to overturned anticline of foliation trending northeast to east-west across the quadrangle. This foliation anticline is folded along northeast-trending axial surfaces. The synclinal zone between the major anticline to the north and the anticline in the Mystic quadrangle is a zone of tight folding part of which appears in the Bindloss Brook area in the northwest corner of the quadrangle. ~~where it~~ Here the zone is cut off or dragged along a northeast-trending shear surface.

Unequivocal folds of a first generation in which the dominant foliation, is axial planar to folded layering were not observed. However, drag folds of foliation and layering related to the development of the anticline are abundant and in places a second foliation parallel to the axial surfaces of these folds has developed. Dips of their axial surfaces are predominantly to the north. They flatten toward the crest of the anticline and dip more gently than the overall dip of the long limbs of the folds to the south of the crest. The attitudes of foliation within the Mamacoke Formation suggests appreciable internal folding is present.

A prominent north-east-trending fold of the third generation is located in the Stonington area. This fold has folded the crest and steep limbs of the older anticline. A similar fold with the opposite sense is present in the Noank area. The anticlinal area between these two folds is not evident, but may be present in the Mason Island-Quiambaug Cove sector. Minor folds related to this episode of folding are evident primarily in the coastal area. The fold at Stonington may reflect drag of a major northeast-trending fault or shear with right lateral offset that lie. in the adjacent Ashaway and Watch Hill quadrangles to the east (Feininger, 1965, Moore, 1967).

Most lineations represent axes of drag folds and their attitudes are controlled by the attitude of the axial surfaces of drag folds and by the trend of fóliation and layering in a particular area. In places the presence of two lineations with different attitudes reflect incongurent folding or an interference pattern produced by folding of more than one generation. Attitudes of lineations north of the crest of the central anticline are fairly consistent except in the Bindloss Brook area. Attitudes of lineations in the coastal area are rather variable and reflect a more general superposition of folding and plastic style of folding in this area. Here axial surface of folds are commonly warped and folded about axes of still later folds. Latest minor folds tend to have a northwest trend.

The northeast-trending trace of a surface of dislocation across the northwest corner of the quadrangle indicated by truncation of rock layers, foliation, and folds has no observable cataclastic rock associated with it and appears to be a plane of shear or drag contemporaneous with tight folding at a time when temperatures of the rocks were high. This feature appears to be continuous with a trace of a surface along which structural discontinuities exist in the adjacent Old Mystic and Ashaway quadrangles to the northeast (Goldsmith, unpublished map; Feininger, 1965).

Granite-filled seams several millimeters in width and as much as several meters long along which the gneissic foliation has been dragged are relatively abundant in the gneisses of the coastal area. The granite within these seams is not foliated. The seams have a predominant northwest trend, but neither horizontal nor vertical displacement seems to be consistent over the area. The seams are observed only in outcrop and in places from conjugate sets bounding edges of blocks of rock that have moved slightly with respect to each other. Similar features are not uncommon in massive igneous rocks. The seams must have formed at a time when the rocks were at or near temperatures at which partial melting could take place. They are cut sharply by dikes related to the Narraganeet Pier and Westerly granite, but appear to be later, though possibly not much later than the drag folds of the second generation.

A series of north-south trending high-angled faults offsets rock units with a relatively consistent east-side-down sense. Control for the north - south trending faults lies mostly in the Old Mystic quadrangle to the north. Greatest displacement appears to be along the Mystic River where the throw is estimated at 245 to 275 m. This fault is part of a zone that extends north to Lantern Hill quartz vein in the Old Mystic quadrangle. The north-south faults are believed to be Triassic in age. A few small faults were observed in outcrop but these are not along the main fault traces which tend to lie in valleys.

Mineral Resources

The Westerly Granite is suitable for monumental granite and has been quarried to some extent almost everywhere it outcrops. However, most of the dikes are narrow and accordingly not of commercial importance. The abandoned quarry near Quambaug Church at the head of Quiambaug Cove is the largest quarry observed in the quadrangle. The gently-dipping dike here is about 2.5 m thick. Dale (1923, p. 387-388) describes a quarry one half mile (0.8 km) northwest of Mystic station where the dike of Westerly Granite is about 25 feet (7.6 m) thick. This quarry was not located.

Most of the Mamacoke Formation and the Hope Valley Alaskite Gneiss is suitable for rip-rap and for foundation stone. Rock from the large abandoned quarry of Mamacoke Gneiss at the northwest end of Mason Island was used as rip-rap for the breakwater at Westerly, Rhode Island and for other breakwaters in the area.

