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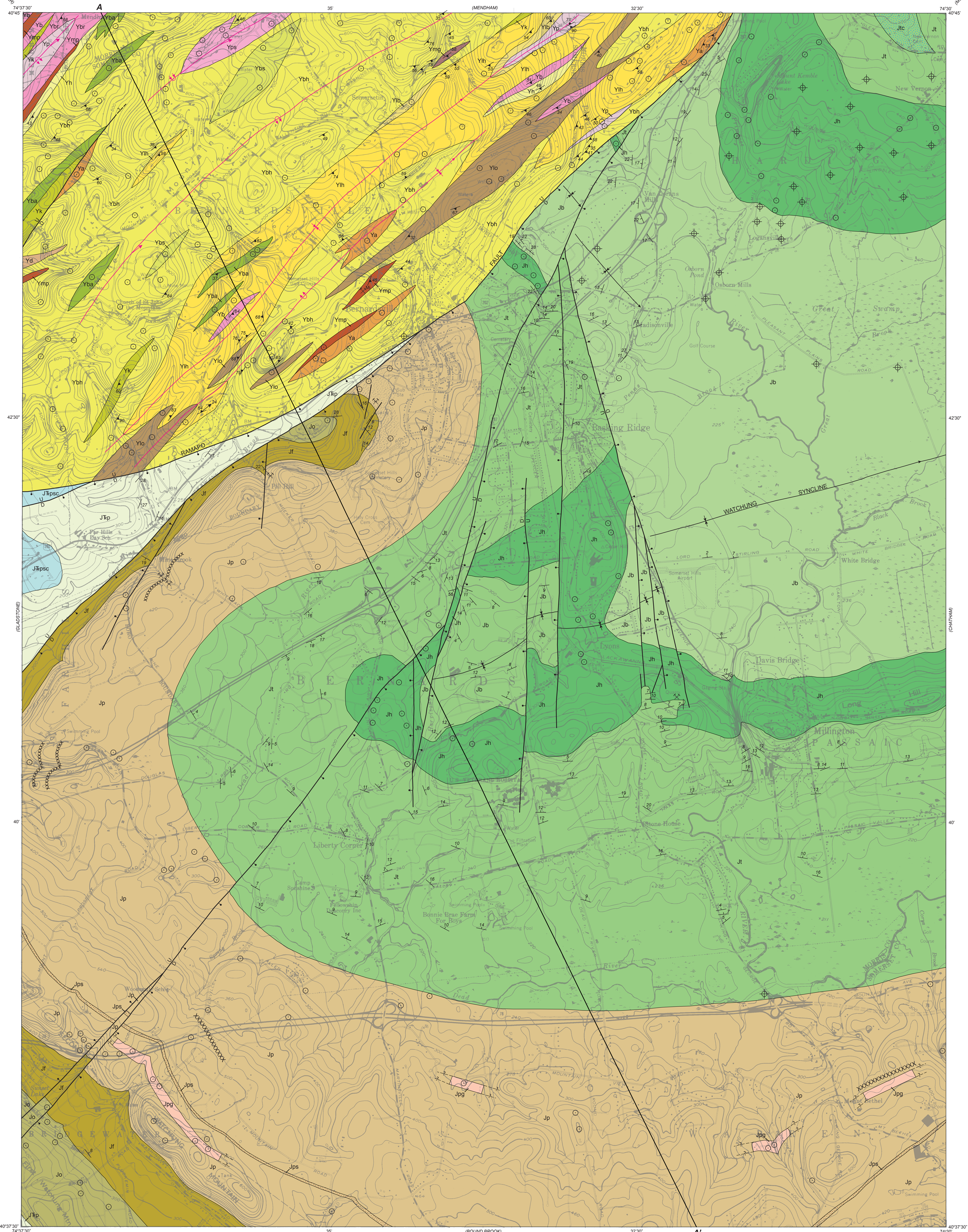

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Bedrock geology mapped by R.A. Volkert and D.H Monteverde in 1984, 1996 and 2011.
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Bedrock Geologic Map of the Bernardsville Quadrangle, Morris and Somerset Counties, New Jersey

by
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2012

INTRODUCTION

The Bernardsville quadrangle is in north-central New Jersey, in Morris and Somerset Counties, and straddles the boundary between the New Jersey Highlands and Piedmont Physiographic Provinces. Mesoproterozoic rocks of the Highlands underlie the northwest part of the map, and Mesozoic igneous and sedimentary rocks of the Piedmont underlie the remainder. The Ramapo fault is a structural and physiographic boundary between the two provinces.

