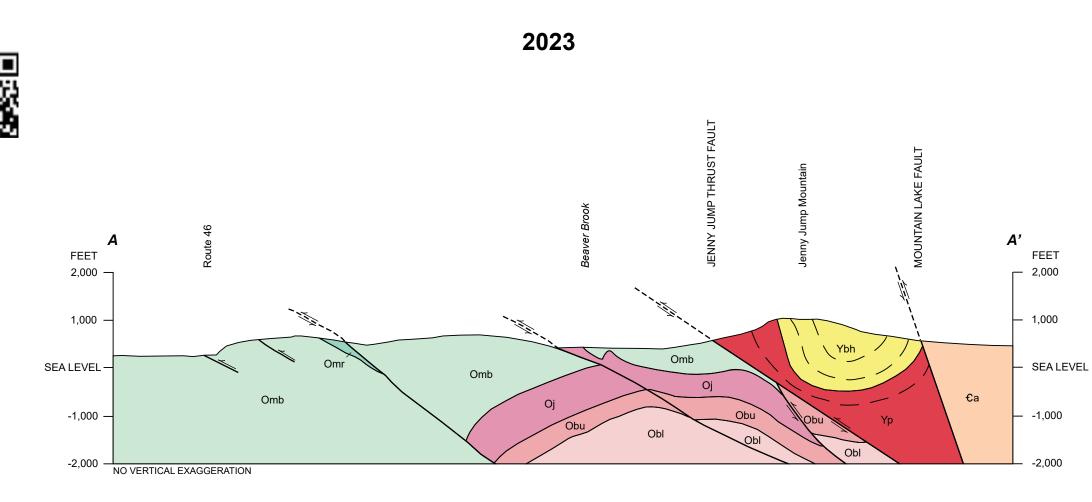


BEDROCK GEOLOGIC MAP OF THE BELVIDERE QUADRANGLE **WARREN COUNTY, NEW JERSEY**

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INTRODUCTION

The Belvidere 7.5-minute guadrangle is located in northwestern New Jersey and in the west-central part of Warren County, where it straddles the boundary between the New Jersey Highlands and the Valley and Ridge Physiographic Provinces. The dominant relief in the area occurs on Scotts Mountain, in the southern area of the map, that attains a maximum elevation of 1,281 feet above sea level. The Delaware and Pequest rivers are the dominant drainages. The geologic interpretations presented here supersede those shown on the bedrock geologic maps of Drake and others (1969. 1985). 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 age rocks of the New Jersey Highlands and Paleozoic age rocks of the Valley and Ridge. This map provides updated, detailed geologic information on the stratigraphy, structure, ages and descriptions of geologic units in the map area. The cross sections show a vertical profile of the geologic units and their structure, and rose diagrams in figures 1a through 1g provide a directional analysis of selected structural features.

STRATIGRAPHY

Paleozoic Rocks Lower Paleozoic rocks of the Kittatinny Valley Sequence underlie the western and northern parts of the map area, and southeastern part in the Pohatcong Valley. They unconformably overlie rocks of Mesoproterozoic and Neoproterozoic age south of the Pequest River, along Buckhorn Creek, and along the Pohatcong Valley. Elsewhere in the quadrangle, Paleozoic rocks are in fault contact with Mesoproterozoic rocks. Formations of Cambrian through Ordovician age, previously considered to be part of the Lehigh Valley Sequence of MacLachlan (1979), were reassigned to the Kittatinny Valley Sequence by Drake and others (1996). The Kittatinny Valley Sequence includes the Kittatinny Supergroup, "Sequence at Wantage", Jacksonburg Limestone, and Martinsburg Formation. All of these except for the "Sequence at Wantage" are exposed in the quadrangle. In ascending age, the Kittatinny Supergroup includes the Leithsville Formation, Allentown Dolomite, and lower and upper parts of the

Beekmantown Group.

Neoproterozoic Rocks Diabase dikes that intruded Mesoproterozoic rocks in the map area strike northeast and have sharp contacts and chilled margins against Mesoproterozoic rocks. Similar dikes are widespread and abundant in the New Jersey Highlands where they are interpreted to have an age of about 600 Ma (million years) based on the fact they intruded only Mesoproterozoic rocks and have geochemical compositions that differ from Paleozoic mafic dikes and Mesozoic diabase and basalt (Volkert and Puffer, 1995). Mesoproterozoic rocks near Bridgeville are unconformably overlain by very weakly metamorphosed sedimentary rocks that include quartz-pebble conglomerate, sandstone and siltstone that are equivalent to the Chestnut Hill Formation of Drake (1984).

