Bedrock Geology of the Kingston Quadrangle Rhode Island

By GEORGE E. MOORE, Jr.

GEOLOGY OF SELECTED QUADRANGLES IN RHODE ISLAND

GEOLOGICAL SURVEY BULLETIN 1158-E

Prepared in cooperation with the State of Rhode Island Development Council

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library card for this publication appears after p. E21.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATION

TABLE

BEDROCK GEOLOGY OF THE KINGSTON QUADRANGLE, RHODE ISLAND

By George E. Moore, Jr.

ABSTRACT

The Kingston quadrangle, in southern Rhode Island, contains rocks ranging in age from Precambrian(?) to Pennsylvanian or younger. The Blackstone Series, of Precambrian(?) age, crops out principally in the west-central part of the area and occurs as roof pendants or inclusions in igneous rocks. Quartz-feldspar-biotite gneiss and quartz-biotite-muscovite schist, of sedimentary origin, are dominant; minor varieties of rocks present are quartz-hornblende schist and gneiss, micaceous quartzite, and amphibolite. The unit appears to be nongraphitic. Highly feldspathic bodies of Blackstone were mapped separately.

The Hope Valley Alaskite Gneiss and the Ten Rod Granite Gneiss underlie most of the northern half of the area. These two formations and the bodies of fine-grained granite shown on the map are igneous rocks of Mississippian(?) or older age. The alaskite gneiss is mostly medium to coarse grained; it has a low content of dark minerals and a strong lineation shown by alined and flattened rod-shaped aggregates of quartz. The Ten Rod Granite Gneiss is medium to coarse grained and gray and generally has 10–15 percent microcline phenocrysts, weak to strong foliation, and moderate to strong lineation. The fine-grained granite shown on the map is flesh colored to light gray, locally porphyritic, and massive to weakly foliated and lineated.

The Rhode Island Formation, Pennsylvanian in age, comprises quartz-feldspar-biotite-muscovite schist and gneiss, quartz-muscovite-biotite schist, quartz-feldspar-biotite gneiss, and some graphite schist.

Most of the southern half of the area is underlain by medium-grained pink, flesh-colored, and gray Narragansett Pier Granite of Pennsylvanian or younger age. The granite is massive or locally weakly foliated and is porphyritic in places. A small body of fine-grained gray massive Westerly Granite is exposed in a pit southwest of Worden Pond. The Westerly is Pennsylvanian or younger and commonly occurs as dikes.

Bedding and schistosity, mutually parallel in most places, strike west or northwest and dip to the north in most of the Blackstone in the western part of the quadrangle; north of Kenyon the formation shows numerous minor folds, and the attitude of bedding is variable. Lineation in most of the Hope Valley Alaskite Gneiss plunges northeastward at low to moderate angles. Lineation in the Ten Rod Granite Gneiss likewise plunges northeastward at moderate angles, and foliation strikes northeast to northwest and dips northward. In Wakefield the foliation and bedding in the Rhode Island Formation strike westward and dip steeply; southeast of Kenyon the general trend is northward.

The rocks display evidence of three episodes of metamorphism. The oldest occurred before the intrusion of the Mississippian(?) or older plutonic rocks and produced minerals in the Blackstone Series that are consistent with the upper range of the almandine-amphibolite facies. Metamorphism during the late stages of intrusion of the Mississippian(?) or older plutonic rocks resulted in local feldspathization of the Blackstone Series and in granulation of minerals in the Hope Valley Alaskite Gneiss and Ten Rod Granite Gneiss. Regional metamorphism younger than the Rhode Island Formation and older than the Narragansett Pier Granite produced minerals in the Rhode Island Formation that are similar to those in the Blackstone and consistent with the upper range of the almandine-amphibolite facies. Because the intensity of this metamorphism was the same as that of the earliest metamorphism, the older rocks were not changed.

INTRODUCTION

The Kingston quadrangle, in southwestern Rhode Island about 25 miles south-southwest of the city of Providence, is in a terrane of igneous and metamorphic rocks that range in age from Precambrian(?) to Pennsylvanian or younger. Most of the northern half of the quadrangle is underlain by plutonic gneisses of Mississippian(?) or older age and by smaller areas of metasedimentary gneiss and schist of Precambrian(?) age (pl. 1). Most of the southern half is underlain by Pennsylvanian or younger granite that extends westward into Connecticut and eastward beyond the shore of Narragansett Bay. Two outcrops in Wakefield, some outcrops southeast of Kenyon, and rock from a drill hole at Tuckertown are metasedimentary rocks of Pennsylvanian age.

The Charlestown moraine, 1–2 miles wide and as much as 150 feet high, extends westward across the area from near the head of Point Judith Pond. The morainal form is most distinct in the western two-thirds of the quadrangle. Most of the area south of this end moraine is an outwash plain with little relief. Isolated low till-covered hills rise above the outwash plain in a few places, and bedrock is exposed in at least two places. North of the end moraine, numerous isolated or partly isolated bedrock hills mantled with till rise sharply from swamps and relatively flat outwash plains. The thickness of till on these hills is as great as 40 feet in places (Kaye, 1960, p. 350); most of the bedrock outcrops are on the tops or south sides of the hills.

The southeastern part of the quadrangle, around Point Judith Pond, is in the Narragansett basin, a topographic and structural basin that extends from the mouth of Narragansett Bay northward into Massachusetts. Topographically, the basin consists of Narragansett Bay and the adjacent lowlands; structurally, it is a synclinorium underlain in most places by less resistant sedimentary rocks of Pennsylvanian age, but in the Kingston quadrangle and in the western part of the Narragansett Pier quadrangle it is underlain by the more resistant Pennsylvanian or younger granite. In most places to the north, the western border of the basin is a sharp escarpment that separates the Pennsylvanian sedimentary rocks from the older more resistant plutonic and metamorphic rocks west of the basin; locally, a resistant basal conglomerate of Pennsylvanian age is exposed along the escarpment. In the Narragansett Pier quadrangle the contact between the Pennsylvanian and the older rocks trends south-southwest toward Wakefield, whereas the escarpment trends southward toward the head of Point Judith Pond. In the Kingston quadrangle the western border of the basin is not clearly marked by topography; the escarpment dies out or is obscured by glacial deposits near the head of Point Judith Pond, whereas the contact between the Pennsylvanian and older rocks extends westward through Wakefield.

Cores were examined from 10 holes drilled in the Kingston quadrangle by the U.S. Geological Survey during a geohydrological study of the Upper Pawcatuck River basin. The location of these 10 drill holes are shown on the map.

This study was made as a part of a cooperative program of the Development Council of the State of Rhode Island and the U.S. Geological Survey. Under this program, reports and maps of the bedrock geology and the surficial geology will be published for each of the quadrangles of the State. Fieldwork for this report was done during parts of the summers of 1957 and 1958.

