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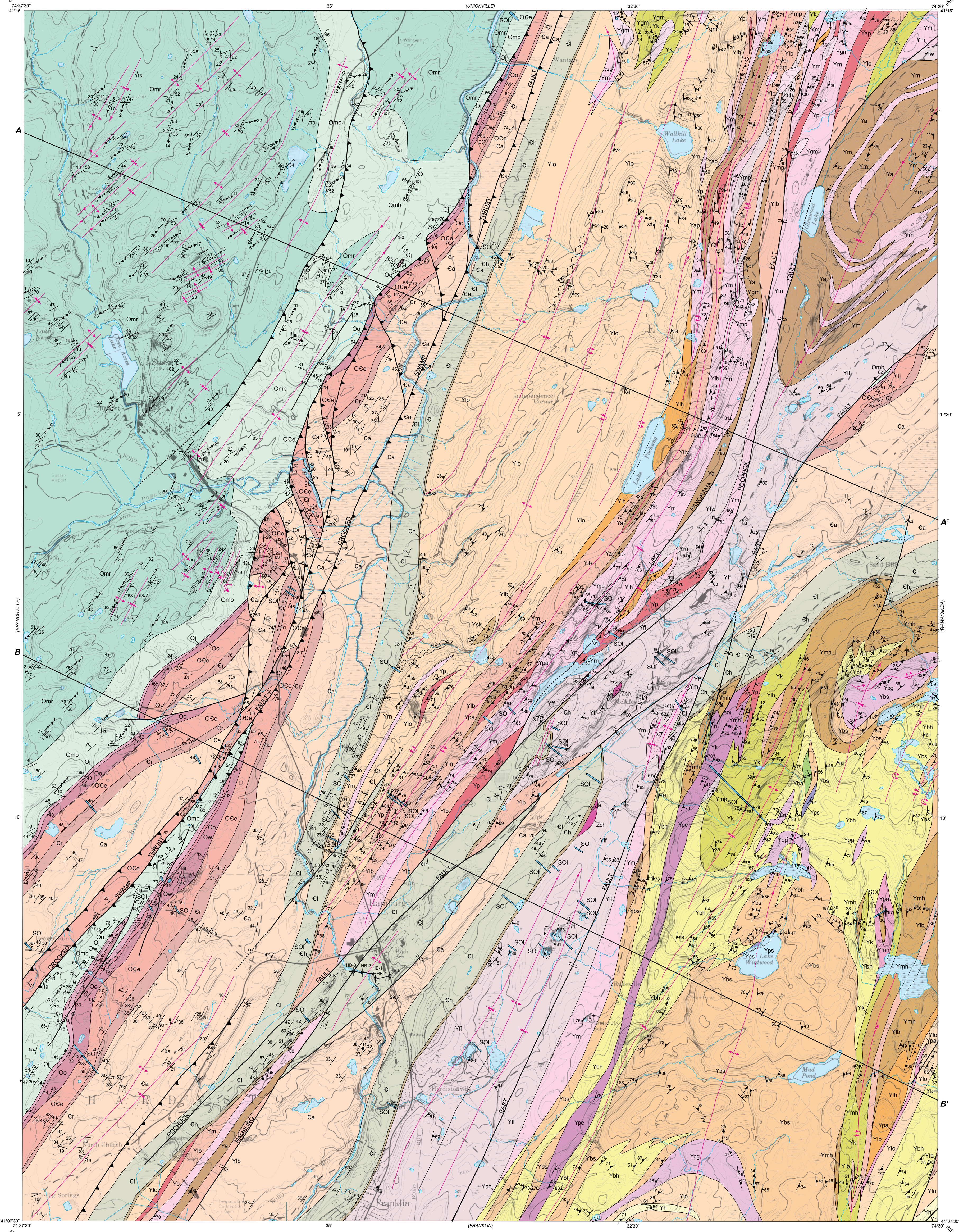

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Polyconic projection. 1927 North American datum 10,000-foot grid based on New Jersey coordinate system 1000-meter Universal Transverse Mercator grid ticks, zone 18.

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET

Bedrock geology mapped by F.J. Markewicz and R.F. Dalton, 1968-1973;
R.J. Canace 1980-1988;
R.F. Dalton, R.J. Canace, R.A. Volkert, D.H. Monteverde and G.C. Herman, 1994-1995;
R.F. Dalton, R.A. Volkert, D.H. Monteverde, G.C. Herman and R.J Canace, 2012-2013

Digital cartography by R.S. Pristas

Reviewed by A. A. Drake, S.D. Stanford and M.J. Hozik

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Bedrock Geologic Map of the Hamburg Quadrangle
Sussex County, New Jersey

by

Richard F. Dalton[1], Richard A. Volkert[1], Donald H. Monteverde[1], Gregory C. Herman[1], and Robert J. Canace[2]

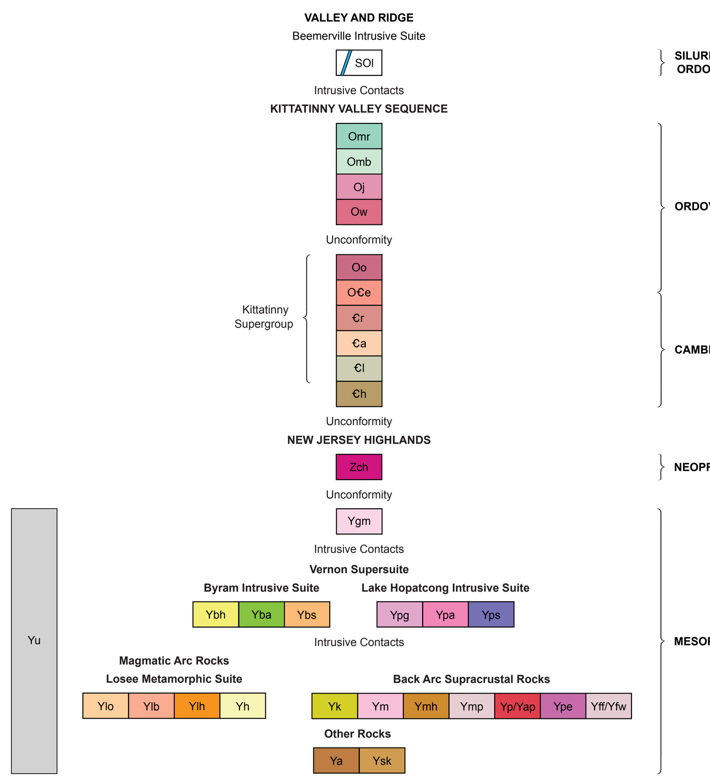
2014

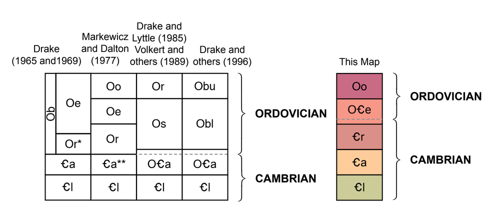
LOCATION IN NEW JERSEY

APPROXIMATE MEAN DECLINATION, 1994

[1] New Jersey Geological and Water Survey, Trenton, New Jersey 08625
[2] Ridge & Valley Conservancy, Blairstown, New Jersey 07825