Mesoproterozoic Rocks Mesoproterozoic rocks that include various granites, gneisses and marble are widespread and abundant throughout the map area. Most Mesoproterozoic rocks were metamorphosed to granulite facies at about 1,045 Ma (Volkert and others, 2010). Among the oldest units are the Losee Suite formed in a continental-margin magmatic arc and spatially associated metasedimentary and metavolcanic supracrustal rocks formed in a back-arc basin, inboard of the Losee magmatic arc (Volkert, 2004). The Losee Suite includes metamorphosed plutonic rocks mapped as guartz-oligoclase gneiss, and metamorphosed volcanic rocks mapped as biotite-quartz oligoclase gneiss and hypersthene-quartz-plagioclase gneiss. Amphibolite intercalated with the Losee Suite also formed from a volcanic protolith that has a geochemical affinity to basalt. Rocks of the Losee Suite yielded U-Pb zircon ages of 1,282-1,248 Ma (Volkert and others, 2010). Supracrustal rocks include quartzofeldspathic gneisses mapped as potassic-feldspar gneiss, biotite-quartz-feldspar gneiss, and clinopyroxene-quartz-feldspar gneiss, calc-silicate rocks mapped as pyroxene gneiss and pyroxene-epidote gneiss, and marble. Most amphibolite intercalated with metasedimentary rocks also formed from a volcanic protolith of basaltic affinity, although some amphibolite interlayered with metasedimentary rocks may also have formed from a sedimentary protolith. Supracrustal rocks yielded U-Pb zircon ages of 1,299-1,251 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) include mainly granite and alaskite. The Lake Hopatcong Suite crops out dominantly 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 vielded similar U-Pb zircon ages of 1.185-1,182 Ma (Volkert and others, 2010). Widespread bodies of hornblende- and clinopyroxene-bearing alaskite mapped as microantiperthite alaskite crop out in the central and northern part of the area. They appear to grade along strike into hornblende granite of the Byram Suite, suggesting that they may share a common age and origin with the Vernon Supersuite. However, these rocks remain undated,

Paleozoic Bedding and Cleavage Bedding in the Paleozoic rocks in the quadrangle is fairly uniform and strikes northeastward at about cally they are overturned steeply southeast. Bedding ranges in dip from 2° to 87° and averages 40°. Cleavage (closely-spaced parallel partings) occurs in most Paleozoic rocks but is best developed in finer-grained rocks such as shale and slate of the Martinsburg Formation. Cleavage in the Paleozoic rocks generally parallels the trend of bedding and strikes northeast an average of N.44°E. Cleavage dips predominantly southeast at 5° to 85° and averages 34° (figs. 1d and 1g), A second (crenulation) cleavage that cuts the primary cleavage occurs only in the Martinsburg Formation. The second cleavage crenulates and locally offsets the primary cleavage (Herman and others, 1997). It occurs in the footwall of large overthrusts (Herman and Monteverde, 1989; Herman and others, 1997) present in the northeastern part of the area. The crenulation cleavage varies in strike from N.65°E. to N.58°W., averaging N.60°E. and dips an average of 51° south.

and therefore are shown as having an uncertain correlation to other granitic rocks in the map area.

STRUCTURE

Proterozoic Foliation Crystallization foliation (the parallel alignment of mineral grains) in the Mesoproterozoic rocks is an inherited feature resulting from compressional stresses during high-grade metamorphism at about 1,045 Ma. Foliation is somewhat varied in strike in the area because of folding. It strikes mainly northeast along the western sides of Scotts and Jenny Jump Mountains where it averages N.40°E. (Fig. 1a). Foliation strikes northwest in the central and eastern parts of Scotts Mountain, where it averages N.35°W. (Fig. 1a). All foliations dip moderately to steeply and average 67°. Northeast-striking foliation dips with near equal abundance southeast or northwest; northwest-striking foliation dips predominantly

