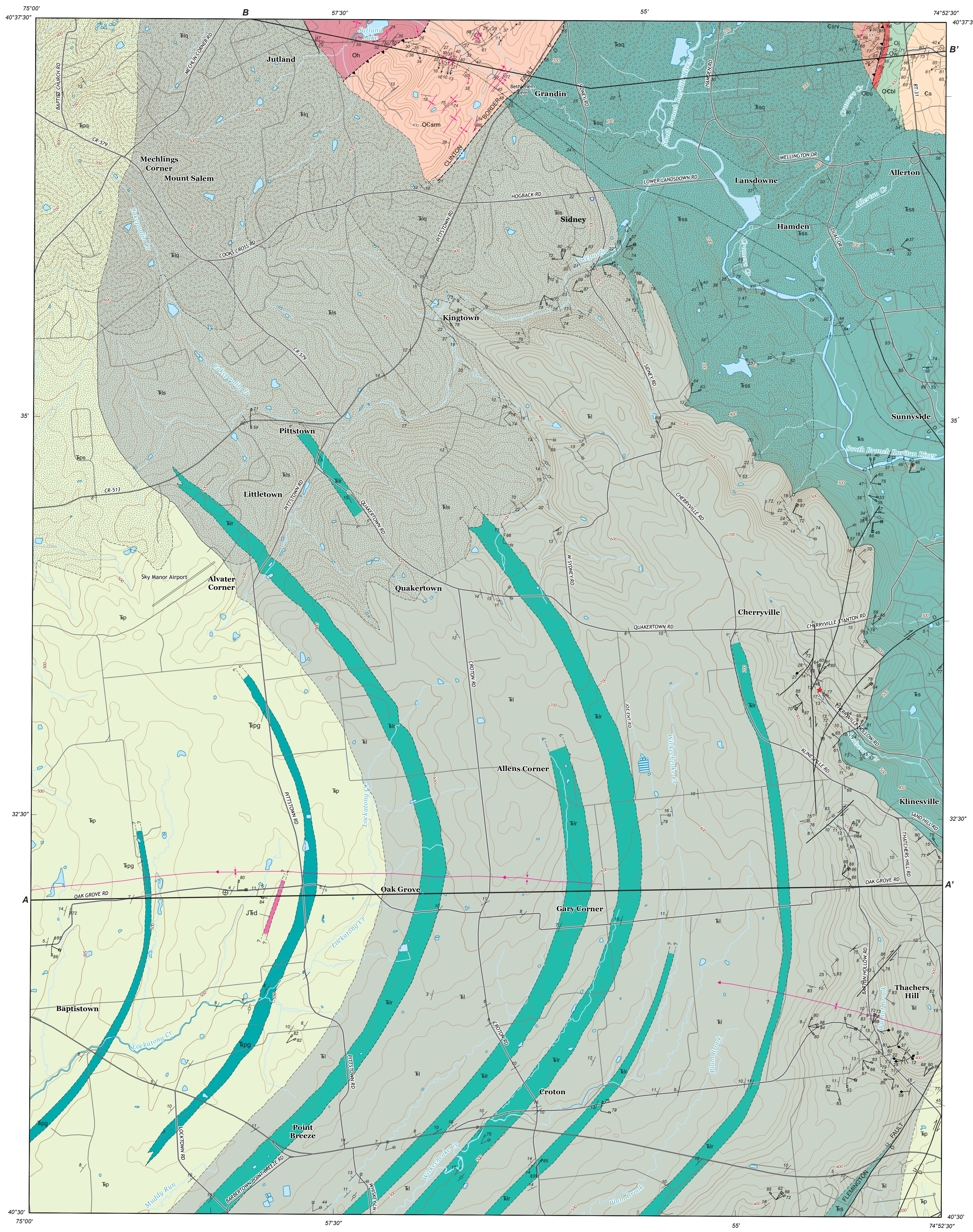
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

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

BEDROCK GEOLOGIC MAP OF THE PITTSTOWN QUADRANGLE
HUNTERDON COUNTY, NEW JERSEY
OPEN FILE MAP OFM 149



**Topographic Map produced by U.S. Geological Survey**
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1,000-meter grid: Universal Transverse Mercator, Zone 18T
10,000-foot ticks: New Jersey Coordinate System of 1983

Roads....HERE, ©2013
Names....GNIS 2013
Hydrography....National Hydrography Dataset, 2010
Countours....National Elevation Dataset, 2000
Boundaries....Multiple sources; see metadata file 1972 - 2013

UTM GRID AND 2014 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

MN 12° 29´ 222 MILS
GN 0° 2´ 1 MILS

| U.S. National Grid |
|---|
| 100,000-m Square ID<br>WL |
| Grid Zone Designation<br>18T |

SCALE 1:24 000

KILOMETERS 1 0.5 0 1 2
METERS 1000 500 0 1000 2000
MILES 1 0.5 0 1
FEET 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

# BEDROCK GEOLOGIC MAP OF THE PITTSTOWN QUADRANGLE
# HUNTERDON COUNTY, NEW JERSEY

by
Ron W. Witte[1], Donald H. Monteverde[1],
and Gregory C. Herman[1]
2022

[1] Retired, New Jersey Geological and Water Survey

Geology mapped by R.W. Witte in 2012-2014
D.H. Monteverde in 1987, 1988, 1990-1991, 2012-2014
G.C. Herman in 1987, 1988, 1990-1991

