DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

Prepared in cooperation with the
U.S. GEOLOGICAL SURVEY
NATIONAL GEOLOGIC MAPPING PROGRAM

BEDROCK GEOLOGIC MAP OF THE MENDHAM QUADRANGLE
MORRIS AND SOMERSET COUNTIES, NEW JERSEY
OPEN FILE MAP OFM 126
Pamphlet containing table 1 accompanies map

Base map by the Defense Mapping Agency.
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Topography by photogrammetric methods from aerial photographs taken 1942-1943. Culture revised by the United States Geological Survey 1954.

Polyconic projection. 10,000-foot grid ticks based on New Jersey coordinate system. 1000-meter Universal Transverse Mercator grid ticks, zone 18. 1927 North American Datum. To place on the predicted North American Datum 1983 move the projection lines 6 meters south and 33 meters west.

There may be private inholdings within the boundaries of the National or State reservations shown on this map.

SCALE 1:24,000

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETE R

CONTOUR INTERVAL 20 FEET

Bedrock geology mapped by R.A. Volkert in 1985-1986, 2008.
Digital cartography by R.S. Pristas and N.L. Malerba.

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NEW JERSEY GEOLOGICAL AND WATER SURVEY 1835

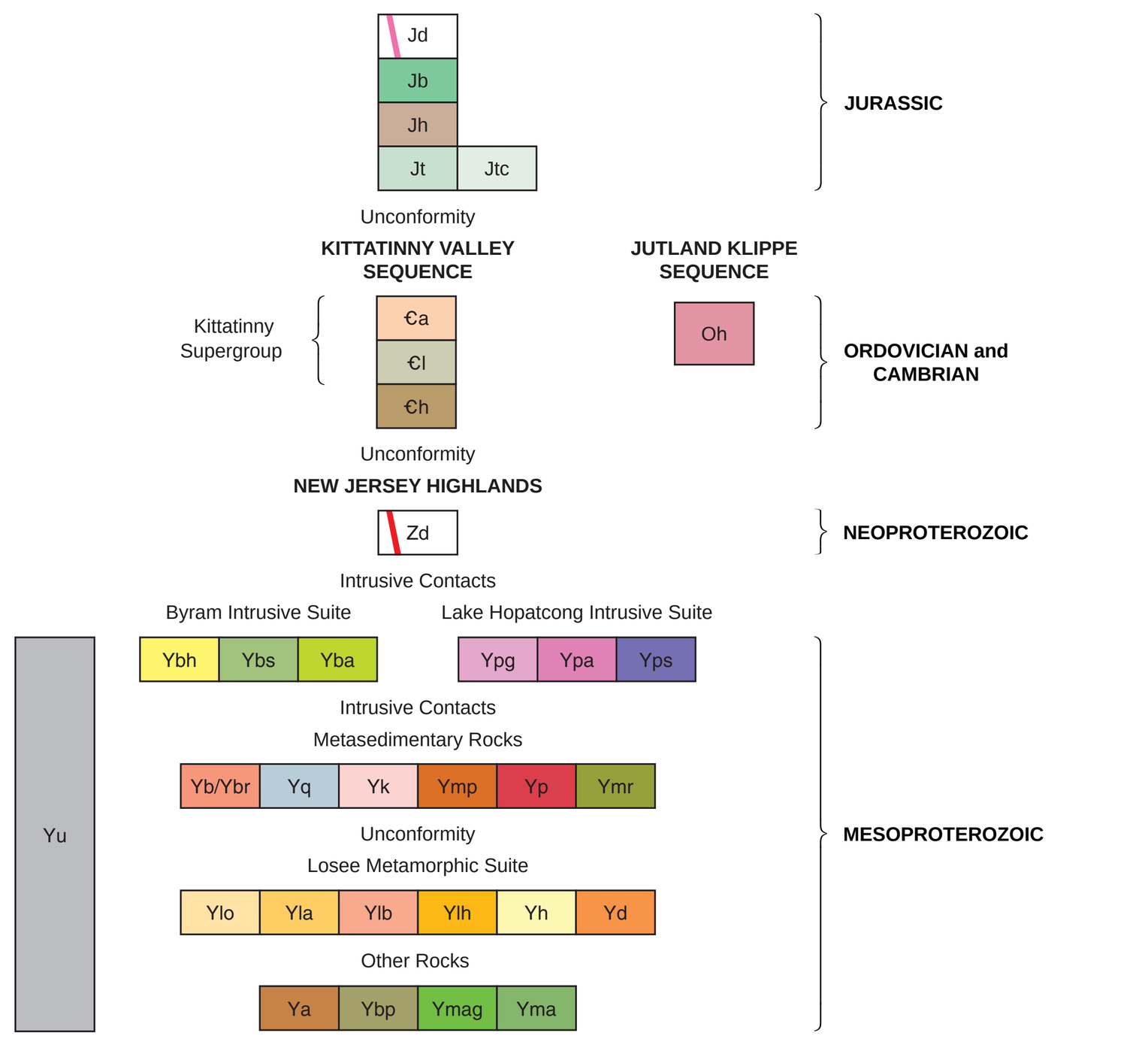
LOCATION IN NEW JERSEY

Bedrock Geologic Map of the Mendham Quadrangle Morris and Somerset Counties, New Jersey

by
Richard A. Volkert
2019

13°
MAGNETIC NORTH
TRUE NORTH
APPROXIMATE MEAN DECLINATION, 2005

CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contact - Dotted where concealed

Fault - Dotted where concealed. Queried where uncertain. Arrow shows dip direction of fault, where known.

U/D **Normal fault** - U, upthrown side; D, downthrown side

D/U **Reverse fault** - U, upthrown side; D, downthrown side

Thrust fault - sawteeth on upper plate

FOLDS

Folds in Proterozoic rocks showing trace of axial surface, direction and dip of limbs, and direction of plunge. Dotted where concealed.

Synform

Antiform

Overturned synform

Overturned antiform

Folds in Mesozoic rocks showing trace of axial surface, direction and dip of limbs, and direction of plunge. Folds in bedding and/or cleavage.

Anticline

PLANAR FEATURES

Strike and dip of crystallization foliation

62 **Inclined**

Vertical

33 **Strike and dip of mylonitic foliation**

40 **Strike and dip of beds**

LINEAR FEATURES

18 **Bearing and plunge of mineral lineation in Proterozoic rocks**

OTHER FEATURES

M **Abandoned mine - M, magnetite; Gr, graphite; Mi, mica; Mr, marble**

R **Abandoned rock quarry**

Bedrock float used to construct map

MUA-2 **Location of borings in the Washington Valley - Numbers correlate to logs in Table 1.**

Form line showing foliation in Mesoproterozoic rocks. Shown in cross section only.

