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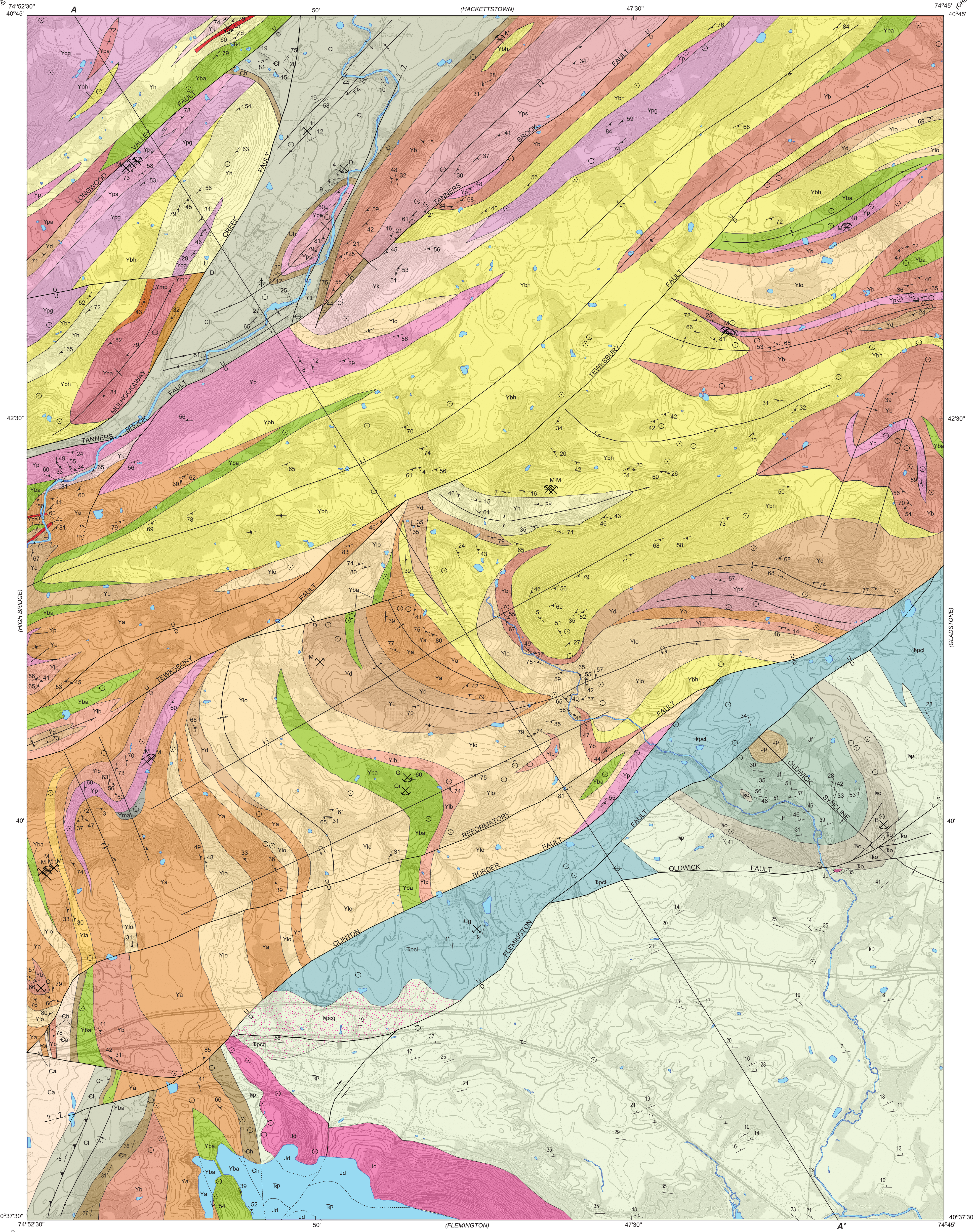

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Polyconic projection. 1927 North American datum 10,000-foot grid based on New Jersey coordinate system 1000-meter Universal Transverse Mercator grid ticks, zone 18

SCALE 1:24,000

1 MILE | 7000 FEET | 1 KILOMETER

CONTOUR INTERVAL 20 FEET

BEDROCK GEOLOGIC MAP OF THE CALIFON QUADRANGLE HUNTERDON AND MORRIS COUNTIES, NEW JERSEY

By

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Bedrock geology mapped by R.A. Volkert in 1999, 2000, 2006-7
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INTRODUCTION

The Califon 7.5-minute quadrangle is located in western New Jersey in Hunterdon and Morris Counties. The quadrangle straddles the boundary between two physiographic provinces, the New Jersey Highlands to the northwest and the Newark basin part of the Piedmont to the southeast. The South Branch Raritan River constitutes the dominant drainage in the map area, and southwest of Hoffmans it has incised deeply into the bedrock creating the scenic Ken Lockwood Gorge.