Digital cartography by R.W. Witte and D.H. Monteverde

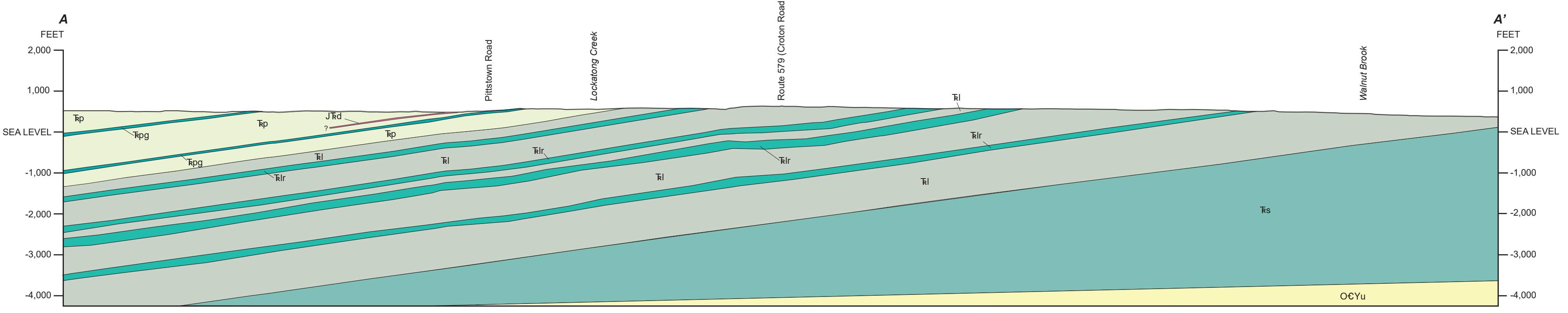
This geologic map was funded in part by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under STATEMAP award number G16AC00284. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

QUADRANGLE LOCATION

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | | 5 |
| 6 | 7 | 8 |

1 Bloomsbury
2 High Bridge
3 Califon
4 Frenchtown
5 Flemington
6 Lumberville
7 Stockton
8 Hopewell

ADJOINING QUADRANGLES



## INTRODUCTION

The Pittstown quadrangle lies in the Piedmont Province, a 1,600 square mile area that makes up about one-fifth of New Jersey. A drainage divide between the Delaware and Raritan Rivers runs through the quadrangle separating drainage between Delaware and Raritan Bays. Streams in the southwestern part of the quadrangle, Lockatong and Wickecheoke Creeks and Plum Brook flow southwest to the Delaware River. In the northern and eastern parts of the quadrangle, Cakepoulin and Assiscong Creeks, and Walnut Brook flow east to the South Branch of the Raritan River. The area is a mix of suburban and rural lands. Patchwork wood lots and cultivated fields cover large areas with larger forested areas covering locations of higher elevation in the northwest. The highest point is approximately 807 feet (246 m) above sea level on a small hill just northwest of Mechlings Corner and the lowest point lies on the South Branch where it leaves the quadrangle, just northeast of Grandin, approximately 135 feet (41 m) above sea level.

The Hunterdon Plateau covers the western two-thirds of the quadrangle. It is a somewhat undulate dissected plain underlain by slightly folded and faulted sedimentary rocks consisting of Triassic age quartzite conglomerate, sandstone, argillite, and mudstone of the Stockton, Lockatong, and Passaic Formations (Herman and others, 1992). The coarsest-grained rocks, consisting of conglomerate, lie to the north. Grain size decreases along a general southward trend, with rocks transitioning to sandstones and then argillites or mudstones. Correlatively, topography changes with underlying lithotype (fig. 1). Areas underlain by conglomerate typically hold up the highest areas. Topography is rugged here, the result of deep dissection. Rock outcrops are few because in many places the rock surface is covered by thick saprolite, fragmentation rubble, and colluvium. Areas underlain by sandstone are similar but have a slightly lower degree of dissection. Elsewhere, the Piedmont is underlain by argillite and mudstone. Topography over these rocks is that of a slightly rolling plain that ranges in elevation from 500 to 600 feet.

A hillshade image of the quadrangle (fig. 1) created from LiDAR data shows two large-scale structural features. The first is a large westward-plunging syncline marked by concentric sets of strike ridges. In many places, streams flow along arcuate courses that parallel the strike ridges. This geometry is especially prevalent in the southern half of the quadrangle where local bedrock is largely argillite or mudstone. The second feature is an escarpment along the east side of the quadrangle that parallels the strike ridge geometry. Elevation change across the scarp is about 200 feet (500 to 300 feet elevation) forming a pronounced rise in the land. In part the scarp is formed along the contact between the easily eroded mudstones of the Passaic Formation and the tough argillites of the Lockatong Formation. In the southeastern part ot the quadrangle the scarp is also in proximity to the Flemington Fault and its many splays (Herman and others, 1992), where the down-thrown side of the fault block underlies areas of lower elevation.

This map updates Herman and others (1992), and provides detailed information on the stratigraphy, structure and lithology of geologic units in the map area. Cross sections A-A' and B-B' show a vertical profile of the bedrock geologic units and their structure. Stereonets in figure 2 provide a directional analysis of bedding and fracture orientations in the map area. Surficial geology of the quadrangle is provided by Witte and Stanford (2018).

## GEOLOGIC SETTING

### Mesozoic Rocks

The youngest bedrock formations in the quadrangle lie in the Newark Basin, a rift basin of Mesozoic age formed during the breakup of Pangea. In New Jersey, the basin forms a northeast-trending half-graben that extends through northern and central parts of the state. The Newark Basin contains approximately 24,600 ft. of interbedded Upper Triassic and Lower Jurassic sedimentary and igneous rocks. The basin fill has been tilted, faulted, and locally folded (see summaries in Schlische, 1992; and Olsen and others, 1996). In the map area, it consists of Upper Triassic conglomerate, sandstone, argillite and mudstone of the Stockton, Lockatong and Passaic formations and a single small diabase body (Kummel, 1898; Kummel used the term Brunswick Formation for the current Passaic Formation).

Most of the tectonic deformation of the Mesozic rocks probably occurred during the Late Triassic to Middle Jurassic (Lucas and others, 1988; de Boer and Clifford, 1988). Southeast-dipping normal faults along the basin's northwestern margin were the primary determinants of the basin morphology, sediment deposition patterns, and the orientation of secondary structures within the basin. Periodic motion on these faults acting on sediment coming into the basin from the Highlands to the northwest, resulted in regional sediment dispersal patterns parallel to the basin's long axis (northeast-southwest). Locally in the northern part of the mapped area, sediment changes in grain size from coarse to fine from north to south. This shows that sedimentation in the northwestern margin of the basin was largely controlled by southwest flowing streams draining uplands north of the border fault.