INTRODUCTION

The Mendham 7.5-minute quadrangle is located in Morris and Somerset Counties, in north-central New Jersey. It is primarily in the New Jersey Highlands Physiographic Province, except for the southeastern part that is in the Piedmont Physiographic Province. The Ramapo fault provides a structural and physiographic boundary between the two provinces. Although the bedrock geology of the quadrangle has been the subject of study for more than a century (Bayley and others, 1914; Sims, 1958; Volkert, 1988), previous mapping was performed on a reconnaissance basis, or concentrated on relatively small areas surrounding economic deposits of magnetite. As a result, the geologic maps shown in these studies lack the detail shown on, and continuity with, recent detailed mapping of adjacent quadrangles, as well as conformity with the present geologic framework proposed for Mesoproterozoic rocks of the highlands. The geologic map and interpretations presented here supersede those shown on all previous bedrock geologic maps of the area.

This report provides updated, detailed geologic information on the stratigraphy, structure, ages and descriptions of geologic units in the map area. Cross-section A-A' shows a vertical profile of the geologic units and their structure. Rose diagrams in figures 1 and 2 provide a directional analysis of selected structural features. Additionally, 18 borings drilled in 1988 in the Washington Valley in the southeastern part of the area were logged by the author, and the data are provided in Table 1.

STRATIGRAPHY

Mesozoic Rocks

The youngest bedrock in the map area is Mesozoic and part of the Newark basin composed of interbedded Upper Triassic to Lower Jurassic sedimentary and igneous rocks. Only the uppermost part of this succession is present. It consists of sandstone of the Boonton Formation, sandstone and conglomerate of the Towaco Formation, and Hook Mountain Basalt, all of Lower Jurassic age. Additionally, a single diabase dike of inferred Mesozoic age is recognized from a gas pipeline trench excavation in the northeastern part of the area where it intrudes Mesoproterozoic rocks. A Mesozoic age for this dike was interpreted by Volkert and Puffer (1995) based on its geochemical composition that closely resembles Mesozoic basalt in the Newark basin.

Paleozoic Rocks

Lower Paleozoic rocks of Cambrian age of the Kittatinny Valley sequence are present in the northwestern and southwestern parts of the Mendham quadrangle where they unconformably overlie Mesoproterozoic rocks. The Kittatinny Valley sequence was previously considered to be part of the Lehigh Valley sequence of MacLachlan (1979) but was reassigned by Drake and others (1996). It includes the Hardyston Quartzite and Kittatinny Supergroup, of which only formations through the Allentown Dolomite crop out in the map area. Locally, in the southwestern part of the area, Paleozoic rocks of Ordovician age of the Jutland klippe sequence are in fault contact with Mesoproterozoic rocks on the west and with Paleozoic rocks of the Kittatinny Valley sequence on the east. These Ordovician rocks are interpreted to correlate lithologically and also temporally to the Hensfoot Formation of the Jutland klippe sequence in the High Bridge quadrangle (Monteverde and others, 2015).

Neoproterozoic Rocks

Diabase dikes of Neoproterozoic age intrude Mesoproterozoic rocks in the area. Dikes strike northeast or northwest and have sharp contacts and chilled margins against Mesoproterozoic rocks. Similar dikes are widespread and abundant in the Highlands and are interpreted to have an age of about 600 million years (Ma) (Volkert and Puffer, 1995).

Mesoproterozoic Rocks

The oldest rocks in the map area are Mesoproterozoic and include various granites, gneisses and marble. Mesoproterozoic rocks were metamorphosed to granulite facies at about 1045 Ma (Volkert and others, 2010) during the Ottawan phase of the Grenville orogeny. Estimated temperature for this high-grade metamorphism is ~769°C based on regional calcite-graphite geothermometry (Peck and others, 2006). Among the oldest units are calc-alkaline rocks of the Losee Suite formed in a continental-margin magmatic arc, as well as spatially associated supracrustal rocks formed in a back-arc basin, inboard of the Losee magmatic arc (Volkert, 2004). In the map area, the Losee Suite includes metamorphosed plutonic rocks mapped as quartz-oligoclase gneiss, albite-oligoclase granite and diorite gneiss, and metamorphosed volcanic rocks mapped as biotite-quartz oligoclase gneiss, hornblende-quartz oligoclase gneiss, hypersthene-quartz-plagioclase gneiss, and amphibolite. Elsewhere in the Highlands rocks of the Losee Suite yielded sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages of 1282-1248 Ma (Volkert and others, 2010). Supracrustal rocks include quartzofeldspathic gneisses mapped as biotite-quartz-feldspar gneiss, potassic-feldspar gneiss, clinopyroxene-quartz-feldspar gneiss, quartzite, calc-silicate rocks mapped as pyroxene gneiss, and metacarbonate rocks mapped as marble. Supracrustal rocks elsewhere in the Highlands yielded (SHRIMP) U-Pb zircon ages of 1299-1251 Ma (Volkert and others, 2010) that closely overlap the age of the Losee Suite.

Granite and related rocks of the Byram and Lake Hopatcong Intrusive Suites that comprise the Vernon Supersuite (Volkert and Drake, 1998) form a complete differentiation series that includes monzonite, quartz monzonite, granite, and alaskite. The Lake Hopatcong Suite predominates in the northern part of the map area, whereas the Byram Suite is well exposed in the southern part. Throughout the quadrangle, rocks of both suites have intruded the Losee Suite and supracrustal rocks. Byram and Lake Hopatcong rocks yielded similar SHRIMP U-Pb zircon ages of 1185-1182 Ma (Volkert and others, 2010). Widespread bodies of hornblende- and clinopyroxene-bearing granite and alaskite mapped as microantiperthite granite and microantiperthite alaskite crop out in the central and northern part of the area. Although undated, they appear to grade along strike into hornblende granite of the Byram Suite suggesting, but not proving that they may share a common age and origin with the Vernon Supersuite. For this reason they are shown as having an uncertain correlation to other granitic rocks in the map area. Similarly, a small body of biotite-plagioclase gneiss in the eastern part of the area and mapped based on boring samples is also of uncertain age and correlation. It is deformed by a penetrative foliation, indicating that it is older than the 1045 Ma high-grade metamorphism.

The youngest Mesoproterozoic rocks in the quadrangle are small, irregular bodies of granite pegmatite too small to be shown on the map. They are undeformed, contain xenoliths of foliated gneiss and intrude most other Mesoproterozoic rocks. Pegmatites elsewhere in the Highlands yielded U-Pb zircon ages of 1004 to 986 Ma (Volkert and others, 2005) indicating they were emplaced following high-grade metamorphism during waning stages of the Grenville orogeny.

STRUCTURE

Mesozoic and Paleozoic bedding

Because of the poor exposure of Mesozoic rocks in the area, lithologic contacts are inferred based on their orientation in adjacent quadrangles where they strike about N.40°W. and dip an average of 7° north or south. Bedding data from Paleozoic rocks in the quadrangle is limited to a single outcrop in the Peapack klippe sequence where the strike is N.85°E. and dip is south at 29°.

Proterozoic foliation

Crystallization foliation, formed by the parallel alignment of mineral grains in the Mesoproterozoic rocks during high-grade metamorphism related to the Grenville orogeny, defines the strike of Mesoproterozoic rocks. Foliations are varied in strike due to deformation of the rocks during folding and also due to drag along faults. Foliations strike an average of N.46°E. (Fig. 1) and dip southeast and, less commonly, northwest at 16° to 90° and average 56°.