Folds in the Paleozoic rocks formed during the Taconic and Alleghanian Orogenies at about 450 Ma and 250 Ma, respectively, and postdate bedding development. These folds are open to tight, upright, to locally overturned, and gently inclined to recumbent. Larger folds in the central map area plunge northeastward. Southwest-plunging folds occur in the northeast at the western culmination of Jenny Jump Mountain. Taconic-aged folds are cut by younger Alleghanian faults (Herman and Monteverde, 1989; Herman and others, 1997). These folds formed in the hinterland of emergent Taconic thrusting to the southeast in the area of Clinton, in the High Bridge quadrangle, in Hunterdon County (Monteverde and others, 2015). Fold intensity and overturning increase toward this Taconic structural culmination in the southeast. Folds in Mesoproterozoic rocks were formed at about 1,045 Ma and they deform crystallization foliation. Characteristic fold patterns on Scotts Mountain include earlier-formed open to tight, north-plunging and west-overturned antiforms and synforms that are deformed by broad northeast-plunging, northwest overturned to locally upright antiforms and synforms. This is a continuation of the same pattern of folding that deforms Mesoproterozoic rocks to the east in the Washington quadrangle (Drake and others, 1994). The fold on Jenny Jump Mountain is a northeast-plunging,

The structural geology of the quadrangle is dominated by a series of northeast-trending faults that deform both Mesoproterozoic and Paleozoic rocks. Some of the faults may have originated in the Proterozoic during Grenvillian orogenesis; all were active during the Taconic and Alleghanian orogenies and possibly during the Mesozoic as well. From the southeast they include the Karrsville thrust fault, Brass Castle thrust fault, Lower Harmony thrust fault, Shades of Death thrust fault, Jenny Jump thrust fault, Mountain Lake fault, and Foul Rift thrust fault. The faults are characterized by brittle deformation fabrics consisting of brecciation, the retrogression of mafic mineral phases, chlorite or epidote-coated fractures or slickensides, and/or close-spaced fracture cleavage. The northeast-trending and moderately southeast-dipping Karrsville thrust fault occurs in Pohatcong Valley, southeast of Scotts Mountain, where it contains Allentown Dolomite on both the footwall and hanging wall blocks. It continues to the northeast where it merges with, or is cut off by, the Brass Castle thrust fault south of County House Mountain in the Washington quadrangle, placing Leithsville Formation on both blocks (Drake and others, 1994). The moderately southeast-dipping Brass Castle thrust fault bounds Scotts Mountain along the southeast side where it places Allentown Dolomite onto Mesoproterozoic rocks. It continues northeastward into the adjacent Washington quadrangle where it bounds County House Mountain on the southeast, placing progressively older Paleozoic rocks onto Mesoproterozoic rocks (Drake and others, 1994; Monteverde and others, 1994). The moderately to steeply southeast-dipping Shades of Death thrust fault occurs south of the Pequest Valley where it bifurcates before merging with the Jenny Jump thrust fault to the west near Hazen. The Shades of Death-Jenny Jump thrus fault system then continues southwestward where it bounds the northwest side of Scotts Mountain. In the Belvidere quadrangle, the Shades of Death thrust fault places Mesoproterozoic rocks onto Mesoproterozoic rocks and then Mesoproterozoic rocks onto Paleozoic rocks after merging with the Jenny Jump thrust fault. The moderately to steeply southeast-dipping Jenny Jump thrust fault bounds the northwest side of Jenny Jump Mountain, crosses the Pequest Valley to the south, and then bounds the northwest side of Scotts Mountain. It places Mesoproterozoic rocks of Jenny Jump and Scotts Mountains onto Paleozoic rocks. The Mountain Lake fault is a steeply southeast-dipping normal fault that bounds the southeast side of Jenny Jump Mountain. In the Belvidere quadrangle it is cut off by the Jenny Jump thrust fault near Bridgeville. The Mountain Lake fault places Mesoproterozoic rocks against Paleozoic rocks in the map area and, further to the northeast in the Washington quadrangle, Mesoproterozoic rocks against Mesoproterozoic rocks (Drake and others, 1994).

CORRELATION OF MAP UNITS

VALLEY AND RIDGE Kittatinny Valley Sequence Omb ORDOVICIAN Unconformity NEW JERSEY HIGHLANDS LATE PROTEROZOIC Lake Hopatcong **Byram Intrusive Suite** undivided Intrusive Suite Back-arc Basin Supracrustal Rocks Yk Yb Ymp Yp Ymr Ype MIDDLE PROTEROZOIC Unconformity Magmatic Arc Rocks Losee Metamorphic Suite Ylo Ylb Yh Other Rocks Ya Yma Ym

Local Connector _____

Secondary Hwy Local Road

78 Interstate Route 830 US Route 57 State Route

The Alleghanian-aged Foul Rift thrust fault (Herman and Monteverde, 1989) parallels the Delaware River in the northern part of the map area, where it is overridden by the Jenny Jump thrust fault. The Foul Rift thrust fault dips moderately to steeply toward the southeast and places Paleozoic rocks against other Paleozoic rocks, but varies along strike in placing younger rocks onto older ones or older rocks onto younger ones. This variation arises from the Foul Rift fault cutting through a previously folded terrain. Faults ascend fold limbs of similar dip direction and often decapitate the fold hinge (Herman and Monteverde, 1989; Herman and others, 1997). Antithetic, northwest-dipping break-back thrust faults deform the Martinsburg Formation. These structures relate to deflection of the dip of the Jenny Jump thrust fault to locally northwest, as shown by a series of klippens composed of Lower Paleozoic and minor Mesoproterozoic rocks that are exposed elsewhere (Drake and others, 1985: Herman and Monteverde, 1989; Herman and others, 1997).