BEDROCK GEOLOGY

PRECAMBRIAN(?) ROCKS

BLACKSTONE SERIES

The name Blackstone Series was originally used by Shaler and others (1899, p. 104–109) and revived by Quinn and others (1949) for the stratified rocks of Precambrian(?) age along the Blackstone River in the Pawtucket quadrangle, where the series contains metamorphic rocks of sedimentary and volcanic origin. This series was considered to be Precambrian by Woodworth (Shaler and others, 1899, p. 105) because it is more highly metamorphosed than are the red fossiliferous Cambrian shale and slate near Hoppin Hill in North Attleboro, 4 miles east of the stratified rocks of the Pawtucket quadrangle. This difference in degree of metamorphism, however, could represent different metamorphic facies within rocks of early Paleozoic age.

Gneiss and schist, mostly of sedimentary origin as indicated by bedding and mineral composition but some possibly of mafic volcanic origin, crop out in the villages of Wakefield and Peace Dale, on Mount

Pleasant near the north-central border of the area, and west of Worden Pond. Several bodies of highly feldspathic gneiss of this series, mapped separately, are exposed in the northwestern part of the quadrangle. These rocks, which occur as roof pendants or inclusions in plutonic rock, are correlated with the Blackstone Series on the basis of lithology and structural relations with other formations. Gneiss and schist in adjacent quadrangles, similar to those under discussion, have also been correlated with the Blackstone (Nichols, 1956, Moore, 1959). The correlation of these rocks with those of the Blackstone valley may be incorrect, however, and these rocks may be equivalent to one of the gneiss and schist formations of eastern Connecticut or to a heretofore unrecognized formation.

The rocks of the Blackstone exposed in Wakefield are like those mapped by Nichols (1956) along the strike 1.45 miles to the northeast in the Narragansett Pier quadrangle. The Blackstone in these two places is possibly continuous, beneath cover, rather than discontinuous as shown by Nichols' map. The Blackstone cropping out along Allen Avenue in Peace Dale is probably an inclusion in plutonic rock and not continuous with that in Wakefield.

Though the Blackstone is lithologically varied, medium- to fine-grained medium- to light-gray or blue-gray quartz-feldspar-biotite gneiss (table 1, column 1) and quartz-biotite-muscovite schist are dominant. Most of these rocks are quartz-rich; some are mica-rich. Much of the schist contains some feldspar; a decrease in the amount of feldspar and an increase in the amount of mica results in rocks that grade from gneiss to schist (table 1, column 2). Garnet and sillimanite occur as conspicuous accessory minerals in some of the gneiss and schist (table 1, column 3, 4). Graphite was not observed.

Intercalated with these rocks and locally common are light- to dark-gray fine- to medium-grained quartz-hornblende schist and gneiss containing varying amounts of feldspar (table 1, column 5, 6, 7, 8) and containing thin beds of micaceous quartzite. Alined hornblendes and, less commonly, biotite streaks impart a pronounced lineation. Lenses of medium-grained light-green nearly massive epidote-quartz-feldspar or epidote-quartz-hornblende rock, generally less than 6 inches thick and 3 feet long, are common; they probably represent original calcareous concretions and thin beds drawn out into boudins. The lenses with epidote and the hornblende schist and gneiss both appear to be diagnostic of the Blackstone Series in this area, for none were observed in rocks mapped as part of the Rhode Island Formation. The Blackstone west of Worden Pond contains a few small pods of coarse-grained hornblende-feldspar-quartz amphibolite.

Locally the gneiss and schist contain lenses of quartz. Some of the lenses in the schist at a point 0.21 mile N. 50° W. of BM 15 in

TABLE 1.—*Modes of rocks from the Kingston quadrangle*

[T, trace]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16a	16b	17
Microcline	16.8	------	------	5.4	T	------	T	T	28.6	4.4	19.9–42.7	25.1	18.8–24.0	27.7	4.4	9.5	------	32.6
Plagioclase	37.5	35.2	11.4	20.1	41.4	29.0	20.1	13.9	41.8	44.1	25.5–34.8	36.5	34.9–38.9	36.4	22.9	8.9	------	37.0
Quartz	18.1	26.3	36.4	33.1	40.7	38.9	62.6	72.9	20.1	42.8	29.0–42.0	31.4	31.9–38.8	34.5	34.2	58.7	56	23.6
Biotite and chlorite	24.6	33.4	29.2	25.2	T	T	3.5	3.1	6.9	6.2	0.6–1.9	6.2	5.3–7.2	1.3	21.4	19.5	3	5.2
Muscovite	T	3.4	10.2	10.6	------	------	------	------	0.8	T	T	T	T–0.8	T	13.9	2.7	9	1.0
Hornblende	------	------	------	------	13.8	29.7	11.6	9.1	------	------	------	------	------	------	------	------	------	------
Sillimanite	------	T	9.7	4.7	------	------	------	------	------	------	------	------	------	------	T	T	32	------
Allanite	T	------	T	------	T	------	------	------	T	------	------	T	T	------	------	------	------	T
Apatite	T	T	T	T	T	T	T	T	T	T	T	T	T	------	T	T	------	T
Epidote-Zoisite	T	------	T	------	------	T	T	T	------	------	------	T	T	------	------	------	------	------
Garnet	------	------	T	------	------	------	------	------	------	------	T	------	------	T	------	T	------	------
Graphite	------	------	------	------	------	------	------	------	------	------	------	------	------	------	2.8	T	------	------
Ilmenite	------	1.2	------	------	3.0	------	1.0	T	------	------	------	------	------	------	------	------	------	------
Magnetite	T	------	T	T	------	2.1	------	------	1.7	T	T	T	T–0.8	T	------	T	------	T
Sphene	T	------	------	------	------	------	T	0.5	------	------	------	T	T	------	------	------	------	------
Tourmaline	------	------	------	------	------	------	------	------	------	------	------	------	T	------	------	------	------	------
Zircon	T	T	T	T	------	T	T	T	T	T	T	T	T	T	T	T	------	T
Calcite	------	------	------	------	------	------	------	------	------	------	------	------	T	------	------	------	------	------
Leucoxene	------	------	------	------	------	------	------	------	------	------	T	------	T	------	------	------	------	T
Sericite	T	T	T	T	T	T	T	------	T	T	T	------	T	T	T	------	------	T
Zeolite	0.5	------	2.1	------	T	T	T	------	------	------	------	------	------	------	------	------	------	------
Total accessories [1]	2.5	0.5	1.0	0.9	1.1	0.3	1.2	0.5	0.1	2.5	1.0–2.2	0.8	0.5–1.9	0.1	0.4	0.7	------	0.6
Composition of plagioclase	An_{28}	An_{34}	An_{75}	An_{32}	An_{47}	An_{83}	An_{39}	An_{34}	An_{18}	An_{25}	An_{10-12}	An_{22}	An_{20-23}	An_{7}	An_{23}	An_{34}	------	An_{22}

[1] Exclusive of those for which percentage is reported separately.