The geologic interpretations presented here supersede those shown on the bedrock geologic maps of Volkert (1989) and Drake and others (1996). The geologic maps shown in these studies lack the detail shown on, and continuity with, more recent detailed mapping of adjacent quadrangles, as well as conformity with the present geologic framework proposed for MesoProterozoic rocks of the New Jersey Highlands. This report provides updated, detailed geologic information on the stratigraphy, structure, ages and descriptions of geologic units in the map area. Cross-section A-A' shows a vertical profile of the geologic units and their structure, and rose diagrams in figures 1 through 6 provide a directional analysis of selected structural features.

STRATIGRAPHY

Mesozoic Rocks

The youngest consolidated bedrock in the quadrangle is Mesozoic in age and is present in the Newark basin, a northeast-trending half-graben in northern and central New Jersey that contains approximately 24,600 ft. of interbedded igneous and sedimentary rocks. Igneous rocks of Jurassic and Triassic age consist of diabase that underlies Cushetunk Mountain and a small body near Oldwick, and tholeiitic basalt flows that include Preakness Basalt that underlies Round Top and Orange Mountain Basalt at McCrea Mills. These outliers of igneous rocks are separated from the principal occurrences of diabase and basalt in the Newark basin. Thus, their identification and correlation were based largely on their stratigraphic position relative to sedimentary units in the quadrangle as well as their geochemical affinity to known igneous formations in northern New Jersey (Houghton and others, 1992). Sedimentary rocks include conglomerate, sandstone, siltstone, and shale of fluvial and lacustrine origin. They include the Feltville Formation of Jurassic age and Passaic Formation of Upper Triassic age. Along the Mesozoic border fault the Passaic Formation contains two distinct conglomeratic facies. The dominant facies is composed of carbonate-clasts and the less common facies is composed of quartzite and green shale chip clasts, with the clast lithology of both facies largely controlled by local source rocks.

Paleozoic Rocks

Lower Paleozoic rocks of Cambrian age of the Kittatinny Valley Sequence are present beneath Long Valley and west of Round Valley Reservoir where they unconformably overlie, or are in fault contact with, rocks of Mesoproterozoic age. They include the Hardyston Quartzite and Kittatinny Supergroup, of which only the Leithsville Formation and Allentown Dolomite are present in the map area. The Hardyston Quartzite was deposited directly on the eroded Mesoproterozoic rocks and formed from sediment mainly derived from them. Hardyston Quartzite is overlain by the Leithsville Formation and Allentown Dolomite, which are marine carbonate rocks that were subsequently dolomitized.

Neoproterozoic Rocks

Diabase dikes intruded Mesoproterozoic rocks in the northwestern part of the map area. The dikes strike northeast and have sharp contacts and chilled margins against Mesoproterozoic rocks. Similar dikes are widespread and abundant in the New Jersey Highlands where they are interpreted to have an age of about 600 Ma (million years) based on the fact they intruded only Mesoproterozoic rocks and have geochemical compositions that differ from Mesozoic diabase and basalt (Volkert and Puffer, 1995).

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 at about 1045 Ma (Volkert and others, 2010). The estimated temperature during this high-grade metamorphism is ~769° C based on regional calcite-graphite geothermometry (Peck and others, 2006). Among the oldest units are the Losee Suite formed in a continental-margin magmatic arc and spatially associated metasedimentary and metavolcanic supracrustal rocks formed in a back-arc basin, inboard of the Losee magmatic arc (Volkert, 2004). The Losee Suite includes metamorphosed plutonic rocks mapped as quartz-oligoclase gneiss, albite-oligoclase granite and diorite gneiss, and metamorphosed volcanic rocks mapped as biotite-quartz oligoclase gneiss and hypersthene-quartz-plagioclase 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 1282-1248 Ma (Volkert and others, 2010). Supracrustal rocks include quartzofeldspathic gneisses mapped as potassic-feldspar gneiss, biotite-quartz-feldspar gneiss, hornblende-quartz-feldspar gneiss, clinopyroxene-quartz-feldspar gneiss, and calc-silicate rocks mapped as pyroxene gneiss and pyroxene-epidote gneiss. Most amphibolite intercalated with metasedimentary rocks formed from a volcanic protolith. Supracrustal rocks yielded U-Pb zircon ages of 1299-1251 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. The Lake Hopatcong Suite crops out dominantly in the northern part of the map area, whereas the Byram Suite is well exposed in the southern part. Throughout the quadrangle, rocks of both suites have intruded the Losee Suite and supracrustal rocks. Byram and Lake Hopatcong rocks yielded similar U-Pb zircon ages of 1185-1182 Ma (Volkert and others, 2010). Widespread bodies of hornblende- and clinopyroxene-bearing granite and alaskite mapped as microantiperthite granite and microantiperthite alaskite crop out in the central and northern part of the area. They appear to grade along strike into hornblende granite of the Byram Suite, suggesting that they may share a common age and origin with the Vernon Supersuite. However, these rocks remain undated, and therefore are shown as having an uncertain correlation to other granitic rocks in the map area.