Joints are a ubiquitous feature in all Paleozoic and Mesoproterozoic rocks in the map area. Joints developed in Paleozoic rocks are more common in massive rocks such as limestone, dolomite, and sandstone than in finer-grained rocks such as shale and slate. Two main joint sets occur. One set strikes northeast an average of N.55°E. (Fig. 1e) and dips moderately to steeply northwest an average of 65° and the other set strikes northwest an average of N.47°W. (Fig. 1e) and dips predominantly southwest an average of 65°.

Joints developed in Mesoproterozoic rocks are characteristically planar, moderately well formed, moderately to widely spaced, and moderately to steeply dipping. Surfaces of joints are typically unmineralized, except where near faults, and are smooth and less commonly slightly irregular. Joints are spaced from one foot to tens of feet apart. Those developed in massive textured rocks, such as granite, are more widely spaced, irregularly formed and discontinuous than joints developed in gneisses and finer-grained crystalline rocks. Joints formed near faults are typically spaced two feet or less apart. The dominant joint trend within the Mesoproterozoic rocks is nearly orthogonal to the strike of crystallization foliation, and this orthogonal relationship of the principal joint set to foliation is a consistent feature that has been observed in Mesoproterozoic rocks throughout the New Jersey Highlands (Volkert, 1996). Thus, joints are not uniform in strike because of the varied strike of foliation due to folding. Two principal joint sets are seen in the Mesoproterozoic rocks. One set strikes northwest at N.30°W. to N.60°W. (Fig. 1b) and dips moderately to steeply southwest or northeast with equal abundance. The other set strikes northeast an average of N.55°E. (Fig. 1b) and dips moderately to steeply southeast and less

commonly northwest. The average dip of all joints in Mesoproterozoic rocks is 66°. **ECONOMIC RESOURCES**

Some Mesoproterozoic, Neoproterozoic and Paleozoic rocks in the quadrangle host deposits of iron ore mined predominantly during the 19th century. Detailed descriptions of most of these mines are given in Bayley (1910, 1941). Iron mines in Mesoproterozoic rocks are present mainly in the central and eastern part of the area, where magnetite was extracted from more than a dozen mines. Hematite was extracted from the Neoproterozoic Chestnut Hill Formation at the Titman mine near Bridgeville, and limonite from the Cambrian Hardyston Quartzite at the Fittz, Shoemaker, and Roseberry mines along Buckhorn Creek. Mesoproterozoic rocks are guarried for crushed stone south of Buttzville. Marble was formerly quarried on a small scale from several locations between Hazen and Buttzville for use as Portland cement and in roasting magnetite ore in the furnace at Oxford (Bayley, 1941). Dolomite was formerly quarried at Sarepta. Deposits of sand and gravel are currently being mined at Bridgeville, and were formerly worked at other locations in the quadrangle (Witte and Ridge,

DESCRIPTION OF MAP UNITS VALLEY AND RIDGE Kittatinny Valley Sequence

 $\textbf{Ramseyburg Member of Martinsburg Formation (upper middle Ordovician)} - \\ \textbf{Interbedded medium-notation} = \textbf{Martinsburg Formation} = \textbf{Martinsburg Form$ to dark-gray to brownish-gray, fine- to medium-grained, thin- to thick-bedded quartzose to graywacke sandstone and siltstone and medium- to dark-gray, laminated to thin-bedded shale and slate. Unit orms fining upward sequences characterized by basal cross-bedded sandstone to siltstone grading upward through planar laminated siltstone into shale or slate. Locally, fining upward cycles may have a lower, medium- to thick-bedded, graded-bedded sandstone overlain by planar laminated sandstone to siltstone beneath the cross-bedded layer. Complete cycles may be an inch to several feet thick. Basal scour, sole marks, and soft-sediment distortion of beds are common in quartzose and graywacke sandstones. Lower contact placed at bottom of lowest thick- to very-thick-bedded graywacke, but contact locally grades through sequence of dominantly thin-bedded slate and minor thin- to mediumbedded discontinuous and lenticular graywacke beds in the Bushkill Member. Parris and Cruikshank (1992) correlate unit with Orthograptus ruedemanni zone to lowest part of Climacograptus spiniferus zone of Riva (1969, 1974) indicating Shermanian age (Caradocian). Regionally, unit is as much as