Blackstone Series:

1. Gneiss, medium-gray, fine-grained; corner of Allen Avenue and Willard Road, Wakefield.
2. Gneiss, schistose, dark-gray, medium-grained; 400 feet south of road corner 98 northeast of Kenyon.
3. Schist, silver-gray, medium-grained; 0.2 mile N. 45° W. of BM 15 in Wakefield.
4. Schist, medium-gray, medium-grained; east side of South County Trail, 600 feet north of Pawcatuck River.
5. Gneiss, schistose, medium-gray, medium-grained; 0.18 mile N. 23° E. of BM 100 in Kenyon.
6. Schist, dark-gray, fine-grained, railroad cut at Kenyon.
7. Gneiss, light-gray, fine-grained; 0.23 mile N. 28° W. of BM 15 in Wakefield.
8. Gneiss, medium-gray, fine-grained; west side of Hundred Acre Pond.

Blackstone Series, feldspathic:

9. Gneiss, light-gray, medium-grained; 0.5 mile west of Larkin Pond.
10. Gneiss, light-gray, fine-grained; east side of South County Trail 0.27 mile south Kingston Road.

Hope Valley Alaskite Gneiss:

11. Range in 3 thin sections; from Kingston, Great Neck, and Tobey Neck.

Ten Rod Granite Gneiss:

12. Quarry 0.5 mile N. 17° W. of BM 184 in Kingston.
13. Range in 4 thin sections; from northeast of Kingston, northeast of Kenyon, west side of the hill at Kingston, and near corner of Laurel Lane and Kingston Road.

Fine-grained granite:

14. 0.67 mile S. 65° E. of road corner 97 south of Kenyon.

Rhode Island Formation:

15. Schist, medium-gray, medium-grained; BM 15 in Wakefield.
16. Schist, conglomeratic, light-gray, medium-grained; 0.23 mile S. 73° E. of road corner 97 south of Kenyon.
    - 16a. Matrix.
    - 16b. Pebbles.

Narragansett Pier Granite:

17. 0.96 mile S. 45° W. of BM 99 on southwest side of Worden Pond.

Wakefield that are as much as 38 mm thick and 180 mm long appear to be stretched pebbles. Larger and more irregularly shaped aggregates of quartz in other beds at the same locality appear to be broken and discontinuous quartz veins. On the southeast side of Mount Pleasant a conglomeratic layer about 2 feet thick contains about 5 percent stretched quartz and quartzite pebbles as much as 8 by 20 by 50 mm; these pebbles are alined to produce a strong lineation.

Sillimanite is most abundant west of Worden Pond, where strongly alined ellipsoidal aggregates of quartz and sillimanite (fibrolite), commonly 5 by 10 by 20 mm (table 1, column 4), locally constitute as much as 10 percent of the rock. On weathered surfaces these aggregates stand out in relief. Although they resemble pebbles, gradational contacts between the aggregates and the matrix indicate that the aggregates formed as a result of metamorphism.

Sillimanite in the Blackstone replaces quartz, feldspar, biotite, and muscovite; the amount of replacement of these minerals is in the order listed. The trace of sillimanite in a schistose gneiss (table 1, column 2) from the outcrop 400 feet south of road corner 98 northeast of Kenyon consists of long slender needles mostly in the central parts of feldspar and quartz grains. The sillimanite is most abundant in grains of feldspar adjacent to muscovite, though none occurs in muscovite or biotite. In other rocks with only a trace of sillimanite, this mineral appears to be confined to quartz but is most abundant near quartz-muscovite grain boundaries. The sillimanite in a schist from Wakefield (table 1, column 3) is in bundles that include shreds of biotite and chlorite and small grains of quartz. Most of this sillimanite appears to have replaced biotite, some has replaced quartz and feldspar, and some has replaced muscovite along the muscovite-biotite grain boundaries.

The feldspathic bodies of the Blackstone Series mapped separately are mostly medium- to fine-grained medium- to light-gray quartz-feldspar-biotite gneiss (table 1, column 9, 10), generally containing metacrysts of flesh-colored or white feldspar commonly 12–20 mm long. The metacrysts constitute about 5–15 percent of the gneiss; some of these are single subhedral grains and some are aggregates. Slight differences in texture and greater differences in mineral composition between adjacent layers indicate the sedimentary origin of the gneiss. The plagioclase of the feldspathic gneiss, in the specimens examined in thin section, is less calcic than that in the remainder of the Blackstone Series. The Blackstone exposed near the border of the Narragansett Pier Granite southwest of Worden Pond is also feldspathic, though not mapped separately. The gneiss in these exposures is mostly medium grained and medium gray and contains aggregates and single grains of white feldspar as much as 40 mm long. The long axis of some of these metacrysts is across the foliation of the gneiss, indicating that the metacrysts are younger than the foliation.

MISSISSIPPIAN(?) OR OLDER ROCKS

HOPE VALLEY ALASKITE GNEISS

The Hope Valley Alaskite Gneiss was named from exposures in the southern part of the Hope Valley quadrangle (Moore, 1958). The body of alaskite gneiss that includes the type locality extends eastward into the northwest corner of the Kingston quadrangle. Smaller bodies also crop out on Great Neck, Tobey Neck, and elsewhere.

The alaskite gneiss is characterized by a low content of dark minerals, much of which is magnetite, and by alined and flattened rod-shaped aggregates of quartz. The gneiss in the northwest corner of the area is pinkish gray to flesh colored and medium to fine grained, somewhat finer grained than at the type locality. Lineation, shown by the aggregates or rows of quartz grains and locally by streaks of biotite, is only moderately formed in most places; foliation is weak or absent. Much of the alaskite gneiss on Great Neck is medium to coarse grained and contains quartz aggregates as much as 4 by 10 by 20 mm; it has moderate lineation and very weak to moderate foliation. Some of the alaskite gneiss in and near the village of Kingston is fine to medium grained and almost structureless. Flesh-colored potassium feldspar, white or colorless plagioclase, smoky quartz, and accessory biotite and magnetite can be identified megascopically in almost all of the alaskite gneiss. Locally it contains a few phenocrysts of potassium feldspar as much as 12 mm long or aggregates of potassium feldspar as much as 25 mm long that appear to be granulated phenocrysts.

