DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER SUPPLY AND GEOSCIENCE
NEW JERSEY GEOLOGICAL AND WATER SURVEY

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U.S. GEOLOGICAL SURVEY
NATIONAL COOPERATIVE GEOLOGIC MAPPING PROGRAM

BEDROCK GEOLOGIC MAP OF THE PENNINGTON QUADRANGLE
HUNTERDON AND MERCER COUNTIES, NEW JERSEY
OPEN FILE MAP SERIES OFM-156

INTRODUCTION

The Pennington 7.5-minute topographic quadrangle lies within the Newark Basin, part of the Piedmont Physiographic Province in Hunterdon and Mercer counties in west-central New Jersey. The Delaware River, marking the border with Pennsylvania, crosses the southwestern corner of the quadrangle. Historically a farming region, the area has become more urbanized in the southern part of the quadrangle. The east-west traversing Interstate 295 separates the more developed southern quarter of the quadrangle from the more rural northern three-quarters of the quadrangle.

Baldpate and Pennington mountains dominate the quadrangle's topography, striking east-northeast and west-southwest and rising above 400 ft elevation. These ridges are comprised of resistant diabase (also known as dolerite), while contact metamorphic Passaic Formation hornfels lie along the mountain flanks. Away from the diabase ridges, the quadrangle has a muted topography, ranging from about 40 to 200 feet above sea level, underlain by sedimentary rocks. Due to high clay content, the sedimentary rocks weather slowly and develop thin soils. This leaves slight weathering differences in the sediments to form strike ridges identifiable on aerial photographs (Stanford, 2018). West of NJ Route 31, south to southwest flowing streams drain into the Delaware River. These streams include Jacobs Creek, Woolsey Brook, Moores Creek, and several other smaller unnamed streams. Stream flow east of NJ Route 31 is east to southeast and includes Stony Brook, Honey Branch, and Shabakunk Creek. Rock ledges frequently crop out along stream beds and banks.

STRATIGRAPHY

The bedrock within the Mesozoic-aged Newark Basin was deposited as sediment and igneous material within a rift basin formed during the breakup of the Pangea supercontinent. The Newark Basin is filled with Triassic-Jurassic sedimentary and igneous rocks that have been tilted, faulted, and locally folded (see summaries in Schlische, 1992; Olsen and others, 1996). Most tectonic deformation is probably Late Triassic to Middle Jurassic age (de Boer and Clifford, 1988; Lucas and others, 1988). Southeast-dipping normal faults along the basin's northwestern margin primarily influenced the basin morphology, sediment deposition patterns, and the orientation of secondary structures within the basin. Episodic, periodic motion on these faults also affected the position where sediments entered the basin from the Highlands Physiographic Province to the west, resulting in a general sediment dispersal pattern parallel to the basin's long axis (northeast-southwest). Intrabasinal faulting occurred during active deposition (Schlische, 1992; 1993). Differential fault slip along individual segments of the border and intrabasinal fault systems resulted in a series of depressions (synforms) and ridges (antiforms) oriented normal to the fault trends along their length (Schlische, 1992). Sediment thickening into the fold troughs indicates the syndepositional nature of these regional fold structures. Tectonic deformation and synchronous sedimentation continued into the Middle Jurassic when extensional faulting and associated tilting and folding ceased. At this stage, the basin likely experienced a period of post-rift contractional deformation and localized basin inversion, which have been recognized in other Mesozoic rift basins (de Boer and Clifford, 1988; Withjack and others, 1995). Flexural loading of the passive margin by Cretaceous sediments of the coastal plain sequence just southeast of the mapped area followed erosion of the rift basin rocks.

Surficial deposits of the Quaternary and Pliocene age, not shown on this map, overlie the bedrock in parts of the quadrangle. They are discontinuous and generally less than 20 feet thick. The surficial deposits are mapped by Stanford (2018).

Sedimentary units dominate the bedrock geology of the quadrangle. They range in age from the Early Jurassic to Late Triassic (Olsen, 1980) and consist of alluvial to lacustrine sedimentary rocks locally intruded by igneous rocks. The basal Stockton Formation (fig. 1) is dominantly an alluvial sequence of red, light brown, gray, buff sandstone, arkosic sandstone, and conglomerate. Conglomerate is more common near the base, while sandstone, siltstone, and mudstone are more common in the upper half of the Stockton Formation (McLaughlin, 1945, 1959). The unit grades upward into the Lockatong Formation, dominantly gray and black, and less common red, shale, siltstone, and argillite cyclically deposited in alternating deep and shallow lacustrine environments. Argillite, a metasedimentary rock, is a term assigned to a claystone or shale that has undergone a high degree of induration but does not possess secondary cleavage as slate does (Pettijohn, 1957).


