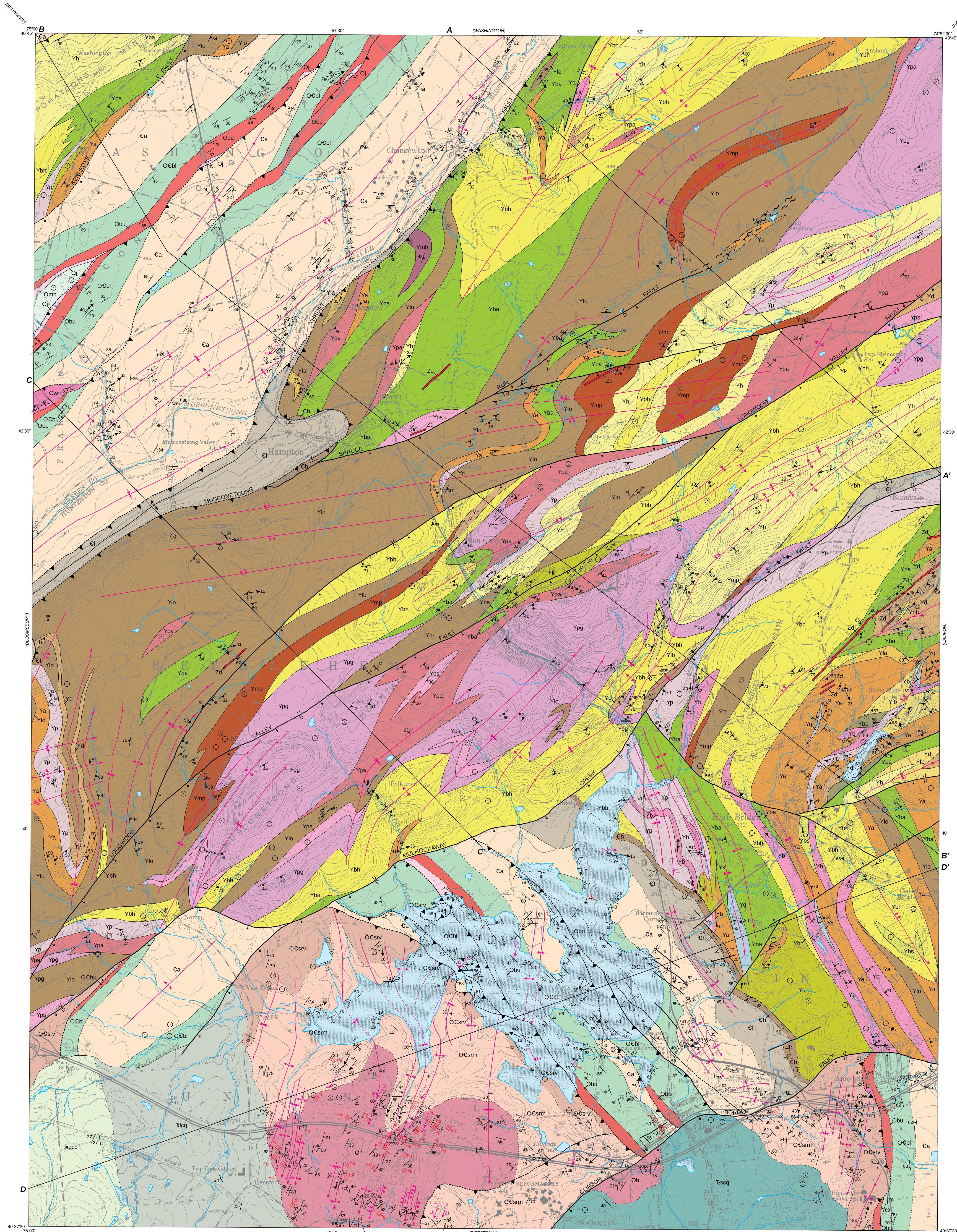
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

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



Topographic base mapped by the Army Map Service.
Edited and published by the United States Geological Survey, 1954.

Control by USC&GS, USSCS, and New Jersey Geodetic Survey.

Topography form aerial photographs by photogrammetric methods. Aerial photographs taken 1942. Field check 1942. Culture revised by the United States Geological Survey 1954. Photorevised 1970.

Polyconic projection. 1927 North American datum 10,000-foot grid based on New Jersey coordinate system 1000-meter Universal Transverse Mercator grid ticks, zone 18.

To place on the predicted North American Datum 1983 move the projection lines 6 meters south and 32 meters west as shown by dashed corner ticks.

LOCATION IN NEW JERSEY

SCALE 1:24,000

1 .5 2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

11°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1970

Bedrock geology mapped by D.H Monteverde and R.A. Volkert in 1984, 1996 and 2011.
Digital cartography by R.S. Pristas
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Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 04HQAG0043. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

Bedrock Geologic Map of the High Bridge Quadrangle
Hunterdon and Warren Counties, New Jersey

by
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2015

INTRODUCTION

The High Bridge quadrangle is located in Warren and Hunterdon Counties, western New Jersey. The dominant streams are the southwest-flowing Musconetcong River in the northwest part of the area and the south-flowing South Branch Raritan River in the eastern part. The latter has a gradient decline of about 240 feet between Califon and High Bridge, resulting in deeply incised bedrock ridges and the cutting of scenic Ken Lockwood Gorge. Smaller streams, such as Spruce Run, Rocky Run, Willoughby Creek, and Mulhockaway Creek, drain other valleys that trend mainly northeast. Damming of Spruce Run, south of Musconetcong Mountain, produced Spruce Run Reservoir, an important source of water for the northern part of the state.

The quadrangle straddles the boundary between the New Jersey Highlands and Piedmont Provinces, and the Mulhockaway Creek border fault provides a structural boundary between the two provinces. Rocks of Mesoproterozoic age of the Highlands underlie Pohatcong and Musconetcong Mountains. Paleozoic rocks underlie the Musconetcong Valley, in the northwest, and Paleozoic and Mesozoic rocks underlie the Spruce Run Reservoir area in the south.

The geology of the High Bridge quadrangle has been studied for more than a century (for example, Lewis and Kummel, 1910; Bayley, 1910, Bayley and others, 1914; Markewicz, 1968; and Drake and others, 1996), initially for economic deposits of various minerals in the area, and later for water resources. This map presents the results of more recent detailed geologic mapping, along with new interpretations and information on the bedrock, that extend previous work and facilitate continuity of lithologic contacts and structures with adjacent quadrangles.