Thin sections show that the potassium feldspar is microcline. Some of the microcline phenocrysts are subhedral, embayed by quartz, and contain quartz and plagioclase inclusions. Most of the larger grains of microcline are microperthitic, whereas the smaller ones are not. If the microperthite is a result of unmixing, its occurrence in only the large grains suggests that the large grains formed at a higher temperature, and are therefore older, than the small grains. In the three thin sections examined, the plagioclase ranges from An_{10}–An_{12} (table 1, column 11); many grains of plagioclase show discontinuous rims of more sodic plagioclase or border areas of myrmekite along plagioclase-microcline grain boundaries. Sodic plagioclase rims like these have been interpreted by Tuttle (1952, p. 115) as a result of unmixing of the sodic plagioclase from microcline. Most of the quartz is in rod-shaped aggregates or in single grains of about the same size as those of the feldspar; this quartz shows strong wavy extinction and some granulation. Quartz is also present as tiny euhedral to round blebs in plagioclase and microcline; as many as 40 blebs were seen in a single grain of feldspar no more than 1.5 mm in diameter.

Outcrops in the Kingston quadrangle afford little evidence as to the age of the alaskite gneiss relative to the age of the other pre-Pennsylvanian rocks. Spatial relationships between the alaskite gneiss and the feldspathic Blackstone on the south end of Greak Neck suggest that the alaskite gneiss caused the feldspathization and is therefore younger than the Blackstone. The alaskite gneiss is intrusive into, and contains inclusions of, the Blackstone Series in the Hope Valley quadrangle (Moore, 1958) and Carolina quadrangle (Moore, 1959). In these quadrangles the alaskite gneiss grades into the Scituate Granite Gneiss, indicating the age equivalence of the two. The Scituate Granite Gneiss in the North Scituate quadrangle is older than the Esmond Granite (Quinn, 1951), which, in turn, is older than the Pondville Conglomerate of Pennsylvanian age and the Spencer Hill Volcanics of Mississippian(?) age (Quinn, 1952). A lead-alpha age determination on zircon from alaskite gneiss on Tower Hill in the Narragansett Pier quadrangle is 303 million years (Quinn and others, 1957, p. 556).

No evidence as to the origin of the Hope Vally Alaskite Gneiss was derived from outcrops in the Kingston quadrangle. Foliation in the alaskite gneiss that is parallel to the contacts with inclusions but at a high angle to foliation in the inclusions is cited as evidence that the alaskite gneiss of the Hope Valley and Carolina quadrangles was intruded as a magma (Moore, 1958). Nichols (1956), however, stated that the contact between the Blackstone Series and the alaskite gneiss in the Narragansett Pier quadrangle is gradational and that the foliation of the alaskite gneiss seems to be inherited from the Blackstone.

TEN ROD GRANITE GNEISS

The Ten Road Granite Gneiss at its type locality in the Hope Valley quadrangle (Moore, 1958) is fine- to medium-grained pinkish-gray to medium-gray gneiss and has strong lineation, moderate to weak foliation, and phenocrysts of microcline, many of which have been granulated and are now lenticular aggregates. Most of the gneiss exposed in Kingston, along the brook east of Kingston, and on the hill west of the intersection of Kingston Road and South County Trail is like that mapped as Ten Rod in the Hope Valley and Carolina quadrangles. The gneiss exposed at those places is also continuous with the unit mapped by Nichols (1956) in the Narragansett Pier quadrangle as the augen gneiss facies of the Scituate Granite Gneiss and with the unit mapped by Power (1959) in the Slocum quadrangle as augen gneiss.

The Ten Rod Granite Gneiss in the Kingston quadrangle is light- to medium-gray and pinkish-gray medium- to coarse-grained gneiss in which smoky quartz, flesh-colored potassium feldspar, white or colorless plagioclase, 5–10 percent biotite, and a trace of magnetite can be identified megascopically. It characteristically has 10–15 percent pink to gray microcline as subrectangular single grains commonly 4 by 8 by 12 mm., but locally as much as 40 mm. long, and as subrectangular to ellipsoidal aggregates commonly 10 by 15 by 20 mm. Foliation is generally weak to strong but locally absent. Lineation is moderate to strong and is expressed by streaks of biotite flakes and by the large microline grains and aggregates.

The large single grains of microcline, as seen in thin sections, have irregular borders that appear to be a result of embayment of the microcline by plagioclase and quartz. They also contain many small subhedral to round blebs of quartz that have different orientations, subrectangular inclusions of plagioclase that commonly have narrow rims of albite along plagioclase-microcline grain contacts, and a few small flakes of biotite. Many of the microcline aggregates consist of a few large grains of microcline in the center, surrounded by borders of fine-grained microcline, plagioclase, and quartz; others are medium-grained microcline, plagioclase, and quartz grains of equal size. The grains of microcline in the aggregates contain inclusions like those in the large single grains. The large single grains and the aggregates appear to be original phenocrysts, perhaps containing some inclusions, that have been granulated and partly replaced during subsequent metamorphism.

Much of the plagioclase in the groundmass has rims of albite, or myrmekite, along plagioclase-microcline grain borders like those around plagioclase inclusions in the phenocrysts and like those in the alaskite gneiss. The quartz, except that occurring as small blebs included in other minerals, shows some granulation and sutured borders and has marked wavy extinction. Modes of the Ten Rod are given in table 1, columns 12 and 13.

In the Hope Valley quadrangle, a dike of Ten Rod having foliation parallel to the dike walls and containing inclusions of the Scituate Granite Gneiss cuts across the foliation of the Scituate. These relations indicate that the Ten Rod is younger than the Scituate and was intruded as a magma (Moore, 1958). In the Kingston quadrangle near the south end of the hill north of Kenyon, the foliation in the Blackstone tends to wrap around the blund end of the body of Ten Rod, suggesting that the Ten Rod was emplaced by forceful injection. At one place here, the Ten Rod contains a small concordant inclusion of fine-grained biotite schist. A lead-alpha age determination on zircon from the Ten Rod at the type locality is 289 million years (Quinn and others, 1957), slightly less than similar age determinations on zircon from the Scituate Granite Gneiss and Hope Valley Alaskite Gneiss. Nichols (1956) stated that conformable structure and gradational contacts between the augen gneiss facies of the Scituate Granite Gneiss (Ten Rod Granite Gneiss) and Blackstone schist in the Narragansett Pier quadrangle suggest that the augen gneiss was formed by feldspathization of the schist. Power (1959) stated that the augen gneiss of the Slocum quadrangle grades into and is intercalated with biotite schist, that the augen gneiss appears to grade into or interfinger with the Hope Valley Alaskite Gneiss, and that coarse-grained rock mapped as Scituate is younger than fine-grained rock mapped as augen gneiss.