Bushkill Member of Martinsburg Formation (upper middle Ordovician) - Medium- to medium dark-gray-weathering, dark-gray to black, thinly laminated to medium-bedded shale and slate; less abundant medium-gray- to brownish-gray-weathering, dark-gray to black, laminated to thin-bedded, greywacke siltstone. Unit forms fining upward sequences characterized by either basal cross-bedded siltstone grading upward through planar laminated siltstone into slate, or laminated siltstone grading upward into slate. Locally, fining upward cycles may have a lower graded sandstone to siltstone overlain by planar laminated siltstone beneath the cross-bedded layer. Complete cycles may be an inch to several feet thick with slate comprising the thickest part. Lower contact with Jacksonburg Limestone gradational, but commonly disrupted by thrust faulting. Parris and Cruikshank (1992) show that regionally the unit contains graptolites of zones *Diplograptus multidens* to *Corynoides americanus* (Riva, 1969; 1974), which they correlate to the Climacograptus bicornis zone to Corynoides americanus subzone of Orthograptus amplexicaulis (Berry, 1968; 1971; 1976) indicating Shermanian (Caradocian) age. Thicknesses regionally range from 1,500 ft. to a maximum of approximately 4,000

Jacksonburg Limestone (middle Ordovician) – Medium-dark-gray-weathering, medium-dark to dark-gray, laminated to thin-bedded, argillaceous limestone (cement-rock facies) and minor arenaceous limestone. Grades downward into medium-bluish-gray-weathering, dark-gray, very thinto medium-bedded, commonly fossiliferous, interbedded fine- and medium-grained limestone and pebble-and-fossil limestone conglomerate (cement-limestone facies). Elsewhere, thick- to very thickbedded dolomite cobble conglomerate occurs within basal sequence. Lower contact unconformable on Beekmantown Group, and on clastic facies of "Sequence at Wantage," and conformable on carbonate facies of "Sequence at Wantage." Unit contains North American Midcontinent province conodont zones Phragmodus undatus to Aphelognathus shatzeri indicating Rocklandian to Richmondian and possibly Kirkfieldian (Caradocian) ages (Sweet and Bergstrom, 1986). Regionally unit ranges in thickness from 150 feet to 1.000 feet.

Beekmantown Group, upper part (lower Ordovician) - Light- to medium-gray- to yellowish-grayweathering, medium-light to medium-gray, aphanitic to medium-grained, thin- to thick-bedded, locally laminated, slightly fetid dolomite. Locally light-gray- to light-bluish-gray- weathering, medium- to darkgray, fine-grained, medium-bedded limestone occurs near the top of unit. Grades downward into medium- to dark-gray on weathered surface, medium- to dark-gray where fresh, medium- to coarsegrained, medium- to thick-bedded, strongly fetid dolomite. Contains pods, lenses and layers of darkgray to black rugose chert. Lower contact conformable and grades into the fine-grained, laminated dolomite of Beekmantown Group, lower part. Contains conodonts of North American Midcontinent province Rossodus manitouensis zone to Oepikodus communis zone (Karklins and Repetski, 1989). so that unit is Ibexian (Tremadocian to Arenigian) as used by Sweet and Bergstrom (1986). In map area, unit correlates with the Epler and Rickenbach Dolomite of Drake and others (1985) and the Ontelaunee Formation of Markewicz and Dalton (1977). Unit averages about 200 feet in thickness but is as much as 800 feet thick.