References

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The Plainfield Formation typically weathers to form low areas with respect to the adjacent feldspathic gneisses of the Mamacoke Gneiss and the Hope Valley Alaskite Gneiss. Topography is one of low ridges or a line of low knobs, with intervening swales, or a series of benches where on a hill slope. Ridges and knobs are underlain by quartzitic beds or thicker, more uniform layers of feldspathic gneiss. The contact with the overlying Mamacoke Formation is drawn above the last quartz-rich layers. Amphibolite interlayered with vitreous quartzite is thus included with the Plainfield Formation rather than the Mamacoke Formation.

The Plainfield represents a sequence of fairly well-sorted epicalastic sediments interlayered with beds containing volcanoclastic material in varying amounts. Calc-silicate-bearing layers probably were sediments containing calcium carbonate cement.

Description of Map Units

Mineral modifiers in rock names are given in order of increasing abundance. Rock types within units are listed in order of decreasing abundance where possible.

Names for plutonic rocks follow the recommendations of the IUGS subcommission on the systematics of igneous rocks (Streckeisen, 1973).

pt Pegmatite (Pennsylvanian or younger) - Dikes of non-foliated, zoned, orange-pink pegmatite as much as two meters thick

w Westerly Granite (Pennsylvanian or younger) - Dikes of light-gray, indistinctly foliated (flow-structure), fine to medium-grained, equigranular granite composed of calcic-oligoclase $>$ microcline $\geq$ quartz, about 5 percent biotite and accessory minerals. Usually weathers out to form shallow swales or to have no positive topographic expression. Most dikes dip moderately to south or east; dip of dikes shown where measured. Largest dike, near head of Quiambaug Cove is about three meters thick. Boulders of Westerly Granite (w or map) indicate unexposed Westerly dike nearby to north

hv Hope Valley Alaskite Gneiss (Mississippian (?) or older) - Orange-pink to light gray, fine- to medium grained, equigranular granite gneiss in concordant to semi-concordant masses. Composed of about equal amounts of quartz, microcline, and albite to sodic oligoclase, and about 1 percent magnetite or as much as 2 percent magnetite and biotite. Foliation marked by parallelism of alternate flat lenses of quartz and feldspars and by parallelism of biotite flakes where present. Foliation indistinct where fine grained and aplititic. Smaller, lenticular masses are usually more varied in composition and contain most biotite. Resistant to weathering and forms massive ledges where thick. Larger masses were intrusive sheets, some smaller lenticular masses may be metamorphosed felsic volcanic rock.

Mamacoke Formation (Pre-Silurian)

m

Biotite - quartz-feldspar gneiss - Distinctly to indistinctly layered, light to dark gray, fine- to medium-grained, mostly equigranular (hornblende)-biotite-quartz-plagioclase gneiss with subordinate but varying amounts of microcline; magnetite a prominent accessory mineral in amounts as much as 1 percent. Subordinate splotchy gneiss with streaks and clusters of hornblende and biotite, amphibolite, and quartz-biotite-plagioclase schist. In places contains light gray aplitic and granitoid layers (modes 3 and 4, table 1) as much as several meters thick. Typical gneiss is characterized by evenly distributed biotite flakes, but biotite may also be concentrated on parting planes between layers of differing composition. Weathers to low ridges and swales which reflect zones of more and less biotitic rock; uniform and massive rock forms large ledges. Represents a metamorphosed sequence of volcanic deposits of mainly intermediate composition but with minor felsic and mafic layers.

mgd

Granodiorite gneiss - non- to indistinctly-layered, medium-grained hornblende biotite-quartz-feldspar gneiss of granodioritic composition, locally splotchy with clusters of biotite and hornblende and, rarely, clinopyroxene In places contains biotite-rich streaks and lenses of biotite-quartz-plagioclase gneiss and amphibolite; boundary with layered gneiss (m) of the Mamacoke Formation is indistinct and gradational except near Noank where it is abrupt. Toward the coast and offshore islands where bedrock is exposed, becomes increasingly coarse-grained, swirled, contains lenses of amphibolite and contains many irregular masses and layers up to a few meters thick of light-colored granitic gneiss (mode 4, table 1) and many sharply cross-cutting aplite and pegmatite dikes. Possibly an inflated and homogenized phase of layered Mamacoke, but also could have been granodiorite intrusive into the volcanic pile.

mg Mafic-poor biotite gneiss - indistinctly layered, light gray to pale orange-pink, equigranular, medium-grained granitic to granodioritic gneiss with about 5% evenly distributed biotite flakes. Originally were layers of felsic volcanic rock or sheets of granite or alpite.

ma Amphibolite-plagioclase=hornblende gneiss in large and small lenticular masses usually contains subordinate biotite more abundant on the margins of the masses. Some amphibolite contains clinopyroxene. Represents metamorphosed mafic dikes or sheets of basalt in the volcanic pile.

