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

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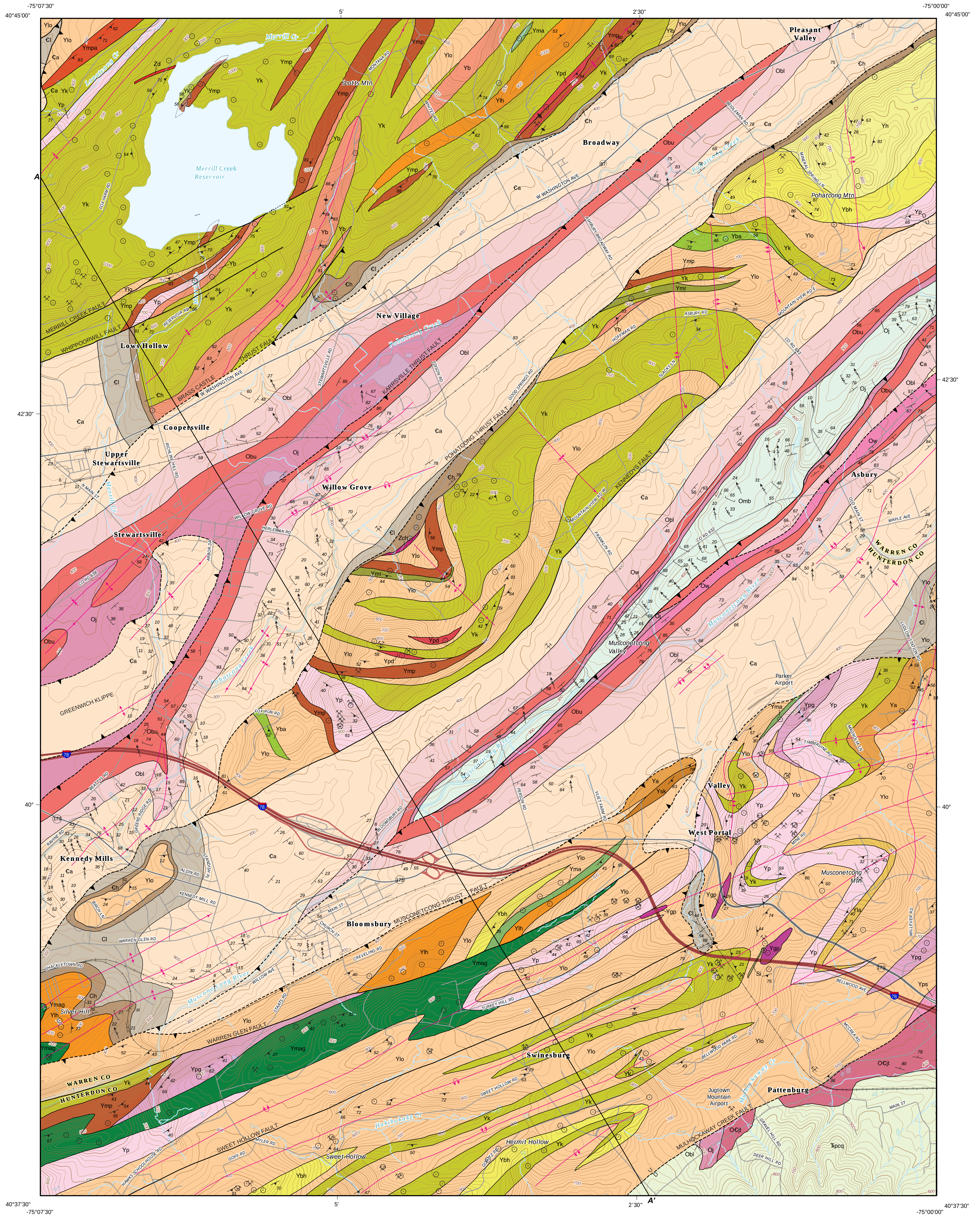
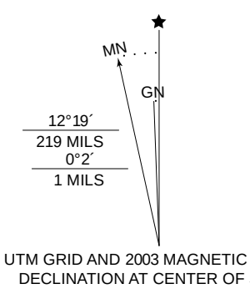
U.S. GEOLOGICAL SURVEY
NATIONAL COOPERATIVE GEOLOGIC MAPPING PROGRAM

BEDROCK GEOLOGIC MAP OF THE BLOOMSBURY QUADRANGLE
WARREN AND HUNTERDON COUNTIES, NEW JERSEY
OPEN FILE MAP OFM 153

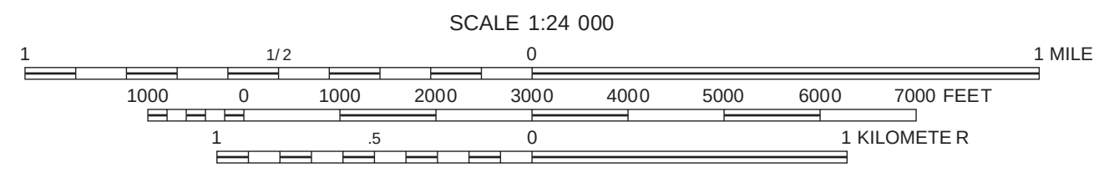


North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1,000-meter grid: Universal Transverse Mercator, Zone 18T