STRUCTURE

Mesozoic bedding

Bedding in the Mesozoic sedimentary formations in the eastern part of the quadrangle is somewhat variable in strike due to folding of the bedrock. However, sedimentary formations in the southern and western parts of the map area become more uniform in strike and bedding averages N.89°E. (Fig. 1). Nearly all of the beds dip northwest at 7° to 58° and average 29°. Bedding steepens in dip along the limbs of folds and also with closer proximity to the border fault.

Paleozoic bedding and cleavage

Bedding in the Paleozoic sedimentary formations is fairly uniform and strikes northeastward and averages N.36°E. (Fig. 2). Most beds dip northwest, but locally where deformed by folding they dip southeast. The dip of bedding ranges from 4° to 75° and averages 37°. Cleavage (closely-spaced parallel partings) in the Paleozoic rocks strikes dominantly northeast and averages N.80°E. Less commonly cleavage strikes northwest and averages N.45°W. A minor cleavage set strikes about N.22°E. The dip of cleavage is mainly toward the east, and less commonly toward the west at 64° to 90° and averages 73°.

Proterozoic foliation

Crystallization foliation (the parallel alignment of mineral grains) in the Mesoproterozoic rocks is an inherited feature resulting from compressional stresses during high-grade metamorphism related to the Grenville Orogeny between 1090 and 1030 Ma. The strike of foliation in the quadrangle is variably oriented because the rocks are deformed by folding. In general, foliation strikes northeast and averages N.51°E. (Fig. 3). Foliation dips predominantly southeast and less commonly northwest. The dip ranges from 8° to 90° and averages 55°.

Folds

Mesozoic rocks of the Passaic Formation through Preakness Basalt are locally deformed into a broad, upright syncline (Oldwick Syncline) that plunges northwest. Beds on both the west and east limbs of the fold dip gently (~30°) to moderately (~55°). Small, parasitic folds present in the hinge area of the fold plunge northwest about 25°. The hinge of the fold is deformed by the Oldwick fault that partitions it into several segments.

Paleozoic rocks of the Hardyston Quartzite and Leithsville Formation in the northern part of the map area are deformed into several tight, upright, southwest-plunging anticlines and synclines. In the southwest part of the area these same formations are deformed into a south-east-overturned syncline with a north-striking axial surface and limbs that dip west ~30°. Paleozoic folds formed during the Taconian and Alleghanian orogenies at about 450 and 360 Ma, respectively.

Folds deforming Mesoproterozoic rocks in the map area formed from compressional stresses during the Grenville Orogeny at approximately 1045 Ma and they postdate the development of crystallization foliation. Characteristic fold patterns are dominated by broad northeast-striking, east-northeast plunging, northwest overturned, and less commonly upright antiforms and synforms. These folds are refolded by east-southeast-striking, east-plunging, north verging overturned to upright antiforms and synforms. South of the Tewksbury fault, Mesoproterozoic rocks are deformed by east-southeast-striking, southeast-plunging, southwest verging overturned folds and southwest-plunging upright folds. Fold geometries displayed by Mesozoic and Paleozoic rocks are absent in Mesoproterozoic rocks, implying the lack of a younger deformational fold event that overprinted folds in the Mesoproterozoic rocks.

Faults

The structural geology of the quadrangle is dominated by a series of northeast-trending faults that deform Mesoproterozoic, Paleozoic and Mesozoic rocks. From the northwest the major faults are the Longwood Valley fault, Mulhockaway Creek fault, Tanners Brook fault, Tewksbury fault (newly named), Reformatory fault (newly named), Clinton Border fault, Flemington fault and Oldwick fault. Most of these faults are characterized by a brittle deformational fabric that consists of breccia, gouge, alteration and retrogression of mafic mineral phases, fractures or slickensides coated by chlorite or epidote, and close-spaced fracture cleavage.

The Longwood Valley fault extends through the northwestern part of the area where it separates Mesoproterozoic rocks on the footwall and both Mesoproterozoic and Paleozoic rocks on the hanging wall. The fault strikes northeast and dips southeast about 75°. The Longwood Valley fault is characterized by brittle deformation fabric. The latest movement sense is normal.