Figure 1. Arkosic sandstone of the Stockton Formation with northwesterly dip (beds are dipping towards the bottom-right in photo) overlain by wind-blown silt (yellow soil). Photo by S. Stanford.

Overlying the Lockatong is the Passaic Formation (figs. 2-4), a thick sequence of red-brown mudstone, siltstone, sandstone, and lesser purple, gray, and black siltstone, mudstone, and rare sandstone. The red and gray to black bedrock units of the Stockton, Lockatong, and Passaic display a cyclical pattern at four time scales that controlled the duration of sedimentary environments. These cycles reflect climatic variations influenced by orbital mechanics (Milankovitch orbital cyclicity; Olsen and others, 1996). The basic Van Houten cycle (Van Houten, 1969) correlates to the 20,000-yr climatic precession cycle and consists of about 20 feet of lacustrine sediment deposited in a shallowing-upward environment. Four to six Van Houten cycles comprise the short modulating cycles controlled by an approximate 109,000-yr eccentricity signal. Four short modulating cycles combine, forming a higher-order McLaughlin cycle representing the 413,000-yr eccentricity signal. The McLaughlin cycle corresponds to formational members first described by McLaughlin (1945, 1946, 1959) and later formalized by Olsen and others (1996). The longest cycle, the long modulating cycle, consists of four or five McLaughlin cycles. It represents the 2-My cycle of eccentricity.


Figure 2. Siltstone of the Passaic Formation showing blocks detached from outcrop along two intersecting vertical joint sets. The dominant set strikes northeast and the less developed set strikes northwest. Bedding dips gently northwest into the stream (to right in photo). Photo by S. Stanford.


Figure 3. Siltstone of the Passaic Formation showing two joint sets and bedding with a relatively shallow dip. Photo by S. Stanford.


Figure 4. Steeply dipping and finely fractured shale of the Stockton Formation along the footwall of a splay off of the Hopewell Fault. Photo by S. Stanford.


Figure 5. Gray shale of the Passaic Formation with two intersecting near-vertical joint sets, one striking northeast and the other striking east-west. Bedding dips gently northwest and forms the base of the gully. Photo by S. Stanford.

Passaic Formation gray-bed sequences (fig. 5) were mapped where observed in outcrop and, in places, by projecting lithologic logs from Olsen and others (1996) and from optical televiewer data to the surface of the quadrangle. Thin, gray-to-black interbeds within the dominantly red-brown Passaic beds were used as markers to depict regional strike and outline folds and faults. This proves to be an effective tool for the Passaic Formation. Generally, gray-to-black mudstone intervals are represented on the map to show bedding trends in the thicker Passaic Formation. The actual thickness of these units is exaggerated on the map to allow better depiction. A difficulty occurs due to limited Passaic exposure, especially of the gray and black units. In select cases, individual members were identified first through comparison with locations depicted in Olsen and others (1996) and then through field characterization along strike. Not all gray beds could be positively correlated to the members identified by Olsen and others (1996). Additional data was collected using the Robertson Geologging Lt. optical televiewer sonde in multiple bedrock wells having open boreholes (Herman and Curran, 2010). These include core holes and observation, monitoring, domestic, public, test, and irrigation wells. Seven wells, near Pennington and Centerville, were particular useful in positively correlating gray beds and are referred to as Wells 99 through 105 in Herman and Curran (2010). This downhole geophysical tool records oriented digital images of open borehole intervals, thereby allowing orientation readings of bedding, faults, joints, and strike and dip measurements that were projected to the surface (fig. 6).The sonde proved especially effective in aiding the location and mapping of gray beds to the surface.