STRATIGRAPHY

Mesozoic Rocks

The youngest rocks in the quadrangle are in the Piedmont Province. They were deposited in the Newark Basin, a northeast-trending half-graben that extends through northern and central New Jersey. The Newark Basin contains approximately 24,600 ft. of interbedded Upper Triassic and Lower Jurassic sedimentary and igneous rocks. In the map area they include conglomerates of the Upper Triassic Stockton, Lockatong and Passaic Formations.

Paleozoic Rocks

Lower Paleozoic rocks of Cambrian through Ordovician age of the Kittatinny Valley Sequence underlie the Musconetcong Valley and Spruce Run Reservoir areas. They are unconformably overlain by Mesozoic rocks of the Piedmont south and west of Spruce Run Reservoir, and are in fault contact with Mesoproterozoic rocks south of Musconetcong Mountain. They 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 Hardyston Quartzite and the Kittatinny Supergroup (from oldest to youngest, Leithsville Formation, Allentown Dolomite, lower and upper parts of the Beekmantown Group), "Sequence at Wantage", Jacksonburg Limestone, and Martinsburg Formation. Lower Paleozoic rocks of the Jutland klippe sequence are in fault contact with Mesoproterozoic rocks south of Musconetcong Mountain, where they are sparsely preserved along the Mesozoic border fault. To the west and south of Spruce Run Reservoir, they are unconformably overlain by Mesozoic rocks. Rocks of the Jutland Klippe Sequence were folded and thrust over rocks of the Kittatinny Supergroup during the Taconian Orogeny.

Neoproterozoic Rocks

Numerous diabase dikes of Neoproterozoic age intrude Mesoproterozoic rocks in the area but are absent in Paleozoic and younger rocks. They were emplaced at about 600 million years ago (Ma) during rifting of the eastern Laurentian continental margin in response to breakup of the supercontinent Rodinia (Volkert and Puffer, 1995). Dikes in the quadrangle are as much as 20 feet thick. They strike mainly northeast and have sharp contacts and chilled margins against enclosing Mesoproterozoic rocks.

Mesoproterozoic Rocks

The oldest rocks in the High Bridge quadrangle are Mesoproterozoic in age and they include various granites and gneisses. Most Mesoproterozoic rocks were metamorphosed to granulite facies about 1050 Ma (Volkert, 2004; Volkert and others, 2010) during the Ottawan orogeny, a phase of the Grenville Orogenic Cycle. Temperature estimates for this high-grade metamorphism are about 769°C based on calcite-graphite thermometry (Peck and others, 2006).

Among the oldest Mesoproterozoic rocks is the Losee Suite, interpreted as a sequence of metamorphosed volcanic and plutonic rocks of calc-alkalic composition formed in a continental-margin magmatic arc (Volkert, 2004). The Losee Suite includes quartz-oligoclase gneiss, albite-oligoclase granite, biotite-quartz-oligoclase gneiss, hypersthene-quartz-plagioclase gneiss, and diorite gneiss. These rocks are associated spatially with a sequence of supracrustal rocks formed in a back-arc basin inboard of the Losee magmatic arc (Volkert, 2004). Supracrustal rocks include potassic feldspar gneiss, biotite-quartz-feldspar gneiss, hornblende-quartz-feldspar gneiss, pyroxene-quartz-feldspar gneiss, pyroxene gneiss, and quartzite. Rocks mapped as amphibolite are associated with both the Losee Suite and supracrustal rocks. Losee Suite and supracrustal rocks yield similar sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages of 1299 to 1248 Ma (Volkert and others, 2010).

Granitic rocks are widely distributed in the map area. They consist of hornblende granite and related rocks of the Byram Intrusive Suite and pyroxene granite and related rocks of the Lake Hopatcong Intrusive Suite that have an A-type geochemical composition (Volkert, 1995; Volkert and others, 2000). Together, these two suites constitute the Vernon Supersuite (Volkert and Drake, 1998). Elsewhere in the Highlands granite of the Byram and Lake Hopatcong suites yields SHRIMP U-Pb zircon ages of 1184 to 1182 Ma (Volkert and others, 2010).

The youngest Mesoproterozoic rocks are small, irregular bodies of granite pegmatite too small to be shown on the map. They are undeformed and have discordantly intruded most other Mesoproterozoic rocks. Regionally, they yield U-Pb zircon ages of 1004 to 987 Ma (Volkert and others, 2005).

STRUCTURE

Paleozoic bedding and cleavage

Bedding in the Paleozoic rocks in the quadrangle is fairly uniform and strikes northeast at about N.35°E. (fig. 1). Most beds dip northwest and, less commonly, southeast, but locally they are overturned steeply southeast. However, in the area of Spruce Run Reservoir beds strike northwest and dip southwest. Bedding ranges in dip from horizontal to 60° overturned and averages about 47°.

Cleavage (closely-spaced parallel partings) occurs in most of the Paleozoic rocks but is best developed in finer-grained rocks such as shale and slate of the Martinsburg Formation and locally in the Jutland klippe sequence. Cleavage in the Paleozoic rocks generally trends northeast with a mean direction of N.38°E. (fig. 2), subparallel to the trend of bedding. Cleavage dips predominantly southeast at 14° to 90° and averages 57°. A second (crenulation) cleavage that cuts the primary cleavage occurs only in the Martinsburg Formation. This 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). The crenulation cleavage ranges in strike from N.30°E. to N.70°W., with a mean direction of N.66°E. and dips 78°S to 53°N.

Proterozoic foliation

Crystallization foliation (the parallel alignment of mineral grains) in the Mesoproterozoic rocks is an inherited feature from compressional stresses that deformed the rocks during high-grade metamorphism. Foliation trends are varied because of multiplefolding, as well as the structural rotation of Mesoproterozoic rocks in fault blocks. Foliations on Pohatcong and Musconetcong Mountains strike predominantly northeast and average N.43°E. (fig. 3). Northeast-trending foliations dip predominantly southeast and, less commonly, northwest. Northwest-trending foliations that dip moderately northeast are in the hinges of major folds and in a rotated fault block near High Bridge. The dip of all foliations ranges from 11° to 90° and averages 53°.