CORRELATION OF MAP UNITS





Oo Ontelaunee Formation
Oe Epler Formation
Or Rickenbach Formation
Or* Rickenbach Dolomite
Os Stonehenge Formation
Ob Beekmantown Group
Obu Beekmantown Group, upper part
Obl Beekmantown Group, lower part
OꞒe Epler Formation
Ꞓr Rickenbach Formation
OꞒa Allentown Dolomite
Ꞓa** Allentown Formation
Ꞓa Allentown Dolomite
Ꞓl Leithsville Formation

Figure 1. Nomenclature of Paleozoic carbonate rock of previous workers, shown in the columns on left. This map follows the scheme proposed by Markewicz and Dalton (1977), along with the revised ages of the carbonate rocks due to changes in the International Stratigraphic Time Scale (U.S. Geological Survey, 2010) shown in the column on right. Dashed line indicates the Cambrian-Ordovician boundary which has been raised stratigraphically based on the acceptance of a Global Stratotype Section and Point for the base of the Ordovician System.

EXPLANATION OF MAP SYMBOLS

Contact - Dotted where concealed. Queried where uncertain.

Fault - Dotted where concealed. Queried where uncertain.

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. Dotted where concealed.

Antiform

Synform

Overturned antiform

Overturned synform

Minor asymmetric fold

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

Anticline

Syncline

Gently inclined to recumbent anticline

Gently inclined to recumbent syncline

PLANAR FEATURES

Strike and dip of crystallization foliation

Inclined

Vertical

Strike and dip of beds

Inclined

Vertical

Overturned

Strike and dip of cleavage in Paleozoic rocks

Strike and dip of parallel bedding and slaty cleavage

LINEAR FEATURES

Bearing and plunge of intersection of bedding and cleavage in Paleozoic rocks

Bearing and plunge of mineral lineation in mesoproterozoic rocks

OTHER FEATURES

Abandoned mine - Fe, magnetite; H, hematite; L, limonite and brown hematite

Active rock quarry

Bore hole and Figure 12

Figures 10, 11, 13, 14

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

DESCRIPTION OF MAP UNITS

Beemerville Intrusive Suite (Drake and Monteverde, 1992)

SOl **Lamprophyre dikes** (Lower Silurian and Upper Ordovician) – 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 (fig. 10). Dikes intrude rocks that are Mesoproterozoic through Ordovician in age.

VALLEY AND RIDGE

Kittatinny Valley Sequence

Omr **Ramseyburg Member of the Martinsburg Formation** (Upper Ordovician) - (Drake and Epstein, 1967) – Interbedded medium- to dark-gray to brownish-gray, fine- to medium-grained, thin- to thick-bedded, locally quartz-rich, greywacke, sandstone and siltstone and medium- to dark-gray, laminated to thin-bedded shale and slate. Unit forms fining-upward sequences characterized by basal cross-bedded sandstone to siltstone grading upward through planar laminated siltstone into shale or slate. Locally, some of the fining-upward cycles may have a lower, medium- to thick-bedded, graded sandstone unit 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 with the Bushkill Member is placed at base of lowest thick- to very-thick-bedded graywacke, but contact locally grades through sequence of dominantly thin-bedded slate and minor thin- to medium-bedded discontinuous and lenticular graywacke beds in the Bushkill. Parris and Cruikshank (1992) correlated unit with Orthograptus ruedemanni zone to lowest part of Climacograptus spiniferus zone of Riva (1969, 1974) indicating an upper Shermanian age (Caradocian). Unit is approximately 3,500 feet thick.

Omb **Bushkill Member of Martinsburg Formation** (Upper Ordovician) (Drake and Epstein, 1967) – 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 upward through planar laminated siltstone into slate, or laminated siltstone grading upward into slate. Locally, some of the fining-upward cycles may have a lower planar laminated siltstone beneath the cross-bedded layer. Complete cycles may be an inch to several feet thick and slate comprises the thickest part. Lower contact with the Jacksonburg Limestone is gradational, but commonly disrupted by thrust faulting. Parris and Cruikshank (1992) showed that regionally, the unit contains graptolites of zones Diplograptus multidens to Corynoides americanus (Riva, 1969, 1974), which they correlated with the Climacograptus bicornis zone to Climacograptus spiniferus subzone of Orthograptus amplexicaulis (Berry, 1960, 1971, 1976; Finney, 1986) indicating a lower Shermanian (Caradocian) age. Parris and others (2001) described a graptolite and shelly fauna about 30 feet above the Jacksonburg Limestone from a site adjacent to the map area and indicated that the basal Bushkill correlates with the Corynoides americannus Subzone, slightly younger than the Climacograptus bicornis zone (Berry, 1960, 1971, 1976; Finney, 1986). Unit approximately 1,500 feet thick.

Oj **Jacksonburg Limestone** (Upper Ordovician) (Spencer and others, 1908, Miller, 1937) – Medium-dark-gray-weathering, medium- 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). At places, the basal sequence contains a thick- to very-thick-bedded dolomite cobble conglomerate that has a limestone matrix. Locally, lower contact is conformable on the discontinuous carbonate facies of "Sequence at Wantage". Elsewhere, it is unconformable on rocks of the Beekmantown Group or the clastic facies of "Sequence at Wantage". Weller (1903), based on extensive fossil collections from numerous localities throughout the region, correlated this unit to the lower Trenton of New York. Unit contains North American Midcontinent province conodont zones Phragmodus undatus to Aphelognathus shatzeri that range from Rocklandian to Richmondian ages (Sweet and Bergstrom, 1986). Harris and others (1995, p. 6) indicate the Jacksonburg is no older than the Plectodina tenuis zone (Kirkfieldian Stage). Unit is as much as 200 feet thick in the quadrangle.

Ow **Sequence at Wantage** (Upper Ordovician) (Monteverde and Herman, 1989) – Interbedded, very-thin- to medium-bedded limestone, dolomite, siltstone, and argillite. Upper carbonate facies is yellowish-brown to olive-gray-weathering, medium- to dark-gray, very-fine- to fine-grained, laminated to medium-bedded limestone and dolomite. Rounded quartz sand occurs locally as floating grains and in very thin lenses. Lower 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-bedded. Unit is restricted to lows on the paleoerosion surface of the Middle Ordovician unconformity. North American Midcontinent province conodonts within the carbonate facies, identified by Harris and others (1995, p. 6) indicate a Rocklandian or Kirkfieldian age. Unit may be as much as 150 feet thick in the quadrangle.