Roads............U.S. Census Bureau, 2016
Names............GNIS, 1979 - 2019
Hydrography............National Hydrography Dataset, 1899 - 2019
Contours............National Eleveation Dataset, 2001 - 2011
Boundaries............Multiple sourcesl see metadata file 2017 - 2018
Wetlands............FWS National Wetlands Inventory 2007



UTM GRID AND 2003 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



CONTOUR INTERVAL 20 FEET

LOCATION IN NEW JERSEY

Bedrock geology mapped by D.H. Monteverde,
G.C. Herman, and R. A. Volkert in 1983-1994 and 2002-2003,
Digital cartography by D. H. Monteverde, N.L. Malerba, and Z.C. Schagrin.
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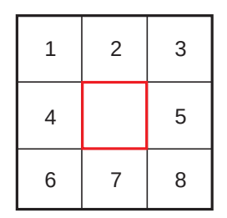
[1]retired, NJGWS

BEDROCK GEOLOGIC MAP OF THE BLOOMSBURY QUADRANGLE WARREN AND HUNTERDON COUNTIES, NEW JERSEY

By

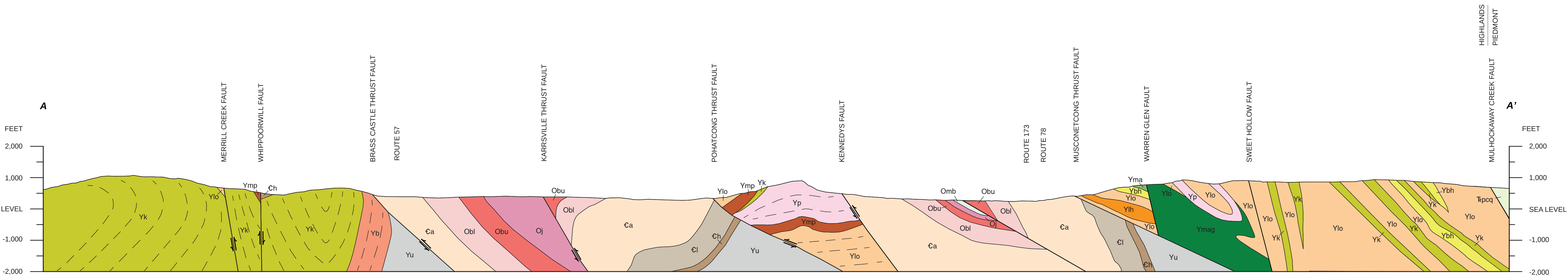
Donald H. Monteverde[1], Richard A. Volkert[1], and Gregory C. Herman[1]

2023



1 Bangor
2 Belvidere
3 Washington
4 Easton
5 High Bridge
6 Riegelsville
7 Frenchtown
8 Pittstown

ADJOINING QUADRANGLES



NO VERTICAL EXAGGERATION. ARROWS ALONG FAULTS SHOW RELATIVE MOTION.

INTRODUCTION

The Bloomsbury 7.5-minute quadrangle is located in western New Jersey in Warren and Hunterdon Counties. The quadrangle straddles the boundary between two physiographic regions; the New Jersey Highlands and the Piedmont. The geologic interpretations presented here supersede those shown on the bedrock geologic maps of Drake (1967) and Drake and others (1996). 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 New Jersey Highlands and Paleozoic rocks of the Valley and Ridge physiographic provinces. This map provides updated detailed geologic information on the stratigraphy, structure, ages and descriptions of geologic units in the map area. The cross section shows a vertical profile of the geologic units and their structure, and rose diagrams and contour plots in figures 1a through 1d provide a directional analysis of selected structural features. Surficial geologic mapping in the Bloomsbury quad was conducted by Witte (2023).

Damming of Merrill Creek on Scotts Mountain resulted in the creation of Merrill Creek Reservoir. The river forms the border between Warren and Hunterdon Counties in the southern third of this map and flows in a southwestern direction toward the Delaware River. The Musconetcong River constitutes the dominant drainage. The highest point is on Scotts Mountain just northeast of Merrill Creek Reservoir and attains a maximum elevation of 1,093 feet above sea level. Because bedrock there is no longer exposed, we relied on the results of geotechnical studies conducted prior to and during construction of the reservoir (Woodward-Clyde consultants, 1979a;b).

STRATIGRAPHY

Mesozoic rocks

The youngest rocks are in the Newark Basin, a northeast-trending half-graben that extends through the southeastern part of the map area. The Newark Basin contains a total of approximately 24,600 feet of interbedded Upper Triassic and Lower Jurassic sedimentary and igneous rocks. The Bloomsbury quadrangle includes approximately 1,500 feet in the middle part of this section, here consisting predominantly of conglomeratic facies of the Upper Triassic Passaic Formation.

Paleozoic rocks

Lower Paleozoic rocks of the Kittatinny Valley Sequence mainly underlie the Pohatcong and Musconetcong valleys. Formations of Cambrian through Ordovician age of the Kittatinny Valley Sequence were previously considered to be part of the Lehigh Valley Sequence of MacLachlan (1979) but were reassigned by Drake and others (1996) to the Kittatinny Valley Sequence. The Kittatinny Valley Sequence includes the Kittatinny Supergroup (Leithsville Formation, Allentown Dolomite, lower and upper parts of the Beekmantown Group), "Sequence at Wantage", Jacksonburg Limestone, and Martinsburg Formation. The Lower Cambrian Hardyston Quartzite rests unconformably on Mesoproterozoic rocks and, where present, on Neoproterozoic rocks.