Folds

Mesozoic rocks are deformed into a broad, open, upright structure, the New Vernon Anticline that plunges southeast. The Towaco Formation cores the anticline and Hook Mountain Basalt and Boonton Formation are preserved on the limbs.

Folds in Mesoproterozoic rocks deform crystallization foliations and therefore formed synchronous with, or slightly later than the peak of high-grade metamorphism at 1045 Ma. Folds are dominated by east-northeast-striking, northeast-plunging, northwest-overturned antiforms and synforms. Axes of minor folds and mineral lineations related to this fold phase plunge 9° to 40°. These folds have been refolded by southeast-plunging, open, upright antiforms and synforms that have northwest-striking axial surfaces. Fold axes and mineral lineations of this fold phase plunge 4° to 50°.

Faults

Mesoproterozoic rocks are deformed by a series of east-northeast-striking faults that from the northwest include the Rockaway Valley fault, Powder Mill fault, Flemington fault, and Ramapo fault. Most of these faults are characterized by brittle deformation fabric that consists of breccia, gouge, retrogression of mafic mineral phases, chlorite- or epidote-coated fractures or slickensides, and or close-spaced fracture cleavage.

The Rockaway Valley fault extends through the northern part of the map area where it contains Mesoproterozoic rocks on both sides. The fault strikes northeast and dips southeast about 65° to 70°. It is characterized mainly by brittle deformation fabric that overprints an earlier, steeply-dipping ductile deformation fabric. The latest movement sense is normal.

The newly-named Powder Mill fault extends through the central part of the area where it contains Mesoproterozoic rocks on both sides. The fault strikes N.40°E. and dips southeast about 60°. It is characterized by an earlier ductile deformation fabric that is overprinted by a brittle deformation fabric. The latest movement sense is reverse.

The Flemington fault extends through the southern part of the map area where it contains Mesoproterozoic rocks on both sides and, very locally, Paleozoic rocks of the Kittatinny Valley and Jutland klippe sequence on the hanging wall against Mesoproterozoic rocks of the footwall. The fault strikes northeast and dips southeast about 50°. It is characterized by brittle deformation fabric along most of its length, but at Pottersville, in the Gladstone quadrangle, a thick zone of ductily deformed Mesoproterozoic rocks is preserved on the footwall of the fault (Houghton and Volkert, 1990). The latest movement sense on the Flemington fault is normal with a component of right-lateral strike-slip.

The Ramapo fault extends through the southeast part of the area. It has a long and complex history of movement that preserves both brittle and ductile deformation fabrics that are consistent with normal, reverse, and dextral strike-slip movement. Latest movement sense is normal. Along most of its length the fault contains Mesoproterozoic rocks on the footwall and Mesozoic rocks on the hanging wall. In the map area the fault strikes about N.40°E. and dips southeast at 50° based on borings drilled to the south at Bernardsville (Ratcliffe and others, 1990) and by a series of borings drilled for Route 287 between Montville and Riverdale (Woodward-Clyde Consultants, 1983).

Joints

Joints are a dominant feature in Mesoproterozoic rocks. They are characteristically planar, moderately well formed, spaced from a foot or less to tens of feet, and dip moderately to steeply. Surfaces are typically unmineralized, except near faults, and are smooth and less commonly slightly irregular. Joints developed in massive rocks such as granite tend to be more widely spaced, irregularly formed and discontinuous than those in the layered gneisses. Joints formed near faults are spaced 2 feet or less apart.

The dominant joint trend in Mesoproterozoic rocks is nearly perpendicular to the strike of crystallization foliations, a consistent feature seen throughout the Highlands (Volkert, 1996). As a result joints in the map area do not strike uniformly because of the varied orientation of foliations due to folding. Two principal joint sets characterized by a dominant cross joint and less common strike joint are seen in the Mesoproterozoic rocks. The cross joint set strikes an average of N.51°W. (Fig. 2) and dips steeply southwest and, less commonly, northeast an average of 71°. The strike joint set trends N.30°E. to N.50°E. (Fig. 2) and dips with near equal abundance to the northwest or southeast.

ECONOMIC RESOURCES

Mesoproterozoic rocks in the map area host economic deposits of iron ore (magnetite), graphite and mica that were mined mainly during the 19th century. Magnetite mines are present throughout the quadrangle but are concentrated more closely in the northwestern part. Descriptions of most of these mines are given in Bayley (1910). Graphite was mined from rusty biotite-quartz-feldspar gneiss and quartzite at numerous locations mainly in the southern part of the area. Descriptions of these mines are summarized in Volkert (1997). Mica (phlogopite) hosted by calc-silicate rock was mined at one location in the southern part of the area. Marble was quarried at one location in the southern part of the area for use as lime and also for its serpentine content.

DESCRIPTION OF MAP UNITS

NEWARK BASIN

Jd **Diabase (Lower Jurassic)** – Dark greenish-gray, fine- to medium-grained diabase composed of plagioclase (An50-70), clinopyroxene (mainly augite), and magnetite-ilmenite. Olivine is rare. Diabase is dense, hard, and is massive. It occurs in the northeast part of the map as a single dike of unknown thickness and length that intrudes Mesoproterozoic rocks.

Jb **Boonton Formation (Lower Jurassic)** (Olsen, 1980) – Reddish-brown to brownish-purple, fine-grained, commonly micaceous sandstone, siltstone, and mudstone, in fining-upward sequences mostly 5 to 13 ft. thick. Red, gray, and brownish-purple siltstone and black, blocky, partly dolomitic siltstone and shale are common in the lower part of unit. Irregular mudcracks, symmetrical ripple marks, hummocky and trough cross-laminated beds, burrows, and evaporite minerals are abundant in red siltstone and mudstone. Gray, fine-grained sandstone may have carbonized plant remains and reptile footprints in middle and upper parts of unit. Conglomerate and conglomeratic sandstone interfingers with unit along the Ramapo fault north of the map area. Maximum thickness regionally is 1,640 ft.

Jh **Hook Mountain Basalt (Lower Jurassic)** (Olsen, 1980) – Dark greenish-gray to black, generally fine-grained amygdaloidal basalt composed of plagioclase, clinopyroxene and iron-titanium oxides. Contains small spherical to tubular gas-escape vesicles above flow contacts, some filled by zeolite minerals or calcite. Unit consists of at least two, and possibly as many as three major flows. Base of lowest flow is intensely vesicular. Tops of flows are weathered and vesicular. Maximum thickness regionally is 360 ft.

Jt, Jtc **Towaco Formation (Lower Jurassic)** (Olsen, 1980) – Reddish-brown to brownish-purple, buff, olive-tan, or light olive-gray, fine- to medium-grained, micaceous sandstone, siltstone, and silty mudstone in fining-upward sequences 3 to 10 ft. thick. Unit consists of at least eight sequences of gray, greenish-gray, or brownish-gray, fine-grained sandstone, siltstone, and calcareous siltstone, and black microlaminated calcareous siltstone and mudstone with diagnostic pollen, fish, and dinosaur tracks. Irregular mudcracks and symmetrical ripple marks may be present. Sandstone is often hummocky and trough cross-laminated, and siltstone commonly planar laminated or bioturbated and indistinctly laminated to massive. Conglomerate and conglomeratic sandstone (Jtc) that contains subrounded clasts of quartzite and quartz in matrix of buff or tan, sand to silt interfinger with unit along the Ramapo fault. Several ft. of unit have been thermally metamorphosed along contact with Hook Mountain Basalt. Maximum thickness regionally is 1,250 ft.