Kittatinny Supergroup (Lower Ordovician and Cambrian)

Beekmantown Group – Ontelaunee and Epler Formations and Rickenbach Dolomite (Lower Ordovician and Upper Cambrian)

Oo **Ontelaunee Formation** (Lower Ordovician) (Hobson, 1957) – Upper beds, locally preserved, are light- to medium-gray to yellowish-gray-weathering, light- to medium-gray, aphanitic to medium grained, thin- to thick-bedded, locally laminated, dolomite, slightly fetid. Medium- to dark-gray, fine-grained, medium-bedded, sparsely fossiliferous limestone lenses occur locally. Lower beds are medium- to dark-gray, medium- to coarse-grained, medium- to thick-bedded dolomite, strongly fetid, and weather to a mottled surface. Contains pods and lenses of white, dark-gray to black chert. Cauliflower-textured black chert beds of varied thickness occur locally. Lower contact gradational and placed at top of laminated to thin-bedded dolomite of the Epler Formation. Contains conodonts high in the Rossodus manitouensis zone to Oepikodus communis zone of the North American Midcontinent province as used by Sweet and Bergstrom (1986). Unit correlates to Beekmantown Group, upper part of Drake and others (1996) (fig. 1). Thickness ranges from 0 to 400 feet in map area.

OꞒe **Epler Formation** (Lower Ordovican and Upper Cambrian) (Hobson, 1957) – Upper part is light-olive- to dark-gray, fine- to medium-grained, thin- to thick-bedded, locally laminated dolomite. Middle part is olive-gray, light-brown, or dark-yellowish-orange-weathering, dark-gray, aphanitic to fine-grained, laminated to medium-bedded dolomite and light-gray to light-bluish-gray-weathering, medium- to dark-gray, fine-grained, thin-to medium-bedded limestone, that is characterized by mottling and reticulate dolomite and light-olive-gray to grayish-orange-weathering, medium-gray dolomitic shale laminae surrounding the limestone lenses. Limestone grades laterally and down section into medium-gray, fine-grained dolomite. Lower part is medium-light- to dark-gray, aphanitic to medium-grained, laminated to medium-bedded dolomite. Contains white and dark-gray chert lenses. Lower contact with the Rickenbach is placed at the transition from a massive, finely laminated, very-fine-`grained, dark gray dolomite to the underlying massive light gray, medium to coarse grained pitted dolomite. Contains conodonts of Cordylodus lindstomi to Rossodus manitouensis zones of the North American Midcontinent province as used by Sweet and Bergstrom (1986). The Cambrian-Ordovician boundary, based on the final acceptance of the Global Stratotype Section and Point base (GSSP) for the Ordovician, at Green Point, Newfoundland (Cooper and others, 2001), now occurs within the lower third of the Epler, at the top of the Cordylodus lindstromi zone, within the fauna B as used in Karlins and Repetski (1989). Unit correlates to Beekmantown Group, lower part of Drake and others (1996) (fig. 1). Unit is approximately 420 feet thick in map area.

Ꞓr **Rickenbach Dolomite** (Upper Cambrian) (Hobson, 1957) – Upper part is medium- to dark-gray, fine- to coarse-grained, medium- to thick-bedded dolomite, locally fetid, and weathers to a mottled surface. Contains pods and lenses of dark-gray to black chert near the upper contact and a distinctive thinly interbedded sequence of medium-grained dolomite with up to seven thin convex upward black chert layers occurs about 50 to 75 feet below the contact. Lower part is medium- to dark-gray, fine- to medium-grained, thin- to medium-bedded dolomite. Floating quartz sand grains and quartz-sand stringers occur in the basal part of unit. Lenses of light-gray, coarse- to very-coarse-grained dolomite locally occur throughout the unit. Lower contact with the Allentown is placed at top of distinctive medium-gray quartzite. Contains conodonts of Cordylodus proavus to Cordylodus lindstomi zones of North American Midcontinent province, as used by Sweet and Bergstrom (1986). Unit correlates to Beekmantown Group, lower part of Drake and others (1996) (fig. 1). Unit may be as much as 300 ft. thick in the quadrangle.

Ꞓa **Allentown Dolomite** (Upper Cambrian) (Wherry, 1909) – Upper sequence is light- 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 sequences 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 the lower sequence (fig. 11). Unit grades down into the Leithsville Formation. Howell (1945) describes Trempealeauian (Late Cambrian) faunas, in the upper part of the formation, from Newton and Blairstown, New Jersey. At Carpentersville the lower part contains a trilobite fauna of Dresbachian (early Late Cambrian) age (Weller, 1903; Howell, 1945). Unit is approximately 1,800 ft. thick in map area.

Ꞓl **Leithsville Formation** (Middle and Lower Cambrian) (Wherry, 1909) – Upper sequence, seldom exposed, is mottled, light- to medium-dark-gray-weathering, medium- to medium-dark-gray, fine- to medium-grained, medium- to thick-bedded dolomite, locally pitted and friable. Middle sequence is grayish-orange to light- to dark-gray to grayish-red to light-greenish- to dark-greenish-gray-weathering, aphanitic to fine-grained, thin- to medium-bedded dolomite, argillaceous dolomite, dolomitic shale, quartz sandstone, siltstone and shale (fig. 12). Lower sequence is 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 were found in the formation nearby in Franklin, New Jersey, 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). Howell (1945) identified as a Dresbachian (early Late Cambrian) fauna in the shaly member of the Leithsville Formation at Peapack, New Jersey. Thickness is approximately 600 feet in map area.

Ꞓh **Hardyston Quartzite** (Lower Cambrian) (Wolff and Brooks, 1898) – Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Unconformably overlies Neoproterozoic and Mesoproterozoic rocks (fig. 13). Elsewhere, contains *Scolithus linearis(?)* and fragments of the trilobite *Olenellus thompsoni* of Early Cambrian age (Nason, 1891; Weller, 1903). Thickness in map area ranges from 5 to 100 feet but rarely exceeds 20 feet.

NEW JERSEY HIGHLANDS

Zch **Chestnut Hill Formation** (Neoproterozoic) – Interbedded sequence of reddish-brown, gray, or buff, medium-grained, thin-bedded quartz-pebble conglomerate, ferruginous sandstone, chloritic siltstone, quartzite, and phyllite. Thickness in the map area ranges from 20 to 50 feet.

Ygm **Mount Eve Granite** (Mesoproterozoic) – Pinkish-gray- to buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, massive, unfoliated granite composed principally of microcline microperthite, quartz, oligoclase, hornblende, and biotite. Locally contains xenoliths of foliated country rock. Unit includes bodies of pegmatite too small to be shown on the map.