Folds

Folds in the Paleozoic rocks formed during the Taconian and Alleghanian orogenies at about 450 Ma and 250 Ma, respectively, and they postdate the development of bedding. Paleozoic folds are open to tight, upright to locally overturned, and gently inclined to recumbent. Larger Paleozoic folds in the map area strike northeastward and plunge predominantly toward the northeast. Folds of Taconian age are cut by younger Alleghanian faults (Herman and Monteverde, 1989; Herman and others, 1997). These folds formed in the hinterland of emergent Taconic thrusting in the area of Clinton, NJ. Fold intensity and degree of overturning increase toward this Taconic structural culmination in the southwest.

Folds that formed from compressional stresses during the Ottawan orogeny deform earlier-formed, planar metamorphic fabrics in Mesoproterozoic rocks. Therefore these folds postdate the development of crystallization foliation. Characteristic fold patterns on Musconetcong Mountain include broad, predominantly northeast to locally southwest-plunging, upright to northwest and, less commonly, southeast overturned antiforms and synforms. Other folds are east-plunging, upright to north-overturned antiforms and synforms. These folds refold earlier-formed open to tight, north-plunging and upright to west-overturned antiforms and synforms. Fold patterns south of High Bridge are characterized by open, southeast-plunging, southwest-overturned-to-upright antiforms and synforms.

Faults

The structural geology of the quadrangle is dominated by a series of northeast-trending faults that deform Mesoproterozoic and Paleozoic rocks. These faults were active during the Ottawan orogeny and reactivated during the Taconian, and Alleghanian orogenies, and subsequently reactivated during the Mesozoic rifting event. From the northwest map corner to the southeast4 they include the Pohatcong Thrust Fault, Kennedys Fault, Musconetcong Fault, Spruce Run Fault, Longwood Valley fault, and Mulhockaway Creek border fault.

The moderately-southeast-dipping Pohatcong Fault borders the north side of Pohatcong Mountain where it places Mesoproterozoic rocks and Hardyston Quartzite onto Paleozoic rocks. It merges with, or is cut off by, Kennedys Fault to the southwest in the Bloomsbury quadrangle, directly south of Pohatcong Mountain.

Kennedys Fault borders the southeast side of Pohatcong Mountain. It is a steeply southeast-dipping reverse fault that places Paleozoic rocks of the hanging wall onto Mesoproterozoic rocks of the footwall.

The moderately-southeast-dipping Musconetcong Fault borders the northwest side of Musconetcong Mountain, placing Mesoproterozoic rocks onto Paleozoic rocks along its entire length in the map area.

The newly recognized Spruce Run Fault is on Musconetcong Mountain, where it places Mesoproterozoic rocks in both the footwall and hanging wall. Good exposures of this fault are visible along Spruce Run at Red Mill. The fault displays brittle deformation along its entire length. It bifurcates north of Bells Crossing: its the southern segment is cut off on the east by the Longwood Valley Fault, and its north segment terminates in a series of splays at Camp Watchung. Both fault segments are cut off on the west by the Musconetcong Thrust Fault.

The steeply-southeast-dipping Longwood Valley Fault extends through Musconetcong Mountain where Mesoproterozoic rocks are on both sides of the fault. However, to the northeast Mesoproterozoic rocks are on the footwall and Paleozoic rocks of the Green Pond Mountain region are on the hanging wall (Herman and Mitchell, 1991; Drake and others, 1996). Along the northwest side of Mt. Kipp the fault deforms magnetite ore and host rocks at an unnamed mine, suggesting that the deformation is Paleozoic in age. The Longwood Valley Fault is characterized by brittle deformation along its entire length. In the High Bridge quadrangle, the fault bifurcates west of Woodglen and rejoins to the southwest at Norton Cemetery. The southern fault segment is exposed in quarry faces at Glen Gardner where it dips ~ 70° southeast and displays dip-slip normal movement. The Longwood Valley Fault terminates to the southwest where it is cut off by the Mulhockaway Creek border fault.

The herein named Mulhockaway Creek border fault is a major structural feature that separates Mesoproterozoic rocks in the footwall and down-dropped Paleozoic and Mesozoic rocks in the hanging wall. This fault dips moderately to gently to the southeast along its length from near Spruce Run Reservoir, westward to the Delaware River. Core drilling along the fault to the southwest in the Riegelsville quadrangle (Ratcliffe and Burton, 1985) indicates a fault dip of 20-35° to the southeast.

Mesoproterozoic rocks throughout the map area are also deformed by smaller, less regionally pervasive, northeast or northwest-trending faults, some of which are restricted to individual outcrops. They are characterized by brittle brecciated fabrics, the retrogression of mafic mineral phases, chlorite or epidote-coated fractures or slickensides, and (or) close-spaced fracture cleavage. Widths of the faults range from a few inches to a few feet, and some of the wider fault zones may be due to the intersection of smaller faults.

Paleozoic rocks in the area of Spruce Run Reservoir are cut by a series of northwest-striking, southwest-dipping thrust faults with Paleozoic rocks occupying both the footwall and hanging wall. These faults telescope the Paleozoic units and probably indicate the southernmost extent of Taconic thrusting.

Joints

Joints are a ubiquitous feature in all bedrock units. Those in Paleozoic and Mesozoic rocks are most common in massive rocks such as limestone, dolomite and sandstone. Two main joint sets were visible, one that strikes parallel to bedding and another that forms a cross-joint set. The bedding-parallel set strikes about N.55°E. (fig. 4) and dips moderately to steeply northwest, averaging 70°. The cross joints strike about N.85°W. (fig. 4) and dip predominantly southwest at an average of 66°. The difference in strike between the Musconetcong Valley (northeast) and Clinton area (northwest) indicates the lack of a dominant joint trend.

Joints developed in Mesoproterozoic rocks are characteristically planar, moderately well formed, moderately to widely spaced, and moderately to steeply dipping. Joint surfaces are typically unmineralized, except near faults, and are smooth, and less commonly, slightly irregular. Joint spacing ranges from a foot to tens of feet. Those in massive rocks such as granite are more widely spaced, irregularly formed and discontinuous than those in layered gneisses and fine-grained rocks. Joints along faults typically are spaced 2 feet or less apart.

The dominant joint trend in Mesoproterozoic rocks is nearly perpendicular to the crystallization foliation, a consistent feature throughout the Highlands (Volkert, 1996). But joints in the map area vary because of folding and the rotation of Mesoproterozoic rocks in fault blocks. Two dominant and two subordinate sets are visible in the Mesoproterozoic rocks. One dominant sets strike N.30°W. to N.70°W., at an average of N.52°W., and N.30°E. to N.60°E., and averages of N.45°E. (fig. 5). Both sets dip moderately to steeply east and west. The subordinate sets strikes east-west and dip predominantly north, and also strike due north and dip predominantly east. The average dip of joints is 67°.