Syn-rift sedimentation continued into the Early Jurassic (Malinconico, 2010). While some of the intra-basinal faulting, transverse folding (Schlische, 1992, 1993), and northwest tilting of the basin occurred during active deposition, most post-date syn-rift sedimentation (Withjack and others, 2013). Post-rift contractional deformation, basin inversion, and associated erosion have been recognized in the Newark and other Mesozoic basins (de Boer and Clifford, 1988; Withjack and others, 1995; R. Schlische, 1996, oral communication). Inversion and erosion of Newark Basin rocks was followed by flexural loading of the passive margin by Cretaceous sediments of the Coastal Plain sequence.

### Paleozoic Rocks

Lower Paleozoic rocks of Cambrian through Ordovician age of the Kittatinny Valley Sequence and Jutland Sequence crop out in the northern part of the quadrangle near Jutland and Allerton and are unconformably overlain by Mesozoic rocks of the Piedmont. The Paleozoic rocks represent deposition mostly in shallow seas with some of the Jutland Sequence in deeper water environments. Later they were uplifted during the Taconic Orogeny when they were extensively faulted and folded. These rocks were again uplifted and folded during the Alleghenian Orogeny which culminated in the forming of the supercontinent Pangea during the terminal Paleozoic. Erosion and normal faulting related to rifting during the Early to Middle Triassic resulted in a low lying erosional surface that was subsequently covered by Mesozoic sediments.

## STRATIGRAPHY

### Mesozoic Rocks

Bedrock units range in age from the Upper Triassic to Lower Jurassic (Olsen, 1980) and consist of a succession of alluvial and lacustrine sedimentary rocks that are locally intruded and overlain by igneous rocks. Sedimentary rocks cover most of the map area. The basal Stockton Formation is dominantly an alluvial succession of red, light-brown, gray, and buff sandstone, arkosic sandstone, and conglomerate deposited primarily in fluvial environments. Sandstone, siltstone and mudstone are more common in the upper half of the Stockton (McLaughlin, 1945, 1959). The overlying Lockatong and Passaic Formations are dominantly red, gray, and black shale, siltstone, and argillite that were deposited primarily in lacustrine environments. The red and gray to black bedrock units display a cyclical pattern at four different scales related to both depth and duration of the lakes (Olsen and others, 1996). Olsen and Kent (1996) and Olsen and others (1996) show that these cycles reflect climatic variations influenced by Milankovitch orbital cyclicity. The 20,000-yr climatic precession cycles each consist of about 20 feet of lacustrine sediment deposited in shallowing lacustrine to mudflat environments.

### Paleozoic Rocks

Bedrock units range in age from lower Cambrian to Upper Ordovician and include rocks of the Kittatinny and Jutland Klippe Sequences. They were previously considered to be part of the Lehigh Valley Sequence of McLaughlin (1959) but were reassigned by Drake and others (1996) to the Kittatinny Valley and Jutland Klippe Sequences. Kittatinny Valley Sequence rocks in the quadrangle include (from oldest to youngest), the Leithsville Formation, Allentown Dolomite, lower and upper parts of the Beekmantown Group, and Jacksonburg Limestone. They represent shallow water, carbonate platform sequences. Jacksonburg deposits lie unconformably atop the older carbonate units due to migration of the peripheral bulge (Jacobi, 1981; Quinlan and Beaumont, 1984) from thrust loading to the east. This was the first indication of the onset of the Taconic Orogeny and basin deepening during the Middle Ordovician. Jutland Sequence deposits, represented by shales and minor limestones, are largely deep water deposits coeval with Kittatinny Valley Sequence rocks. The Jutland rocks were thrust westward in the Taconic Orogeny. In the Pittstown quadrangle, the lower Paleozoic rocks, and possibly metamorphic rocks of Middle Proterozoic age, form the basement on which the Mesozoic sediments were deposited.

## STRUCTURE

The Flemington Fault (Kummel, 1897, 1898) crosses the southeastern corner of the quadrangle where it trends northeastward displaying a dominantly normal offset. Several splays branch off the fault including small faults that bisect the footwall blocks along the eastern side of the quadrangle. Most faults are normal with footwalls located on their western side away from the Flemington Fault. A few faults also exhibit strike-slip motion, possibly the result of differential motion between the main fault and footwall blocks (figure 3). The Clinton Border Fault, showing normal offset, crosses the northern map boundary with the High Bridge quadrangle (Monteverde and others, 2015). It separates Stockton and Lockatong Formations on the hanging wall from Cambrian and Ordovician Jutland sediments in the footwall. It terminates within the quadrangle with normal offset backstepping to the northwest onto the Triassic border fault on the Bloomsbury quadrangle (Drake, 1967). The Jutland sediments bounded by the Clinton Border Fault form a rider block (Schlische, 1992).

Withjack and others (2013) suggested that motion on the intra-basinal faults like the Flemington Fault had initial normal offset which began during the early stages of the Central Atlantic Magmatic Province (CAMP) igneous activity (Marzoli and others, 1999). CAMP include the Orange Mountain, Preakness and Hook Mountain Basalts and associated intrusive deposits. Later strike-slip motion on the intrabasinal faults postdates the CAMP activity. Elsewhere, extensional fault-related folds are on the Flemington Fault hanging-wall block. They result from differential motion along a single fault that combines with more regional faults such as the Flemington (Schlische, 1995). The largest displacement occurred at the center of the fault trace with decreasing offset to either end. A transverse basin developed from the differential offset. Anticlinal structures formed where displacement was minimal or where fault segments intersected. Synclines are generally broader than the corresponding anticlines.

Stereonet software (Allmendinger and others, 2013, Cordozo and Allmendinger, 2013) enabled analysis of bedding and fracture orientations of sedimentary rocks throughout the map area (figure 2). Bedding trends of Passaic, Lockatong and Stockton Formations show low data variability within formations and a trend of shallower dips and more easterly strikes from Stockton to Passaic (figure 2A, 2B, 2C). Decrease in bedding dip into the Passaic probably relates to proximity to, and uplift, of the Flemington Fault footwall. Fracture data is most numerous in the Lockatong argillite due to the higher number of outcrops. Contoured stereonets of fractures within the Passaic and Lockatong (figure 2A, 2B) outline similar trends that parallel bedding strike, with the Passaic having a more northerly trend. Subsidiary trends are orthogonal to the dominant trends.