JUTLAND KLIPPE SEQUENCE

Oh **Hensfoot Formation (Upper to Lower Ordovician)** – Interbedded red, tan, gray, and green, thin bedded shale and less abundant siltstone, fine-grained sandstone, pinkish-gray quartzite, and quartz pebble conglomerate. Locally contains interbedded dark-gray, fine-grained to aphanitic, thin- to medium-bedded limestone; limestone can be crossbedded, contain floating quartz sand grains and edgewise conglomerate. Unit correlates to the Hensfoot Formation in the High Bridge quadrangle (Monteverde and others, 2015) and Jutland klippe upper unit B (Perissoratis and others, 1979). The upper part of the shale contains graptolite faunas of the *Nemagraptus gracilis* to *Climacograptus bicornis* zones of Ross and others, 1982 (S. Finney written commun. to R. Dalton, 1991 [on file at New Jersey Geological and Water Survey]) now considered the lower part of the Upper Ordovician. Lower dolomite beds contain conodonts of North Atlantic Province *Oepikodus eve* to *Baltoniodus navis* (Harris and others, 1995) high E to 2 and are late Early Ordovician to early Middle Ordovician. Thickness varies and may be as much as 1,500 ft.

KITTATINNY VALLEY SEQUENCE

€a **Allentown Dolomite (Upper Cambrian)** - Upper sequence is light-gray- to medium-gray-weathering, medium-light- to medium-dark-gray, fine- to medium-grained, locally coarse-grained, medium- to very thick-bedded dolomite; local shaly dolomite near the bottom. Floating quartz sand and two series of medium-light- to very light-gray, medium-grained, thin-bedded quartzite and discontinuous dark-gray chert lenses occur directly below upper contact. Lower sequence is medium- to very-light-gray-weathering, light- to medium dark-gray, fine- to medium-grained, thin- to medium-bedded dolomite and shaly dolomite. Weathered exposures characterized by alternating light- and dark-gray beds. Ripple marks, oolites, algal stromatolites, cross-beds, edgewise conglomerate, mud cracks, and paleosol zones occur throughout but are more abundant in lower sequence. Lower contact is gradational into Leithsville Formation. Unit contains a trilobite fauna of Dresbachian (early Late Cambrian) age (Weller, 1903; Howell, 1945). Approximately 1,800 ft. thick regionally.

€l **Leithsville Formation (Middle to Lower Cambrian)** - Upper sequence, rarely exposed, is mottled, medium-light- to medium-dark-gray-weathering, medium- to medium-dark-gray, fine- to medium-grained, medium- to thick-bedded, locally pitted and friable dolomite. Middle sequence is grayish-orange or light- to dark-gray, grayish-red, light-greenish-gray- or dark-greenish-gray-weathering, aphanitic to fine-grained, thin- to medium-bedded dolomite, argillaceous dolomite, dolomitic shale, quartz sandstone, siltstone, and shale. Lower sequence is medium-light- to medium-gray-weathering, medium-gray, fine- to medium-grained, thin- to medium-bedded dolomite. Quartz-sand lenses occur near lower gradational contact with Hardyston Quartzite. Archaeocyathids of Early Cambrian age are present in formation at Franklin, New Jersey, suggesting an intraformational disconformity between Middle and Early Cambrian time (Palmer and Rozanov, 1967). Unit also contains *Hyolithellus micans* (Offield, 1967; Markewicz, 1968). Approximately 800 ft. thick regionally.

€h **Hardyston Quartzite (Lower Cambrian)** - Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Unit contains *Scolithus linearis* (?) and fragments of the trilobite *Olenellus thompsoni* of Early Cambrian age (Nason, 1891; Weller, 1903). Thickness is less than 20 ft. regionally.

NEW JERSEY HIGHLANDS

Zd **Diabase dikes (Neoproterozoic)** – Light gray- or brownish-gray-weathering, dark-greenish-gray, aphanitic to fine-grained dikes. Composed principally of plagioclase (labradorite to andesine), augite, and ilmenite and (or) magnetite. Local pyrite blebs are common. Contacts are chilled and sharp against enclosing Mesoproterozoic country rock. Dikes are as much as 10 ft. thick.

Vernon Supersuite (Volkert and Drake, 1998)

Byram Intrusive Suite (Drake, 1984)

Ybh **Hornblende granite (Mesoproterozoic) -** Pinkish-gray or buff weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, foliated granite composed of microcline microperthite, quartz, oligoclase, and hornblende. Some variants are quartz monzonite or quartz syenite. Includes small bodies of pegmatite too small to be shown on map.

Yba **Microperthite alaskite (Mesoproterozoic)** – Pinkish-gray- or buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, moderately foliated alaskite composed of microcline microperthite, quartz, and oligoclase. Locally contains small bodies of pegmatite too small to be shown on map.

Ybs **Hornblende monzonite (Mesoproterozoic)** – Pinkish-gray- or buff-weathering, pinkish-gray or greenish-gray, medium- to coarse-grained, foliated monzonite and less abundant quartz monzonite. Composed of microcline microperthite, oligoclase, hornblende, magnetite and local quartz.

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

Ypg **Pyroxene granite (Mesoproterozoic)** – Gray-, buff- or white-weathering, greenish-gray, medium- to coarse-grained, massive, moderately foliated granite containing mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Common accessory minerals include titanite, apatite, magnetite, and trace amounts of pyrite. Locally includes small bodies of pyroxene alaskite.

Ypa **Pyroxene alaskite (Mesoproterozoic)** – Buff- or white-weathering, greenish-buff to light pinkish-gray, medium- to coarse-grained, massive, moderately foliated granite composed of mesoperthite to microantiperthite, quartz, oligoclase, and sparse amounts of clinopyroxene. Common accessory minerals include titanite, magnetite, apatite, and trace amounts of zircon.

Yps **Pyroxene monzonite (Mesoproterozoic)** – Gray to buff- or tan-weathering, greenish-gray, medium- to coarse-grained, massive, moderately foliated monzonite or syenite and less abundant quartz monzonite or quartz syenite. Composed of mesoperthite, microantiperthite to microcline microperthite, oligoclase, clinopyroxene, titanite, magnetite, and sparse apatite and local quartz. Locally contains sparse amounts of hornblende.

Back-Arc Basin Supracrustal Rocks

Yb/Ybr **Biotite-quartz-feldspar gneiss (Mesoproterozoic)** – Pinkish-gray- or gray-weathering (Yb), locally rusty (Ybr), gray, tan, or greenish-gray, medium-grained, moderately layered and foliated gneiss composed of microcline microperthite, oligoclase, quartz, biotite, garnet, and sillimanite. Graphite and pyrrhotite are present in rusty variants which host graphite deposits. Commonly layered with quartzite containing locally abundant graphite.