ECONOMIC RESOURCES

Mesoproterozoic rocks in the quadrangle were host to economic deposits of iron ore mined predominantly during the 19th century. Descriptions of most of the mines are given in Bayley (1910). Magnetite was extracted from mines mainly on Musconetcong Mountain. Graphite was mined from rusty, sulfidic Mesoproterozoic gneiss and quartzite at several locations in the southeast part of the map area. Descriptions of these mines are given in Volkert (1997). Manganese was mined from Paleozoic rocks of the Jutland klippe sequence at one location near Clinton (Monteverde, 1997).

Mesoproterozoic granite and gneiss are currently quarried for crushed stone at Glen Gardner. They were formerly quarried north of Glen Gardner and near Stone Mill, east of South Branch Raritan River. Paleozoic dolomite was formerly quarried at several locations in the Musconetcong Valley, at Clinton, and Mariannes Corner. Paleozoic rocks of the Jutland Klippe Sequence are currently quarried near Perryville, and were formerly quarried at several other sites from Perryville east to Annandale.

DESCRIPTION OF MAP UNITS

Newark Basin

Ŧpcq **Passaic Formation** (conglomerate lithofacies) (Upper Triassic) – Light-red to dark-reddish-brown-weathering, grayish-red to dark-reddish-brown, medium- to very-thick-bedded, pebble-to-boulder conglomerate in fine- to medium-grained sand matrix. Clasts are subrounded and composed of vein quartz, quartz sandstone, siltstone and shale. Interbedded grayish-red to dark-brownish-red, fine-grained, thin- to medium-bedded sandstone, arkosic sandstone and siltstone occur in fining-upward sequences. Overall clast and grain size of unit decreases wth distance from border fault. Unit poorly exposed and commonly mapped on float. Where exposed, sandstone and siltstone dominate over conglomerate. Lower contact is gradational and mapped by projection from known relations in Pittstown quadrangle to south (Herman and others, 1992, Parker, 1993). Thickness estimated at 4,000 ft.

Ŧlcq **Lockatong Formation** (conglomerate lithofacies) (Upper Triassic) – Light-red to dark-reddish-brown-weathering, grayish-red to dark-reddish-brown, medium- to very-thick-bedded, pebble to boulder conglomerate in fine- to medium-grained sand matrix. Clasts are subrounded and consist of vein quartz, quartz sandstone and siltstone. Interbedded grayish-red to dark-brownish-red, fine-grained, thin- to medium-bedded, sandstone and siltstone occur in fining-upward sequences. Overall clast and grain size of unit decreases with distance from border fault. Unit poorly exposed and commonly mapped on float. Lower contact is gradational and mapped by projection from known relations on Pittstown quadrangle to south (Herman and others, 1992, Parker, 1993). Thickness estimated at 4,000 ft.

Ŧscq **Stockton Formation** (conglomerate lithofacies) (Upper Triassic) – Light-red to dark-reddish-brown-weathering, grayish-red to dark-reddish-brown, medium- to very-thick-bedded, pebble-to-boulder conglomerate in fine- to coarse-sand matrix. Clasts are subrounded to subangular, dominated by quartz and quartzite and rare dark-reddish-brown to yellowish-gray shale and sandstone. Interbedded dark-brownish-red, fine- to medium-grained, thin- to medium-bedded sandstone and siltstone occur in fining-upwards sequences. Overall clast and grain size of unit decreases with distance from border fault. Unit poorly exposed and mostly mapped on float. Lower contact is an unconformity. Regional thickness estimated at 4,700 ft.

Jutland Klippe Sequence

Oh **Hensfoot Formation** (Upper to Lower Ordovician) – Heterogeneous sequence of interbedded red and green, thin-bedded shale, interlaminated dolomite and shale, thinly interbedded fine-grained graywacke-siltstone to medium-grained sandstone and shale, yellow, red, green, pale brown, and gray shale, and light-gray to pale pinkish-gray quartzite. Lower contact lies in a red shale bed approximately 50 to 100 ft above a prominent limestone sequence. Graptolites ranging from *Pendeograptus frutiosus* to *Climacograptus bicornus* zones of Berry (1968) (Perissoratis and others, 1979; S. Finney, written commun.,1991). Carbonate and pelitic rocks locally contain conodonts of *Prioniodus triangularis* to *Pygodus anserinus* faunas of North Atlantic Realm (Ethington and others, 1958; Karklins and Repetski, 1989, J. Repetski, oral commun., 1992) and sparse brachiopod fragments. On basis of graptolites, unit is Ibexian (Floian) to lower Mohawkian (Upper Sandbian). Thickness varied due to structural complexity but estimated at 1,500 to 1,800 ft. Best exposure is along the train tracks between Jutland and Grandin on the Pittstown quadrangle to the south.

O€srm **Mulhockaway Creek Member of the Spruce Run Formation** (Lower Ordovician to Upper Cambrian) – Interbedded red, pale brown and green, thin-bedded shale and lesser fine-grained sandstone. Locally contains interbedded dark-gray, fine-grained to aphanitic, thin- to medium-bedded limestone; limestone may be crossbedded and contain floating quartz sand grains and edgewise conglomerate. Grades downward into thinly interbedded sequence of red, green, and pale brown shale and siltstone. Lower contact placed at top of medium-gray to brown, fine- to coarse-grained sandstone and quartz-pebble conglomerate. Contains graptolites in span of *Clonograpts* to *Pendeograptus frutiosus* of Berry (1968) (Perissoratis and others, 1979) and conodonts *Euconodontus notchpeakensis* and protoconodont *Phakelodus* (Harris and others, 1995) and younger *Cordylodus proavus* to *Paroistidus proteus* faunas of North Atlantic Realm (J. Repetski, oral commun., 1992). Fossil assemblage suggests age of late Cambrian (Millardon, Furongian) to early Ordovician (middle Ibexian, Floian). Thickness estimated at 1,500 ft. from cross-section construction. Best exposure along banks of Spruce Run Reservoir during periods of low water.