Lower Paleozoic rocks of the Jutland Klippe Sequence are in fault contact with Mesoproterozoic rocks near Pattenburg where they are locally preserved along the Mesozoic border fault. These rocks become more abundant to the east in the High Bridge quadrangle (Monteverde and others, 2015). Rocks of the Jutland Klippe Sequence were folded and thrust over rocks of the Kittatinny Supergroup during the Taconic Orogeny. Alkalic dikes that have a geochemical affinity to lamprophyre intruded Mesoproterozoic rocks on Musconetcong Mountain and on Pohatcong Mountain. The dikes are interpreted to be lower Silurian based on radiometric ages of 435 ± 20 million years (Ma) (Zartman and others, 1967) to 422 ± 14 Ma (Eby and others, 1992) and they correlate to the Beemerville Intrusive Suite in the Branchville quadrangle (Drake and Monteverde, 1992).

Neoproterozoic rocks

A single diabase dike intruded Mesoproterozoic rocks along the northern edge of Merrill Creek Reservoir in the northwestern part of the area. The dike strikes northeast and has 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 ago) based on the fact they intruded only Mesoproterozoic rocks and they have geochemical compositions that differ from Paleozoic dikes and Mesozoic diabase and basalt (Volkert and Puffer, 1995). On the north side of Pohatcong Mountain, felsic volcanic rocks of inferred Neoproterozoic age of the Chestnut Hill Formation of Drake (1984) unconformably overlie Mesoproterozoic rocks.

Mesoproterozoic rocks

Mesoproterozoic rocks that are part of the New Jersey Highlands are widespread and abundant throughout all but the southeastern part of the map area. Most Mesoproterozoic rocks were metamorphosed to granulite facies during the Grenvillian Orogeny about 1,045 Ma (Volkert and others, 2010). 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 quartz-oligoclase gneiss and hornblende-quartz-oligoclase gneiss, and metamorphosed volcanic rocks mapped as biotite-quartz oligoclase gneiss. Some amphibolite intercalated with the Losee Suite also formed from a volcanic protolith. 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, hornblende-quartz-feldspar gneiss, and clinopyroxene-quartz-feldspar gneiss, calc-silicate rocks mapped as pyroxene gneiss, and marble. Most amphibolite intercalated with metasedimentary rocks formed from a volcanic protolith, although locally some amphibolite interlayered with metasedimentary rocks may 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, alaskite and local quartz syenite, quartz monzonite, syenite, and monzonite. Rocks of both suites have intruded the Losee Suite and supracrustal rocks. Byram and Lake Hopatcong rocks yielded similar U-Pb zircon ages of 1,185-1,182 Ma (Volkert and others, 2010). Widespread bodies of hornblende- and clinopyroxene-bearing granite and alaskite mapped as microantiperthite alaskite 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, and therefore are shown as having an uncertain correlation to other granitic rocks in the map area.

The youngest Mesoproterozoic rocks in the quadrangle are granite pegmatites that are undeformed and lack penetrative crystallization (metamorphic) foliation. They intruded most other Mesoproterozoic rocks in the area as tabular to irregular bodies that are highly discordant to foliation. Elsewhere in the Highlands similar undeformed pegmatites yielded U-Pb zircon ages of 1,004-986 Ma (Volkert and others, 2005).

STRUCTURE

Paleozoic bedding and cleavage

Bedding in the Paleozoic rocks is fairly uniform and strikes northeast an average of N.46°E. (Fig. 1a). Most beds dip northwest and less commonly southeast, although locally they are overturned steeply southeast. Bedding ranges in dip from 4° to 86° and averages 51°.

Cleavage (closely-spaced parallel partings) is present in most Paleozoic rocks but is best developed in finer-grained lithologies such as shale and slate of the Martinsburg Formation. Cleavage in the Paleozoic rocks typically strikes northeast an average of N.38°E. (Fig. 1c), parallel to the strike of bedding. Cleavage dips predominantly southeast at 11° to 86° and averages 51°. 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 is developed in the footwall of large overthrusts (Herman and Monteverde, 1989; Herman and others, 1997). The crenulation cleavage varies in strike from N.89°E. to N.89°W. and averages N.66°E. It dips an average of 29° south or an average of 34° north.

Proterozoic foliation

Crystallization foliation (the parallel alignment of mineral grains) in the Mesoproterozoic rocks is an inherited feature resulting from compressional stresses during the Grenvillian Orogeny about 1,045 Ma. The strike of foliation is fairly uniform throughout the area and strikes northeast an average of N.47°E. (Fig. 1d). Foliation varies locally due to folding and strikes mainly northwest in the hinges of major folds. Northeast-trending foliations dip southeast and less commonly northwest at 21° to 90° and average 58°. Northwest-striking foliation dips gently to moderately northeast and locally southwest at 19° to 40°.

Folds

Folds in the Paleozoic rocks formed during the Taconic and Alleghanian Orogenies at about 450 Ma and 250 Ma, respectively. Paleozoic folds are open to tight; upright to locally overturned; and are gently inclined to recumbent. Larger folds in the map area plunge northeast. 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 southwest in the area of Clinton in Hunterdon County. Fold intensity and overturning increase toward this Taconic structural culmination.