The Mulhockaway Creek fault extends through the northwestern part of the area where it separates Mesoproterozoic and Paleozoic rocks on the footwall and Paleozoic rocks on the hanging wall. To the west, Paleozoic and Mesozoic rocks are present on the hanging wall (Monteverde and others, 2015). The fault strikes northeast and dips southeast about 40°, although core drilling to the southwest near the Delaware River indicates a gentler dip of about 20 to 35°. To the north, in the Hackettstown quadrangle, the fault is cut off by the Longwood Valley fault (Volkert, 2018). The Mulhockaway Creek fault is characterized by brittle deformation fabric. The latest movement sense is normal.

The Tanners Brook fault extends through the northern part of the area where it separates Mesoproterozoic and Paleozoic rocks on the footwall and mainly Mesoproterozoic rocks on the hanging wall. The fault strikes northeast and dips southeast about 75°. The Tanners Brook fault is characterized by brittle deformation fabric. The latest movement sense is normal, although evidence for reverse movement sense is also recognized in the Chester quadrangle (Volkert, 2018) and Dover quadrangle (Herman and Mitchell, 1991).

The Tewksbury fault extends through the central and northeastern part of the area where it separates Mesoproterozoic rocks on both the footwall and hanging wall. Near Cokesbury the fault bifurcates into northern and southern segments that merge to the southwest in the High Bridge quadrangle (Monteverde and others, 2015). Northeast, in the Chester quadrangle, the fault is cut off by the Flemington fault (Volkert, 2018). The Tewksbury fault strikes northeast and dips southeast about 75°.The fault is characterized by brittle deformation fabric that overprints a steeply southeast-dipping ductile deformation fabric. The latest movement sense is normal.

The newly named Reformatory fault extends through the southern part of the area where it separates Mesoproterozoic rocks on the footwall and Mesoproterozoic and Paleozoic rocks on the hanging wall. Within the map area it is cut off by the Clinton Border fault to the northeast and by a segment of this fault to the southwest. The fault strikes northeast and dips southeast about 60 to 70°. The Tewksbury fault is characterized by brittle deformation fabric. The latest movement sense is normal but with a component of right-lateral strike-slip.

The Clinton Border fault extends through the southern part of the area where it separates Mesoproterozoic and Paleozoic rocks on the footwall and Paleozoic, Mesozoic and locally occurring Mesoproterozoic rocks on the hanging wall. It merges with the Flemington fault at the eastern edge of the area and continues east as the Flemington fault into the Morristown quadrangle (Volkert, 2013), where it was misnamed the Mendham fault. To the west it forms a separate fault that terminates in the High Bridge quadrangle (Monteverde and others, 2015). The fault strikes northeast and dips gently southeast about 40°. The Clinton Border fault is characterized by brittle deformation fabric along most of its length. The latest movement sense is normal.

The Flemington fault extends through the southern part of the map area where it separates Mesozoic diabase and Passaic Formation on the footwall and Preakness Basalt through Passaic Formation and diabase on the hanging wall. The fault strikes north-northeast and dips east-southeast about 50° (Houghton and Volkert, 1990; Herman and others, 1992). It is characterized by brittle deformation fabric, but to the east, in the Gladstone quadrangle, a thick zone of ductily deformed Mesoproterozoic rocks named the Pottersville Mylonite is preserved on the footwall (Houghton and Volkert, 1990). The latest movement sense is normal with a component of right-lateral strike-slip that appears to overprint the normal movement.

The newly named Oldwick fault is confined to the southeastern part of the area where it appears to terminate in a series of splays on its eastern end and is cut off by the Flemington fault on its western end. The Oldwick fault separates Mesozoic rocks of the Passaic Formation and Orange Mountain Basalt on both the footwall and hanging wall. The fault strikes east and dips north about 35°. It is characterized by brittle deformation fabric. The latest movement sense is normal.

A short segment of an unnamed thrust fault extends through the southwestern part of the area where it separates Paleozoic Leithsville Formation on both the footwall and hanging wall. To the south, at Leigh Cave in the Flemington quadrangle, the fault separates Leithsville on the footwall and Mesoproterozoic rocks on the hanging wall (Bayley and others, 1914; Dalton, 1976). The fault strikes north and dips west about 35°. It is characterized by brittle deformation fabric. The latest movement sense is reverse.