€srv **Van Syckel Member of the Spruce Run Formation** (Upper Cambrian) – Medium-gray to brown, fine- to coarse-grained sandstone and quartz-pebble conglomerate; poorly- to moderately-sorted, grades downward into thin-bedded, medium-to dark-gray shale and siltstone and local thin-bedded, dark-gray fine-grained-to-aphanitic limestone. Lower contact is a fault. Best exposed in Beaver Brook south of Annandale. Thickness estimated at 800 ft., based on cross-section construction.

Kittatinny Valley Sequence

Omb **Bushkill Member of Martinsburg Formation** (Upper 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, graywacke 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 underlying the cross-bedded layer. Complete cycles may be an inch to several feet thick of which slate is 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* of Riva (1969; 1974), which they correlate with the *Corynoides americanus* to *Climacograptus spinifer* subzones of *Orthograptus amplexicaulis* of Berry (1960; 1971; 1976) indicating a Mohawkian (lower Katian) age. Thickness range from 1,500 ft. to a maximum of approximately 4,000 ft. near Belvidere to the north of the mapped area.

Oj **Jacksonburg Limestone** (Upper 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). Regionally, 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 *Plectodina tenuis* to *Belodina confluers* indicating Rocklandian to Richmondian and possibly Kirkfieldian (Katian) ages (Sweet and Bergstrom, 1986; Repetski and others, 1995). North Atlantic Realm conodonts also occur north and east of the town of Clinton (Barnett, 1965; Repetski and others, 1995). Regionally unit ranges in thickness from 150 ft. to 1,000 ft.

Ow **"Sequence at Wantage"** (Upper Ordovician) – Interbedded, very thin- to medium-bedded limestone, dolomite, siltstone, and argillite. Medium-gray, grayish-red to grayish-green, thin- to medium-bedded mudstone, siltstone and fine-grained to pebbly sandstone compose a clastic facies. 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. 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. Unit is restricted to lows on surface of Beekmantown unconformity. Regional relations and North American Midcontinent province conodonts within carbonate facies (Repetski and others, 1995) limits age range from no older than Rocklandian to no younger than Kirkfieldian (Sandbian to Katian) (Taylor and others, 2013). May be as much as 150 ft. thick. Unit is well exposed in vicinity of Asbury.

Beekmantown Group

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. 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 transitional 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 Florian) as used by Sweet and Bergstrom (1986). In map area, unit correlates with the Epler of Drake and others (1996) and the Ontelaunee Formation of Markewicz and Dalton (1977). Unit averages about 200 ft. in thickness but is as much as 800 ft. thick.

O€bl **Beekmantown Group, lower part** (Lower Ordovician to Upper Cambrian) – 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 laminas enclosing lenses of limestone. Limestone is 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 dolomite having quartz-sand laminas 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 Skullrockian, and lower 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.

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

€l **Leithsville Formation** (Middle to Lower Cambrian) – Upper sequence, rarely exposed, is mottled, medium-light- to medium-dark-gray-weathering, medium- to medium-dark-gray, fine- to medium-grained, medium- to thick-bedded, locally pitted and friable dolomite. Middle sequence is grayish-orange or light- to dark-gray, grayish-red, light-greenish-gray- or dark-greenish-gray-weathering, aphanitic to fine-grained, thin- to medium-bedded dolomite, argillaceous dolomite, dolomitic shale, quartz sandstone, siltstone, and shale. Lower sequence is medium-light- to medium-gray-weathering, medium-gray, fine- to medium-grained, thin- to medium-bedded dolomite. Quartz-sand lenses occur near lower gradational contact with Hardyston Quartzite. Archaeocyathids of Early Cambrian age are present at Franklin, N.J., suggesting an intraformational disconformity between Middle and Early Cambrian time (Palmer and Rozanov, 1967; McMenamin and others, 2000). Unit also contains *Hyolithellus micans* (Offield, 1967; Markewicz, 1968). Approximately 800 ft. thick regionally.

€h **Hardyston Quartzite** (Lower Cambrian) – Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Contains *Scolithus linearis* (?) and fragments of the trilobite *Olenellus thompsoni* of Early Cambrian age (Nason, 1891; Weller, 1903). Thickness ranges from absent to a maximum of 200 ft. regionally.

New Jersey Highlands

Zd **Diabase dikes** (Neoproterozoic) – Light gray- or brownish-gray-weathering, dark-greenish-gray, aphanitic to fine-grained dikes. Composed principally of plagioclase (labradorite to andesine), augite, and ilmenite and (or) magnetite. Local pyrite blebs are common. Contacts are typically chilled and sharp against enclosing Mesoproterozoic rocks. Dikes are as much as 20 ft. thick and a mile or more long.

Vernon Supersuite (Volkert and Drake, 1998)

Byram Intrusive Suite (Drake, 1984)

Ybh **Hornblende granite** (Mesoproterozoic) – Pinkish-gray- or buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, foliated granite composed of microcline microperthite, quartz, oligoclase, and hornblende. Some variants are quartz monzonite or quartz syenite. Includes small bodies of pegmatite not shown on the map.

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

Ybs **Hornblende monzonite** (Mesoproterozoic) – Tan- 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, hornblende, magnetite, and local quartz.

Ybb **Biotite granite** (Mesoproterozoic) – Pink- or buff-weathering, light pinkish-white, medium- to coarse-grained, massive, moderately foliated granite composed of microcline microperthite, quartz, oligoclase, and biotite.

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

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

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

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

Back Arc Supracrustal rocks

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

Yb **Biotite-quartz-feldspar gneiss** (Mesoproterozoic) – Gray-weathering, locally rusty, gray, tan, or greenish-gray, medium- to coarse-grained, moderately layered and foliated gneiss composed of microcline microperthite, oligoclase, quartz, and biotite. Locally contains garnet, sillimanite and magnetite. Graphite and pyrrhotite occur in rusty variants which host graphite deposits in the area. Commonly contains layers of light-gray, vitreous, medium-grained, massive to foliated quartzite composed of quartz and local feldspar and graphite.

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

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

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

Yq **Quartzite** (Mesoproterozoic) – Light gray-weathering, light-gray, vitreous, medium-grained, massive foliated rock composed predominantly of quartz and local feldspar, biotite, and graphite. Commonly interlayered with rusty, sulfidic biotite-quartz-feldspar gneiss.