FINE-GRAINED GRANITE

Fine-grained granite occurs as sills, dikes, and lenticular bodies, only a few of which are large enough to show on the map. The most accessible of the bodies mapped is the one west of Worden Pond. The fine-grained granite, which appears to be like that of adjacent quadrangles, is slightly coarser in larger bodies than in smaller bodies; it is flesh colored to light gray, and dark minerals are sparse. Most of it is even grained, with grains commonly 0.75–1.0 mm long; but some has a few phenocrysts of microcline commonly 3–5 mm long or, as near the south end of Great Neck, as much as 25 mm long. The granite in the body west of Worden Pond has lineation produced by narrow streaks of biotite flakes; that along the brook east of Kingston is massive to slightly foliated; and some uncovered by excavation on the University of Rhode Island campus is massive to slightly foliated and lineated. Foliation is parallel to the walls of the body at places where this relation could be determined, as in a narrow dike (not shown on the map) in the Ten Rod Granite Gneiss 0.42 mile N. 24° E. of BM 100 at Kenyon.

Much of the quartz, particularly the larger grains, shows marked strain shadows in thin section, and some shows mildly sutured borders. Foliation is primarily a result of parallel orientation of most of the biotite flakes, though in some of the rock the quartz grains are slightly flattened in the plane of foliation. Microcline and plagioclase grains show no apparent preferred orientation. Some grains of plagioclase have narrow rims of albite along plagioclase-microcline grain borders like those in the Ten Rod Granite Gneiss and Hope Valley Alaskite Gneiss. A mode is listed in table 1, column 14.

The fine-grained granite is intrusive into the Hope Valley Alaskite Gneiss and the Ten Rod Granite Gneiss. Dikes of the granite having foliation parallel to the dike walls indicate a magmatic origin.

PENNSYLVANIAN ROCKS

RHODE ISLAND FORMATION

Woodworth (in Shaler and others, 1899, p. 134) described the coal-bearing beds of the Narragansett basin as the Rhode Island coal measures and described the conformably underlying conglomerate, which is discontinuous, as the Pondville Conglomerate. Emerson (1917, p. 54) used the name Rhode Island Formation for the coal-bearing beds. The Pennsylvanian age of these beds has been determined by means of plant fossils (Providence Franklin Society, 1887, p. 68–79; Knox, 1944).

Two outcrops in Wakefield were mapped as a part of the Rhode Island Formation—one in the basement of a mill building, along a mill race, and in the west abutment of the dam at BM 15 in the southern part of town, and the other 0.2 mile west-northwest of BM 15. These rocks are possibly continuous with Pennsylvanian strata along the east side of Indian Run in the Narragansett Pier quadrangle rather than discontinuous as indicated by Nichols (1956). Bedrock is not known to crop out along the line of strike between these two places.

The exposure 0.2 mile northwest of BM 15 includes a bed about 4 feet thick that grades from graphite schist having very irregular foliation through graphite-muscovite-quartz schist into quartz-mica schist. A thin section of the most graphitic part of the bed shows 92–94 percent matrix, composed of about 60 percent graphite and 40 percent muscovite, and 6–8 percent aggregates of chlorite, muscovite, and biotite. Grains in the matrix are mostly 0.03–0.05 mm long; those in the aggregates are mostly 0.75–1.0 mm long. Graphite, graphitic schist, or meta-anthracite occur in many places in the Rhode Island Formation; one such place is along the east slope of Tower Hill, about 3 miles northeast of the outcrop just described, where two small mines were once worked for graphite (Nichols, 1956).

The beds at BM 15 are medium-grained medium-gray quartz-feldspar-biotite-muscovite schist and schistose gneiss, locally containing sparse sillimanite; thin beds of coarse-grained silvery quartz-muscovite-biotite schist containing small garnets; and some beds of fine-grained medium-gray quartz-feldspar-biotite gneiss. These beds were mapped as a part of the Rhode Island Formation because of the relative abundance of muscovite; their position on the basinward side of the graphitic beds described above; and the absence of pods of epidote, quartz, and hornblende that are seemingly characteristic of the Blackstone Series in this area. Furthermore, a thin section of schist from this locality contains 2.8 percent graphite in flakes 0.1–0.15 mm long (table 1, column 15). The schist and gneiss have been intruded by thin sills of pegmatite and massive Narragansett Pier Granite.

To verify the identification of the graphite in the schist at BM 15, a small sample of the rock was digested in hydrofluoric acid, which concentrated the graphite by dissolving quartz and feldspar. Because graphite is abundant in many of the pelitic rocks of the Rhode Island Formation but has not been reported from pelitic rocks of the Blackstone, 30 other samples were digested in acid to test for graphite. Of these, 4 were from rocks mapped as Rhode Island Formation and 20 were from the Blackstone Series of the Kingston quadrangle, 3 were from rocks from two outcrops of Rhode Island Formation in the Narragansett Pier quadrangle, and 3 were from the Blackstone in the Carolina quadrangle. Graphite was not found in any of the samples of Blackstone, it is present in the samples of the Rhode Island Formation from the Kingston quadrangle and in one sample from the two outcrops of the Rhode Island Formation in the Narragansett Pier quadrangle.

The rocks in the small body of the Rhode Island Formation southeast of Kenyon originally were mapped in the field as part of the Blackstone Series. They are now considered part of the Rhode Island Formation because some contain graphite and stretched pebbles more like those of the Rhode Island Formation elsewhere than like those of the Blackstone.

The outcrop of this body 0.23 mile S. 73° E. of road corner 97 south of Kenyon reveals an alternating sequence of thin beds of conglomeratic schist (table 1, columns 16a, b) containing pebbles commonly 5 by 13 by 32 mm, and beds of medium-grained rusty-weathering quartz-feldspar-biotite schist and impure quartzite in which pebbles are scarce or absent. The more conglomeratic beds are as much as 20 percent pebbles. This outcrop is probably the one described by Martin (1925, p. 21) as "metaconglomerate from Wordens Pond." She described the metaconglomerate as part of the ancient schist series or, according to modern nomenclature, the Blackstone Series. The pebbles are fine-grained light-gray quartz schist and show a strong lineation. A mode of parts of four pebbles is 56 percent quartz, 32 percent sillimanite, 9 percent muscovite, 3 percent biotite, and minor accessory minerals. In thin section the pebbles show strong schistose structure. Quartz grains in the pebbles are commonly about 0.2 mm thick and 0.4 mm long, whereas those in the matrix are commonly about 0.5 by 0.7 mm. Most of the sillimanite in the pebbles is in bundles of fibers that lie in the plane of schistosity and between the quartz grains; the remainder occurs as randomly oriented needles in quartz or, less commonly, in muscovite. The matrix of the schist contains only a trace of sillimanite, most of which is in needles in quartz adjacent to the pebbles. It is suggested that the pebbles were originally highly argillaceous and that some of the alumina migrated into the matrix during metamorphism. Samples from this outcrop and from the one 0.35 mile N. 43° E. of road corner 97 contain small euhedral to anhedral plates of graphite.