Folds in Mesoproterozoic rocks deform planar metamorphic fabrics and, therefore, postdate the development of crystallization foliation. Characteristic fold patterns on Scotts Mountain include broad northeast-plunging, upright to locally northwest-overturned antiforms and synforms. Folds on Pohatcong Mountain are characterized by open, south-southeast-plunging, west-overturned or upright antiforms and synforms. Folds on Musconetcong Mountain include east-northeast-plunging, north-northwest overturned antiforms and synforms that refold earlier-formed open to tight, south-plunging and west-overturned antiforms and synforms. Throughout the map area the average plunge of east-northeast trending folds is 22° and of south trending folds is 40°.

Faults

The structural geology of the Bloomsbury quadrangle is dominated by a series of northeast-trending faults that deform both Mesoproterozoic and Paleozoic rocks. These faults were active during the Grenvillian, Taconic and Alleghanian Orogenies and during the Mesozoic. Most faults are characterized by brittle deformation fabric consisting of brecciation, the retrogression of mafic mineral phases, chlorite or epidote-coated fractures or slickensides, and/or close-spaced fracture cleavage. A few faults are characterized by ductile deformation fabric, noted in the fault description below. Starting from the north and moving south, the principal faults include the Merrill Creek fault, Whippoorwill fault, Brass Castle thrust fault, Karrsville thrust fault, Pohatcong thrust fault, Kennedys fault, Musconetcong thrust fault, Warren Glen fault, Sweet Hollow fault, and Mulhockaway Creek fault. The newly recognized and named Merrill Creek fault on Scotts Mountain strikes northeast and dips steeply southeast. It contains Mesoproterozoic rocks on both the hanging wall and footwall along its entire length. Kinematic indicators suggest components of both reverse and strike-slip movement but the relative timing of each is not well constrained. Good exposures of this fault are seen along a small drainage north of Lows Hollow and along the gorge south of Merrill Creek Reservoir. The Whippoorwill fault strikes northeast, parallel to the Merrill Creek fault on Scotts Mountain, and it dips steeply southeast to vertically. Drake (1967) interpreted this fault as a moderately southeast-dipping thrust fault, whereas Kummel (ca. 1900), Bayley (1941) and Monteverde and others (1994) interpreted it as a normal fault. Our current mapping recognizes kinematic indicators that are consistent with a normal movement sense. The fault displays consistent brittle fault fabric much like that of the Merrill Creek fault. The fate of both faults along strike to the northeast is uncertain because of poor bedrock exposure, but it appears they are losing displacement and terminate just east of the reservoir. The northeast-striking, southeast-dipping Karrsville thrust fault occurs in the Pohatcong Valley. It contains Paleozoic rocks on the hanging wall and footwall along its entire length. The fault merges with, or is cut off by, the Brass Castle thrust fault south of County House Mountain in the Washington quadrangle (Drake and others, 1994). The northeast-striking, southeast-dipping Brass Castle thrust fault bounds the southeast side of Scotts Mountain where it contains Paleozoic rocks on the hanging wall and Mesoproterozoic rocks on the footwall. 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 northeast-striking, southeast-dipping Pohatcong thrust fault borders the north side of Pohatcong Mountain. It contains Mesoproterozoic rocks and Hardyston Quartzite on the hanging wall and Paleozoic rocks on the footwall. This fault merges with, or is cut off by, Kennedys fault just south of Pohatcong Mountain. The northeast-striking, southeast-dipping Kennedys fault borders the southeast side of Pohatcong Mountain. It is a steeply dipping reverse fault that contains Paleozoic rocks on the hanging wall and Mesoproterozoic rocks on the footwall. South of Pohatcong Mountain it contains Paleozoic rocks on both sides of the fault. The northeast-striking, southeast-dipping Musconetcong thrust fault borders the northwest side of Musconetcong Mountain. It contains Mesoproterozoic rocks on the hanging wall and Paleozoic rocks on the footwall along its entire length. At West Portal, Leithsville Formation is exposed in a small window through Mesoproterozoic rocks. The northeast-striking, moderately to steeply southeast-dipping Warren Glen fault bounds the west side of Musconetcong Mountain where it contains Mesoproterozoic rocks on both the hanging wall and footwall. Drake (1967) recognized this fault but ended it just inside the quadrangle. Our mapping extends the fault to West Portal where it is cut off by the Musconetcong thrust fault. A ductile deformation fabric characterizes the Warren Glen fault that is well exposed in a stream valley south of Bloomsbury. The newly recognized and named Sweet Hollow fault occurs along the crest of Musconetcong Mountain where it contains Mesoproterozoic rocks on both sides. The fault strikes northeast and dips steeply southeast to vertically. It is characterized by a ductile deformation fabric. Kinematic indicators suggest the dominant movement sense is right lateral strike-slip. The Mulhockaway Creek border fault is a major structural feature that contains Mesoproterozoic rocks on the footwall and Mesozoic and local Paleozoic rocks on the hanging wall. The fault strikes northeast and dips southeast. Mesoproterozoic and Paleozoic rocks throughout the map area are locally deformed by small, northeast or northwest-trending faults, most of which occur at outcrop scale. Widths of these faults range from inches to a few feet, with some of the wider fault zones likely resulting from the intersection of smaller anastomozing faults.

Joints

Joints are a common feature in the Paleozoic and Mesoproterozoic rocks. They are developed in all Paleozoic rocks, but 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.45°E. (Fig. 1b) and dips moderately to steeply northwest an average of 62°. The other set strikes northwest an average of N.49°W. (Fig. 1b) and dips predominantly southwest an average of 67°.