Vernon Supersuite (Volkert and Drake, 1998)

Byram Intrusive Suite (Drake and others, 1991b)

Ybh **Hornblende granite** (Mesoproterozoic) – Pinkish-gray to buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, foliated granite and sparse granite gneiss composed principally of microcline microperthite, quartz, oligoclase, hornblende, and magnetite. Some variants are quartz syenite or quartz monzonite. Locally contains clinopyroxene where in contact with rocks of the Lake Hopatcong Intrusive Suite. Unit includes small bodies of pegmatite too small to be shown on the map.

Yba **Microperthite alaskite** (Mesoproterozoic) – Buff or pale-pinkish-white-weathering, pinkish-gray to light-grayish-tan, or pinkish-white, medium- to coarse-grained, foliated granite composed of microcline microperthite, quartz, and oligoclase, Locally contains hornblende and magnetite.

Ybs **Hornblende monzonite** (Mesoproterozoic) – Tan to buff-weathering, pinkish-gray or greenish-gray, medium- to coarse-grained, foliated monzonite and, less commonly, quartz monzonite composed of microcline microperthite, oligoclase, hornblende, and magnetite. Locally contains quartz. Sparse to moderate amounts of clinopyroxene may be present where in contact with rocks of the Lake Hopatcong Intrusive Suite.

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

Ypg **Pyroxene granite** (Mesoproterozoic) – Light-gray to buff or white-weathering, greenish-gray, medium- to coarse-grained, massive, foliated granite composed of mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Commonly contains titanite, magnetite, apatite, and pyrite. Sparse to moderate amounts of hornblende may be present where in contact with rocks of the Byram Intrusive Suite. Unit includes small bodies of pegmatite too small to be shown on the map.

Ypa **Pyroxene alaskite** (Mesoproterozoic) – Light-gray or tan-weathering, greenish-buff to light-pinkish-gray, medium- to coarse-grained, massive, foliated granite composed of mesoperthite to microantiperthite, oligoclase, and quartz. Commonly contains clinopyroxene, titanite and magnetite.

Yps **Pyroxene monzonite** (Mesoproterozoic) – Gray to buff or tan-weathering, greenish-gray, medium- to coarse-grained, massive, foliated rock composed of mesoperthite to microantiperthite, oligoclase, clinopyroxene, titanite and magnetite. May contain sparse to moderate amounts of hornblende where in contact with rocks of the Byram Intrusive Suite.

Back-Arc Basin 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, foliated gneiss composed of quartz, microcline microperthite, and oligoclase. Commonly contains biotite, garnet, sillimanite, and magnetite.

Ym **Microcline gneiss** (Mesoproterozoic) – Pale pinkish-white-weathering, tan to pinkish-white, fine- to medium-grained, layered and foliated rock composed of quartz, microcline microperthite, oligoclase, and biotite. Common accessory minerals include garnet, magnetite and sillimanite. Locally contains conformable clots and lenses of partial melt. Well exposed on Pochuck Mountain, where unit is intercalated with amphibolite.

Ymh **Hornblende-quartz-feldspar gneiss** (Mesoproterozoic) – Pinkish-gray to buff-weathering, light-pinkish-white to pinkish-gray, medium-grained, massive to moderately well layered and foliated gneiss containing microcline, quartz, oligoclase, hornblende, and magnetite. Locally contains garnet and biotite.

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/Yap **Pyroxene gneiss** (Mesoproterozoic) – White- or tan-weathering, greenish-gray, medium-grained, layered and foliated gneiss containing oligoclase, clinopyroxene, and titanite. Locally contains quartz, epidote, scapolite, or calcite. Mafic variants (Yap) containing abundant hornblende, clinopyroxene, and titanite are interlayered with quartz-poor pyroxene gneiss. Unit is spatially associated with amphibolite and marble.

Ype **Pyroxene-epidote gneiss** (Mesoproterozoic) – Light greenish-gray to greenish-pink-weathering, pale pinkish-white to light-gray to light-greenish-gray, medium-grained, layered and foliated gneiss composed of quartz, oligoclase, pyroxene, epidote, microcline, titanite, and magnetite. Locally contains scapolite and trace amounts of calcite. Unit grades into clinopyroxene-quartz-feldspar gneiss with a decrease in epidote.

Yff/Yfw **Franklin Marble and Wildcat Marble** (Mesoproterozoic) – White- to light-gray-weathering, white or grayish-white, coarse-crystalline, calcitic to locally dolomitic marble with accessory graphite, phlogopite, amphibole, clinopyroxene and chondrodite. Separated by New Jersey Zinc Company geologists (Hague and others, 1956) into a lower Franklin marble layer (Yff) and an upper Wildcat marble layer (Yfw), separated by gneiss. Locally contains relict karst features in the form of bedrock pinnacles, solution caves, and paleo-solution breccia. Franklin Marble layer is host rock for Zn-Fe-Mn deposits at the Franklin and Sterling Hill mines to the south, in the Franklin quadrangle.

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 varied amounts of hornblende, biotite and clinopyroxene. Locally intercalated with amphibolite.

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.

Ylh **Hornblende-quartz-oligoclase gneiss** (Mesoproterozoic) – Unit consists of two main variants. At Hamburg Mountain, unit is white weathering, light-greenish-gray, medium- to coarse-grained, foliated gneiss containing oligoclase or andesine, quartz, hornblende, and magnetite. This variant is spatially associated with quartz-oligoclase gneiss. At Pochuck Mountain, unit is gray-weathering, greenish-gray, medium-grained, well-layered gneiss containing oligoclase or andesine, quartz, hornblende, biotite, and magnetite. This variant is interlayered with biotite-quartz-plagioclase gneiss and amphibolite. Both variants contain local clinopyroxene.

Yh **Hypersthene-quartz-plagioclase gneiss** (Mesoproterozoic) – Gray or tan-weathering, greenish-gray to greenish-brown, medium-grained, greasy-lustered, foliated gneiss composed of andesine or oligoclase, quartz, clinopyroxene, hornblende, and orthopyroxene. Commonly intercalated with amphibolite and mafic-rich quartz-plagioclase gneiss.

Other Rocks

Ya **Amphibolite** (Mesoproterozoic) – Grayish-black, fine- to medium-grained, foliated rock composed of hornblende, andesine and local clinopyroxene. Most amphibolite is interpreted to be metavolcanic, and amphibolite east of Glenwood Lake contains relict pillow structures (Hague and others, 1956; Volkert and others, 1986). Some amphibolite layers within metasedimentary rocks may be metasedimentary in origin. Unit is associated with rocks of the Losee Suite and with supracrustal rocks; both types are shown undivided on the map. Unit is exposed throughout Pochuck Mountain.