Yq **Quartzite (Mesoproterozoic)** – Light gray-weathering, light-gray, vitreous, medium-grained, layered and foliated rock composed predominantly of quartz and local feldspar, biotite and graphite. Commonly interlayered with rusty biotite-quartz-feldspar gneiss and less commonly with buff to light green diopside-rich rock too thin to be shown separately, but mapped as diopsidite elsewhere regionally.

Yk **Potassic feldspar gneiss (Mesoproterozoic)** – Light-gray- or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, medium-grained, moderately foliated gneiss composed of quartz, microcline microperthite, oligoclase, and biotite. Locally contains garnet, sillimanite and magnetite.

Ymp **Clinopyroxene-quartz-feldspar gneiss (Mesoproterozoic)** – Pinkish-gray or pinkish-buff-weathering, white or pale-pinkish-white, medium-grained, massive, moderately foliated gneiss composed of microcline, quartz, oligoclase, clinopyroxene, and trace amounts of titanite and opaque minerals.

Yp **Pyroxene gneiss (Mesoproterozoic)** – White-weathering, greenish-gray, medium-grained, well-layered gneiss composed of oligoclase and clinopyroxene. Quartz content is highly varied. Contains local titanite, epidote, scapolite and calcite. Commonly interlayered with pyroxene amphibolite and biotite-quartz-feldspar gneiss.

Ymr **Marble (Mesoproterozoic)** – White-weathering, white, light gray, or pale pink, medium-crystalline, calcitic to dolomitic marble containing calcite, antigorite, phlogopite, and trace amounts of graphite and pyrrhotite. Chrysotile is locally developed along shear surfaces. Spatially associated with rusty biotite-quartz-feldspar gneiss.

Magmatic Arc Rocks

Losee Metamorphic Suite (Drake, 1984; Volkert and Drake, 1999)

Ylo **Quartz-oligoclase gneiss (Mesoproterozoic)** – White-weathering, light-greenish-gray, medium- to coarse-grained, layered to indistinctly foliated gneiss composed of oligoclase or andesine, quartz, and local hornblende, biotite and clinopyroxene. Locally contains thin layers of amphibolite.

Yla **Albite-oligoclase granite (Mesoproterozoic)** – Pale pink- or white-weathering, light-greenish-gray or light-pinkish-green, medium- to coarse-grained alaskite and local granite composed of microantiperthite, pale pink or white albite or oligoclase, quartz, local hornblende and (or) augite, magnetite, and trace amounts of rutile. Appears to be spatially related to quartz-oligoclase gneiss from which it may have formed through sodium metasomatism.

Ylb **Biotite-quartz-oligoclase gneiss (Mesoproterozoic)** – White- or light-gray-weathering, medium-gray or greenish-gray, medium- to coarse-grained, layered and foliated gneiss composed of oligoclase or andesine, quartz, biotite, and local garnet. Some outcrops contain hornblende. Locally interlayered with amphibolite.

Ylh **Hornblende-quartz-oligoclase gneiss (Mesoproterozoic)** – White- or light-gray- weathering, medium-gray or greenish-gray, medium- to coarse-grained, moderately foliated gneiss composed of oligoclase or andesine, quartz, hornblende, and local biotite. Commonly contains thin layers of amphibolite.

Yh **Hypersthene-quartz-plagioclase gneiss (Mesoproterozoic)** – Gray- or tan-weathering, greenish-gray or greenish-brown, medium-grained, moderately layered and foliated gneiss composed of andesine or oligoclase, quartz, clinopyroxene, hornblende, and hypersthene. Contains thin, conformable layers of amphibolite and mafic-rich quartz-plagioclase gneiss.

Yd **Diorite gneiss (Mesoproterozoic)** – Gray- or tan-weathering, greenish-gray or greenish-brown, medium- to coarse-grained, massive, moderately foliated rock containing andesine or oligoclase, clinopyroxene, hornblende, hypersthene, and magnetite. Contains thin mafic layers or schlieren having the composition of amphibolite.

Other Rocks

Ya **Amphibolite (Mesoproterozoic)** – Grayish-black, medium-grained, foliated gneiss composed of hornblende and andesine. Some amphibolite contains biotite and/or clinopyroxene. Amphibolite associated with the Losee Suite is metavolcanic in origin. Amphibolite associated with supracrustal rocks may be metavolcanic or metasedimentary. All types are undifferentiated on the map.

Ybp **Biotite-plagioclase gneiss (Mesoproterozoic)** – White- or light-gray-weathering, greenish-gray, medium-grained, foliated and layered gneiss composed of biotite, oligoclase, and local graphite and sulfide minerals.

Ymag **Microantiperthite granite (Mesoproterozoic)** – Tan- or buff-weathering, light-greenish-gray, medium- to coarse-grained, massive, indistinctly foliated granite composed of microantiperthite to microperthite, quartz that is locally brown rust-stained, oligoclase, and hornblende. Locally contains biotite, altered clinopyroxene, and magnetite.

Yma **Microantiperthite alaskite (Mesoproterozoic)** – Tan- or buff-weathering, light-greenish-gray, medium- to coarse-grained, massive, indistinctly foliated alaskite composed of microantiperthite to microperthite, brown rust-stained quartz, and oligoclase.

Yu **Mesoproterozoic rocks, undifferentiated** – Shown in cross section only.