Joints in Mesoproterozoic rocks are characteristically planar, moderately well formed, moderately to widely spaced, and moderately to steeply dipping. Surfaces are typically unmineralized, except where near faults, and are smooth and less commonly slightly irregular. Joints are typically spaced from a foot to tens of feet apart. Those in massive-textured rocks such as granite tend to be more widely spaced, irregularly formed and discontinuous than joints in layered gneiss. Those formed near faults typically are spaced more closely and one foot or less apart. The dominant joint strike in Mesoproterozoic rocks is nearly orthogonal to the strike of crystallization foliation, and this orthogonal relationship is present in Mesoproterozoic rocks throughout the Highlands (Volkert, 1996). As a result, joint sets are not uniform due to folding. The dominant set strikes northwest an average of N.40°W. and dips moderately to steeply southwest and less commonly northeast. A subordinate set strikes northeast an average of N.50°E. and dips moderately to steeply southeast and the northwest with equal abundance. The average dip of all joints is 71°.

ECONOMIC RESOURCES

Mesoproterozoic and Paleozoic rocks hosted deposits of iron ore mined predominantly during the 19th century. Detailed descriptions of most of these mines are given in Bayley (1910, 1941). Magnetite was extracted from numerous mines hosted by various Mesoproterozoic rocks on Scotts Mountain, Pohatcong Mountain and Musconetcong Mountain. Limonite was mined from Paleozoic rocks in the Pohatcong and Musconetcong Valleys. Mica (phlogopite) was mined from Mesoproterozoic rocks on Scotts Mountain, one of which is currently beneath Merrill Creek Reservoir. Mesoproterozoic granite and gneiss were quarried for crushed stone on Musconetcong Mountain and marble was quarried on Pohatcong Mountain. Paleozoic dolomite was quarried at several locations in the Pohatcong and Musconetcong Valleys. Deposits of sand and gravel were formerly worked in the map area (Witte, 2023).

DESCRIPTION OF MAP UNITS

MESOZOIC ROCKS

TRpcq **Passaic Formation (Lower Jurassic and Upper Triassic)** – Reddish-brown to brownish-red, medium- to coarse-grained pebble conglomerate, pebbly sandstone and feldspathic sandstone in upward-fining sequences 3 to 6 ft. thick. Clasts are subangular to subrounded, quartz and quartzite in sandstone matrix. Sandstone is medium- to coarse-grained, feldspathic, and locally contains pebble and cobble layers. Maximum thickness unknown.

PALEOZOIC ROCKS

Sl **Lamprophyre dikes (Lower to Middle Silurian)** – Light-medium- to medium-dark-gray, fine-grained to aphanitic dikes and small intrusive bodies of mainly alkalic composition. Contacts are typically chilled and sharp against enclosing country rock. Dikes intrude rocks that range in age from Mesoproterozoic through Ordovician. Field relationships in combination with radiometric age data of dikes indicate a lower Silurian age.

Jutland Klippe Sequence

OЄjt **Rocks of the Jutland Klippe Sequence, undifferentiated (Middle Ordovician to upper Cambrian)** – Heterogeneous sequence of interbedded red, green, tan and gray shale to sandstone; interbedded fine-grained graywacke siltstone and beds or lenses of sandstone. Regionally interbedded fine-grained, thin-bedded limestone, plus or minus floating quartz-sand grains. Limestone locally resembles an intraformational conglomerate. Contains graptolites in the span of *Anisograptus* to *Isograptus caduceus* (Berry, 1960) and conodonts of the *Cordylodus proavus* to *Paroistodus proteus* and *Prioniodus triangularis* to *Pygodus anserinus* faunas of the North Atlantic Realm (Karklins and Repetski, 1989). Lower contact probably a fault. Thickness is unknown.

Kittatinny Valley Sequence

Omb **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 upwards through planar laminated siltstone into slate, or laminated siltstone grading upwards 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 Jackonsburg 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) indicating Shermanian (Caradocian) age. Thicknesses regionally range from 1,500 ft. to a maximum of approximately 4,000 ft. near Belvidere to the north of the Bloomsbury quadrangle.

Oj **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 thin- to medium-bedded, commonly fossiliferous, interbedded fine- and medium-grained limestone and pebble-and-fossil limestone conglomerate (cement-limestone facies). Elsewhere, thick- to very thick-bedded 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 ft. to 1,000 ft.

Ow **"Sequence at Wantage" (Middle Ordovician)** – Interbedded, very thin- to medium-bedded limestone, dolomite, siltstone, and argillite. Upper carbonate facies, locally present outside of the map area, is moderate-yellowish-brown to olive-gray weathering, light- to dark-gray, very fine- to fine-grained, laminated to medium-bedded limestone and dolomite. Rounded quartz sand occurs locally as floating grains and very thin lenses. Clastic facies contains medium-gray, grayish-red to grayish-green, thin- to medium-bedded mudstone, siltstone and fine-grained to pebbly sandstone. Fine-grained beds commonly contain minor disseminated subangular to subrounded, medium-grained quartz sand and pebble-sized chert. Some coarse-grained beds are cross-stratified. Unit is restricted to lows on surface of Beekmantown unconformity. Regional relations and North American Midcontinent province conodonts within carbonate facies, identified by Anita Harris (U.S. Geological Survey, written communication, 1990) limit age range from no older than Rocklandian to no younger than Kirkfieldian. May be as much as 150 ft. thick. Unit is well exposed in vicinity of Asbury.