Magmatic Arc Rocks

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

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

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

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

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

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

Other Rocks

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

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

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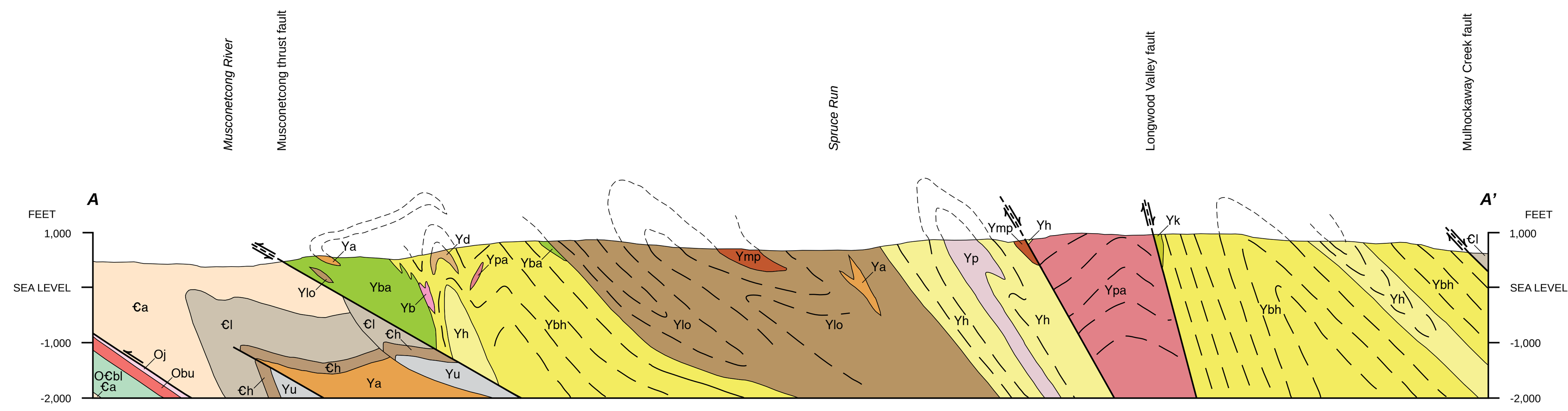
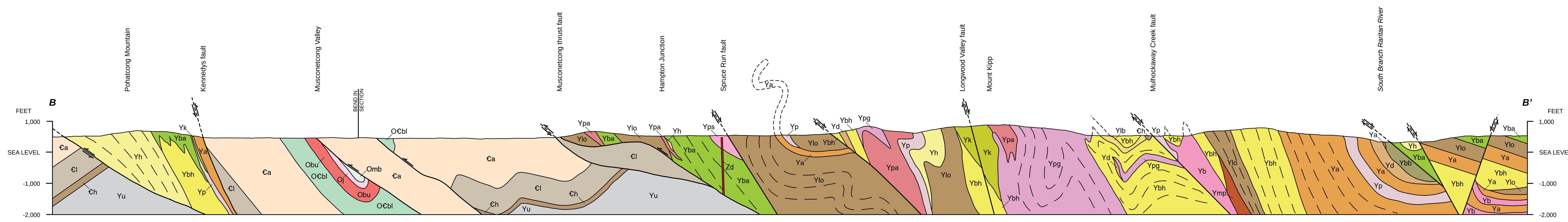
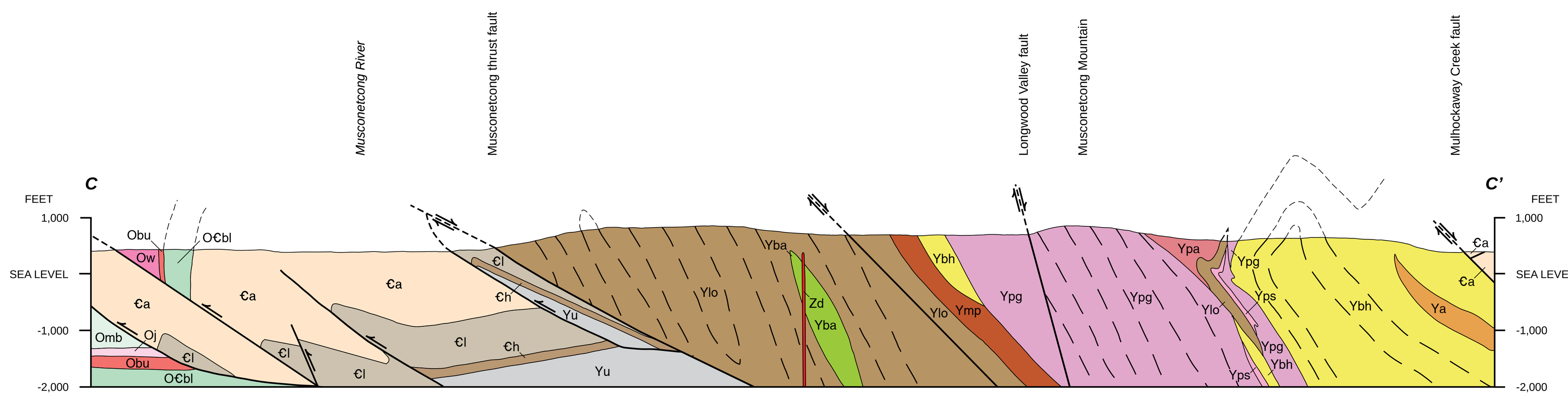
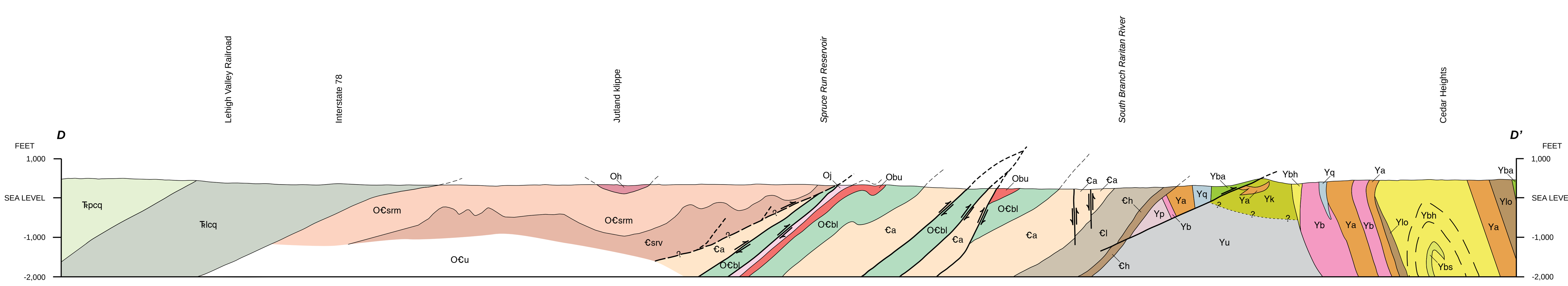
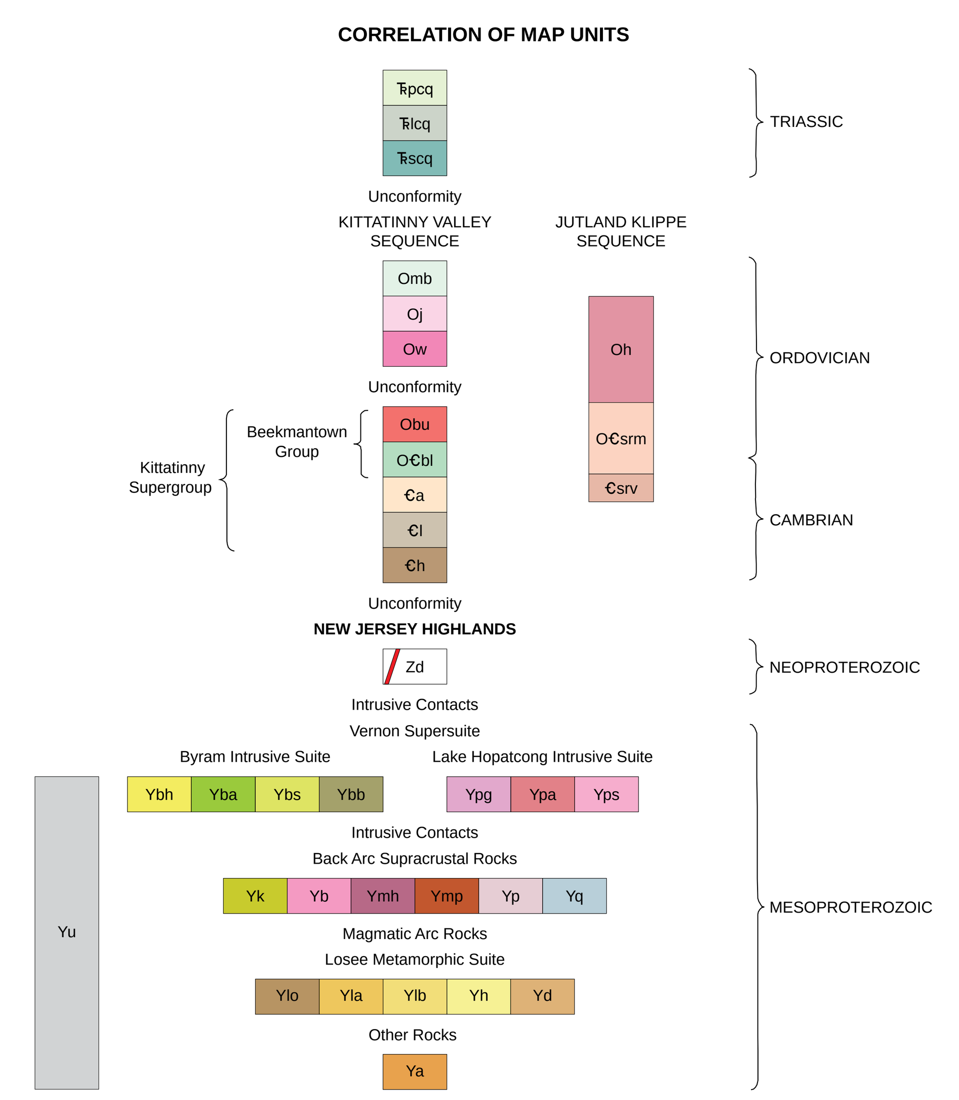
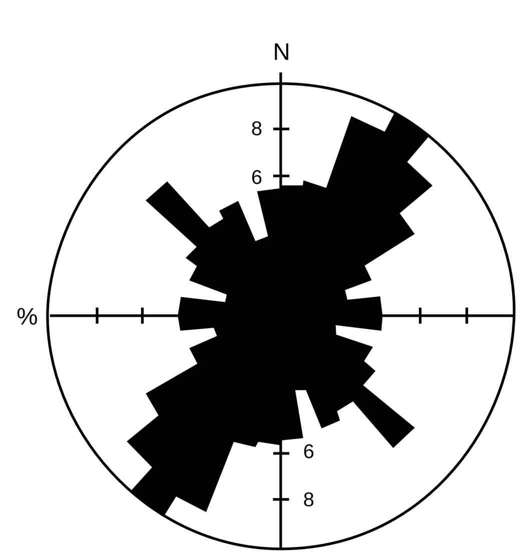