The concealed body of Rhode Island Formation at Tuckertown is based on the core from a hole drilled by the U.S. Geological Survey. A core of soft, partly weathered quartz-muscovite schist containing some biotite, feldspar, and garnet was taken from depths of 112.66–128.66 feet; the feldspar near the top of the core appears to be partly kaolinized. Small euhedral to subhedral plates of graphite are abundant in the core to a depth of 125.25 feet. Because the core from the unexposed rocks at Tuckertown contains graphite and much muscovite and because these rocks are on the line of strike of the Pennsylvanian beds in Wakefield, they are correlated with the Rhode Island Formation.

PENNSYLVANIAN OR YOUNGER ROCKS

NARRAGANSETT PIER GRANITE

The Narragansett Pier Granite was named from exposures along the shore in the southern part of the Narragansett Pier quadrangle (Nichols, 1956), where the granite is typically reddish and medium grained and has inconspicuous linear and local planar structures. This granite can be recognized at least as far west as Westerly, R.I., and Stonington, Conn., where it was quarried for many years.

The granite extends from the type locality westward into the Kingston quadrangle, where it is exposed south of Perryville, along the south side of the hill about 1 mile southwest of Worden Pond, and elsewhere in masses that are too small to show on the map. The rock south of Perryville is medium-grained massive pink granite containing scattered euhedral phenocrysts of pink potassium feldspar commonly 20 mm long. Smoky quartz, pink potassium feldspar, colorless to white plagioclase, 2–4 percent biotite, and magnetite can be identified megascopically in the rock.

The granite exposed southwest of Worden Pond is variable in color, texture, and structure, probably because it is along the border of the intrusive body. It contains many highly feldspathized inclusions of the Blackstone Series as much as 6 feet thick and is generally gray or flesh colored, weakly foliated, and biotite-rich adjacent to the inclusions. The abundant biotite adjacent to inclusions was probably derived from the inclusions. The foliation appears to be in part a result of flow in the magma and in part inherited from partially digested inclusions. Apophyses of granite in the Blackstone are numerous; some of these, as well as some irregular dikes in the granite, have a sugary medium-grained aplitic texture. Most of the granite is even grained; some contains euhedral phenocrysts of pink feldspar as much as 25 mm long. The small body of granite on the southwest side of the same hill is medium to fine grained, pink, and massive. A mode is given in table 1, column 17.

The Narragansett Pier Granite is intrusive into, and therefore younger than, the Blackstone Series and the Rhode Island Formation. Intrusive relationships between the granite and the Rhode Island Formation are well exposed in the eastern part of Wakefield at the south end of Tower Hill, where the bending of schistosity parallel to the rounded end of a sill indicates forceful injection of a magma.

WESTERLY GRANITE

The Westerly Granite, which is blue gray or locally pink, fine grained, and nearly massive, has long been quarried near Westerly and Bradford, R.I., as a monument stone (Kemp, 1899; Emerson, 1917, p. 230). It commonly occurs as dikes that trend eastward and dip gently to the south. It is intrusive into the Narragansett Pier Granite and older rocks.

The granite exposed in a pit about 30 feet square on the north side of Worden Pond Road southwest of Worden Pond is correlated with the Westerly Granite. The granite of this body is light gray, fine grained, and massive and contains about 5 percent biotite; most of the biotite is in flakes 0.5–0.6 mm in diameter, but some is in flakes 2.5 mm in diameter. Scattered flakes of biotite four to five times as large as the average size are characteristic of some of the Westerly Granite near Bradford and Westerly. Viewed in thin section, the granite mapped as Westerly in the Kingston quadrangle shows some zoned plagioclase that has gradational boundaries between zones. Zoned plagioclase is present in the Westerly Granite elsewhere but is unknown in rocks mapped as fine-grained granite in the Kingston quadrangle.

The contacts of the granite along Worden Pond Road are not exposed; hence its shape is unknown. The nearest bedrock exposed is the Blackstone Series.

APLITES, PEGMATITES, VEINS

Thin dikes, sills, and lenticular pods of aplite and pegmatite as well as quartz veins are common in the area; none are large enough to show at the map scale.

The aplite is a fine-grained pink to light-gray massive rock composed of quartz, feldspar, and traces of biotite and magnetite; locally it contains muscovite and garnet. The aplite commonly has narrow borders of pegmatite or contains irregular streaks of pegmatite; the contacts between aplite and pegmatite are gradational in most places.

Most of the pegmatite bodies are composed of pink microcline, white plagioclase, smoky quartz, biotite, and locally some muscovite; some apparently contain no microcline. Graphic texture of quartz and microcline is common. Pegmatite bodies in an outcrop east of road corner 97 on Shannock Road in the western part of the area contain sillimanite probably derived from the adjacent gneiss and schist, and a pegmatite 0.45 mile N. 15° E. of BM 100 in Kenyon contains small grains of malachite. Zoning is shown by some pegmatite bodies. A narrow pegmatite in the outcrop along the brook southwest of BM 184 at Kingston has a muscovite-rich zone along both sides; a pod of pegmatite in the roadcut along South County Trail southwest of BM 116 has a core that is mainly very coarse-grained quartz and pink microcline and a border of finer grained white plagioclase, quartz, and biotite. A few pegmatite bodies grade into aplite along their borders.

Thin veins and small pods of quartz are common locally. Most of these contain a small amount of pink microcline; some of them also contain a trace of white plagioclase.

The variety of crosscutting relations observed between the pegmatite, aplite, and quartz veins suggests that most of these are of about the same age. Their wide distribution and the fact that some pegmatite pods grade into the alaskite gneiss or granite gneiss suggest that many of the pegmatites, aplites, and quartz veins are genetically related to the Mississippian (?) or older igneous intrusions. Others, however, intrude the Pennsylvanian or younger Narragansett Pier Granite. Field relations show that some of the pegmatites of the Carolina quadrangle are younger, and others older, than the Westerly Granite (Moore, 1959).

SUMMARY OF AGE RELATIONS

The Blackstone Series is the oldest formation exposed in the quadrangle, for these rocks occur as inclusions in the Hope Valley Alaskite Gneiss, Ten Rod Granite Gneiss, and Narragansett Pier Granite. Inclusions of the Blackstone in the alaskite gneiss can be seen in exposures along the south side of Great Neck; a few small inclusions of fine-grained schist of the Blackstone occur in exposures of the Ten Rod on the southern end of the hill north of Kenyon; and the Narragansett Pier Granite contains many inclusions of the Blackstone in exposures southwest of Worden Pond.

The age relations of the Hope Valley Alaskite Gneiss in the larger bodies shown on the map cannot be determined. The rock in these bodies could be younger or older than the adjacent Ten Rod Granite Gneiss. Dikes and sills (some too small to show at a scale of 1:24,000) of rock that is most like the alaskite gneiss intrude the Ten Rod on the hill at Kingston. Field evidence in the Hope Valley quadrangle (Moore, 1958) indicates that the alaskite gneiss is the older of the two. Lead-alpha age determinations of zircon from these rocks also suggest that the alaskite gneiss is the older (Quinn and others, 1957). The relative age of these two rocks may not be the same in all parts of the region.