Obu **Beekmantown Group, upper part (Lower Ordovician)** – Light- to medium-gray- to yellowish-gray-weathering, 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 dark-gray, 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 coarse-grained, medium- to thick-bedded, strongly fetid dolomite. Contains pods, lenses and layers of dark-gray 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 ft. in thickness but is as much as 800 ft. thick.

Obl **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 dark-yellowish-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-gray-weathering, medium- to dark-gray, fine-grained, thin- to medium-bedded limestone. Limestone has "reticulate" 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 sequence consists of medium- to medium-dark-gray, aphanitic to coarse-grained, thinly-laminated to thick-bedded, slightly fetid domolite having quartz-sand 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 ft. thick.

Єa **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 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.

Єl **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.

Єh **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). Thickness ranges from 0 ft. to a maximum of 200 ft. regionally.

PROTEROZOIC ROCKS

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. Locally occurring pyrite blebs are common. Contacts are typically chilled and sharp against enclosing Mesoproterozoic country rock.

Zch **Chestnut Hill Formation (Neoproterozoic)** – Dark greenish-gray, medium-grained, thin bedded feldspathic sandstone and possible felsic volcanic rock composed of euhedral to subhedral, equidimensional, pinkish-white K-feldspar grains in a dark greenish-gray, fine-grained matrix. Unit is exposed as a very thin remnant that unconformably overlies Mesoproterozoic rocks on the west side of Pohatcong Mountain.

Ygp **Granite pegmatite (Neoproterozoic)** - Pinkish-gray- to buff-weathering, pinkish-white or light-pinkish-gray, coarse- to very-coarse-grained, undeformed and nonfoliated granite bodies of variable thickness. Intrude most other Mesoproterozoic rocks in the map area as tabular to irregular bodies that are highly discordant to crystallization foliation. Composed principally of microcline microperthite, quartz, and oligoclase. Locally contains abundant hornblende. Most pegmatite in the area is interpreted to be part of the Byram Intrusive Suite.

Vernon Supersuite (Volkert and Drake, 1998)
Byram Intrusive Suite (Drake, 1984)

Ybh **Hornblende granite (Mesoproterozoic)** – Pinkish-gray- to 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 bodies of pegmatite and amphibolite too small to be shown.

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

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

Ypg **Pyroxene granite (Mesoproterozoic)** – Buff- or white-weathering, greenish-gray, medium- to coarse-grained, foliated granite containing mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Common accessory minerals include titanite, magnetite, apatite, and sparse pyrite.

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

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

Back-arc Basin Supracrustal Rocks

Yk **Potassic feldspar gneiss (Mesoproterozoic)** – Light-gray- or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, medium- to locally coarse-grained, foliated gneiss composed of quartz, microcline microperthite, oligoclase, and varied amounts of biotite, garnet, tourmaline, sillimanite, and magnetite.

Yb **Biotite-quartz-feldspar gneiss (Mesoproterozoic)** – Gray-weathering, locally rusty, gray, tan, or greenish-gray, medium- to coarse-grained, compositionally 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 interlayered with amphibolite or quartzite too thin to be shown.

Ymh **Hornblende-quartz-feldspar gneiss (Mesoproterozoic)** – Light-gray- or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, foliated gneiss composed of quartz, microcline microperthite, oligoclase, hornblende, and varied amounts of biotite and magnetite.

Ymp **Clinopyroxene-quartz-feldspar gneiss (Mesoproterozoic)** – Pinkish-gray- or pinkish-buff- weathering, white, pale-pinkish-white, or light-gray, medium- to coarse-grained, foliated gneiss composed of quartz, microcline, oligoclase, clinopyroxene, and local epidote, biotite, titanite, and magnetite.

Yp **Pyroxene gneiss (Mesoproterozoic)** – White- or tan-weathering, greenish-gray, fine- to medium-grained, compositionally layered and foliated gneiss containing oligoclase and clinopyroxene. Quartz content is highly varied. Contains sparse amounts of epidote, titanite, scapolite, or calcite. Commonly interlayered with amphibolite and (or) marble, or contains pods and layers of clinopyroxene-rich rock mapped as diopsidite.

Ymr **Marble (Mesoproterozoic)** – White- or light-gray-weathering, white or grayish-white, medium- to coarse-grained, calcitic to locally dolomitic marble containing graphite, phlogopite, chondrodite, and clinopyroxene. Contains pods and lenses of clinopyroxene-hornblende skarn or scapolite-phlogopite rock. Locally contains relict karst features that include bedrock pinnacles, solution openings, and paleo-solution breccia.

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

Yla **Albite-oligoclase alaskite (Mesoproterozoic) –** Pale pink, or white-weathering, light-greenish-gray or light-pinkish-green, medium to coarse-grained, foliated rock composed of albite or oligoclase, quartz, and variable amounts of hornblende, augite and magnetite. Locally contains rutile. Commonly contains conformable layers of amphibolite.

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

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

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 magnetite. Some outcrops contain minor clinopyroxene.

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

Other Rocks

Ya **Amphibolite (Mesoproterozoic)** – Grayish-black, fine- to medium-grained, foliated rock composed of hornblende and andesine. Some amphibolite contains biotite and (or) clinopyroxene. Most of the unit is interpreted to be metavolcanic, although some of it layered with metasedimentary rocks may be metasedimentary. All types are undifferentiated on the map.

Yma **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.