The quadrangle is in the central Passaic River drainage basin, and this river drains the eastern part of the quadrangle from north to south. The northeast part of the map, east of Basking Ridge Township, contains the Great Swamp, a large tract of poorly drained natural wetland underlain by sediments of Pleistocene and recent age (Stanford, 2008), deposited on bedrock of the Boonton Formation.

STRATIGRAPHY

Mesozoic Rocks

The youngest bedrock in the quadrangle is Mesozoic and was deposited in the Newark basin, which contains approximately 24,600 ft. of interbedded Upper Triassic to Lower Jurassic sedimentary and igneous rocks. Mesozoic formations become progressively younger from west to east, although the stratigraphy is complicated by faults and broad, regional folds. Sedimentary units, from oldest to youngest, are the Passaic, Feltville, Towaco, and Boonton Formations. Most of these are well exposed, except for the Boonton Formation, which is now largely covered by unconsolidated sediments. Conglomeratic facies of the Towaco Formation locally crop out in the eastern part of the map. Igneous units are the Orange Mountain Basalt, Preakness Basalt, and Hook Mountain Basalt that support the moderate relief in the Piedmont part of the map. The Hook Mountain Basalt and Preakness Basalt contain coarse-grained layers and local basaltic pegmatite at several stratigraphic intervals that are mapped as gabbroid. Gabbroid and pegmatite layers within the Preakness Basalt are interpreted to have formed through fractionation from fine-grained basalt (Puffer and Volkert, 2001). Gabbroid layers within the Hook Mountain Basalt, although not exposed in the map area, formed through a similar process.

Mesoproterozoic Rocks

The oldest rocks in the quadrangle are Mesoproterozoic and include various granites and gneisses metamorphosed to granulite facies about 1050 Ma during the Ottawan phase of the Grenville orogeny (Volkert, 2004). Temperature estimates for this high-grade metamorphism are 769°C from calcite-graphite thermometry (Peck et al., 2006).

The youngest Mesoproterozoic rocks are small, irregular bodies of granite pegmatite that are undeformed and have discordantly intruded most other Mesoproterozoic rocks. None of the pegmatites are large enough to be shown on the map, but they are most common in areas underlain by hornblende granite. Pegmatites regionally have yielded U-Pb zircon ages of 1004 to 987 Ma (Volkert et al., 2005).

Granitic rocks are widely distributed in the map area. They include hornblende granite, alaskite and monzonite of the Byram Intrusive Suite, and monzonite of the comagmatic Lake Hopatcong Intrusive Suite, that together constitute the Vernon Supersuite (Volkert and Drake, 1998). Rocks of the Vernon Supersuite yield sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages of 1188 to 1182 Ma (Volkert et al., 2010).

Among the oldest Mesoproterozoic rocks are those of the Losee Suite, a sequence of metamorphosed volcanic and plutonic rocks of calc-alkaline composition formed in a continental-margin magmatic arc (Volkert, 2004). The Losee Suite includes quartz-oligoclase gneiss, biotite-quartz-oligoclase gneiss, hornblende-quartz-oligoclase gneiss, hypersthene-quartz-plagioclase gneiss, and diorite gneiss. These rocks are spatially associated with a sequence of supracrustal rocks formed in a back-arc basin inboard of the Losee magmatic arc (Volkert, 2004). They include potassic feldspar gneiss, monazite gneiss, biotite-quartz-feldspar gneiss, clinopyroxene-quartz-feldspar gneiss, pyroxene gneiss, and amphibolite. Losee Suite and supracrustal rocks yield similar SHRIMP U-Pb zircon ages of 1299 to 1248 Ma (Volkert et al., 2010).

STRUCTURE

Mesozoic Bedding

Bedding in the Mesozoic rocks is varied and affected by numerous faults, as well as by the location of the quadrangle at the southwest end of the Watchung Syncline. Beds dip north in the southern part of the map and generally south in the northern part, defining the gently-dipping limbs of the syncline. The strike of beds displays two populations that are about N.70°E. and N.50°W. (fig. 1). Beds range in dip from 2° to 56° and average 12°.