Joints

Joints are a ubiquitous feature in all of the Mesozoic, Paleozoic and Mesoproterozoic bedrock in the quadrangle. Joints in Mesozoic sedimentary rock tend to be better developed in outcrops of sandstone and siltstone than in finer-grained lithologies such as shaly siltstone and shale. All joints are variably spaced from <1 ft. to several feet apart, although those near faults are spaced much closer, typically on the order of <1 ft. Two main joint sets occur in Mesozoic sedimentary rocks, a dominant set that strikes an average of N.65°W. and dips about 82° northeast and a subordinate set that strikes about N.25°E. (Fig. 4). All joints are characteristically planar, moderately well formed, and unmineralized, except near faults where they may contain quartz or calcite. Joint surfaces typically are smooth and less commonly irregular.

Joints in Mesozoic igneous rocks consist of two types, columnar (cooling) and tectonic. Columnar joints are characteristically polygonal, arrayed vertically to radially and are variable in height and spacing. Tectonic joints occur in basalt and diabase but are commonly obscured by the more pervasive cooling joints. Tectonic joints are best preserved in the Orange Mountain Basalt where they are typically vertical, planar, moderately to well formed, smooth to slightly irregular, steeply dipping, unmineralized, and variably spaced from a few ft. to tens of ft. apart. In outcrops that are near faults they are spaced 1 foot or less apart.

Joints in Paleozoic rocks are typically moderately well developed, smooth to slightly irregular, and steeply dipping. They strike predominantly northeast an average of N.76°E. (Fig. 5) and dip steeply east and less commonly west an average of 72°. A subordinate joint set strikes nearly due north and dips predominantly east.

Joints in Mesoproterozoic rocks are characteristically planar, well developed, moderately to widely spaced, and moderately to steeply dipping. Joint surfaces are smooth and less commonly slightly irregular and joints are variably 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 developed in layered gneisses and finer-grained crystalline rocks. Joints formed near faults are more closely spaced, typically 2 feet or less, and commonly mineralized by chlorite and/or epidote.

The dominant joint trend in the Mesoproterozoic rocks is nearly orthogonal to the trend of the crystallization foliation, and this orthogonal relationship of the principal joint set to foliation is a consistent feature that has been observed in Mesoproterozoic rocks throughout the Highlands (Volkert, 1996). Consequently, joint trends are not uniform because of the variable orientation of foliation in the map area due to folding. Two principal joint sets are seen in the Mesoproterozoic rocks. The dominant set strikes northwest an average of N.55°W. (Fig. 6) and dips northeast and less commonly southwest an average of 69°. A subordinate set strikes an average of N.45°E. (Fig. 6) and dips northwest and less commonly southeast an average of 64°.

ECONOMIC RESOURCES

Mesozoic Preakness Basalt is presently quarried for crushed stone and aggregate at McCrea Mills. Carbonate-clast conglomerate of the Passaic Formation was quarried northwest of Potterstown. Hematite was mined from the Cambrian Leithsville Formation north of Califon, and the formation was quarried at Califon. Some Mesoproterozoic rocks were host to economic deposits of iron ore (magnetite) mined predominantly during the 19th century. Detailed descriptions of most iron mines in the map area are provided in Bayley (1910). Graphite was mined from rusty, sulfidic biotite gneiss and quartzite at locations near Lower Fairmount and Annandale. Descriptions of these graphite mines and others in the Highlands are summarized in Volkert (1997, and references therein). Mesoproterozoic granite and gneiss were quarried for crushed stone at several locations in the map area.

DESCRIPTION OF MAP UNITS

NEWARK BASIN

Jd — **Diabase (Lower Jurassic)** – Dark-greenish-gray to black, fine- to medium-grained diabase composed of plagioclase, clinopyroxene (mainly augite), and magnetite ± ilmenite. Olivine is rare. Diabase is dense, hard, and is massive to columnar jointed.

Jp — **Preakness Basalt (Lower Jurassic)** (Olsen, 1980) – Dark-greenish-gray to black, fine-grained, dense, hard basalt composed mainly of intergrown calcic plagioclase and clinopyroxene. Basalt contains small spherical tubular gas-escape vesicles, some filled by zeolite minerals or calcite, just above scoriaceous flow contacts. Unit consists of at least three major flows, although the presence of all three in the map area cannot be confirmed because of the poor exposure. Tops of the flows are marked by prominent vesicular zones up to 8 ft. thick. Radiating slender columns 2 to 24 in. wide, due to shrinkage during cooling, are abundant near the base of the lowest flow. Maximum thickness regionally is about 1,040 ft. but unit is considerably thinner in the map area

Jf — **Feltville Formation (Lower Jurassic)** (Olsen, 1980) – Reddish-brown or light-grayish-red, fine- to coarse-grained sandstone, siltstone, shaly siltstone, and silty mudstone, and light- to dark-gray or black, locally calcareous siltstone, silty mudstone, and carbonaceous limestone. Upper part of unit is predominantly thin- to medium-bedded, reddish-brown siltstone and locally cross-bedded sandstone. Reddish-brown sandstone and siltstone are moderately well sorted, commonly cross-laminated, and interbedded with reddish-brown, planar-laminated silty mudstone and mudstone. As much as 2 ft. of unit have been thermally metamorphosed along the contact with the Preakness Basalt. Thickness is about 480 ft.