Ymag **Microantiperthite granite (Mesoproterozoic)** – Tan- to 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 minor amounts of biotite, altered clinopyroxene, and magnetite. Unit is tentatively interpreted to be petrogenetically related to intrusive rocks of the Byram and Lake Hopatcong Suites.

Ympa **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 partial 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, in the Wawayanda, Stanhope, Dover, and Belvidere quadrangles.

Ypd **Diopsidite (Mesoproterozoic)** – Dark grayish-green-weathering, light- to medium-green, medium-grained, nearly monomineralic rock composed of clinopyroxene (diopside). Unit is typically thin and discontinuous over distances of a few hundred ft. Commonly spatially associated with, or interlayered with, pyroxene gneiss.

Ysk **Skarn (Mesoproterozoic)** – Dark green to black, medium- to very-coarse-grained, weakly foliated to undeformed rock composed of hornblende, clinopyroxene and sparse local epidote.Formed by the metasomatic alteration of rocks that were originally carbonate-bearing. At West Portal unit is intruded by abundant quartz-microcline-albite pegmatite and spatially associated with quartz-tourmaline rock with locally developed symplectic texture.

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

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EXPLANATION OF MAP SYMBOLS

Contact - approximately located; dotted where concealed.

Faults - solid where well located; dashed where approximately located.

Normal fault - U, upthrown side; D, downthrown side.

Inclined thrust fault - teeth on upper plate.

FOLDS

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

Syncline
Anticline
Overturned syncline
Overturned anticline

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

Synform
Antiform
Overturned synform
Overturned antiform

PLANAR FEATURES

40 **Strike and dip of beds**
20 **Strike and dip of cleavage in Paleozoic rocks**
40 **Strike and dip of crenulation cleavage in Paleozoic rocks**
Strike and dip of crystallization foliation in Proterozoic rocks
62 **Inclined**
Vertical