Proterozoic Foliation

Crystallization foliation (the parallel alignment of mineral grains) in Mesoproterozoic rocks is an inherited feature from compressional stresses that deformed the rocks during high-grade metamorphism. Foliation is fairly uniform and strikes northeast at an average of N.47°E. (fig. 2). Foliations dip mainly southeast, and less commonly, northwest from 15° to 90° and average 56°.

Folds

Mesozoic rocks are deformed into the Watchung Syncline, a broad, upright, northeast-plunging fold that dominates the structure in the Piedmont part of the map. The Boonton Formation crops out in the core of the fold and Preakness Basalt defines the limbs. Rocks in the northeast part of the map are part of the upright, southeast-plunging New Vernon anticline. This fold is cored by Towaco Formation, and Hook Mountain Basalt forms the limbs. Only the southern limb of the fold is present in the quadrangle. A complimentary upright, southeast-plunging syncline cored by Boonton Formation, and highly dissected by faults, is mapped south of the anticline.

Folds that deform Mesoproterozoic rocks formed during the Grenville orogeny. The folds deform earlier-formed planar metamorphic fabrics, so they postdate the development of crystallization foliation. Characteristic fold styles include antiforms and synforms that are northwest-overturned, southeast-overturned, or upright. Mineral lineations plunge gently northeast at 5° to 24° at an average of N.52°E., parallel to the axes of minor folds in outcrop and the axes of major folds.

Faults

The Ramapo Fault is a dominant structural feature that extends northeast from the Gladstone quadrangle (Houghton and Volkert, 1990) into New York State (Drake et al., 1996). The fault has a complex and protracted history of movement that began in the Proterozoic. Multiple episodes of subsequent reactivation have left overprinting brittle and ductile fabrics that record normal, reverse, and strike-slip movement. The fault strikes about N.40°E. and dips 50° southeast, as indicated by borings drilled at Bernardsville Township (Ratcliffe et al., 1990) and for Route 287 between Montville and Riverdale Boroughs (Woodward Clyde Consultants, 1983). However, outcrops of Mesoproterozoic rocks on the footwall of the fault, especially to the north in the Pompton Plains and Ramsey quadrangles, record mylonitic foliations of probable Proterozoic and Paleozoic age that dip steeply southeast at 60° to 85° (Volkert, 2010; 2011).

A series of north- to northeast-striking, steeply dipping faults south of the Ramapo Fault displace the axis of the Watchung Syncline and formation contacts from a few hundred to as much as 1,000 feet. Some of the northeast faults may be splays of the Ramapo Fault. Northwest-striking faults cut the north faults and, therefore, appear to be younger. All faults are characterized by very closely-spaced joints, thin zones of breccia and (or) clayey-silty gouge, slickensides locally coated by chlorite and (or) calcite, and eroded gaps in outcrops. Slip lineations on fault surfaces record mainly oblique to high-angle dip-slip movement. Northeast faults strike N.10°E. to N.30°E. (fig. 3) and dip southeast, and less commonly, northwest. North faults strike about N.05°W. (fig. 3) and dip nearly equally west and east. The average dip of all faults is 83°.

Joints

Joints are a dominant structural feature in all rocks in the quadrangle. Those in Mesozoic sedimentary rocks are characteristically planar, moderately well formed, and unmineralized, except near faults. Surfaces are smooth and less commonly irregular. Joints in sandstone are better developed than those in siltstone and shale. Joints are spaced from <1 foot to several feet apart, except near faults where they are spaced <1 foot apart. Two dominant joint sets and a subordinate set are present in the sedimentary rocks. The strike of joints displays populations that are about N.10°E., N.25° W. and a subordinate set strikes about N.70°E. (fig. 4). Northeast striking joints dip southeast, and less commonly, northwest, and northwest striking joints dip southwest, and less commonly, northeast. The average dip of all joints is 83°.

Joints in Mesozoic igneous rocks are of two types, columnar (cooling) and tectonic. Columnar joints are present in all basalt formations in the area. They are characteristically polygonal, arrayed radially and varied in height and spacing. A comprehensive study of the origin and orientation of cooling joints in the basalts was undertaken by Faust (1978). Tectonic joints are present in all basalt formations, but they are commonly obscured by the more pervasive cooling joints. Tectonic joints are planar, moderately to well formed, smooth to slightly irregular, steeply dipping, unmineralized, and varied in their spacing from a few feet to tens of feet. In outcrops near faults, spacing is 1 foot or less apart and surfaces are locally mineralized by calcite and (or) chlorite.