Ysk **Hornblende-pyroxene skarn** (Mesoproterozoic) – Greenish-black, medium- to coarse-grained, poorly foliated rock composed mainly of hornblende and clinopyroxene. Grades into massive, dark-green, nearly monomineralic clinopyroxene skarn, with both rock types spatially associated with quartz-poor pyroxene gneiss. Unit occurs as a single body on Pochuck Mountain.

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

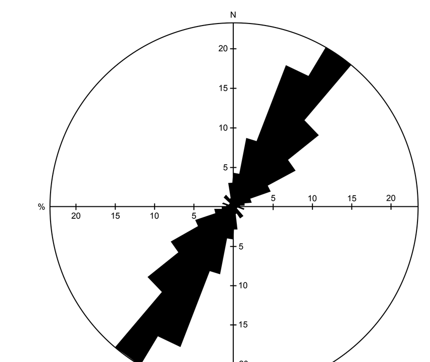

N = 781
Circle = 23%

Figure 2. Rose diagram of bedding strikes in the Paleozoic rocks. N is the number of surfaces analyzed on this and subsequent figures.

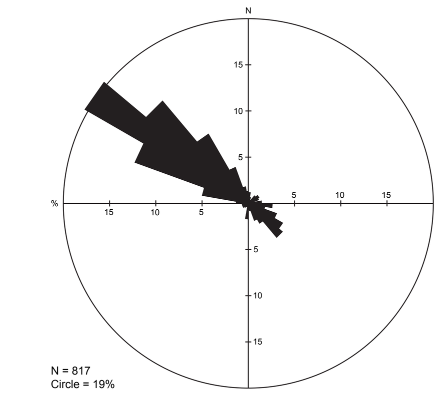

N = 817
Circle = 19%

Figure 3. Rose diagram of bedding dips in the Paleozoic rocks.

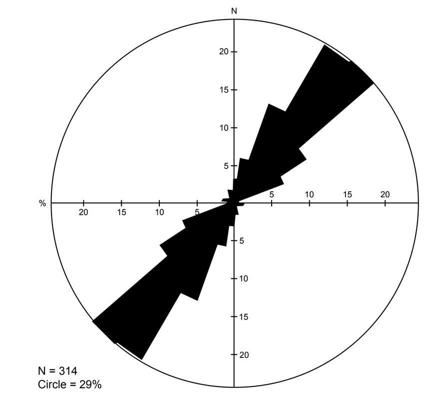

N = 314
Circle = 29%

Figure 4. Rose diagram of cleavage strikes in the Paleozoic rocks.

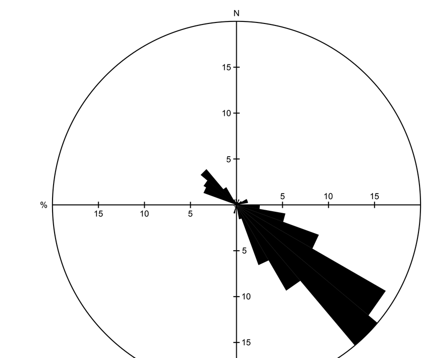

N = 315
Circle = 20%

Figure 5. Rose diagram of cleavage dips in the Paleozoic rocks.

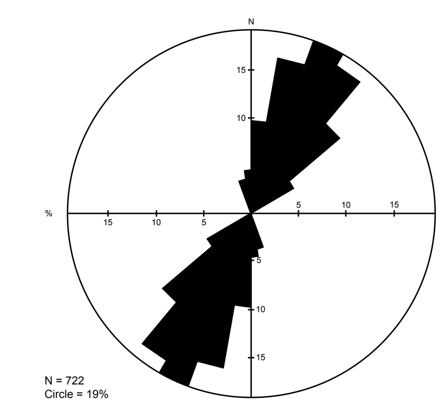

N = 722
Circle = 19%

Figure 6. Rose diagram of foliation strikes in the Proterozoic rocks.

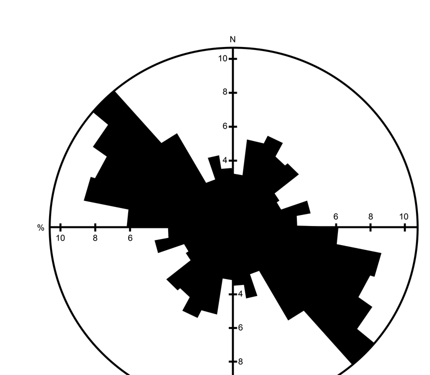

N = 608
Circle = 11%

Figure 7. Rose diagram of joint strikes in the Paleozoic rocks.

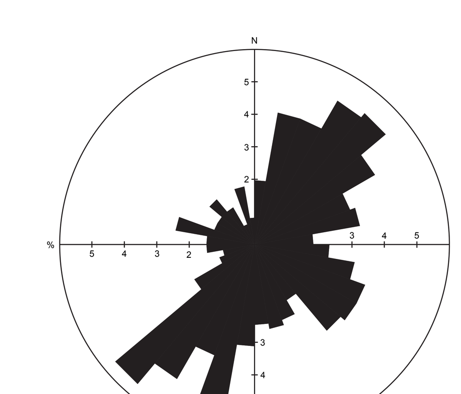

N= 607
Circle = 6%

Figure 8. Rose diagram of joint dips in the Paleozoic rocks.

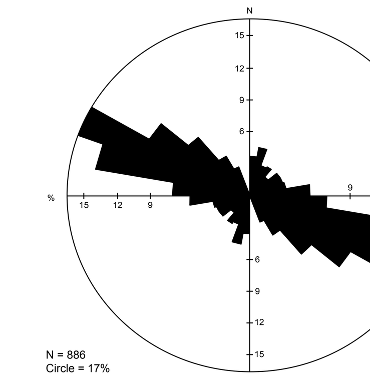

N = 886
Circle = 17%

Figure 9. Rose diagram of joint strikes in the Proterozoic rocks.