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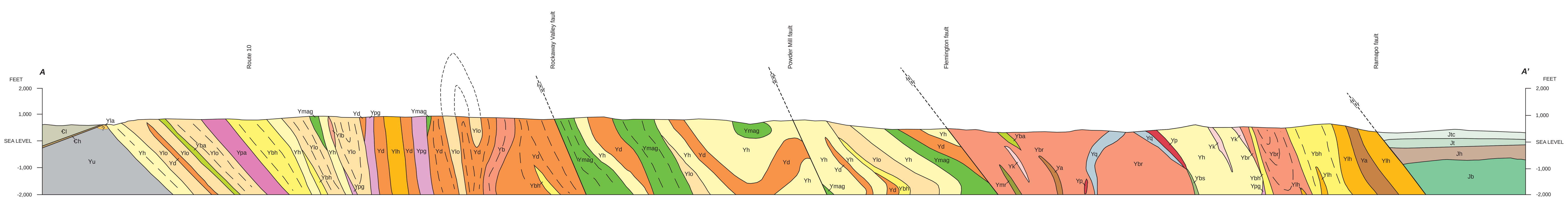
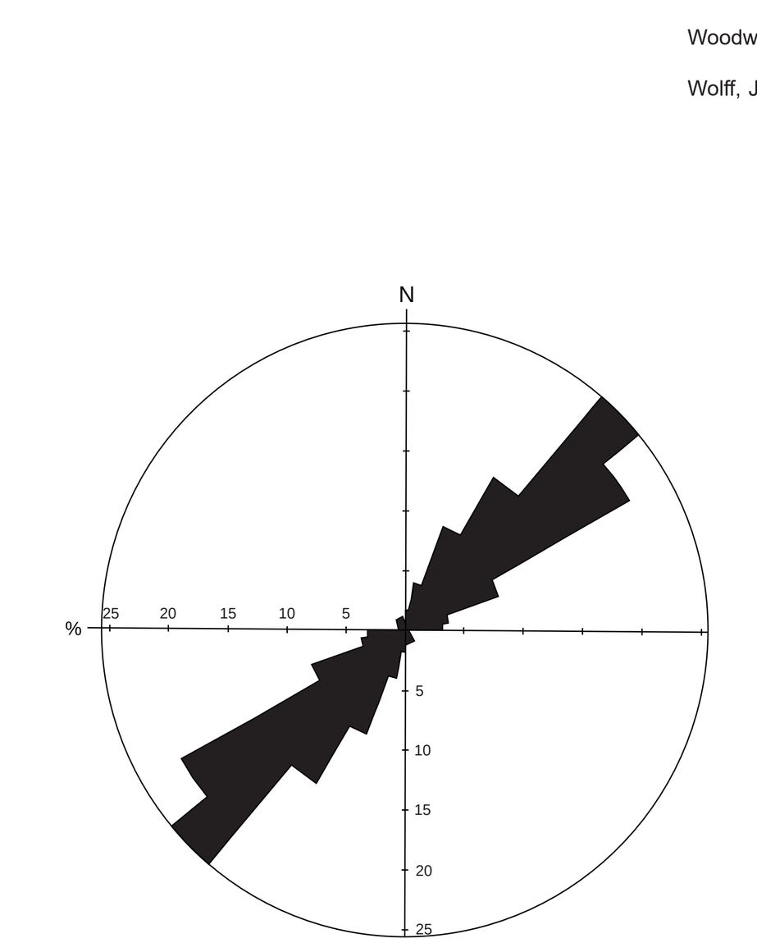
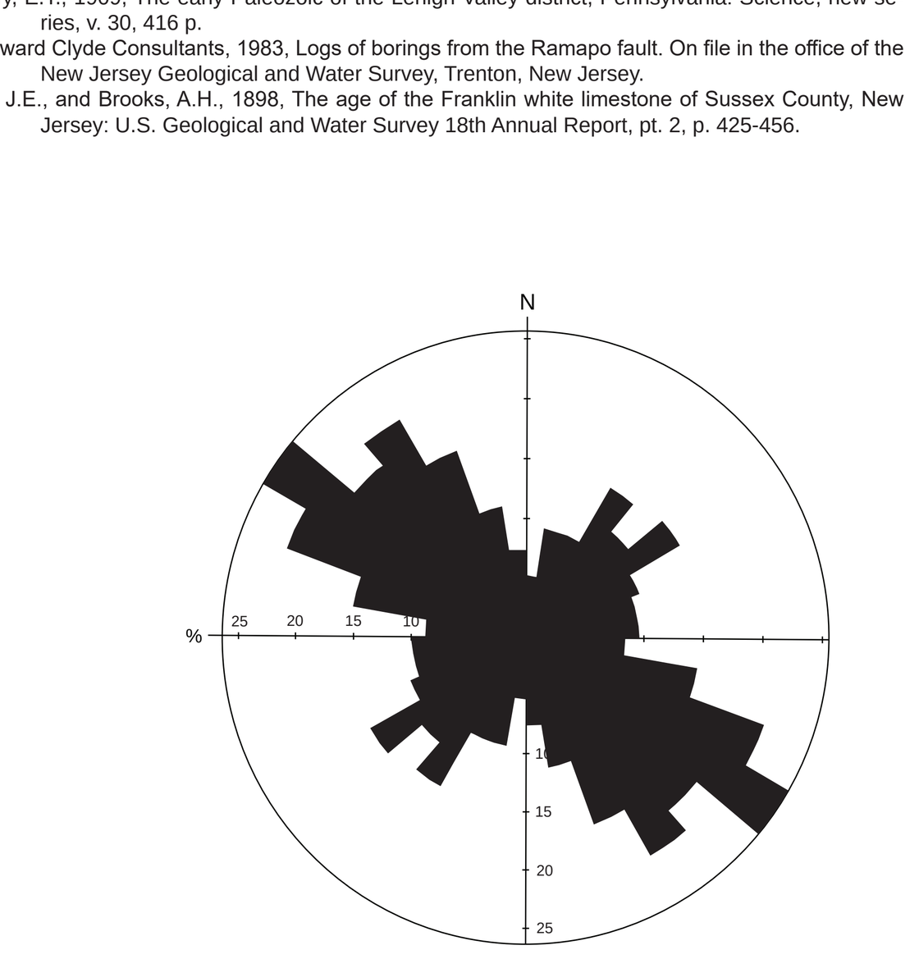




Sector angle = 10°
n = 344

Figure 1. Rose diagram of the strike of crystallization foliations in Mesoproterozoic rocks.



Sector angle = 10°
n = 655

Figure 2. Rose diagram of the strike of joints in Mesoproterozoic rocks.

Bedrock Geologic Map of the Mendham Quadrangle

Morris and Somerset Counties, New Jersey

New Jersey Geological and Water Survey

Open File Map OFM 126

2019

Pamphlet with table 1 accompanies map

Table 1. Selected boring records.

Well Identifier	Depth (feet)	Description
B-1	0-40	Overburden
	40-52	Brittly deformed, medium- to coarse-grained, pale pinkish-white to pale buff microperthite alaskite with trace accessory clinopyroxene
	52-67.5	White to light-gray weathering, medium-grained, greenish-gray, layered and foliated calc-silicate gneiss composed of biotite, clinopyroxene, untwinned feldspar, scapolite, trace sulfide, and graphite. Quartz poor overall. Effervesces slightly in hydrochloric acid (HCl) and probably contains minor carbonate.
	67.5-74.5	Medium- to coarse-grained, pale pinkish-white to pale buff microperthite alaskite
	74.5-80	Dominantly brittly deformed calc-silicate gneiss as above. Intruded by thin apophyses of microperthite alaskite that have sharp contact with gneiss.
	80-84	Medium- to coarse-grained, pale pinkish-white to pale buff microperthite alaskite
	84-96	Alternating light and dark calc-silicate gneiss. Dark layers contain abundant biotite and clinopyroxene. Foliation dips at a moderate angle.
	96-120	Highly brittly deformed sequence of the same gneiss. Dominant brittle fabric is subvertical. Brittle fractures are slickensided and coated by chlorite. Foliation dips steeply to subvertically.
	120-130	Still quite fractured and brittly deformed calc-silicate gneiss with sparse graphite. Some fractures contain fine crystalline, white calcite.
B-2	0-39	Overburden
	39-53	Light gray, medium-crystalline calcitic marble with accessory serpentine, clinopyroxene, phlogopite, sparse graphite, titanite, and trace sulfide.
	53-54	Ductile deformation zone dipping ~60^{o}
	54-70	More silicated marble. Moderately brittly deformed to depth of ~70'.
	70-78	Silicated marble containing more clinopyroxene and titanite than above. Somewhat less deformed.
B-3	0-60	Overburden
	60-72.5	Highly brittly deformed and decomposed, medium-grained, pale pinkish-white clinopyroxene-quartz-feldspar gneiss with potassium feldspar>plagioclase feldspar.
	72.5-77	More of the same but with mainly quartz and feldspar and sparse altered clinopyroxene. Well developed brittle fault zone at depth of ~75'.
	77-82.5	Content of clinopyroxene is beginning to increase. Rock is still brittly deformed and in variable state of decomposition.
	82.5-92.5	Same gneiss but a little biotite here. Still brittly deformed but a little less decomposed.