Paleozoic rocks in the quadrangle experienced several major tectonic events beginning with the Taconic and Alleghenian Orogenies. These tectonic events passed into the major Mesozoic extensional event creating the Newark Basin finally leading to the breakup of Pangea. Jutland rocks representing a deeper marine depositional environment are age equivalent to the shallow water carbonates of the Allentown Dolomite and Beekmantown Group but are separated from them by thrust faults. Thrusting is thought to have originated during the Taconic and been subsequently reactivated during Alleghenian compressive deformation. Bedding trends of the Allentown and younger Beekmantown carbonates (figure 2E, 2F) display broadly similar strike trends though with much steeper dips in comparison to the Mesozoic rocks. This strike trend differs dramatically from other lower Paleozoic sedimentary rocks in New Jersey (Drake and others, 1996). The Paleozoic strike alignment on this quadrangle parallels those of the Mesozoic units, probably due to Mesozoic extensional rift deformation.

Due to a low number of outcrops in the Allentown and Beekmantown carbonates, only a small number of fractures were recorded. These may not give a strong enough record for robust analysis. Allentown fracture density shows a moderately well developed trend of near east-west striking and south dipping fractures that mirror a subordinate trend observed in the Stockton and Lockatong rocks (figures 2B, 2C, and 2F). Beekmantown fracture trends do not mimic this trend (figure 2E).

Shales, siltstone and sandstones and minor limestone of the Jutland Klippe display many small-scale folds and northeast directed thrust faults. Beds dominantly dip southeast, but contours of poles to planes form a fairly well-developed girdle suggesting a southwest trending fold axis (figure 2D). Jutland fractures (figure 2D) show a dominant west-northwest orientation with a northeast dip. This trend is similar to that of the Allentown and, to a lesser extent, the Lockatong and Stockton Formations.

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## DESCRIPTION OF MAP UNITS

### Newark Basin

JTRd

**Diabase** (Lower Jurassic to Upper Triassic) – Regionally fine-grained to aphanitic dikes or sills containing dark-gray to dark greenish-gray, sub-ophitic diabase; massive-textured, hard, and sparsely fractured. Composed dominantly of plagioclase, clinopyroxene, and opaque minerals. Contacts are typically fine-grained, display chilled, sharp margins adjacent to enclosing sedimentary rock. Intrusion west of Oak Grove mapped by Kummel (1897) based on float and soil color. Current mapping only located rare diabase float fragments. Thickness unknown but probably less than 20 ft.

TRp
TRpg
TRps
TRpq

**Passaic Formation** (Upper Triassic) (Olsen, 1980) - Interbedded sequence of reddish-brown to maroon and purple, fine-grained sandstone, siltstone, shaly siltstone, silty mudstone and mudstone, separated by interbedded olive-gray, dark-gray, or black siltstone, silty mudstone, shale and lesser silty argillite. Reddish-brown siltstone (TRp) is medium- to fine-grained, thin- to medium-bedded, planar to cross-bedded, micaceous, locally containing mud cracks, ripple cross-lamination, root casts and load casts. Shaly siltstone, silty mudstone, and mudstone form rhythmically fining upward successions up to 15 feet thick. They are fine-grained, very-thin- to thin-bedded, planar to ripple cross-laminated, fissile, locally bioturbated, and locally contain evaporite minerals. Gray bed successions (TRpg) are medium- to fine-grained, thin- to medium-bedded, planar- to cross-bedded siltstone and silty mudstone. Gray to black mudstone, shale and argillite are laminated to thin-bedded, and commonly grade upwards into desiccated purple to reddish-brown siltstone to mudstone. Thickness of gray bed successions range from less than 1 foot to several feet thick. Thickness is exaggerated on the map to show these thin beds. The Passaic becomes coarser, northward toward the border fault, where a sandstone facies (TRps) occurs. This facies contains reddish-brown to light-brown, feldspathic, very fine to coarse sandstone and pebbly sandstone in fining upwards successions. Cross-bedding is common. Contact between sandstone facies and finer-grained rocks is gradational and interfingering. Sandstone facies becomes coarser, northward toward the border fault where a quartz-pebble conglomerate facies (TRpq) occurs. This facies is light-red to dark-reddish-brown-weathering, grayish-red to dark reddish-brown, medium- to very-thickly-bedded, pebble to cobble conglomerate in fine- to medium-grained sand matrix. Clasts are subrounded and chiefly consist of vein quartz, quartz sandstone, siltstone and shale. Interbedded grayish-red to dark-brownish-red, thin- to medium-bedded sandstone, arkosic sandstone, and siltstone occur in fining-upward successions. The Passaic Formation is generally poorly exposed and commonly mapped on float. Contact with sandstone facies is gradational along interbedded boundaries and mapped by projection from finer-grained units. Thickness of the formation is estimated at 2,000 feet in quadrangle.