Beekmantown Group, lower part (lower Ordovician) - Upper sequence is light- to medium-gray- to dark-yellowish-orange-weathering, light-olive-gray to dark-gray, fine- to medium-grained, very thin- to medium-bedded locally laminated dolomite. Middle sequence is olive-gray- to light-brown- and darkyellowish-orange-weathering, medium- to dark-gray, aphanitic to medium-grained, thin-bedded, locally well laminated dolomite which grades into discontinuous lenses of light-gray- to light-bluish-grayweathering, medium- to dark-gray, fine-grained, thin- to medium-bedded limestone. Limestone has freticulate" mottling characterized by anastomosing light-olive-gray- to grayish-orange-weathering, silty dolomite laminae surrounding lenses of limestone. Limestone may be completely dolomitized locally. Grades downward into medium dark- to dark-gray, fine-grained, well laminated dolomite having local pods and lenses of black to white chert. Lower seguence consists of medium- to medium-dark-gray, aphanitic to coarse-grained, thinly-laminated to thick-bedded, slightly fetid dolomite having quartzsand laminae and sparse, very thin to thin, black chert beds. Individual bed thickness decreases and floating quartz sand content increases toward lower gradational contact. Contains conodonts of North American Midcontinent province Cordylodus proavus to Rossodus manitouensis zones (Karklins and Repetski, 1989) as used by Sweet and Bergstrom (1986), so that unit is Ibexian (Tremadocian). Entire unit is Stonehenge Limestone of Drake and others (1985) and Stonehenge Formation of Volkert and others (1989). Markewicz and Dalton (1977) correlate upper and middle sequences as Epler Formation and lower sequence as Rickenbach Formation. Unit is about 600 feet thick.

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 darkgray chert lenses occur directly below upper contact. Lower sequence is medium- to very-light-grayweathering, 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 gradational into Leithsville Formation. Unit contains a tribolite fauna of Dresbachian (early late Cambrian) age (Weller, 1903; Howell, 1945). Approximately 1,800 feet thick regionally.

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 mediumgrained, medium- to thick-bedded, locally pitted and friable dolomite. Middle sequence is grayishorange 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 feet thick regionally. Shown in cross section only.

Hardyston Quartzite (lower Cambrian) - Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Contains Scolithus linearis (?) and fragments of the trilobite Olenellus thompsoni of early Cambrian age (Nason, 1891; Weller, 1903). hickness ranges from 0 feet to a maximum of 200 feet regionally.

NEW JERSEY HIGHLANDS

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. Locally occurring pyrite blebs are common. Contacts are typically

chilled and sharp against enclosing Mesoproterozoic country rock. Dikes are tholeiitic to alkalic in composition and hypersthene normative. Chestnut Hill Formation (Neoproterozoic) - Interbedded sequence of greenish-gray, locally

ferruginous quartz-pebble conglomerate, sandstone, siltstone, and shale. Unit is not exposed in the map area and is known only from highly sheared dump material at the Titman mine. Vernon Supersuite (Volkert and Drake, 1998)

Byram Intrusive Suite (Drake, 1984)

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

Microperethite alaskite (Mesoproterozoic) - Pinkish-gray- to buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, moderately foliated alaskite composed principally of microcline microperthite, quartz, and oligoclase. Locally contains small clots and disseminated grains of magnetite.

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

Pyroxene granite (Mesoproterozoic) - Buff- or white-weathering, greenish-gray, medium- to coarsegrained, gneissic to indistinctly foliated granite containing mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Common accessory minerals include titanite, magnetite, apatite, and trace amounts of pyrite.

Back-arc Basin Supracrustal Rocks

Potassic feldspar gneiss (Mesoproterozoic) - Light-gray- or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, fine- to medium-grained and locally coarse-grained, moderately foliated gneiss and less abundant granofels composed of quartz, microcline microperthite, and variable amounts of biotite, garnet, tourmaline, sillimanite, and magnetite.

Biotite-quartz-feldspar gneiss (Mesoproterozoic) - Gray-weathering, locally rusty, gray, tan, or greenish-gray, medium- to coarse-grained, moderately layered and foliated gneiss containing microcline microperthite, oligoclase, quartz, and biotite. Locally contains garnet, tourmaline, sillimanite, and magnetite; graphite and pyrrhotite occur in rusty gneiss. Locally contains layers of amphibolite or guartzite too thin to be shown.

Clinopyroxene-quartz-feldspar gneiss (Mesoproterozoic) - Pinkish-gray- or pinkish-buffweathering, white, pale-pinkish-white, or light-gray, medium-grained and locally coarse-grained, moderately well foliated gneiss composed of quartz, microcline, oligoclase, clinopyroxene, and trace amounts of epidote, biotite, titanite, and magnetite.