Well Identifier	Depth (feet)	Description
B-3	92.5-119.5	More clinopyroxene-quartz-feldspar gneiss. Becoming less brittly deformed. Foliation dips ~ 70^{o} at 111'.
MUA-1	0-60	Samples missing.
	60-105	Light gray to buff, medium-grained, foliated, biotite-rich clinopyroxene gneiss with locally abundant biotite. Quartz poor overall. Rock is quite porous and leached with voids probably filled previously by carbonate.
	105-125	Mainly more clinopyroxene gneiss. Beginning to see some white, medium-crystalline calcitic marble with serpentine and trace sulfide.
	125-135	More clinopyroxene gneiss but no marble in this interval.
	135-143	Mainly clinopyroxene gneiss but a little interlayered marble at depth of ~143'
MUA-2	0-55	Samples missing
	55-90	Medium-grained, rusty weathering, foliated biotite-plagioclase feldspar gneiss and minor amphibolite.
	90-100	Brittly deformed amphibolite.
	100-140	Greenish-gray, medium-grained, massive, foliated diorite composed of plagioclase feldspar, hornblende, clinopyroxene, and trace biotite. Brittly deformed at depth of ~110'.
	140-160	Medium-grained, greenish-gray biotite-plagioclase feldspar gneiss. Somewhat brittly deformed through this interval.
	160-180	Samples missing.
	180-200	Medium-grained, foliated, quartz poor clinopyroxene gneiss composed of plagioclase feldspar, local biotite and trace titanite. Not especially deformed here.
	200-310	Greenish-gray, medium-grained, massive, foliated diorite composed of plagioclase feldspar, clinopyroxene and trace biotite. Locally abundant sulfide at depth of ~250'. Brittly deformed from 200-240'.
	310-330	Medium-grained, foliated amphibolite.
	330-340	Medium-grained, greenish-gray biotite-plagioclase feldspar gneiss.
	340-385	Medium-grained, foliated, quartz poor clinopyroxene gneiss with trace titanite. Abundant sulfide at depth of 340'.
	385-470	Medium-grained, light greenish-gray, indistinctly foliated scapolite gneiss w/sparse biotite, graphite, and sulfide. Abundant sulfide at depth of ~390' and abundant graphite at depth of ~450'.
	470-490	Mainly dark gray, fine-grained to aphanitic rock with abundant sulfide. Looks more like a cataclasite than a dike.
	490-520	Light gray, fine-crystalline, calcitic marble with serpentine. Brittly deformed at 490' but much less so throughout rest of interval.
	520-530	Samples missing.
	530-540	Light gray, fine-crystalline, calcitic marble with serpentine.
	540-?	Mainly medium-grained, foliated amphibolite.
MUA-3	0-168	Mixed cuttings of mainly medium-grained, foliated, quartz poor clinopyroxene gneiss with trace titanite and sulfide and less abundant amphibolite with locally abundant biotite, and white, fine-crystalline, calcitic marble. All lithologies relatively undeformed.
MUA-4	0-60	Overburden.
	60-80	Samples missing.
	80-90	Tan to chalky white, weathered, medium-grained quartz-feldspar gneiss w/ trace sulfide.
	90-190	Medium-grained, foliated, quartz poor clinopyroxene gneiss composed of plagioclase feldspar, biotite, trace titanite and sulfide. Abundant biotite at depth of ~140' and 190'.
	190-220	More clinopyroxene gneiss with variable amounts of biotite and trace graphite.
MUA-5	0-70	Overburden

Well Identifier	Depth (feet)	Description
MUA-5	70-180	Medium- to coarse-grained, pale pinkish-white microperthite alaskite or partial melt of potassic feldspar gneiss.
	180-200	More of the same but rock is generally quartz poor and more of a monzonite
	200-250	Dramatic increase in quartz and more of an alaskite here.
	250-260	Quartz poor and more of a monzonite gneiss.
	260-450	Back to being quartz rich and more of an alaskite. Trace garnet at depth of ~320'. Minor biotite from 330-370'. Rock is brittly deformed from 373-375' and contains trace fluorite. Much less deformed from 375-450'.
	450-480	Much less quartz in this interval and more of a monzonite gneiss.
MUA-6	0-50	Overburden.
	50-80	Rusty weathering, tan, medium-grained, foliated biotite-quartz-feldspar gneiss.
	80-120	Light gray, medium-grained biotite-plagioclase gneiss.
	120-130	Buff, medium-grained quartz-feldspar gneiss.
	130-140	Light gray, medium-grained biotite-plagioclase gneiss with trace graphite.
	140-180	White, medium-crystalline, calcitic marble with serpentine and trace graphite.
	180-190	Light greenish-gray, medium-grained clinopyroxene-scapolite gneiss.
	190-210	White, medium-crystalline, calcitic marble with serpentine and phlogopite.
	210-280	Light greenish-gray, medium-grained clinopyroxene-scapolite gneiss with trace sulfide.
	280-290	Highly brittly deformed sequence of dark gray to black, fine-grained amphibolite(?) and white calc-silicate gneiss.
	290-310	Somewhat less deformed calc-silicate gneiss.
	310-320	Graphitic calc-silicate gneiss and white, calcitic marble with serpentine, graphite and trace titanite. Still somewhat brittly deformed.
	320-330	Brittly deformed calc-silicate gneiss.
	330-350	Brittly deformed, white, calcitic marble with serpentine and phlogopite. NOTE: Entire boring from depth of 80-345' encountered strongly developed brittle fault zone.
	350-410	White calcitic marble with serpentine, and trace amounts of graphite and sulfide. Relatively undeformed throughout this interval.
	410-520	Samples missing.
	520-?	White calcitic marble with serpentine, and trace amounts of graphite and sulfide. Still relatively undeformed.
MUA-7	0-20	Samples missing.
	20-30	Weathered, medium-grained, greenish-gray biotite-plagioclase gneiss with trace graphite.
	30-40	Samples missing.
	40-50	Weathered, medium-grained, greenish-gray biotite-plagioclase gneiss with abundant graphite.
	50-90	Same with abundant sulfide at depth of ~50'.
	90-100	Samples missing.
	100-110	More biotite-plagioclase gneiss but with much less biotite at depth of ~100'.
	110-120	Samples missing.
	120-180	Weathered, medium-grained, greenish-gray biotite-plagioclase gneiss with trace sulfide. Fairly brittly deformed from 120-140'. Abundant biotite and sulfide in samples at depth of ~170'.
	180-200	Medium-grained, foliated, quartz poor clinopyroxene gneiss composed of plagioclase, sparse biotite, and trace amounts of titanite, graphite and sulfide.
MUA-8	0-70	Samples missing.
	70-80	Light gray, medium-grained scapolite gneiss.
	80-90	Tan, weathered quartz-feldspar gneiss without accessories
	90-100	Light gray, medium-grained scapolite gneiss.