TRlr
TRl
TRls
TRlq

**Lockatong Formation** (Upper Triassic) (Kummel, 1897) - Cyclically deposited successions of mainly gray to greenish-gray, and dark-gray to black shale and mudstone (TRl). Thin reddish-brown siltstone to silty argillite (TRlr) occurs locally within the unit. TRlr thickness is exaggerated on the map and cross sections to show these thin beds. Siltstone is medium- to fine-grained, thin-bedded, planar to cross-bedded with mud cracks, ripple cross-laminations and locally abundant pyrite. Shale and mudstone are very thin-bedded to thin laminated, platy, locally containing desiccation features. Lower contact gradational into Stockton Formation and placed at base of lowest continuous black siltstone bed (Olsen, 1980). Maximum thickness of unit regionally is about 2,200 feet (Parker and Houghton, 1990). Unit becomes coarser northward toward the border fault where a sandstone facies (TRls) occurs. This facies contains reddish-brown to light-brown, feldspathic, very fine to coarse sandstone and pebbly sandstone in fining upwards sequences. Cross-bedding is common. Contact between sandstone facies and finer-grained rocks is gradational and interfingering. Sandstone facies becomes coarser northward toward the border fault where a quartz-pebble conglomerate facies (TRlq) occurs. This facies is light-red to dark-reddish-brown-weathering, grayish-red to dark reddish-brown, medium- to very-thickly-bedded, pebble to cobble conglomerate in fine- to medium-grained sand matrix. Clasts are subrounded and chiefly consist of vein quartz, quartz sandstone, siltstone and shale. Interbedded grayish-red to dark-brownish-red, thin- to medium-bedded sandstone, arkosic sandstone, and siltstone occur in fining-upward sequences. Unit is very poorly exposed and commonly mapped on float. Contact with sandstone facies is gradational and interbedded. Mapped by projection from finer-grained units. Maximum thickness of the formation regionally is about 3,700 feet (Olsen and others, 1996).

TRs
TRss
TRsq

**Stockton Formation** (Upper Triassic) (Kummel, 1897) - Unit is interbedded succession of gray, grayish-brown, or slightly reddish-brown, medium- to fine-grained, thin- to thick-bedded, poorly sorted, to clast imbricated conglomerate, planar to trough cross-bedded, and ripple cross laminated arkosic sandstone (TRss), and reddish-brown clayey fine-grained sandstone, siltstone and mudstone (TRs). Coarser units commonly occur as lenses and are locally graded. Finer units are bioturbated sequences that fine upward. Conglomerate and sandstone units are deeply weathered and more common in the upper half; siltstone and mudstone are generally less weathered and more common in lower half. Lower contact is an erosional unconformity. Unit becomes coarser, northward toward the border fault where a sandstone facies (TRss) occurs. This facies contains reddish-brown to light-brown, feldspathic, very fine to coarse sandstone and pebbly sandstone in fining upwards sequences. Cross-bedding is common. Contact between sandstone facies and finer-grained rocks is gradational and interfingering. Sandstone facies becomes coarser, northward toward the border fault where a quartz-pebble conglomerate facies (TRsq) occurs. This facies is light-red to dark-reddish-brown-weathering, grayish-red to dark reddish-brown, medium- to very-thickly-bedded, pebble to cobble conglomerate in fine- to medium-grained sand matrix. Clasts are subrounded and chiefly consist of vein quartz, quartz sandstone, siltstone and shale. Interbedded grayish-red to dark-brownish-red, thin- to medium-bedded sandstone, arkosic sandstone, and siltstone occur in fining-upward sequences. Unit is very poorly exposed and commonly mapped on float. Contact with sandstone facies is gradational along interbedded boundaries and mapped by projection from finer-grained units. Formation thickness is approximately 4,000 feet.

### 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. Contains 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 uncertain due to structural complexity but estimated at 1,500 to 1,800 ft. Best exposure is along the train tracks between Jutland and Grandin.

OЄsrm

**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 cross-bedded 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 *Clonograputs* 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.

Єsrv

**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. Where mapped at surface lower contact is a fault. Thickness estimated at 800 ft.

### Kittatinny Valley Sequence

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, just north of the quadrangle boundary along the South Branch (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 unconformity on top of Beekmantown Group. 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). May be as much as 100 ft. thick.

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.

OЄbl

**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.

Єa

**Allentown Dolomite** (Upper Cambrian) – Upper section 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 section 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.

Єl

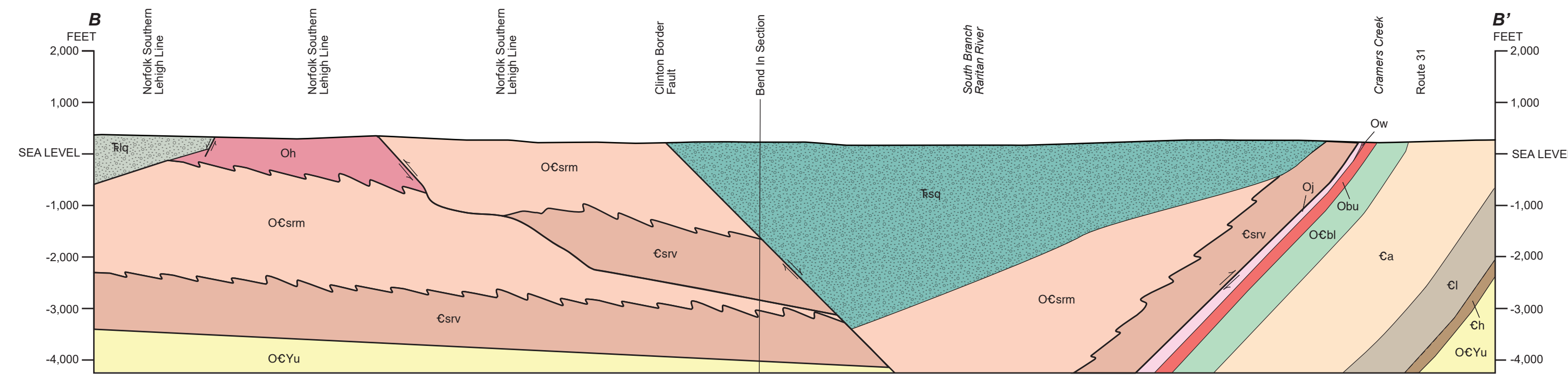
**Leithsville Formation (**Middle to Lower Cambrian) – Upper section, rarely exposed, is mottled, medium-light- to medium-dark-gray-weathering, medium- to medium-dark-gray, fine- to medium-grained, medium- to thick-bedded, locally pitted and friable dolomite. Middle section is grayish-orange or light- 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 section 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. (Franklin quadrangle), 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. Only in cross section B-B'.

Єh

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

OЄYu

**Undivided rocks of Middle Proterozoic through Ordovician age**. May include rocks of the Lehigh Valley and Jutland Sequences and Middle Proterozoic rocks of the New Jersey Highlands. Only in cross-section B-B'.