Plainfield Formation (Cambrian?)

p Thick-to thin-bedded, locally laminated, dark-gray to gray biotite-quartz-feldspar gneiss and schist, and biotite-feldspar-quartz gneiss with flat lenses of quartz as much as 10 centimeters long; light gray to brownish-gray biotite-feldspar quartzite with interbedded biotite schist and sillimanite-biotite schist; (hornblende)-biotite-quartz-plagioclase gneiss; garnet (muscovite)-sillimanite-quartz-feldspar schist and gneiss; subordinate amphibolite and calc-silicate-bearing gneiss. In Birdloss Brook area light gray, vitreous quartzite in beds as much as 0.6 meters thick with biotite schist partings, passes laterally into amphibolite and into thinner-bedded more micaceous quartzite interlayered with schist. Bronze-colored biotite and accessory tourmaline are characteristic of the quartzitic and pelitic rocks.

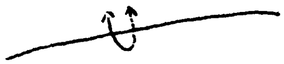
MAJOR FOLDS

Asymmetric anticline. Approximate trace of axial surface ~~of~~

Short arrow indicates steeper limb

Trace of axial surface of younger syncline

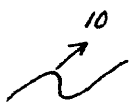
Overturned syncline



Overturned anticline

MINOR FOLDS

One fold or a group of folds observed in outcrop; map sense of fold shown where determinable. May be combined with axial plane data and lineation symbol. Most folds involve both foliation and bedding or compositional layering. Axial surfaces of minor folds are in places warped and folded non-systematically in the coastal area and offshore islands.



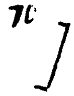
Bearing and plunge of axis

Sense of fold indicated by pattern

Abandoned quarry

Sample locality

Showing number of sample for which mode is given in Table 1.



inclined

vertical

Strike and dip of axial surface of small folds of foliation and layering

Generalized strike of folded foliation

Strike and horizontal sense of movement of granite-filled shears

vertical

near vertical
(dip not measured accurately)

inclined

Joints

Showing strike and dip of prominent joints

LINEAR FEATURES

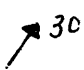
May be combined with any of the above planar features

inclined

horizontal

Bearing and plunge of lineation

Tail of arrow at point of observation. Letter symbols indicate nature of lineation: FA, fold axis; b, streaks of biotite; h, hornblende; q, quartz rods.



Bearing and plunge of slickensides

A:

One fol
where deter
Most folds
surfaces of
the coastal

Showin
Conn

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Bedrock exposures

~~Individual outcrops and areas of abundant outcrops~~

Contact

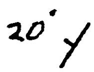
Dotted where concealed by water. Distribution of outcrops indicates degree of control for location of contacts

Fault

Showing relative displacement, U - Upthrown side, D - Downthrown side
Dotted where concealed by water.

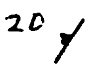
Trace of surface marking discontinuity in folation and layering

PLANAR FEATURES



inclined

Strike and dip of bedding

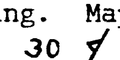


inclined

vertical

gently folded

Strike and dip of first generation mineral foliation and compositional layering parallel to it not clearly bedding. May be combined with bedding symbol.



inclined

Strike and dip of second generation mineral foliation mostly subparallel to axial surfaces of folds of first generation foliation and compositional layering