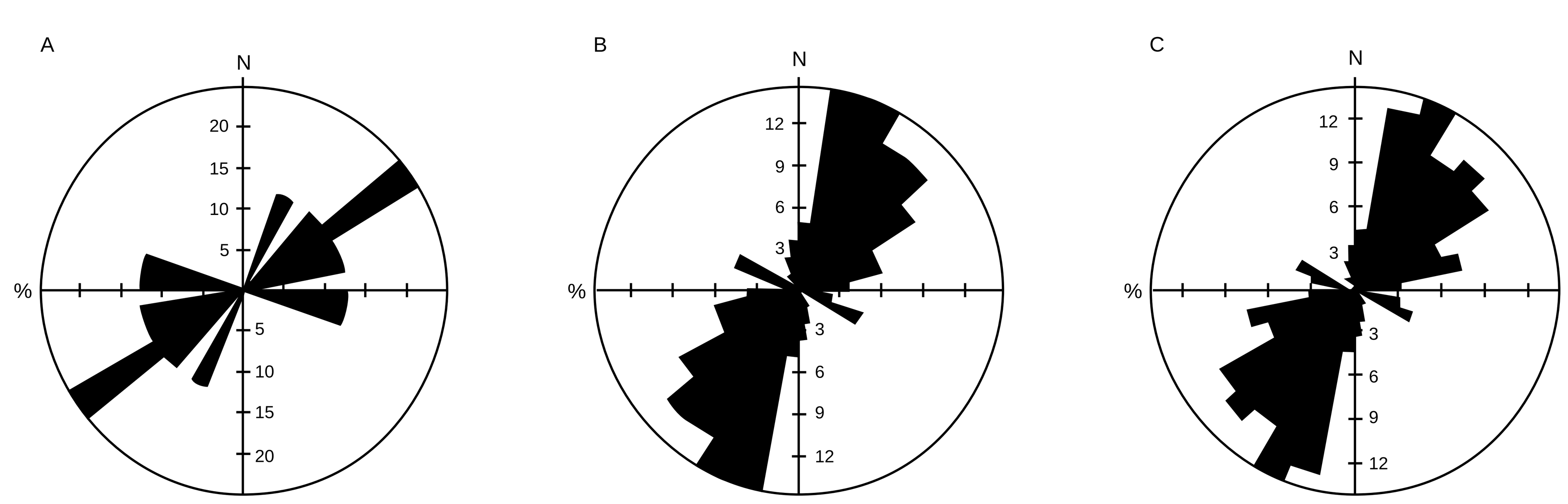






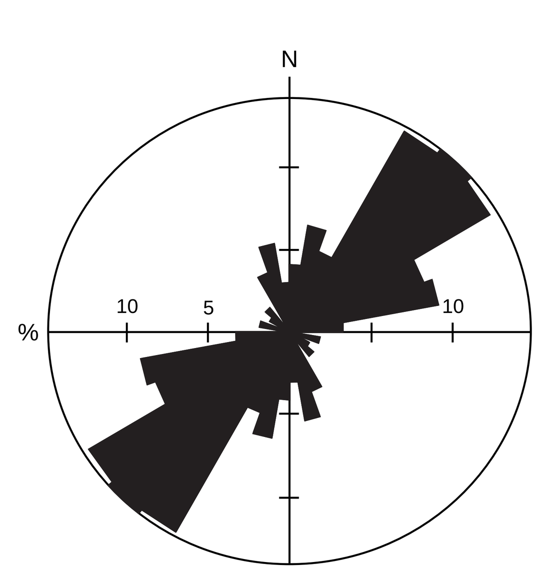
Sector angle = 10°
n = 597

Figure 1. Rose diagram showing the orientation of bedding in Paleozoic rocks.



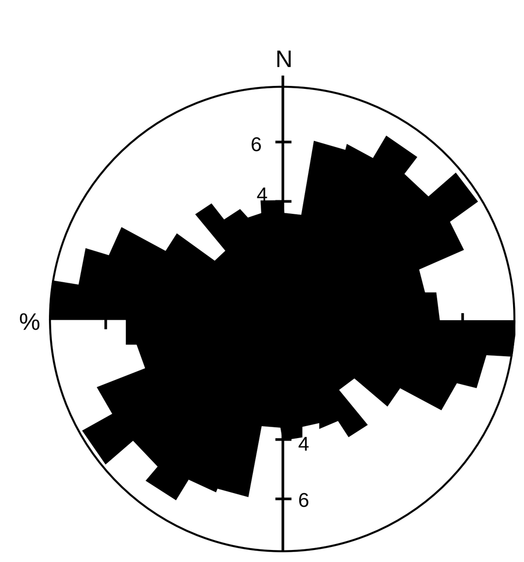
Sector angle = 10° n = 9 | Sector angle = 10° n = 83 | Sector angle = 10° n = 92

Figure 2. Rose diagram showing the orientation of (A) crenulation cleavage, (B) slaty and spaced cleavage, and (C) all cleavage in Paleozoic rocks.



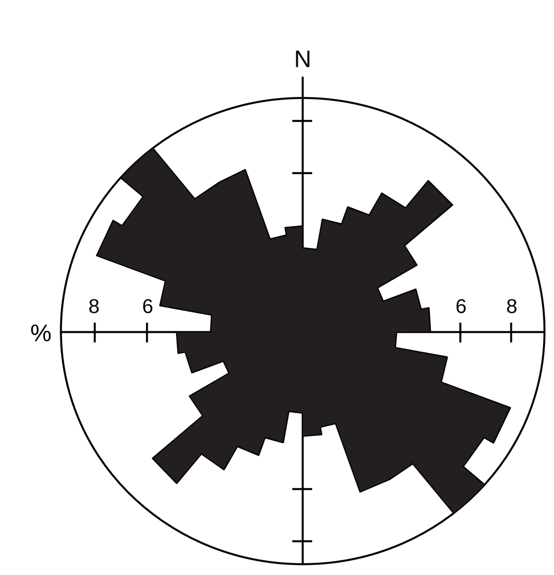
Sector angle = 10°
n = 368

Figure 3. Rose diagram showing the orientation of crystallization foliation in Mesoproterozoic rocks.



Sector angle = 10°
n = 589

Figure 4. Rose diagram showing the orientation of joints in Paleozoic rocks.



Sector angle = 10°
n = 675

Figure 5. Rose diagram showing the orientation of joints in Mesoproterozoic rocks.

EXPLANATION OF MAP SYMBOLS

Contact - Dotted where concealed

Fault - Dotted where concealed. Queried where uncertain. Bar and ball show direction of dip of fault plane.

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

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

Inclined thrust fault - teeth on upper plate

Brittle deformation zone

FOLDS

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

Antiform

Synform

Overturned antiform

Overturned synform

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

Anticline

Syncline

Overturned anticline

Minor asymmetric fold

PLANAR FEATURES

Strike and dip of crystallization foliation

Inclined

Vertical

Strike and dip of mylonitic foliation

Strike and dip of beds - Ball shows top of beds from sedimentary structures

Inclined

Vertical

Overturned

Strike and dip of cleavage in Paleozoic rocks

Strike and dip of crenulation cleavage in Paleozoic rocks

LINEAR FEATURES

Bearing and plunge of mineral lineation in Proterozoic rocks

Fold axis

Bearing and plunge of intersection of bedding and cleavage

Bearing and plunge of intersection of crenulation cleavage and cleavage

OTHER FEATURES

Abandoned mine - M, magnetite; Gr, graphite; Mn, manganese

Abandoned rock quarry

Active rock quarry

Location of bedrock subcrop or float used to draw unit contacts

Form lines showing foliation in Proterozoic rocks in cross section

Bedrock Geologic Map of the High Bridge Quadrangle Hunterdon and Warren Counties, New Jersey

by
Donald H. Monteverde, Richard A. Volkert and Richard F. Dalton

2015