Tro — **Orange Mountain Basalt (Upper Triassic)** (Olsen, 1980) – Dark-greenish-gray to black, fine-grained, dense, hard basalt composed mostly of calcic plagioclase and clinopyroxene. Locally contains small spherical to tubular gas-escape vesicles, some filled by zeolite minerals, quartz, or calcite lined with prehnite, typically above base of flow contact. Unit consists of three major flows that are separated in places by a weathered zone, a bed of thin reddish-brown siltstone, or by volcaniclastic rock. Lower part of upper flow is locally pillowed; upper part has pahoehoe flow structures. Middle flow is massive to columnar jointed. Lower flow is generally massive with widely spaced curvilinear joints and is pillowed near the top with the space between pillows lined with zeolites and other secondary minerals. Individual flow contacts are characterized by vesicular zones up to 8 ft. thick. Thickness is about 590 ft.

Trpcl, Trpcq, Trp — **Passaic Formation (Upper Triassic)** (Olsen, 1980) – Interbedded sequence of reddish-brown, and less commonly maroon or purple conglomerate, pebbly sandstone, sandstone, siltstone, shaly siltstone, silty mudstone, and mudstone. Conglomeratic rocks are subdivided into limestone (Trpcl) or quartzite (Trpcq) facies. Limestone conglomerate is medium-bedded to massive, pebble to boulder conglomerate, commonly matrix-supported. Clasts are subangular to subrounded dolomite and limestone in matrix of reddish-brown- to purplish-red sandstone to mudstone. Quartzite conglomerate is reddish-brown cobble and pebble conglomerate, pebbly sandstone, sandstone, and locally mudstone in upward-fining sequences as thick as 6 ft. Clasts are subangular to subrounded, locally imbricated quartz and quartzite in sandstone matrix. Sandstone is medium to coarse grained, feldspathic (up to 20 percent feldspar), and locally contains pebble and cobble layers. Conglomerate contains an erosive base and beds fine upward through red sandstone and mudstone. Sandstone and siltstone are reddish-brown to brownish-red, thin- to medium-bedded, planar to cross-bedded, micaceous, and locally mudcracked and ripple cross-laminated. Root casts and load casts are common. Shaly siltstone, silty mudstone, and mudstone are fine-grained, very thin- to thin-bedded, planar to ripple cross-laminated, locally fissile, bioturbated, and contain evaporite minerals. They form rhythmically fining-upward sequences up to 15 ft. thick. As much as 2 ft. of unit have been thermally metamorphosed along the contact with Orange Mountain Basalt. Approximately 6,000 ft. of unit is present in the map area.

Kittatinny Valley Sequence

Ca — **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 is present 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 is 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.

Cl — **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.

Ch — **Hardyston Quartzite (Lower Cambrian)** – Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Unit contains *Scolithus linearis* (?) and fragments of the trilobite *Olenellus thompsoni* of Early Cambrian age (Nason, 1891; Weller, 1903). Thickness is typically less than 50 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. Locally occurring pyrite blebs are common. Contacts are typically chilled and sharp against enclosing Mesoproterozoic country rock. Dikes are as much as 10 ft. thick and nearly one mile long.

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 principally of microcline microperthite, quartz, oligoclase, and hornblende. Locally contains clinopyroxene and trace amounts of graphite east of Lower Fairmount. Unit commonly grades into alaskite and with a decrease in modal quartz into quartz monzonite or quartz syenite. Includes small bodies of pegmatite too small to be shown.

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

Lake Hopatcong Intrusive Suite (Drake and Volkert, 1991)

Ypg — **Pyroxene granite (Mesoproterozoic)** – Gray-, buff- or white-weathering, greenish-gray, medium- to coarse-grained, massive, moderately foliated granite containing mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Common accessory minerals include titanite, apatite, magnetite, and trace amounts of pyrite. Unit commonly grades into alaskite and with a decrease in modal quartz into quartz monzonite or quartz syenite.

Ypa — **Pyroxene alaskite (Mesoproterozoic)** – Buff- or white-weathering, greenish-buff to light pinkish-gray, medium- to coarse-grained, massive, moderately 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, moderately foliated monzonite or syenite and less abundant quartz monzonite or quartz syenite. Composed of mesoperthite, microantiperthite to microcline microperthite, oligoclase, clinopyroxene, titanite, magnetite, and sparse apatite and quartz. Locally contains hornblende.