The bodies of fine-grained granite shown on the map intrude the Blackstone Series, the Hope Valley Alaskite Gneiss, and the Ten Rod Granite Gneiss. The internal structure of these rocks indicates that they are closely related to the Ten Rod or Hope Valley and are therefore Mississippian(?) or older. Other bodies of fine-grained granite, too small to show on the map, intrude the Narragansett Pier Granite.

The rocks mapped as the Rhode Island Formation were correlated with this formation elsewhere on the basis of lithology, particularly because of the graphite and graphitic schist, and on the basis of position of the outcrops. The formation in the Narragansett basin contains fossils of Pennsylvanian age (Providence Franklin Society, 1887).

The Narragansett Pier Granite is intrusive into the Rhode Island Formation in exposures at BM 15 in Wakefield; it is also intrusive into the Blackstone Series in exposures southwest of Worden Pond. The Westerly Granite southwest of Worden Pond is partly surrounded by exposures of the Blackstone; the contacts are not exposed. Elsewhere in southwestern Rhode Island, the Westerly is intrusive into the Narragansett Pier Granite.

STRUCTURAL GEOLOGY

The rocks of the Blackstone Series along the west border of the Kingston quadrangle are part of a roof pendant that extends about 1.5 miles into the Carolina quadrangle. The Hope Valley Alaskite Gneiss in the northwest corner of the quadrangle is part of a pluton that extends to the north, northwest, and west. The Ten Rod Granite Gneiss in the map area is part of a pluton that extends to the north and northeast.

Bedding can be seen in much of the Blackstone Series of the Kingston quadrangle. Schistosity is present throughout the formation, and in most places the bedding and schistosity are parallel. The bedding and schistosity strike west or west-northwest and dip to the north in most of the Blackstone exposed across the central part of the area. North of Kenyon the formation shows many minor folds, and the attitude of the beds differs from place to place, though the general trend of bedding and schistosity is northward. Fold axes and lineation of mineral grains and pebbles plunge northeastward at moderate angles in most of the west-central and north-central parts of the area. The few folds observed in the Blackstone in Wakefield plunge gently west.

Lineation in most of the Hope Valley Alaskite Gneiss in the mapped area plunges northeastward at low to moderate angles. Foliation, where present, strikes northwestward and dips to the north. In most of the Ten Rod Granite Gneiss, lineation plunges northeastward at moderate angles; foliation strikes northeast to northwest and dips north. The fine-grained granite west of Worden Pond has lineation that plunges northeastward at moderate angles.

The contact between the Pennsylvanian sedimentary rocks and older rocks in the northwestern part of the East Greenwich quadrangle is an angular unconformity (Quinn, 1952). In the Kingston quadrangle this contact is not exposed and could be an unconformity or a fault. From East Greenwich, the contact trends southward to the northwestern part of the Narragansett Pier quadrangle where it curves rather sharply into the west-southwest trends in the eastern part of the Kingston quadrangle. The Rhode Island Formation of the map area shows both bedding and schistosity; these are parallel in all places where bedding was seen. In Wakefield the bedding and schistosity strike nearly west and dip steeply. In the body southeast of Kenyon the strike of bedding and foliation is somewhat variable, but the general trend is north.

The foliation in the Narragansett Pier Granite, where present, is parallel to the foliation in adjacent outcrops of the Blackstone Series and is believed to be a result of flow, parallel to the walls of the body, of a partly liquid magma.

METAMORPHISM

The rocks of Rhode Island display evidence of at least three episodes of metamorphism. The oldest metamorphism occurred before the Mississippian(?) or older plutonic rocks were emplaced, because the foliation in some inclusions of the Blackstone Series is at a high angle to the foliation of the enclosing plutonic rock, which, in turn, is parallel to the borders of the inclusions (Moore, 1959). Metamorphism that probably started during emplacement of the plutonic rocks but continued for some time after their emplacement is revealed by highly feldspathic areas of the Blackstone Series adjacent to the plutonic rocks, by cleavage expressed by oriented minerals in shear zones across the foliation in the plutonic rocks, and by granulation of minerals in the plutonic rocks. Metamorphism younger than the Rhode Island Formation but older than the Narragansett Pier Granite is shown by beds of Pennsylvanian age in the southern part of the Narragansett basin. Metamorphic changes in these beds are less intense toward the north, and, in the Pawtucket quadrangle (Quinn and others, 1949), unmetamorphosed Pennsylvanian beds overlie schist, greenstone, and quartzite of the Blackstone Series.

In the Kingston quadrangle, as elsewhere in Rhode Island, the record of the oldest metamorphism is in the Blackstone Series. This metamorphism was regional; it caused changes in mineral composition, produced schistosity, and, in some of the rocks, produced lineation. Folding accompanied the metamorphism. The changes in mineral composition probably involved little or no addition of material. The most abundant minerals formed at this time were quartz, feldspar, biotite, muscovite, hornblende, garnet, and sillimanite, minerals consistent with the upper range of the almandine-amphibolite facies (Turner and Verhoogen, 1960, p. 548). Impure argillaceous rocks were metamorphosed to quartz-mica schist, sandstone to quartzite, highly aluminous rocks to sillimanite-bearing schist, and calcareous sedimentary rocks or mafic volcanic rocks to hornblende schist. The exact age of the metamorphism is not known; it could be Precambrian or it could be as young as the early part of the orogeny during which the Hope Valley Alaskite Gneiss and Ten Rod Granite Gneiss were intruded. The latter two formations have been dated by field relations and by lead-alpha age determinations of zircon as Mississippian(?) or older.

A later episode of metamorphism is reflected by feldspathized areas in the Blackstone and by granulation of minerals in the Hope Valley Alaskite Gneiss and Ten Rod Granite Gneiss. The feldspathization is believed to have occurred during late stages of emplacement of the intrusives and as a result of emanations from the intrusives. The feldspathized rocks are mostly quartz-feldspar-biotite gneiss containing as much as 15 percent feldspar metacrysts. Not only is the total amount of feldspar greater in the feldspathized rock than elsewhere, but there appears to be more potassium feldspar, and the plagioclase is less calcic in the feldspathized rock. Lenticular aggregates of feldspar that appear to be granulated phenocrysts and quartz that shows granulation and strong undulatory extinction indicate that the alaskite gneiss and granite gneiss are syntectonic instrusives.