The dominant joint orientation in Mesoproterozoic rocks is nearly perpendicular to the strike of crystallization foliation, and this relationship is a consistent feature throughout the Highlands (Volkert, 1996). Joints are characteristically planar, moderately well formed, moderately to widely spaced, and moderately to steeply dipping. Surfaces of joints are smooth, and less commonly, slightly irregular. They are typically unmineralized except near faults where they are coated by chlorite and (or) epidote. Joints are variably spaced from 1 foot to tens of feet apart. Those developed in massive rocks such as granite are spaced wider, irregularly formed and more discontinuous than in layered gneisses. Joints formed near faults are spaced 2 feet or less apart. The dominant joint set strikes N.20°W. to N.70°W. and averages N.32°W. (fig. 5). The dip is nearly equal to the northeast and southwest. Subordinate sets strike about N.45°E. and N.70°E. and dip mainly northwest. The average dip of all joints is 75°.

ECONOMIC RESOURCES

Lower Jurassic Preakness Basalt was quarried near Bernardsville Borough for use as aggregate and dimension stone and Hook Mountain Basalt was quarried near Millington. A small, unnamed mica mine in Mesoproterozoic gneiss at Bernardsville was likely worked during the 19th century, but no information is available on the mine.

NATURALLY OCCURRING RADIATION

Background levels of naturally occurring radioactivity were measured in Mesozoic bedrock outcrops using a hand-held Micro R meter and the results are given under the individual map unit descriptions. In general, basalts yield consistently low readings of about 6 Micro R/Hr regardless of stratigraphic position, texture, or composition. Sedimentary units yield higher, more varied readings that range from 9 to 21 Micro R/Hr and appear to be related mainly to grain size. Values recorded from sandstone and pebbly sandstone are lower than those from siltstone and shale, suggesting that clay minerals may be the host for the radiogenic phases.

DESCRIPTION OF MAP UNITS

NEWARK BASIN

Jb — **Boonton Formation** (Lower Jurassic) (Olsen, 1980a) – Reddish-brown or brownish-purple, fine-grained, commonly micaceous sandstone, siltstone, and mudstone in fining-upward sequences 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 mud cracks, symmetrical ripple marks, hummocky and trough cross-laminated beds, burrows, and evaporite minerals are abundant in red siltstone and mudstone. Gray, fine-grained sandstone locally contains carbonized plant remains and reptile footprints in middle and upper parts of unit. Maximum thickness regionally is about 1,640 ft. Levels of natural radioactivity range from 13 to 15 (mean=14) Micro R/Hr in reddish-brown rocks and 15 to 17 (mean=16) Micro R/Hr in gray rocks.

Jh — **Hook Mountain Basalt** (Lower Jurassic) (Olsen, 1980a) – Dark greenish-gray to black, generally fine-grained basalt composed of plagioclase, clinopyroxene, and iron-titanium oxides. Contains small spherical to tubular gas-escape vesicles above scoriaceous flow contacts, some of which are filled by zeolite minerals or calcite. Unit consists of at least two, and possibly three major flows. Base of lowest flow is intensely vesicular. Tops of flows are weathered and vesicular. Maximum thickness regionally is about 360 ft. Levels of natural radioactivity range from 4 to 10 (mean=6) Micro R/Hr.

Jt, Jtc — **Towaco Formation** (Lower Jurassic) (Olsen, 1980a) – 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 mud cracks and symmetrical ripple marks are present locally. Sandstone is commonly hummocky and trough cross-laminated, and siltstone commonly planar laminated or bioturbated and indistinctly laminated to massive. As much as several feet of unit have been thermally metamorphosed along the contact with Hook Mountain Basalt. Conglomerate and conglomeratic sandstone (Jtc) containing subrounded clasts of quartzite and quartz in matrix of buff or tan, sand to silt interfinger with unit in northeastern part of the map. Maximum thickness regionally is about 1,250 ft. Levels of natural radioactivity range from 12 to 21 (mean=15) Micro R/Hr in reddish-brown rocks, 13 to 20 (mean=16) Micro R/Hr in gray rocks (Jt), and 9 to 13 (mean=11) Micro R/Hr in conglomerate (Jtc).