Figure 10. Cross cutting relationships between a Lamprophyre dike striking N30°W and dipping 90° cutting microcline gneiss and fault related breccia veins striking N70°E and dipping 70°S. Notice the sharp contact between the dike and the country rock. (Richard Volkert)

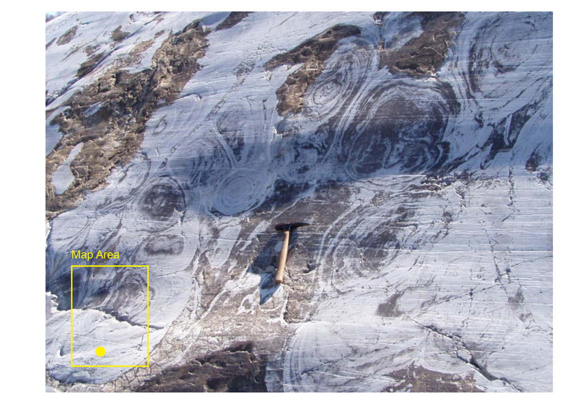


Figure 11. Stromatolites on a glacially polished bedding plane surface in the Allentown Dolomite. The near horizontal lines (grooves) which parallel the hammerhead are glacial striae. (Donald Monteverde)

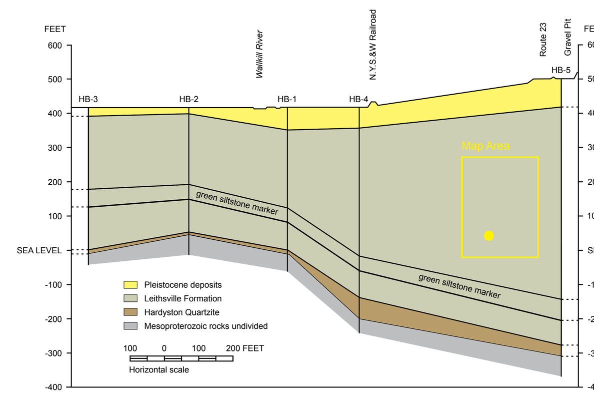


Figure 12. Cross section, based on five New Jersey Zinc (NJZ) Company borings, showing an open fold in the Hardyston Quartzite and Leithsville Formation. Note the green siltstone maker bed of NJZ is the middle sequence of the Leithsville. Revised from New Jersey Zinc Company drawings (1953) on file at the New Jersey Geological and Water Survey.

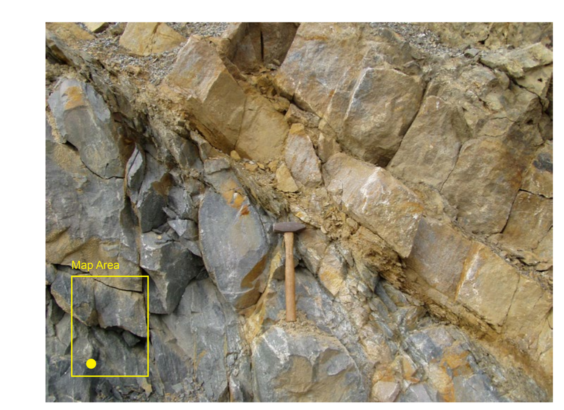


Figure 13. Angluar unconformity at hammerhead between Hardyston Quartzite (top right) and biotite-quartz-oligoclase gneiss (lower left). (Richard Volkert)

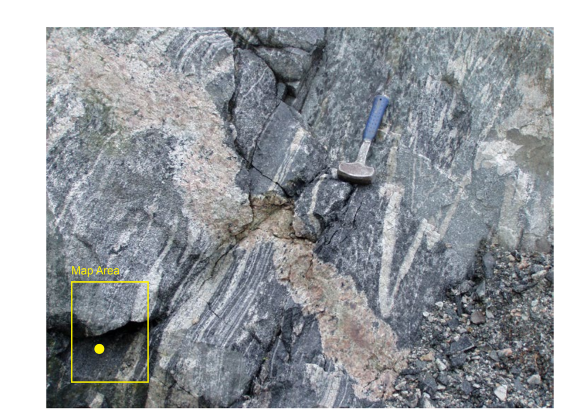
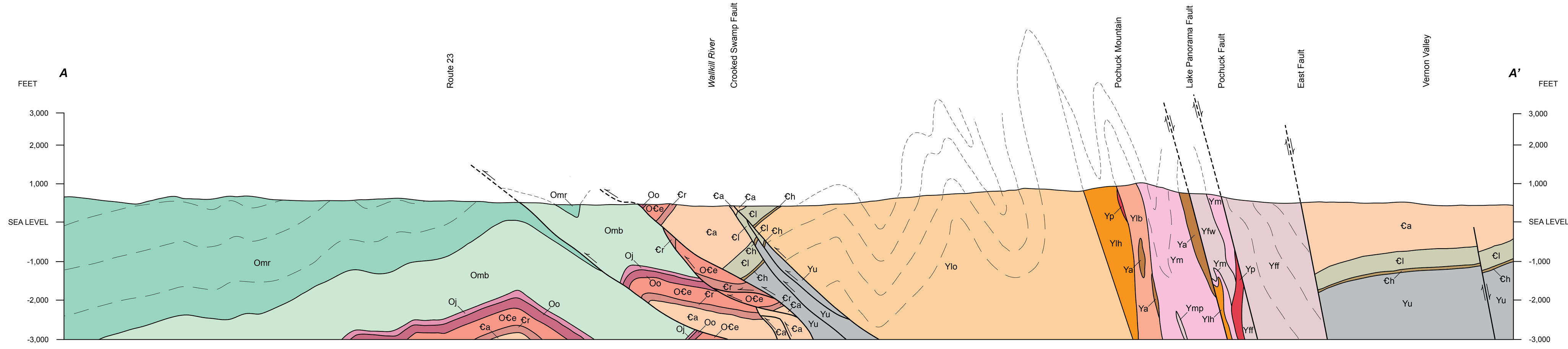
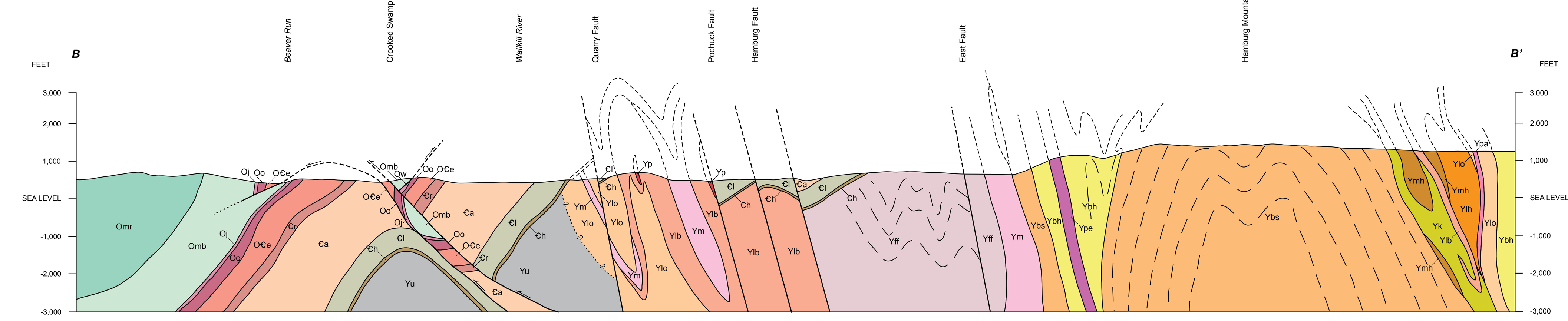