Back-Arc Basin Supracrustal Rocks

Yk — **Potassic feldspar gneiss (Mesoproterozoic)** – Light-gray- or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, fine- to medium-grained and locally coarse-grained, moderately foliated gneiss composed of quartz, microcline microperthite, and variable amounts of biotite, garnet, 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, sillimanite, graphite, magnetite, and pyrrhotite. Graphite and pyrrhotite are present in rusty variants which host graphite deposits. Commonly layered with quartzite containing locally abundant graphite.

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

Ymp — **Pyroxene-quartz-feldspar gneiss (Mesoproterozoic)** – Pinkish-gray- or pinkish-buff- weathering, white, pale-pinkish-white, or light-gray, medium-grained and locally coarse-grained, moderately well foliated gneiss composed of quartz, microcline, oligoclase, clinopyroxene, and trace amounts of epidote, biotite, titanite, and magnetite. Locally interlayered with amphibolite or pyroxene amphibolite.

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 variable. Contains sparse amounts of titanite, scapolite, or calcite. Commonly interlayered with amphibolite.

Ype — **Pyroxene-epidote gneiss (Mesoproterozoic)** – Light greenish-gray to greenish-pink weathering, pale pinkish-white to light greenish-gray, medium-grained, compositionally layered and foliated gneiss containing quartz, oligoclase, pyroxene, epidote, microcline, and titanite.

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 variable amounts of hornblende, biotite, and clinopyroxene. Locally contains thin layers of amphibolite.

Yla — **Albite-oligoclase alaskite (Mesoproterozoic)** – Pale pink- to white-weathering, light-greenish-gray to light-pinkish-green, medium- to coarse-grained alaskite composed of characteristic pink albite or oligoclase, quartz, and variable amounts of hornblende and (or) augite, and magnetite. Unit appears to be spatially related to quartz-oligoclase gneiss from which it may have formed through partial melting.

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

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 trace amounts of garnet. Hornblende is present locally.

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. Contains thin, conformable layers of amphibolite.

Other Rocks

Ya — **Amphibolite (Mesoproterozoic)** – Grayish-black, fine- to medium-grained, moderately layered and foliated rock composed of hornblende and andesine. Some amphibolite contains biotite and/or clinopyroxene. Associated with most Mesoproterozoic rocks in the map area. Unit formed mainly from a volcanic protolith of basalt affinity, although some amphibolite layers within metasedimentary rocks may be sedimentary in origin. All types of amphibolite are undifferentiated on the map.

Yma — **Microantiperthite alaskite (Mesoproterozoic)** – Tan- to buff-weathering, light-greenish-gray, medium- to coarse-grained, massive-textured, indistinctly foliated granite of uncertain affinity composed of microantiperthite, brown rust-stained quartz and oligoclase. Locally contains sparse amounts of biotite, hornblende, altered clinopyroxene, and magnetite.

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

EXPLANATION OF MAP SYMBOLS

Contact - Dotted where concealed.

Faults - Dotted where concealed. Queried where uncertain. Arrows show movement direction on fault, where known.

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

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

Thrust fault - sawteeth on upper plate.

FOLDS

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

Synform

Antiform

Overturned Synform

Overturned Antiform

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

Syncline

Anticline

Overturned syncline

FA — Bearing and plunge of axis or minor fold in Paleozoic rocks

PLANAR FEATURES

Strike and dip of crystallization foliation

10 — Inclined

Vertical

10 — Strike and dip of mylonitic foliation

12 — Strike and dip of inclined beds

12 — Strike and dip of cleavage in Paleozoic rocks

LINEAR FEATURES

20 — Bearing and plunge of mineral lineation in Proterozoic rocks

OTHER FEATURES

Gr — Abandoned rock quarry - Gr, granite; D, dolomite; Cg, carbonite-clast conglomerate; B, basalt

M — Abandoned mine – M, magnetite; G, graphite; H, hematite

Drill hole bottoming in bedrock

Bedrock outcrop or float

Form lines showing bedding in Mesozoic and Paleozoic rocks, and foliation in Proterozoic rocks. Shown in cross section.