Jp, Jpg, Jps — **Preakness Basalt** (Lower Jurassic) (Olsen, 1980a) – Dark greenish-gray to black, fine-grained, dense, hard basalt composed mainly of calcic plagioclase, clinopyroxene and iron-titanium oxides. Unit contains small spherical to tubular gas-escape vesicles directly above scoriaceous flow contacts, some of which are filled by zeolite minerals or calcite. Dark-gray, coarse- to very-coarse-grained gabbroid (Jpg) composed of clinopyroxene grains as much as 0.5 in. long and plagioclase grains as much as 1.0 in. long occurs at several stratigraphic intervals in the unit. Gabbroid has sharp upper contacts and gradational lower contacts with fine-grained basalt. Unit consists of at least three major flows, the tops of which are marked by prominent vesicular zones as much as 8 ft. thick. Radiating slender columns 2 to 24 in. wide, due to shrinkage during cooling, are abundant near the base of the lowest flow. A bed of reddish-brown siltstone 6 to 25 ft. thick (Jps) separates the lower flows. Maximum thickness of unit is about 1,040 ft. Levels of natural radioactivity range from 4 to 6 (mean=5.5) Micro R/Hr.

Jf — **Feltville Formation** (Lower Jurassic) (Olsen, 1980a) – Reddish-brown or light grayish-red, fine- to coarse-grained sandstone, siltstone, shaly siltstone, and silty mudstone; and light- to dark-gray or black, locally calcareous siltstone, silty mudstone, and carbonaceous limestone. Upper part of unit is predominantly thin- to medium-bedded, reddish-brown siltstone, but south of the map area it contains beds of light-gray, fine-grained calcareous sandstone interbedded with light-gray, reddish-brown, or light greenish-gray, fine-grained quartzose sandstone that contains locally abundant carbonized plant remains. Reddish-brown sandstone and siltstone are moderately well sorted, commonly cross-laminated, and interbedded with reddish-brown, planar-laminated silty mudstone and mudstone. Two thin, laterally continuous sequences, each as much as 10 ft. thick of dark-gray to black carbonaceous limestone, light-gray limestone, and medium-gray calcareous siltstone, and gray or olive, desiccated shale to silty shale occur near the base, and along with the red beds between, make up the Washington Valley Member of Olsen (1980b). Gray beds contain fish, reptiles, arthropods, and diagnostic plant fossils. As much as several feet of unit have been thermally metamorphosed along its contact with Preakness Basalt. Thickness regionally is about 510 ft. Levels of natural radioactivity from reddish-brown sandstone and siltstone range from 11 to 17 (mean=12.5) Micro R/Hr.

Jo — **Orange Mountain Basalt** (Lower Jurassic) (Olsen, 1980a) – Dark greenish-gray to black, fine-grained, dense, hard basalt composed mostly of calcic plagioclase, clinopyroxene and iron-titanium oxides. Locally contains small spherical to tubular gas-escape vesicles above base of flow contact, some of which are filled by zeolite minerals or calcite. Unit consists of three major flows that are separated in places by a weathered zone, a bed of thin reddish-brown siltstone, or by volcaniclastic rock. Lower part of upper flow is locally pillowed; upper part has pahoehoe flow structures. Middle flow is massive to columnar jointed. Lower flow is generally massive with widely spaced curvilinear cooling joints and is pillowed near the top. Individual flow contacts are characterized by vesicular zones as much as 8 ft. thick. Thickness of unit is about 590 ft. Levels of natural radioactivity range from 3 to 6 (mean=5) Micro R/Hr.

JTrp, JTrpsc — **Passaic Formation** (Lower Jurassic and Upper Triassic) (Olsen, 1980a) – Interbedded sequence of reddish-brown, and less commonly maroon or purple, fine- to coarse-grained sandstone, siltstone, shaly siltstone, silty mudstone, and mudstone (JTrp) and conglomeratic sandstone (JTrpsc). Reddish-brown sandstone and siltstone are thin- to medium-bedded, planar-to cross-bedded, micaceous, and locally mud-cracked and ripple cross-laminated. Root casts and load casts are common. Shaly siltstone, silty mudstone, and mudstone are fine-grained, very-thin to thin-bedded, planar to ripple cross-laminated, locally fissile, bioturbated, and contain evaporite minerals. They form rhythmically fining-upward sequences as much as 15 ft. thick. Conglomeratic sandstone is medium-to coarse grained, feldspathic, and locally contains pebble and cobble layers. Clasts are subangular to subrounded, locally imbricated quartz and quartzite in sandstone matrix. Conglomerate has an erosive base and beds fine upwards through red sandstone and mudstone. Several feet of formation have been thermally metamorphosed along its contact with the Orange Mountain Basalt. Unit is sparsely exposed in southwestern part of the map, but regionally is as much as 11,480 ft. thick. Levels of natural radioactivity are 13 to 24 (mean=17) Micro R/Hr in reddish-brown sandstone and siltstone and 11 Micro R/Hr in reddish-brown pebbly sandstone and conglomerate.