## EXPLANATION OF MAP SYMBOLS

Where multiple measurements were taken, the station location is shown preferentially by bedding, small faults, cleavage, lineation, then jointing. Other symbols are fitted as closely as possible.

**Contact** - dashed where approximately located, queried where inferred.

### FAULTS

**High angle** - U, upthrown side; D, downthrown side. Arrows indicate relative strike-slip component. Dashed where approximately located, queried where inferred.

**Thrust fault** - Sawteeth on upper plate. Dashed where approximately located.

**Fault** - showing right-lateral strike-slip offset, arrows show relative motion.

**Small fault in outcrop** - showing fault strike, bearing and plunge of slickenline(s) indicated where observed.

### FOLDS

**Anticline** - showing crest line and direction of plunge.

**Syncline** - showing trough line and direction of plunge.

**Overturned anticline** - showing trace of axial surface, direction of dip of limbs, and direction of plunge.

**Overturned syncline** - showing trace of axial surface, direction of dip of limbs, and direction of plunge.

### MINOR FOLDS

20 **Minor anticline** - showing bearing and plunge.

25 **Minor syncline** - showing bearing and plunge.

30 **Minor fold** - showing bearing and plunge.

15 **Minor fold, sinistral rotation sense (S-shaped asymmetry)** - showing bearing and plunge.

12 **Minor fold, dextral rotation sense (Z-shaped asymmetry)** - showing bearing and plunge.

### PLANAR FEATURES

⊕ **Strike and dip of bedding**
**Horizontal**

40 **Inclined**

**Vertical**

65 **Overturned**

20 **Strike and dip of spaced cleavage**
**Inclined**

21 **Strike and dip of joints**
**Inclined**

**Vertical**

45 53 **Multiple joint readings**

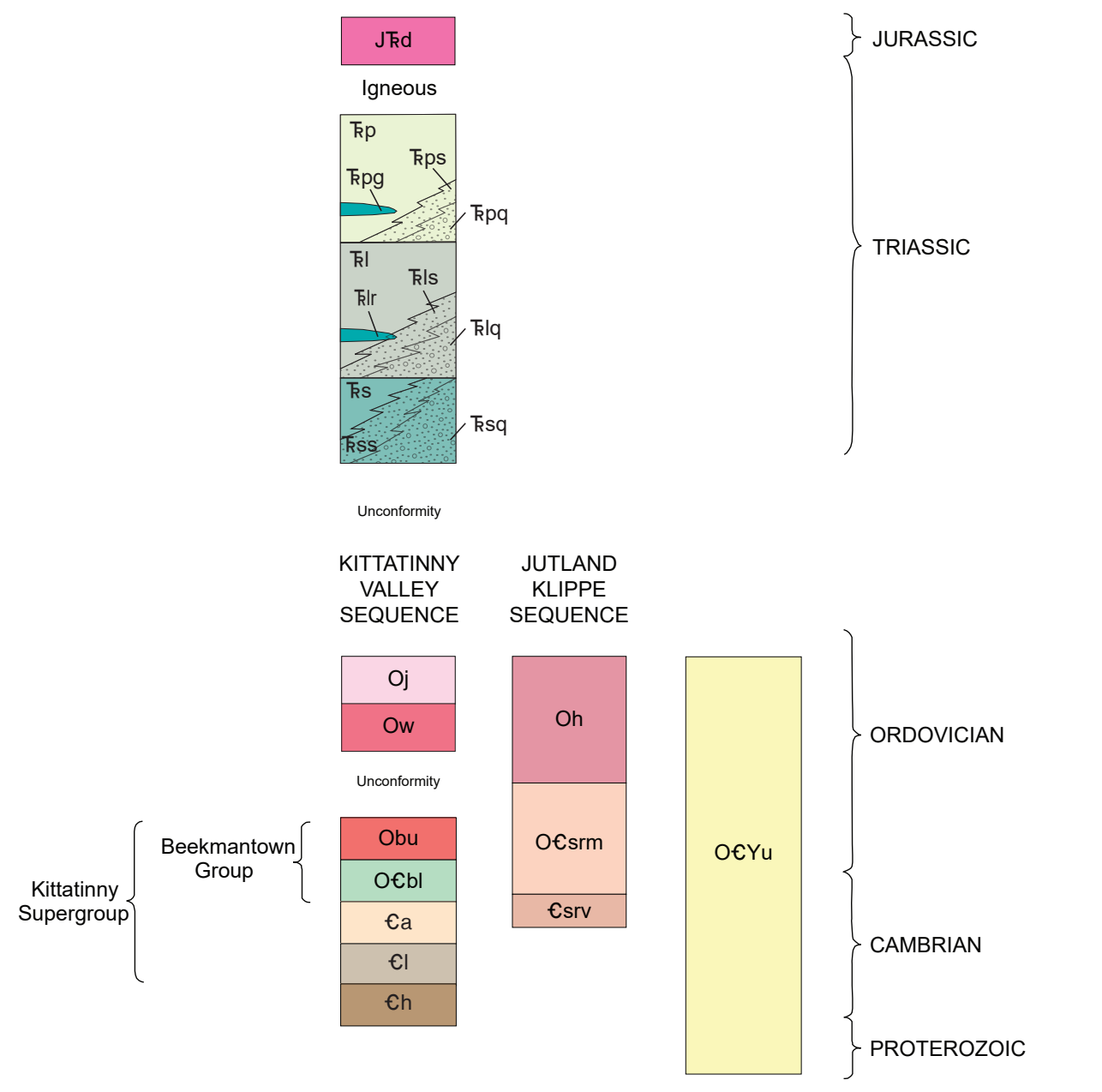
### LINEAR FEATURES

42 **Intersection of bedding and cleavage** - showing bearing and plunge.