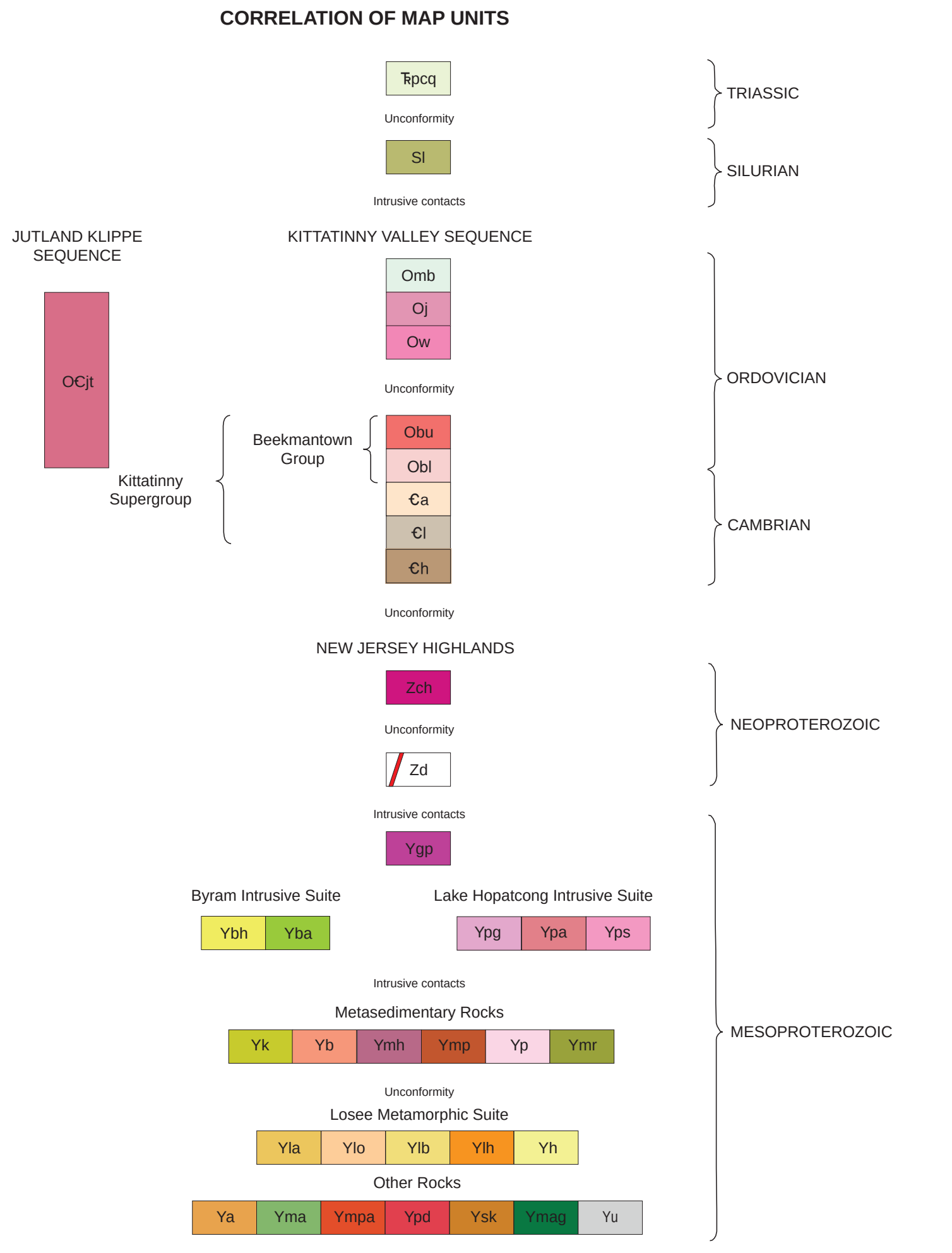
LINEAR FEATURES

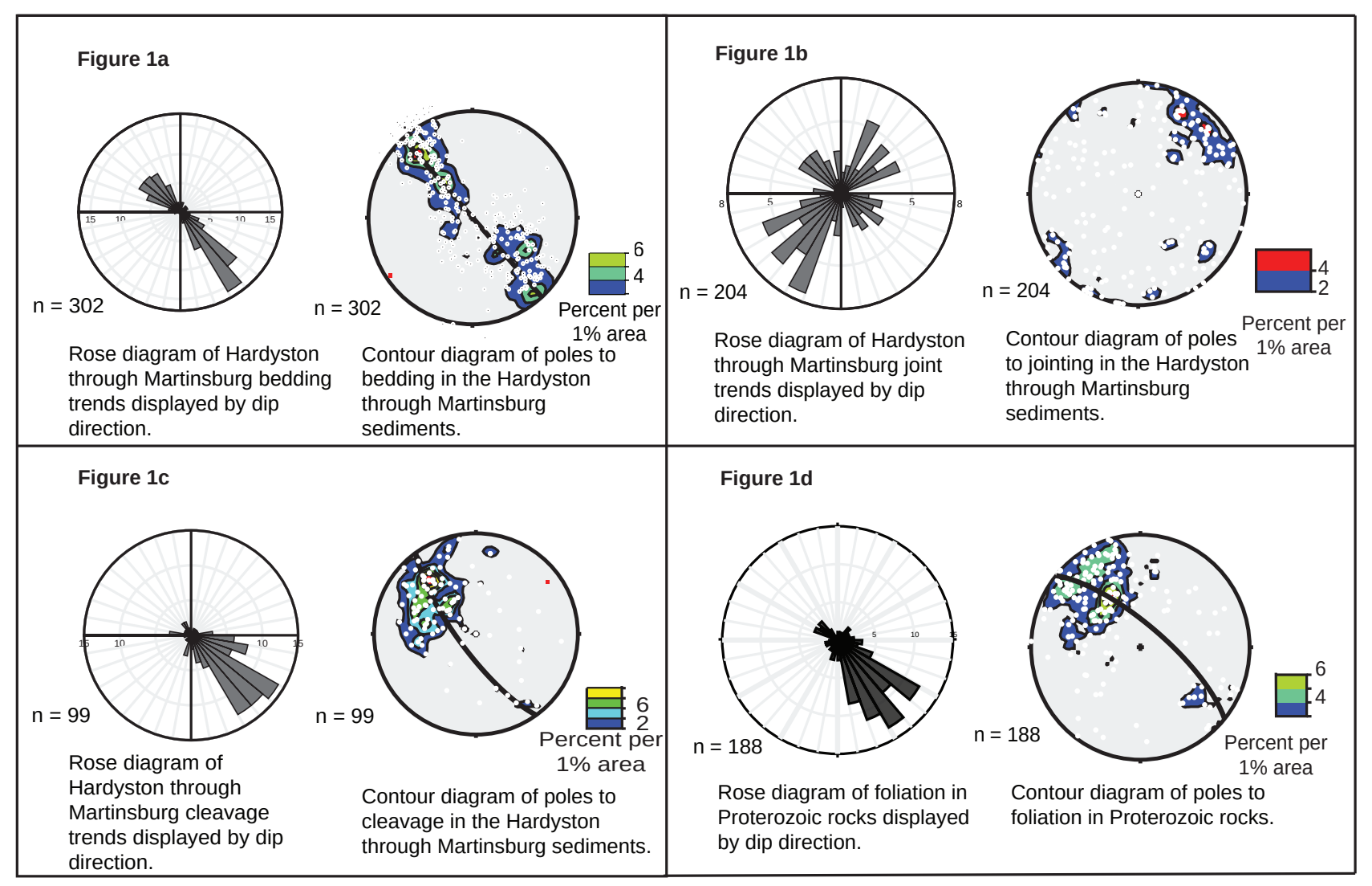
18 **Bearing and plunge of intersection of bedding and cleavage**
18 **Bearing and plunge of intersection of crenulation cleavage and cleavage**

OTHER FEATURES

⚒ **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
57 **State highway**
78 **Interstate highway**

CORRELATION OF MAP UNITS





Rose diagram of Hardyston through Martinsburg bedding trends displayed by dip direction.

Contour diagram of poles to bedding in the Hardyston through Martinsburg sediments.

Rose diagram of Hardyston through Martinsburg joint trends displayed by dip direction.

Contour diagram of poles to jointing in the Hardyston through Martinsburg sediments.

Rose diagram of Hardyston through Martinsburg cleavage trends displayed by dip direction.

Contour diagram of poles to cleavage in the Hardyston through Martinsburg sediments.

Rose diagram of foliation in Proterozoic rocks displayed by dip direction.

Contour diagram of poles to foliation in Proterozoic rocks.

Figure 1: Contour plots and rose diagrams showing dip direction of bedding planes (fig.1a) joint planes (1b), and cleavage planes (1c) within the Hardyston through Martinsburg Formations and showing dip direction of foliation in Proterozoic rocks (1d). N is the number of readings used in the diagram.