NEW JERSEY HIGHLANDS

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 mesoperthite, microcline microperthite, quartz, oligoclase, and hornblende. Unit includes bodies of pegmatite too small to be shown on the map.

Yba — **Microperthite alaskite** (Mesoproterozoic) – Pale pinkish-white weathering, light-pinkish-gray, medium- to coarse-grained, foliated granite composed of microcline microperthite, quartz, oligoclase, and trace amounts of hornblende and magnetite.

Ybs — **Hornblende monzonite** (Mesoproterozoic) – Tan, pinkish-gray or buff weathering, pinkish-gray or greenish-gray, medium- to coarse-grained, foliated rock of syenitic to monzonitic composition composed of mesoperthite, microcline microperthite, oligoclase, and hornblende. Locally contains quartz and (or) clinopyroxene.

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

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

Back Arc Rocks

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.

Ymg — **Monazite gneiss** (Mesoproterozoic) – Buff weathering, light-greenish-gray or greenish-buff, medium-grained, moderately foliated gneiss composed of microcline microperthite, quartz, oligoclase, hornblende, and monazite. Unit is confined to one small body along Indian Grove Brook.

Yb, Ybr — **Biotite-quartz-feldspar gneiss** (Mesoproterozoic) – Pale pinkish-white-weathering, pinkish-gray and gray-weathering (Yb), locally rusty (Ybr), gray, tan, or greenish-gray, medium-to coarse-grained, moderately layered and foliated gneiss containing microcline microperthite, oligoclase, quartz, biotite, garnet, and sillimanite. Graphite and pyrrhotite are confined to the variant that weathers rusty. This variant is commonly spatially associated with thin, moderately foliated to well-layered quartzite that contains biotite, feldspar, and graphite.

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

Yp — **Pyroxene gneiss** (Mesoproterozoic) – White weathering, greenish-gray, medium-grained, foliated and layered gneiss composed of oligoclase, clinopyroxene, variable amounts of quartz, and trace amounts of opaque minerals and titanite. Commonly spatially associated with pyroxene amphibolite and biotite-quartz-feldspar gneiss.

Magmatic Arc Rocks

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

Ylo — **Quartz-oligoclase gneiss** (Mesoproterozoic) – White weathering, light-greenish-gray, medium- to coarse-grained, foliated gneiss composed of oligoclase or andesine, quartz, and local hornblende, clinopyroxene and (or) biotite. Commonly contains thin, conformable layers of amphibolite not shown on the map.

Ylb — **Biotite-quartz-oligoclase gneiss** (Mesoproterozoic) – White or light-gray-weathering, medium-gray or light greenish-gray, medium- to coarse-grained, foliated and layered gneiss composed of oligoclase or andesine, quartz, biotite, and local garnet. Some outcrops contain hornblende. Unit grades into quartz-oligoclase gneiss with decrease in biotite. Locally contains thin, conformable layers of biotite-bearing amphibolite.

Ylh — **Hornblende-quartz-oligoclase gneiss** (Mesoproterozoic) – White or light-gray-weathering, greenish-gray, medium- to coarse-grained, foliated gneiss composed of oligoclase or andesine, quartz, hornblende, and local biotite. Some outcrops contain clinopyroxene. Locally contains thin, conformable layers of amphibolite.

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

Yd — **Diorite gneiss** (Mesoproterozoic) – Light-gray or tan-weathering, greenish-gray or greenish-brown, medium- to coarse-grained, greasy lustered, massive, foliated rock containing andesine or oligoclase, clinopyroxene, hornblende, and hypersthene, contains thin, mafic layers having the composition of amphibolite.

Other Rocks

Ya — **Amphibolite** (Mesoproterozoic) - Gray to grayish-black, medium-grained, foliated gneiss composed of hornblende and andesine. Some variants contain biotite and (or) clinopyroxene. Amphibolite associated with the Losee Suite is metavolcanic in origin. Amphibolite associated with metasedimentary rocks may be metavolcanic or metasedimentary in origin. Both types are shown undifferentiated on the map.