Figure 14. Pink-granite pegmatite cutting folded foliation of biotite-quartz-oligoclase gneiss at the Hamburg Quarry. (Richard Volkert)





NEW JERSEY GEOLOGICAL AND WATER SURVEY
GEOLOGIC MAP SERIES GMS 14-3

BEDROCK GEOLOGIC MAP OF THE HAMBURG QUADRANGLE
SUSSEX COUNTY, NEW JERSEY

by

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Booklet accompanies the map
Bedrock Geologic Map of the Hamburg Quadrangle
Sussex County, New Jersey
scale 1:24,000
(GMS 14-3)

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Cover photo:

This photograph shows a west-east trending wall (left to right) of the Franklin Marble exposed in a quarry at McAfee. Here the Franklin displays an atypical high density of near-vertical northeast-trending jointing paralleling the trend of the nearby Hamburg Fault which is about five hundred feet east of the quarry. Elsewhere Franklin joints are much wider spaced. A large block of gneiss within the marble is evident on the west side of the bedrock exposure. Note people outlined by a circle for scale. (Richard Dalton)

INTRODUCTION

The Hamburg quadrangle is located in northeastern Sussex County, where it spans the border between the New Jersey Highlands and the Kittatinny Valley segment of the Appalachian Valley and Ridge physiographic provinces. Mesoproterozoic rocks of the Highlands underlie the eastern part of the quadrangle, and lower Paleozoic rocks of the Valley and Ridge underlie the western part. All geologic age designations conform to U.S. Geological Survey Geologic Names Committee (2010) Fact Sheet 2010-3059.

This map provides detailed geologic information on the distribution and lithologic character of the various bedrock types and the structures that affect them. It provides a geologic framework for geologic and environmental investigations, as well as for the hydrogeologic characterization of the Cambrian through Ordovician carbonate rocks that constitute the most productive bedrock aquifer in the map area. Additionally, new interpretations of bedrock geologic relationships have rendered some previous work obsolete. Therefore, the interpretations presented here supersede those shown on previous bedrock geologic maps of the quadrangle.

Previous work on the bedrock geology of the quadrangle includes that of Bayley and others (1914), Hague and others (1956), Buddington and Baker (1961), and Drake and others (1996). In addition to the previous bedrock mapping, Stanford and others (1998) mapped the surficial deposits of the quadrangle.

STRATIGRAPHY

Paleozoic rocks

The youngest Paleozoic rocks in the quadrangle include lamprophyre dikes and related rocks of Lower Silurian to Upper Ordovician age of the Beemerville Intrusive Suite (Drake and Monteverde, 1992) that intrude rocks ranging from Upper Ordovician through Mesoproterozoic age mainly in the southern half of the map, from McAfee south to Hardistonville. Dikes strike predominantly northwest. Biotite from nepheline syenite at Beemerville yields an Rb-Sr and K-Ar cooling age of 435 ± 20 Ma (Zartman and others, 1967). Eby (2004) obtained a titanite fission-track age from nepheline syenite at Beemerville of 420 ± 6 Ma. Biotite in a minette dike from the adjacent Branchville quadrangle, collected by the New Jersey Geological Survey and analyzed by the U.S. Geological Survey (Charles Milton, written communication, 1972), yields a K-Ar cooling age of 422 ± 14 Ma. More recently, titanite from nepheline syenite at Beemerville yields a Thermal Ionization Mass Spectrometry (TIMS) U-Pb crystallization age of 447 ± 2 Ma (Ratcliffe and others, 2012).

Cambrian and Ordovician rocks of the Kittatinny Valley sequence crop out in lowland areas mainly west of Pochuck Mountain and are preserved along faults north and west of Hamburg Mountain. These rocks previously were considered part of the Lehigh Valley sequence of MacLachlan (1979), but were later reassigned to the Kittatinny Valley sequence by Drake and others (1996). They consist of the Hardyston Quartzite; the Kittatinny Supergroup (fig. 1 on map), which includes the Leithsville Formation, Allentown Dolomite, and Beekmantown Group; the Sequence at Wantage; the Jacksonburg Limestone; and the Martinsburg Formation. These sedimentary rocks record the formation of the eastern Laurentian passive margin and the approaching Taconic orogenic events. Hardyston sandstone marks the beginning of a major marine transgression along the entire eastern Laurentian margin. Conditions of the margin evolved to allow deposition of shallow water carbonate rocks of the Kittatinny Supergroup. Dominated by dolomite these units were originally deposited as limestones. Few limestone beds remain and can only be found in the Beekmantown Group sediments. The secondary dolomitization locally still preserves some of the original sedimentology, such as oolites and cross beds. The approaching Taconic orogenic event is first noted by uplift and erosion of the Kittatinny Supergroup as the peripheral bulge of the approaching foreland basin arrives. The margin subsequently resubmerged as evidenced by deposition of the Sequence at Wantage and Jacksonburg Limestone. The foreland basin continued to deepen allowing the flysch deposition of the Martinsburg Formation.

The Taconic collisional event caused cessation of sedimentation as the region was uplifted and deformed. Folding and minor faulting of the sedimentary rocks in the mapped region mark the Taconian event. Subsequent deformation of the younger Alleghanian orogenic event left a much stronger deformational impact on the geology of the mapped area as evidenced by more intense folding and thrust faulting.

Neoproterozoic rocks

Unmetamorphosed coarse- to fine-grained clastic rocks, and less abundant felsic volcanic rocks, of the

Chestnut Hill Formation of Neoproterozoic age (Drake, 1984; Gates and Volkert, 2004) are sparsely preserved throughout the New Jersey Highlands. In the map area they crop out at two places near McAfee, where they host small deposits of hematite, and at a single location on Pochuck Mountain, east of Wallkill Lake. At McAfee the Chestnut Hill Formation unconformably overlies Mesoproterozoic Franklin Marble and is unconformably overlain by the Lower Cambrian Hardyston Quartzite. On Pochuck Mountain the Chestnut Hill unconformably overlies Mesoproterozoic gneiss. Rocks of the Chestnut Hill Formation were formed from alluvial, fluvial, and lacustrine sediments, and volcanic rocks deposited in a series of small sub-basins along the eastern Laurentia rifted margin, in the present-day Highlands (Volkert and others, 2010a).

Mesoproterozoic rocks

Mesoproterozoic rocks in the map area consist of an assemblage of granites, gneisses, and marble. Most Mesoproterozoic rocks were metamorphosed to granulite facies during the Ottawan orogeny at 1045 to 1024 Ma (Volkert and others, 2010b). Temperature estimates for this high grade metamorphism are constrained from regional calcite-graphite geothermometry to 769°C (Peck and others, 2006).