Well Identifier	Depth (feet)	Description
MUA-8	100-110	Mixture of tan, rusty weathering, medium-grained biotite-quartz-feldspar gneiss and light greenish-gray, medium-grained, quartz poor clinopyroxene gneiss with plagioclase and trace titanite.
	110-140	More clinopyroxene gneiss, rusty and sulfidic at depth of ~110'.
	140-170	White, medium-crystalline, calcitic marble with serpentine and trace sulfide.
	170-210	Light greenish-gray, medium-grained, quartz poor clinopyroxene gneiss with trace titanite and sulfide.
	210-220	Samples missing.
	220-280	White, medium-crystalline, calcitic marble with trace titanite and sulfide.
	280-290	Medium-grained, quartz poor clinopyroxene gneiss.
	290-300	Medium-grained, foliated amphibolite with biotite and clinopyroxene.
	300-310	Medium-grained, quartz poor clinopyroxene gneiss.
	310-400	Mainly white, medium-crystalline, calcitic marble. Some interlayered quartz poor clinopyroxene gneiss at depths of ~320' and 400'.
MUA-9	0-80	Samples missing.
	80-100	Weathered, white, fine-crystalline, calcitic marble with trace graphite. Somewhat brittly deformed at depth of ~90'.
	100-110	Mainly light greenish-gray, medium-grained calc-silicate gneiss with graphite.
	110-140	Dark greenish-black, fault gouge and breccia. Highly graphitic at depth of ~120' and carbonate bearing at depth of ~130'.
	140-160	Light greenish-gray, medium-grained, quartz poor clinopyroxene gneiss.
	160-200	Dark greenish-black, fault gouge and breccia similar to interval at 110-140'. Quite a bit of graphite throughout this interval. Carbonate bearing at depth of ~180'.
MUA-10	0-90	Samples missing.
	90-120	Saprolitic, medium-grained, greenish-gray biotite-plagioclase gneiss.
	120-130	Same but quite a bit of quartz and more of a biotote-quartz-plagioclase gneiss.
	130-210	More saprolitic, medium-grained, greenish-gray biotite-plagioclase gneiss.
	210-220	Increase again in quartz to biotite-quartz-plagioclase gneiss.
	220-240	Pale pinkish-gray, light gray, medium-grained biotite-quartz-feldspar gneiss.
	240-260	White weathering, medium-grained clinopyroxene gneiss with quartz plagioclase, and trace amounts of biotite and titanite.
	260-280	Medium-grained, greenish-gray biotite-plagioclase gneiss with trace sulfide.
	280-290	Samples missing.
	290-300	Pale pinkish-gray, medium-grained biotite-quartz-feldspar gneiss with abundant garnet.
	300-330	Samples missing.
MUA-11	0-40	Overburden
	40-80	Medium-grained, light gray, foliated biotite-quartz-feldspar gneiss with accessory sillimanite and graphite. Fairly quartz rich at depth of ~50'.
	80-100	More of the same but beginning to develop brittle deformed fabric, especially at ~90'
	100-160	More biotite-quartz-feldspar gneiss. Sulfides at ~110', sparse garnet at ~120' and sillimanite at ~130'.
	160-170	Light gray, decomposed fine to medium-crystalline dolomitic marble with trace amounts of phlogopite and graphite. Probable fault contact between gneiss and marble at depth of ~160'.
	170-193	Decomposed and friable, medium-grained biotite-quartz-feldspar gneiss with sparse sillimanite and garnet. Has a moderate brittle fabric throughout this interval.
MUA-12	0-40	Samples missing (overburden)?
	40-50	Medium-grained, light gray to greenish-gray, locally rusty biotite-quartz-feldspar gneiss with accessory sillimanite, garnet and trace amounts of graphite and sulfide.
	50-80	More of the same but mainly composed of quartz and feldspar.
	80-110	Same but much more biotite, graphite and sulfide here.

Well Identifier	Depth (feet)	Description
MUA-12	110-130	Same but abundant garnet and decreased biotite and graphite.
	130-140	Same but much less mafic and composed mainly of quartz and feldspar.
	140-170	Same but increase in amount of biotite and sulfide.
	170-?	Same but beginning to develop strong brittle deformation fabric. Amount of sulfide is also increased here.
MUA-13	0-50	Overburden.
	50-80	Weathered, medium-grained, foliated, grayish-black clinopyroxene amphibolite with graphite, sulfide and trace amounts of titanite. Abundantly graphitic at depth of ~60'.
	80-90	More amphibolite but not much clinopyroxene here, mainly hornblende and biotite.
	90-100	Greenish-gray, medium-grained, quartz poor clinopyroxene gneiss composed of plagioclase, titanite, sulfide and sparse amounts of calcite.
	100-110	Dominantly light gray, fine-crystalline calcitic marble. Layered with minor calc-silicate gneiss composed of clinopyroxene, plagioclase, titanite, quartz, scapolite, sulfide, and trace amounts of wollastonite.
	110-120	Mainly more of the same calc-silicate gneiss with abundant graphite
	120-220	White, medium-crystalline, calcitic marble with clinopyroxene, serpentine, graphite and trace amounts of titanite. Becomes finer crystalline at depths of ~170' and 190'.
	220-?	Heterogeneous sequence of mainly clinopyroxene amphibolite similar to interval at 50-60' and minor interlayered calcitic marble and quartz poor clinopyroxene gneiss.
MUA-14	0-30	Samples missing.
	30-40	Weathered, medium-grained quartz-feldspar gneiss with sparse graphite. Contact with quartz poor scapolite gneiss toward bottom of interval.
	40-60	Greenish-gray, quartz poor scapolite gneiss. Contains quartz at depth of ~50'.
	60-70	Dark gray, aphanitic rock (probably cataclasite) and tan, fine-grained, brittly deformed rock in fault zone.
	70-110	Greenish-gray, medium-grained quartz poor scapolite gneiss. Not especially deformed throughout entire interval.
	110-120	Brittly deformed and altered, pale pinkish-white microperthite alaskite.
	120-130	Mainly dark gray, aphanitic brittle deformed rock (probably cataclasite).
	130-240	Decomposed and brittly deformed, pinkish-buff, medium-grained alaskite with sparse biotite and sulfide. Possible highly altered hornblende at depth of ~140'.
	150-180	More microperthite alaskite. Not especially deformed throughout this interval. Quite a bit of magnetite at depth of ~170'. Abundant amphibolite at 160-170'.
	180-190	More alaskite. Becoming brittly deformed with mafic altered to chlorite.
	190-240	More alaskite. Somewhat less brittly deformed.
MUA-15	0-20	Overburden.
	20-50	Weathered, medium-grained, buff quartz-feldspar gneiss with abundant graphite.
	50-60	Pale pinkish-white, medium-grained, massive microperthite alaskite.
	60-80	Interlayered sequence of buff, graphitic quartz-feldspar gneiss and medium-grained, greenish-gray, quartz poor clinopyroxene gneiss.
	80-90	Mainly quartz poor clinopyroxene gneiss with accessory titanite.
	90-120	Mainly medium-grained layered calc-silicate gneiss composed of scapolite, calcite and local wollastonite. Some minor buff quartz-feldspar gneiss at depth of ~95'. No wollastonite at 100'. Abundantly graphitic at ~110-120'.