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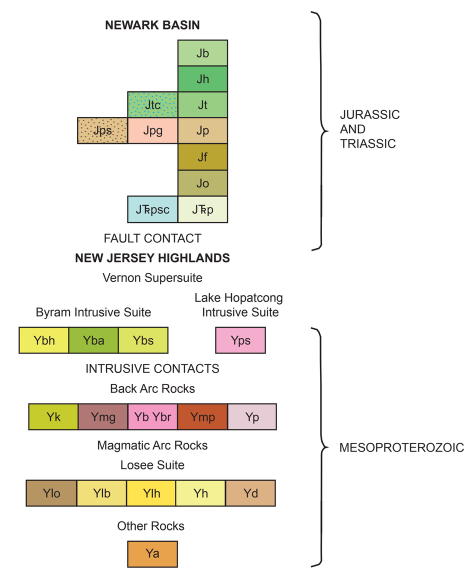
CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contact - Dotted where concealed. Dashed and queried where uncertain.

Fault - Dotted where concealed. Dashed and queried where uncertain.

Normal fault - U, upthrown side; D, downthrown side. Bar and ball show direction of dip of fault plane.

Reverse fault - U, upthrown side; D, downthrown side. Bar and ball show direction of dip of fault plane.

High-angle fault of unknown movement.

FOLDS

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

Syncline

Folds in Mesoproterozoic rocks showing trace of axial surface, direction of dip of limbs, and direction of plunge.

Synform

Antiform

Overturned Synform

Overturned Antiform

PLANAR FEATURES

Strike and dip of crystallization foliation

62 **Inclined**

Vertical

40 **Strike and dip of inclined beds**

LINEAR FEATURES

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

OTHER FEATURES

Active rock quarry

Abandoned rock quarry

Mi **Abandoned mica mine**

Bedrock outcrop or float used in construction of map

XXXXXX **Scoriaceous flow contact**

Boring log or water-well record from Stanford (2008)

Form lines showing foliation in Proterozoic rocks. Shown in cross section only.

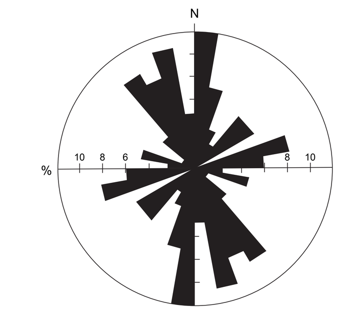


Figure 4. Rose diagram of joint orientations in Mesozoic sedimentary rocks.

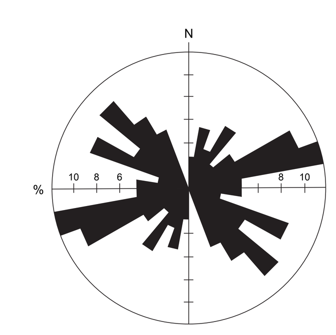


Figure 1. Rose diagram of bedding orientations in Mesozoic sedimentary rocks.

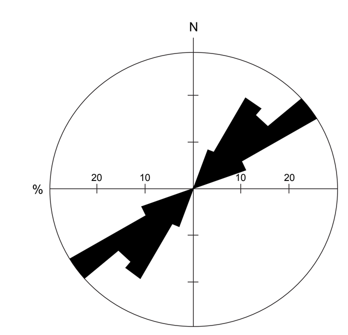


Figure 2. Rose diagram of crystallization foliation orientations in Mesoproterozoic rocks.

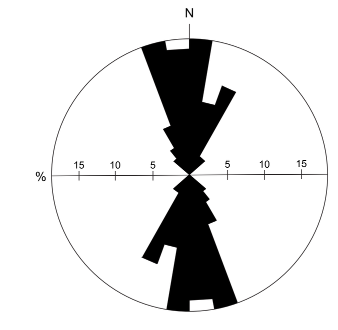


Figure 3. Rose diagram of fault orientations in Mesozoic rocks.

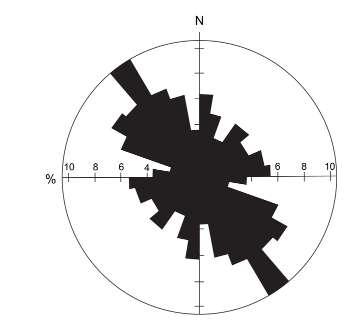


Figure 5. Rose diagram of joint orientations in Mesoproterozoic rocks.