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Correlation of map units

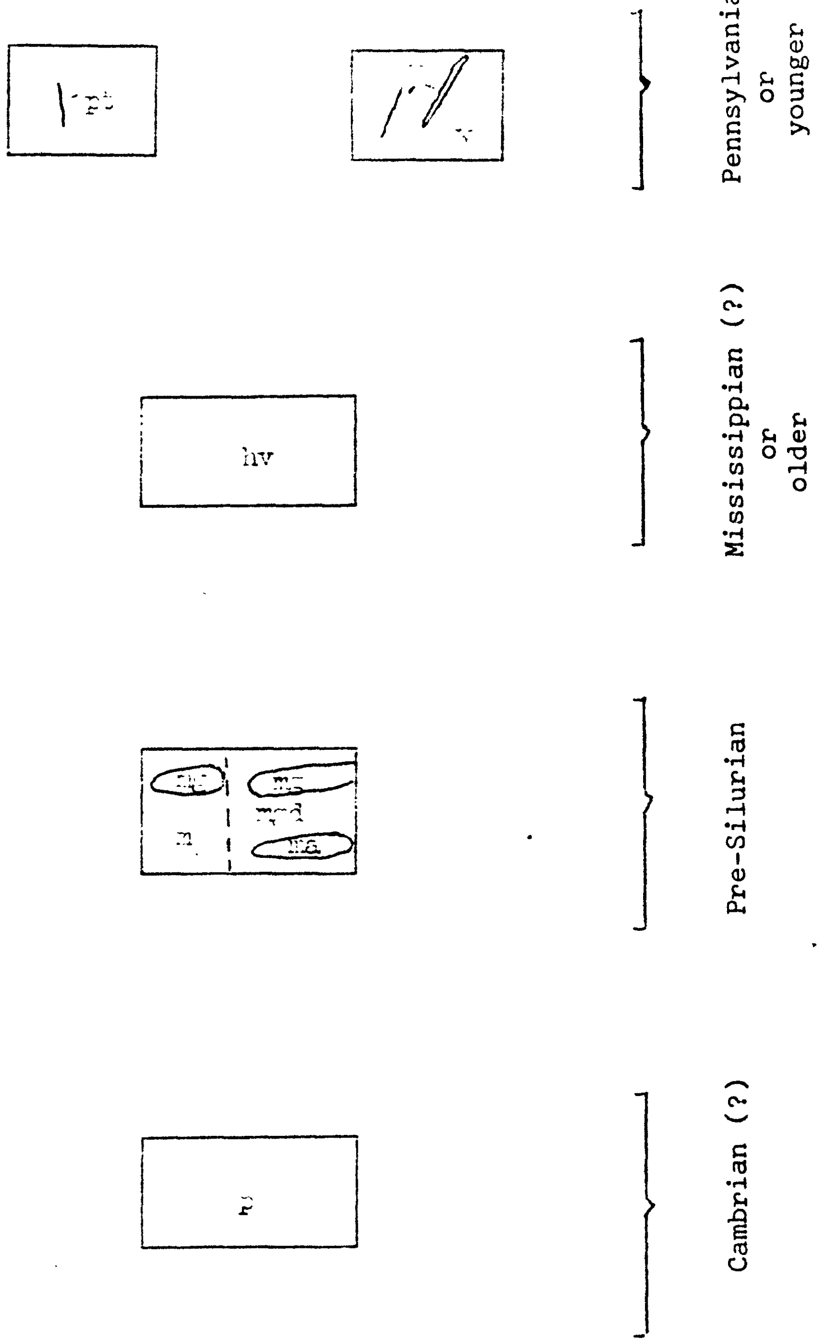

Table 1. Selected modal anayses of rocks from the Mystic Quadrangle, Connecticut[1]

Rock unit	m	m	mg	m[2]	mgd	mgd	mgd[3]	ma	hv	hv	w	p[4]
Sample Number	1	2	3	4	5	6	7	8	9	10	11	12
Quartz	35	29	29	35	23	32	27	5	40	44	20	45
Plagioclase	50	48	65	35	54	45	37	38	32	29	48	28
Microcline	1	8	2	23	8	12	30	-	25	26	22	2
Biotite	13	10	3	6	8	7	5	-	2	0.8	8	24
Hornblende		3	-	-	5	2	-	53	-	-	-	
Pyroxene	-	-	-	-	-	-	-	2	-	-	-	-
Magnetite/ilmenite	0.3	0.9	0.7	0.1	1.0	1	0.1	0.4	0.1	0.1	0.4	0.4
Sphene	T	0.2	0.2	-	0.3	0.2	0.5	0.6	-	-	0.4	-
Apatite	-	0.4	0.2	0.1	0.2	0.4	0.2	0.5	T	-	0.3	0.2
Allanite	0.2	0.1	-	-	-	0.1	0.2	-	-	-	0.1	-
Zircon	T	0.1	T	T	-	T	-	T	-	T	0.1	T
Muscovite	-	0.1	0.1	-	-	-	-	-	-	0.2	0.1	-
Calcite	-	0.5	-	-	-	-	-	T	-	-	0.1	-
Garnet	-	-	-	-	-	-	-	-	T	-	-	T
Rutile	-	-	-	-	-	-	-	-	-	-	-	0.2
Approx. Anorthite comp. of plagioclase	28	26	15	23	28	24	24	39	12	10	25-16[5]	26

1) Each mode is based on one thin section. Over 1100 points were counted per thin section.
2) Granitoid layer
3) Granitoid layer
4) Biotite-plagioclase-quartz gneiss layer in Plainfield Formation; a fairly abundant rock type in the Formation
5) Plagioclase has oscillatory zoning, but in general has more calcic core and less calcic shell.

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