Pyroxene gneiss (Mesoproterozoic) - White- or tan-weathering, greenish-gray, fine- to mediumrained, well layered and foliated gneiss containing oligoclase and clinopyroxene. Quartz content is highly variable. Contains sparse amounts of epidote, titanite, scapolite, or calcite. Locally grades into marble. Commonly interlayered with amphibolite too thin to be shown. Marble (Mesoproterozoic) - White- or light-gray-weathering, white, grayish-white, or less commonly

pale green, fine- to coarse-crystalline, calcitic to locally dolomitic marble with accessory graphite,

phlogopite, chondrodite, and clinopyroxene. Contains pods and lenses of clinopyroxene-garnet skarn

hornblende skarn, and clinopyroxene-rich rock, and thin quartzite layers. Unit locally displays karst-like

Pyroxene-epidote gneiss (Mesoproterozoic) - White- or light-gray-weathering, light- greenish-gray or greenish-buff, fine- to medium-grained, moderately layered and foliated gneiss composed of quartz, plagioclase, pyroxene, epidote, and sparse titanite. Some layers are quartz-rich.

features in the form of bedrock pinnacles and solution joints and openings

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

Quartz-oligoclase gneiss (Mesoproterozoic) - White-weathering, light-greenish-gray, medium- to coarse-grained, moderately foliated gneiss composed of oligoclase or andesine, quartz, and variable amounts of hornblende, biotite, and clinopyroxene. Locally contains thin layers of amphibolite. Biotite-quartz-oligoclase gneiss (Mesoproterozoic) - White- or light-gray-weathering, medium-

gray or greenish-gray, medium- to coarse-grained, moderately well layered and foliated gneiss

composed of oligoclase or andesine, quartz, biotite, and trace amounts of garnet. Some outcrops

Hypersthene-quartz-plagioclase gneiss (Mesoproterozoic) - Gray- or tan-weathering, greenishgray or greenish-brown, medium-grained, moderately well layered and foliated, greasy lustered gneiss composed of andesine or oligoclase, quartz, clinopyroxene, hornblende, and hypersthene. Locally

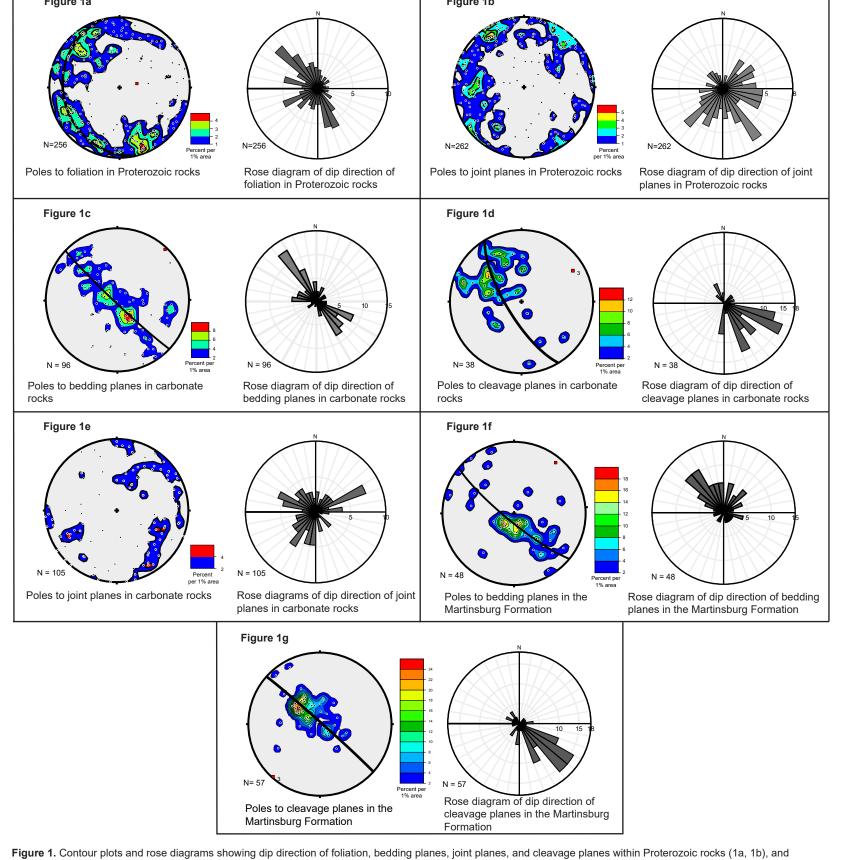
contains thin, conformable layers of amphibolite and mafic-rich quartz-plagioclase gneiss.