The oldest Mesoproterozoic rocks in the area are calc-alkalic rocks of the Losee Metamorphic Suite that formed in a continental-margin magmatic arc, and a thick assemblage of supracrustal metavolcanic and metasedimentary rocks that formed in a back arc basin inboard of the Losee arc (Volkert, 2004). The Losee Metamorphic Suite includes plutonic rocks that are tonalite gneiss and diorite gneiss, and a layered sequence of metamorphosed volcanic rocks formed from dacite, andesite, rhyolite, and basalt protoliths (Volkert and Drake, 1999). Rocks of the Losee Metamorphic Suite yield sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages of 1282 ± 7 to 1248 ± 12 Ma (Volkert and others, 2010b).

Rocks of the Losee Metamorphic Suite are spatially and temporally associated with supracrustal rocks that include a bimodal suite of felsic and mafic metavolcanic rocks that are rhyolite gneiss and amphibolite, respectively, and metasedimentary rocks that include quartzofeldspathic gneisses, calc-silicate rocks, and marble. Metavolcanic rocks are most abundant in the area of Pochuck Mountain. Supracrustal rhyolite gneiss yields U-Pb (SHRIMP) zircon ages of 1299 ± 8 to 1251 ± 6 Ma (Volkert and others, 2010b) that overlap ages of rocks of the Losee Suite.

Granite and related rocks of the Byram and Lake Hopatcong Intrusive Suites intrude rocks of the Losee Metamorphic Suite and supracrustal rocks. Plutonic variants of both granite suites are abundantly exposed on Hamburg Mountain, near Vernon, which is designated as the type section of the Vernon Supersuite (Volkert and Drake, 1998). Byram and Lake Hopatcong rocks form a complete differentiation series that includes monzonite, quartz monzonite, granite, and alaskite, all of which have a distinctive A-type geochemical composition (Volkert and others, 2000). Granites of both suites yield similar U-Pb (SHRIMP) zircon ages of 1188 ± 6 to 1182 ± 11 Ma (Volkert and others, 2010b).

The youngest Mesoproterozoic rocks in the area are post-orogenic potassic granites and granite pegmatites that are undeformed, contain xenoliths of foliated gneiss, and intrude other Mesoproterozoic rocks in the map area as tabular to irregular bodies that are discordant to metamorphic foliation. The most abundant of these is the Mount Eve Granite that forms two prominent intrusive bodies known as Mount Adam and Mount Eve directly north of the map area, as well as more than 30 smaller bodies in adjacent areas. In the Hamburg quadrangle, Mount Eve Granite is confined to the northern part of Pochuck Mountain, whereas pegmatites are more widespread. Mount Eve Granite has an A-type geochemical composition that is similar to that of the Byram and Lake Hopatcong rocks (Gorring and others, 2004) and compositions that range from granite to syenogranite (Drake and others, 1991a).

Mount Eve Granite from Mount Adam yields a zircon U-Pb age of 1020 ± 4 Ma (Drake and others, 1991a), and from Mt. Eve a zircon U-Pb age of 1019 ± 4 Ma (Volkert and others, 2010b). Small bodies of granite north of the map area yield a zircon U-Pb age of 1004 ± 3 Ma, and pegmatites from elsewhere in the Highlands yield zircon U-Pb ages of 990 to 986 ± 4 Ma (Volkert and others, 2005).

STRUCTURE

Paleozoic bedding and cleavage

Bedding in the Paleozoic formations is fairly uniform and strikes northeast at an average of N.36°E. (fig. 2 on map). Most beds are upright and dip northwest and less commonly southeast (fig. 3 on map), and locally are overturned steeply southeast. Beds range in dip from 3^o to 90^o and average 44^o.

Cleavage develops in finer grained sedimentary rocks or where localized faulting is present. Average strike of cleavage is N.39^{o}E. (fig. 4 on map), and dips range from 10^o to 90^o and average 56^o. Generally cleavage is southeast dipping (fig. 5 on map) but some vertical to northwest dips occur. Locally a crenulation cleavage or second spaced cleavage has been observed in some units in the map area.

Proterozoic foliation

Crystallization foliation in the Mesoproterozoic rocks is formed by the parallel alignment of constituent mineral grains and it defines the trend of the bedrock units. Foliations strike mainly northeast at an average of N.25^{o}E. (fig. 6 on map). They dip southeast, and locally northwest, at 11^o to 90^o and average 59^o.

Joints

Joints are a common feature in Paleozoic and Mesoproterozoic rocks. They are characteristically planar, moderately well formed, and moderately to steeply dipping. Surfaces are typically unmineralized, except near faults, and are smooth and, less commonly, slightly irregular. Joints are variably spaced from a foot to tens of feet. Those developed in massive rocks, such as Mesoproterozoic granite or Paleozoic carbonate and quartzite, tend to be more widely spaced, irregularly formed and discontinuous than joints in Mesoproterozoic layered gneisses and fine-grained Paleozoic rocks. Joints formed near faults are spaced 2 feet or less.

In the Paleozoic rocks, northwest-trending cross joints are the most common. They strike an average of N.56^{o}W. (fig. 7 on map), and dip mainly northeast at an average of 69^o (fig. 8 on map). The dominant joint trend in Mesoproterozoic rocks strikes northwest at an average of N.64^{o}W. (fig. 9 on map), and dips southwest, and less commonly, northeast. A subordinate set strikes about N.15^{o}E. and dips southeast, and less commonly, northwest. The dip of all joints ranges from 31^o to 90^o and averages 75^o.

ECONOMIC RESOURCES

Mesoproterozoic rocks in the quadrangle host economic deposits of magnetite that were mined mainly during the early 19th century at the Copperas or Green and Bird mines. Descriptions of these mines are given in Bayley (1910). Limonite and brown hematite deposits were mined at the Pochuck and Edsall mines in the 19th century (Bayley, 1910), most likely from Mesoproterozoic rocks as well, although descriptions of the host rocks are ambiguous and no dump material is available for inspection. Earthy hematite was mined during the 19th century from Neoproterozoic rocks of the Chestnut Hill Formation at the Cedar Hill and Simpson mines. Detailed descriptions of these mines are given in Bayley (1910) and Volkert and others (2010a).

Mesoproterozoic marble was quarried mainly during the 19th and early 20th centuries at numerous locations from McAfee south to Hardistonville. Rocks of the Losee Metamorphic Suite are presently being quarried north of Hamburg. Paleozoic dolomite is currently commercially quarried from a single location near the edge of the map at Beaver Run. Numerous small farm quarries in the dolomite were encountered during mapping of the quadrangle.

Deposits of sand and gravel of glaciogenic origin were mined from numerous locations throughout the map area.

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