### OTHER FEATURES

★ **Photo location**

### CORRELATION OF MAP UNITS



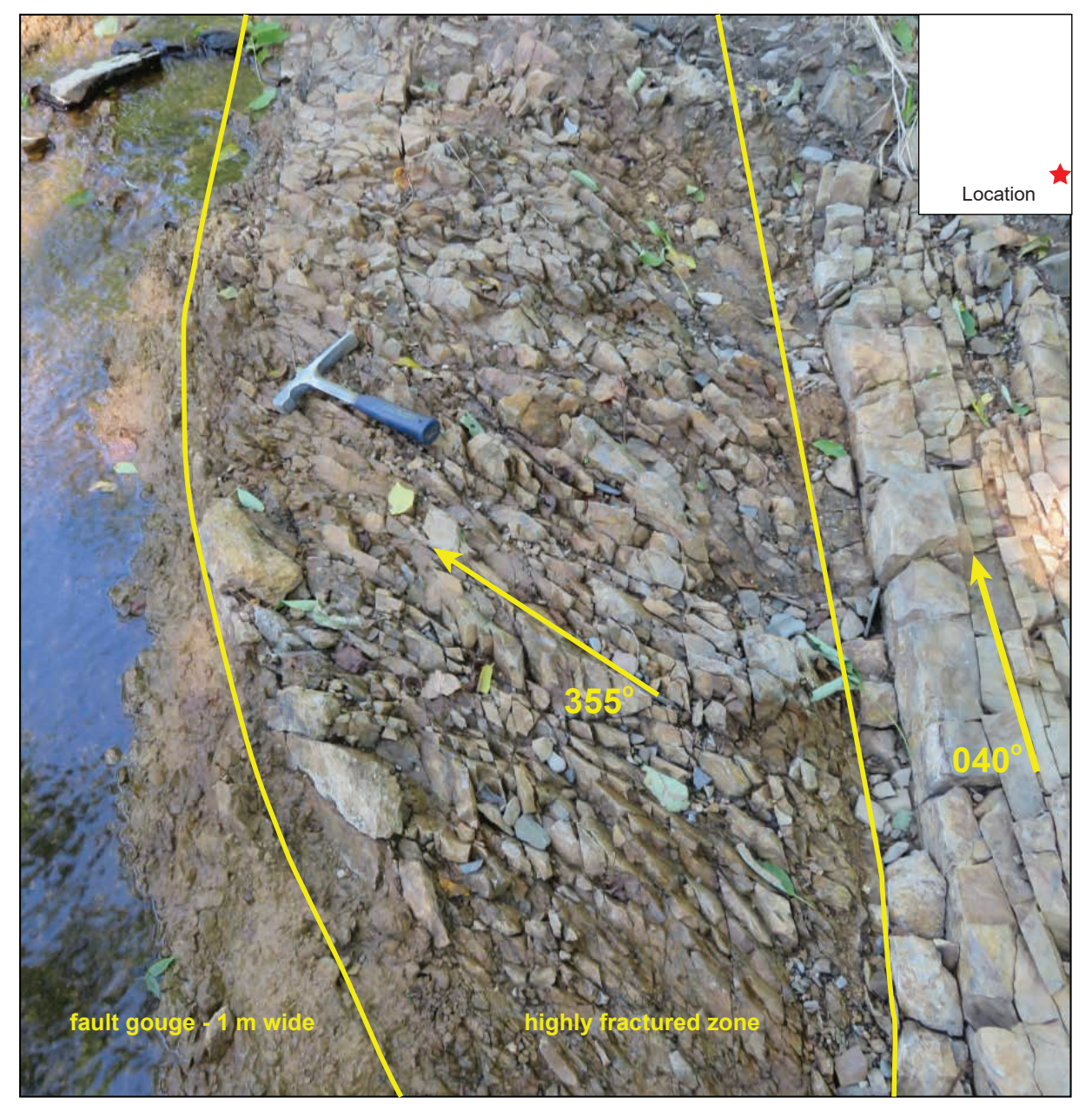


**Figure 3**. Small strike-slip fault in the Lockatong Formation along Walnut Creek in the footwall block of the Flemington Fault. Stream flow is toward the bottom of the photo. Orientation of the fault gouge is about 035˚, a trend that parallels 040˚ systematic joints. 355˚ joints in highly fractured zone were probably formed by shear across the fault. Deflection of joints farthest away from fault gouge, show right-lateral slip.