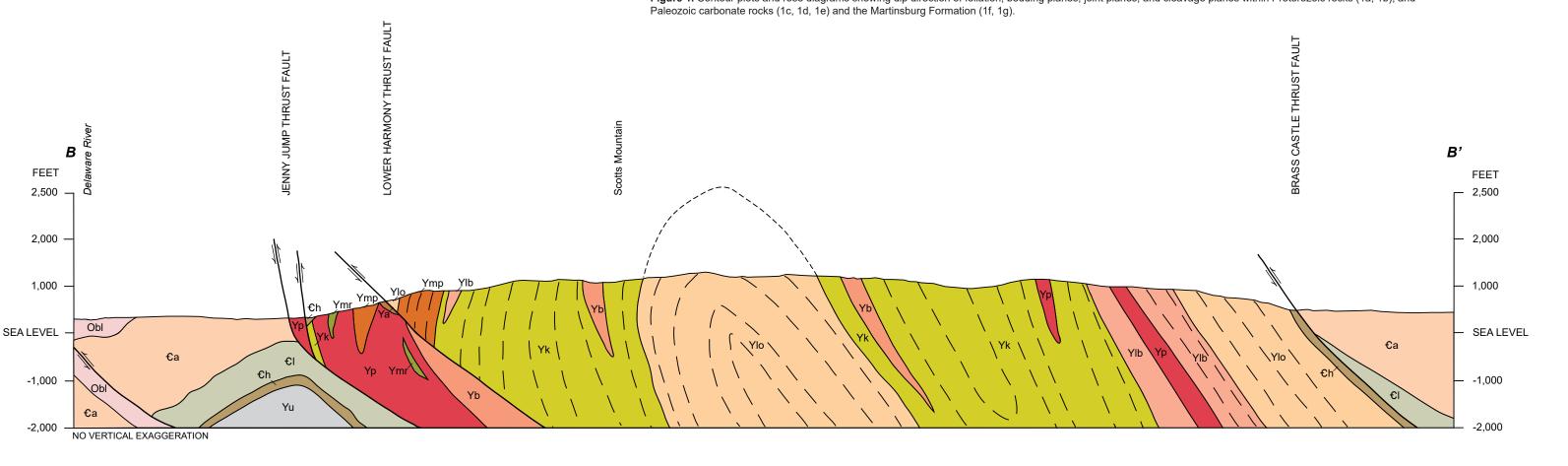
Amphibolite (Mesoproterozoic) - Grayish-black, fine- to medium-grained, moderately layered and foliated rock composed of hornblende and andesine. Some amphibolite contains biotite and/or clinopyroxene. Associated with almost all other Mesoproterozoic rocks in the map area. Most of the unit is interpreted to be metavolcanic, although some amphibolite layers within metasedimentary rocks may be metasedimentary in origin.

Microantiperthite alaskite (Mesoproterozoic) - Tan- to buff-weathering, light-greenish-gray, medium- to coarse-grained, massive, indistinctly foliated alaskite composed of microantiperthite brown rust-stained quartz, and oligoclase. Locally contains minor amounts of biotite, hornblende, altered clinopyroxene, and magnetite.

Anatectite (Mesoproterozoic) - Pinkish-gray- or pinkish-buff-weathering, white, pale-pinkish-white, or light-gray, coarse- to very coarse-grained, moderately foliated rock composed of quartz, microcline, oligoclase, clinopyroxene, and trace amounts of epidote, biotite, titanite, and magnetite. Unit is interpreted to represent large-scale melting of clinopyroxene-quartz-feldspar gneiss because large bodies of foliated, coarse-grained rocks of similar composition are spatially associated with this gneiss elsewhere in the New Jersey Highlands.

Mesoproterozoic rocks, undifferentiated – Shown in cross section only.





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EXPLANATION OF MAP SYMBOLS Contact - approximately located; dotted where concealed. **Faults** - Approximately located. Normal fault - U, upthrown side; D, downthrown side.

Inclined thrust fault - teeth on upper plate.

Folds in Paleozoic rocks showing trace of axial surface, direction and dip of limbs, and direction of plunge. Folds in bedding. Overturned syncline

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

→ Synform Overturned synform Overturned antiform

PLANAR FEATURES 40 Strike and dip of beds

Stike and dip of overturned beds 20 Strike and dip of cleavage in Paleozoic rocks

51 Strike and dip of crenulation cleavage in Paleozoic rocks Strike and dip of crystallization foliation in Proterozoic rocks Strike and dip of mylonitic foliation

LINEAR FEATURES

→ ⁶ Bearing and plunge of mineral lineation in Proterozoic rocks 18 Bearing and plunge of intersection of bedding and cleavage

18 Bearing and plunge of intersection of crenulation cleavage and cleavage

OTHER FEATURES Abandoned iron mine - M, magnetite; L, limonite

★ Abandoned rock quarry or mine Location of bedrock float used to draw contacts

— Form lines showing foliation in Proterozoic rocks in cross section Relative motion along faults in cross section