More recent folding and regional metamorphism are displayed by the Rhode Island Formation. This metamorphism predates the intrusion of the Narragansett Pier Granite, which occurred about 235 million years ago as determined by a lead-alpha age determination on zircon from the granite (Quinn and others, 1957, p. 556). This metamorphism caused changes much like those of the Mississippian(?) or older metamorphism; it resulted in new minerals, schistosity, and lineation in the Rhode Island Formation. The minerals formed at this time include quartz, feldspar, mica, garnet, graphite, and sillimanite; these could have formed without the addition of material. The mica flakes formed along parallel planes to form the schistosity which parallels bedding in the outcrops seen. Lineation is shown by elongate mineral grains and locally by stretched pebbles. At this time the older rocks must have been subjected to essentially the same agents of deformation and metamorphism as was the Rhode Island Formation. Because the intensity of this metamorphism was the same as that of the earlier metamorphism, the older rocks were not changed. No structures, such as refolded folds and deformed lineation, resulting from this deformation were detected in the older rocks; deformation appears to have been guided by the earlier formed schistosity and other surfaces of weakness.

The Blackstone Series along the border of the Narragansett Pier Granite southwest of Worden Pond locally contains as much as 15 percent metacrysts and augen of feldspar as much as 40 mm long. Some euhedral metacrysts are in the plane of schistosity, whereas others are across the schistosity. Rocks of this kind also occur in the granite as inclusions having gradational borders. The parallel arrangement of inclusions and of biotite flakes in part derived from reworked inclusions account for local foliation in the granite. The metacrysts and augen in the Blackstone along this contact are believed to have been introduced by emanations from the Narragansett Pier Granite, though they could have been introduced by emanations from the Mississippian (?) or older intrusives.

ECONOMIC AND ENGINEERING GEOLOGY

Building stone for several buildings on the University of Rhode Island campus was quarried from the Ten Rod Granite Gneiss on the west side of the hill at Kingston. One abandoned quarry is on the east side of the street, 500 feet north of BM 184 in Kingston; larger abandoned quarries are about 1,000 feet and about 2,500 feet north-northwest of BM 184. Rock is still well exposed in the northernmost of these quarries.

An outcrop of the Rhode Island Formation 0.2 mile northwest of BM 15 in Wakefield contains graphite schist that grades into quartz-muscovite schist. Although this probably is not a graphite deposit of economic value, it does contain good mineral specimens.

Most of the granite and granite gneiss of the area is strong, hard, and resistant to weathering. Locally, as in part of the hill west of the intersection of South County Trail and Kingston Road, the granite gneiss has disintegrated into "rottenstone." The rottenstone is sufficiently friable to be dug with a shovel. The schist and gneiss of the Blackstone Series and the Rhode Island Formation are weaker than the other bedrock formations and tend to slip along planes of schistosity.

Glacial deposits of sand and gravel are the most valuable mineral resource of the quadrangle; these have been described by Kaye (1960). Such deposits are most extensive and thickest along the stream valleys north of the Charlestown moraine; extensive but probably thinner deposits underlie the flat areas south of the moraine. Most of the material in these deposits is hard and sound, but the sand and gravel along Point Judith Pond contain much soft graphitic and micaceous rocks from the Rhode Island Formation. Most of the surface material in the uplands is glacial till, an unsorted deposit of all sizes from clay to boulders. The till here is generally very sandy and is suitable for fill and road bases.

Ground-water resources of the quadrangle were described by Bierschenk (1956). Glacial deposits of sand and gravel provide the largest supply of water; wells drilled into bedrock are generally much less productive but do provide a domestic supply in many places. Most of the water in bedrock is in fissures or other secondary openings, and it is generally impossible to predict where or at what depth these openings will be penetrated by a well.

REFERENCES CITED

Bierschenk, W. H., 1956, Groundwater resources of the Kingston quadrangle, Rhode Island: Rhode Island Devel. Council Geol. Bull. 9, 60 p.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U.S. Geol. Survey Bull. 597, 289 p.

Kaye, C. A., 1960, Surficial geology of the Kingston quadrangle, Rhode Island: U.S. Geol. Survey Bull. 1071–I, p. 341–396.

Kemp, J. F., 1899, Granites of southern Rhode Island and Connecticut, with observations on Atlantic Coast granites in general: Geol. Soc. America Bull., v. 10, p. 361–382.

Knox, A. S., 1944, A Carboniferous flora from the Wamsutta Formation of southeastern Massachusetts: Am. Jour. Sci., v. 242, p. 130–138.

Martin, L. H., 1925, The geology of the Stonington region, Connecticut: Connecticut Geol. Nat. History Survey Bull. 33, 70 p.

Moore, G. E., Jr., 1958, Bedrock geology of the Hope Valley quadrangle, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–105.

——— 1959, Bedrock geology of the Carolina and Quonochontaug quadrangles, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–117.

Nichols, D. R., 1956, Bedrock geology of the Narragansett Pier quadrangle, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–91.

Power, W. R., Jr., 1959, Bedrock geology of the Slocum quadrangle, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–114.

Providence Franklin Society, 1887, Report on the geology of Rhode Island: Providence, 130 p.

Quinn, A. W., 1951, Bedrock geology of the North Scituate quadrangle, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–13.

——— 1952, Bedrock geology of the East Greenwich quadrangle, Rhode Island: U.S. Geol. Survey Geol. Quad. Map GQ–17.

Quinn, A. W., Ray, R. G., and Seymour, W. L., 1949, Bedrock geology of the Pawtucket quadrangle, Rhode Island–Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ–1.

Quinn, A. W., Jaffe, H. W., Smith, W. L., and Waring, C. L., 1957, Lead-alpha ages of Rhode Island granitic rocks compared to their geologic ages: Am. Jour. Sci., v. 255, p. 547–560.

Shaler, N. S., Woodworth, J. B., and Foerste, A. F., 1899, Geology of the Narragansett basin: U.S. Geol. Survey Mon. 33, 402 p.

Turner, F. J., and Verhoogen, John, 1960, Igneous and metamorphic petrology: New York, McGraw-Hill Book Co., 694 p.

Tuttle, O. F., 1952, Origin of the contrasting mineralogy of extrusive and plutonic salic rocks: Jour. Geology, v. 60, p. 107–124.

The U.S. Geological Survey Library has cataloged this publication as follows:

Moore, George Emerson, 1914–
Bedrock geology of the Kingston quadrangle, Rhode Island. Washington, U.S. Govt. Print. Off., 1964.
iii, 21 p. fold. col. map (in pocket) table. 24 cm. (U.S. Geological Survey. Bulletin 1158–E)
Geology of selected quadrangles in Rhode Island.
Prepared in cooperation with the State of Rhode Island Development Council.
Bibliography: p. 21.

(Continued on next card)

Moore, George Emerson, 1914– Bedrock geology of the Kingston quadrangle, Rhode Island. 1964. (Card 2)

1. Geology—Rhode Island—Kingston quadrangle. I. Rhode Island. Development Council. II. Title. (Series)