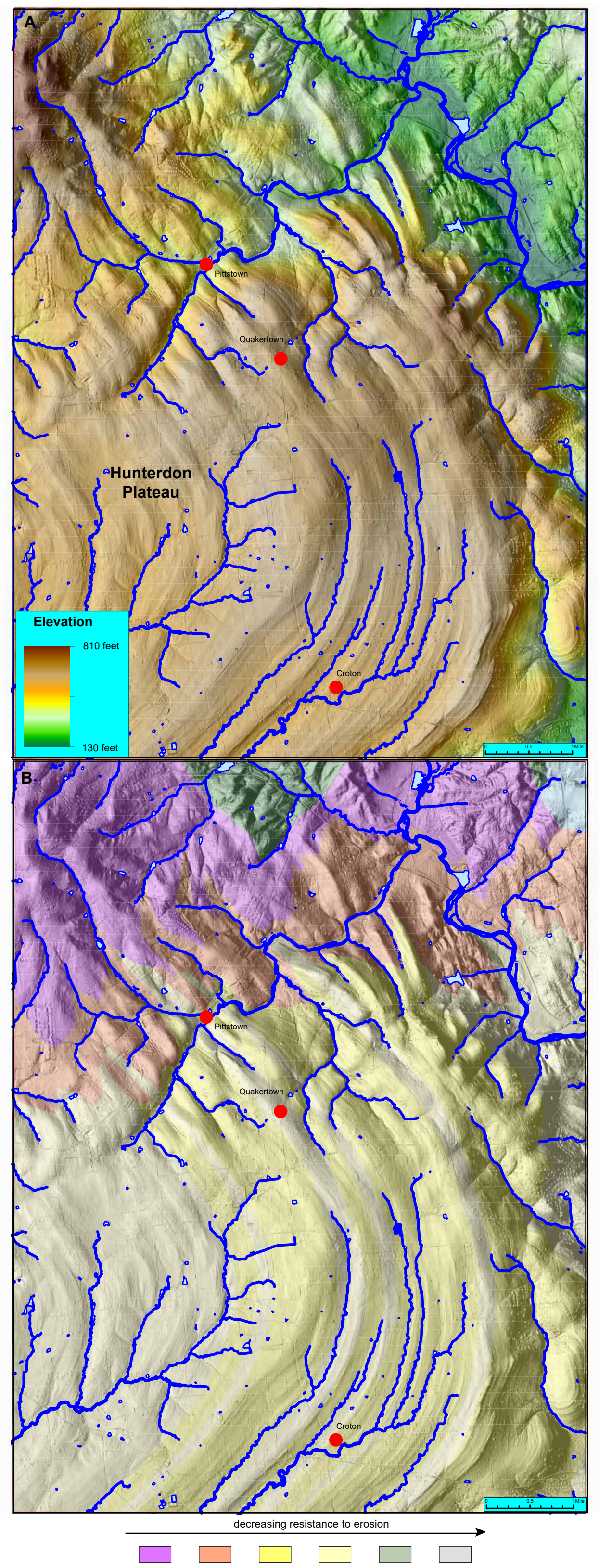


**Figure 1**. Color-shaded relief map (A) and simplified bedrock map (B) of the Pittstown quadrangle. The highest land lies in the northwest corner of the quadrangle, an area underlain by Mesozoic conglomerate that is rich in quartzite clasts. Elsewhere, Mesozoic sandstone, argillite, and Paleozoic shale typically underlie areas of high to intermediate elevation with Mesozoic mudstone and Paleozoic carbonate underlying the lowest land.

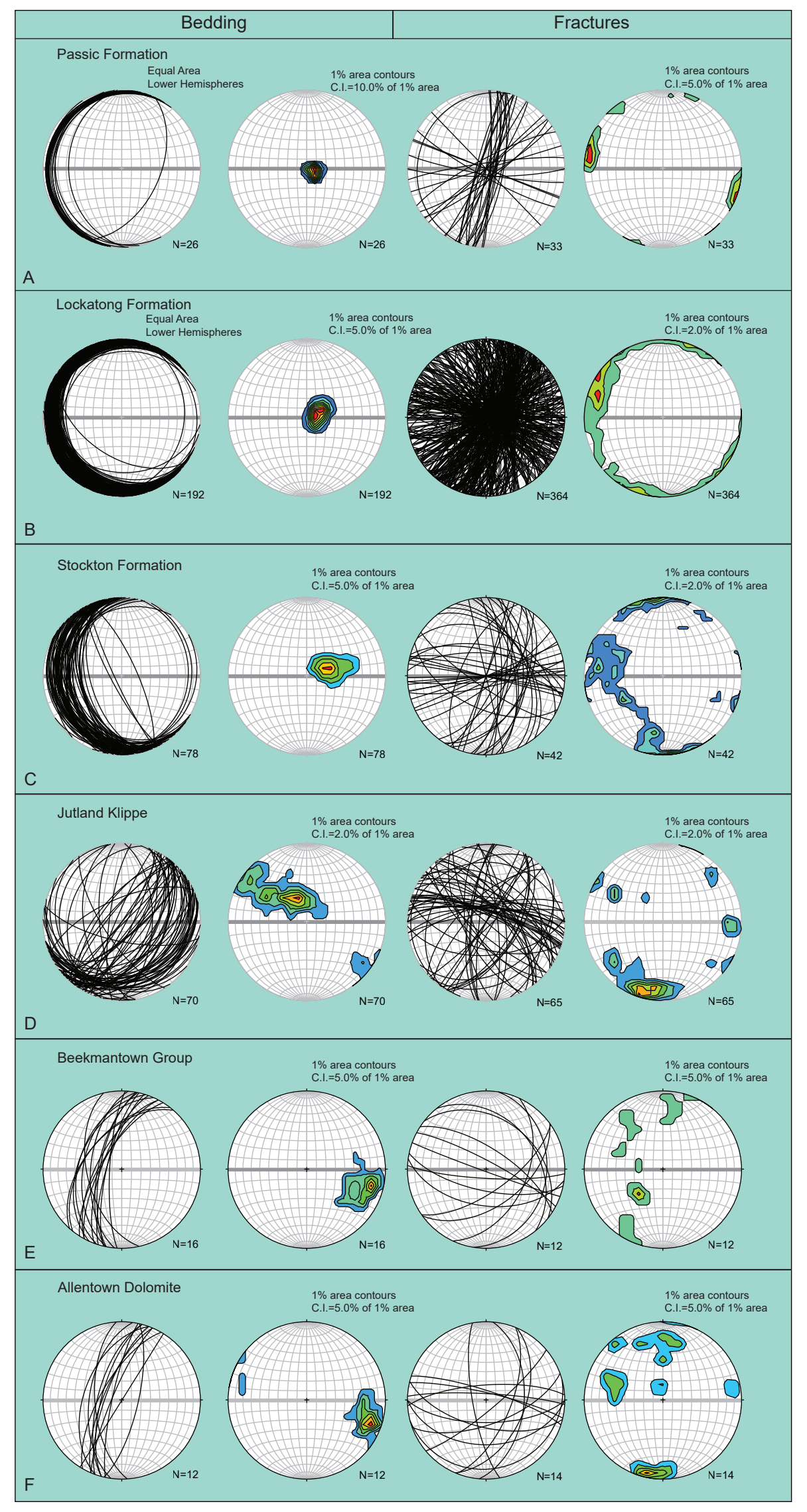


Figure 2. Stereonet analysis of bedding and fracture trends of the Passaic Formation (2A), Lockatong Formation (2B), Stockton Formation (2C), Jutland Klippe (2D), Beekmantown Group (2E) and Allentown Dolomite (2F). All plots are lower hemisphere equal area stereonets. Stereonets display from left to right: 1) bedding planes; 2) contoured poles to bedding planes; 3) fracture planes; and 4) contoured poles to fracture planes. N values record the number of orientations. Note that contour intervals shown in top right hand corner of individual stereonets vary from plot to plot. Stereonet software is from Allmendinger and others (2013) and Cardozo and Allmendinger (2013).