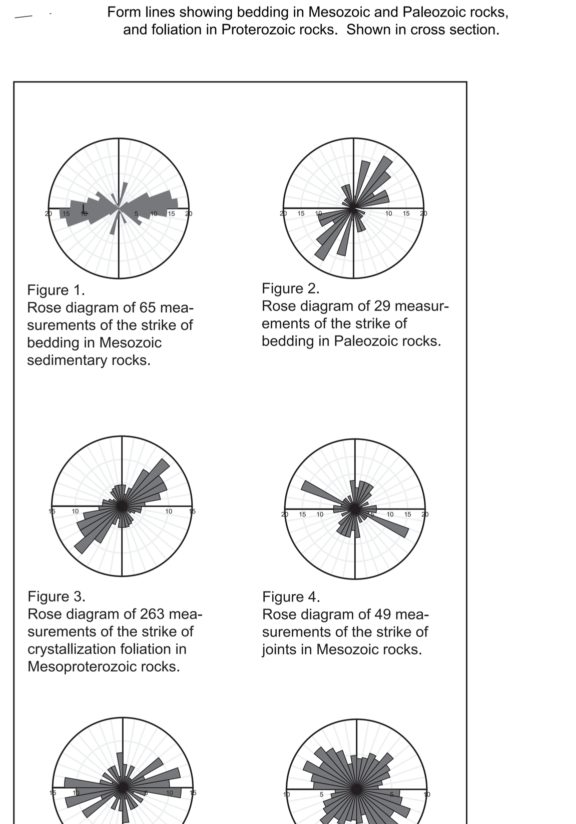


Figure 1. Rose diagram of 65 measurements of the strike of bedding in Mesozoic sedimentary rocks.

Figure 2. Rose diagram of 29 measurements of the strike of bedding in Paleozoic rocks.

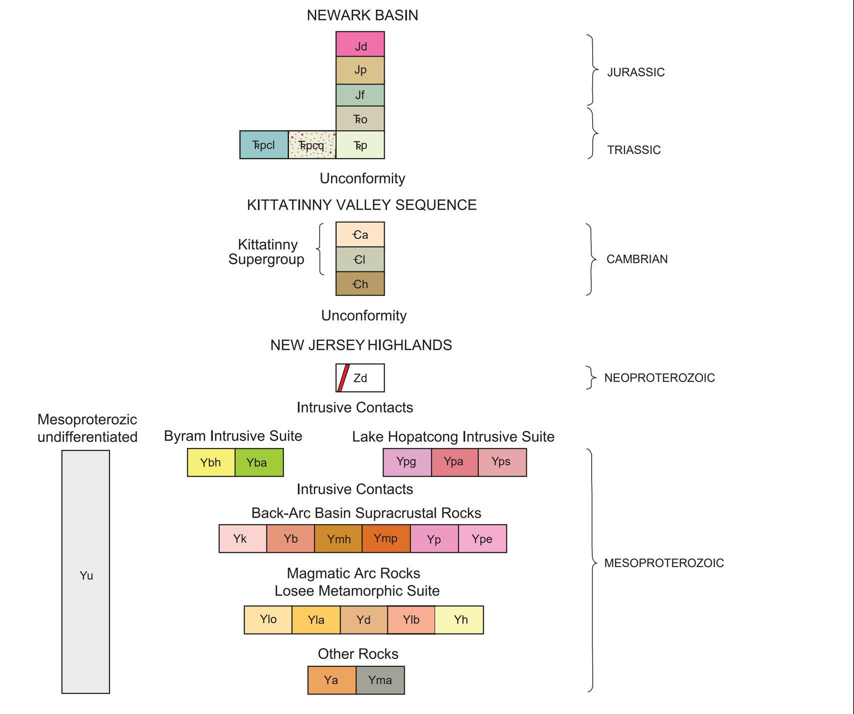
Figure 3. Rose diagram of 263 measurements of the strike of crystallization foliation in Mesoproterozoic rocks.

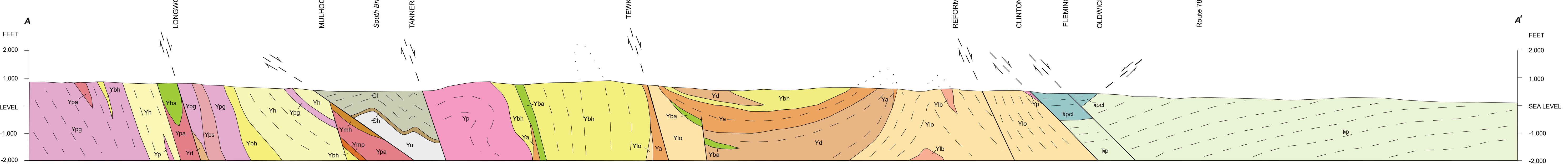
Figure 4. Rose diagram of 49 measurements of the strike of joints in Mesozoic rocks.

Figure 5. Rose diagram of 40 measurements of the strike of joints in Paleozoic rocks.

Figure 6. Rose diagram of 455 measurements of the strike of joints in Mesoproterozoic rocks.

CORRELATION OF MAP UNITS





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