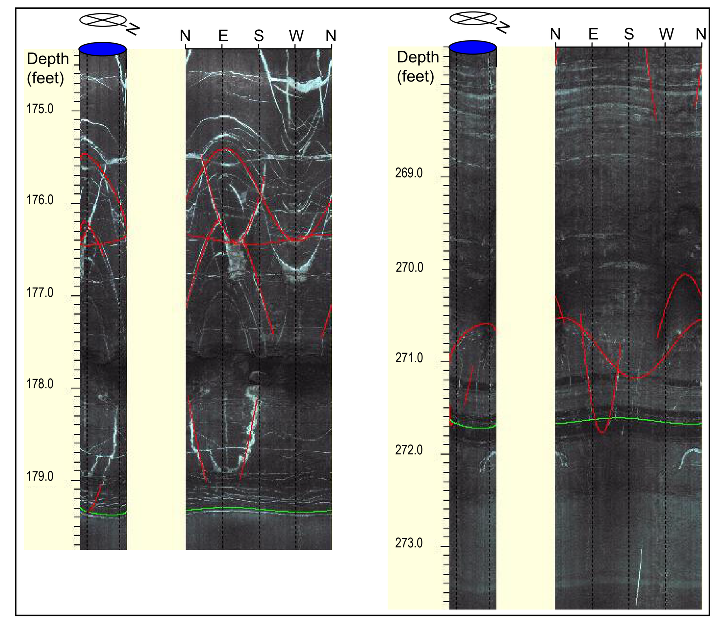

Figure 6. Examples of optical televiewer data collected from borehole POW-1 (see map for location) displaying grey and grey-black sequences at 174' to 180' and 267' to 274'. Each segment of the borehole data shown above begins with the top of a grey/grey-black sequence and ends at the bottom of the sequence.The red lines show the locations and orientations of tectonic fractures that were infilled by calcite to create veining within the rock. The green lines show location and orientation of notable bedding.

Diabase sills and dikes intrude Triassic sedimentary rock in the Pennington quadrangle. The largest intrusive bodies underlie Baldpate and Pennington Mountain (fig. 7) and occur as sills that only intrude the Passaic Formation. The current mapping effort suggests that the underlying sills were later folded into synclinal structures. A smaller intrusion crosses the extreme northeastern edge of the quadrangle on Mount Rose. This body continues onto the Hopewell quadrangle to the north and the Princeton quadrangle to the east. Mineralogy and chemistry categorize them as diabase bodies. Similar bodies exist both to the west on the Lambertville quadrangle (Herman and others, 2023) and also across the Rocky Hill (Parker and Houghton, 1990a), Monmouth Junction (Parker and Houghton, 1990b; Beetle-Moorcroft and others, 2018), and New Brunswick quadrangles (Stanford and others, 1998) to the east and ultimately connect to the Palisades Sill. To the north in the Hopewell and Stockton quadrangles, the diabase sheets intrude older sediments of the Lockatong Formation and are again brought to the surface due to faulting. Various authors (Hozik and Colombo, 1984; Husch, 1988; Houghton and others, 1992) have suggested the diabase and the Orange Mountain Basalt, a series of flows resting atop the Passaic elsewhere in the basin, originated from the same source based on geochemical and paleomagnetic data.


Figure 7. Vertical joints in diabase at the west end of Pennington Mountain. Photo by S. Stanford.

The extent of the diabase bodies was mapped using float as a proxy for the contacts, as the contacts are not exposed. Thermally metamorphosed sediments are mapped that surround the diabase intrusions. The first occurrence of hornfelsic sediment downslope marked the contact as the diabase underlies topographic highs.

STRUCTURE

The bedding strike of sedimentary units is dominantly between N40°E and S70°E with north-northwesterly dip directions (fig. 8, row 1).

The Hopewell Fault is the mapped area's primary structure that cuts the quadrangle's northwestern corner. The Hopewell Fault is one of two major intrabasinal faults that cut the Newark Basin. A southeast dipping normal fault repeats the section in this quadrangle by placing the Passaic Formation and the diabase intrusion on the hanging wall against the Stockton Formation on the footwall. The fault trends easterly in the western part of the quadrangle before rotating to a northeasterly trend before exiting the northern boundary of the quadrangle.

Small-scale faults occur throughout the quadrangle (fig. 8, rows 3 and 4). In the northwest corner of the quadrangle within the Hopewell footwall, several faults parallel the easterly trend of the Hopewell Fault. Similar trending faults probably exist but could not be documented due to limited exposure. Both northwest and north-trending faults portraying limited offset cut the Hopewell hanging wall. These faults are projected by mapping and observed on the optical televiewer data. These faults are probably related to inversion when the extensional regime responsible for the opening of the Newark Basin and subsequent Atlantic Ocean switched to compression created by rising asthenospheric material during initial ridge activity (Schlische and others, 2003).

Systematic sets of extension fractures (joints) occur along two primary strike trends ranging from 040-060 and 020-040 (fig. 8, row 2). Other sets of fractures and brittle shear planes are mapped that may post-date the extension-fracture sets. These fracture sets can occur in relative isolation or in combination with one another at different locations (Herman, 1997, 2001).

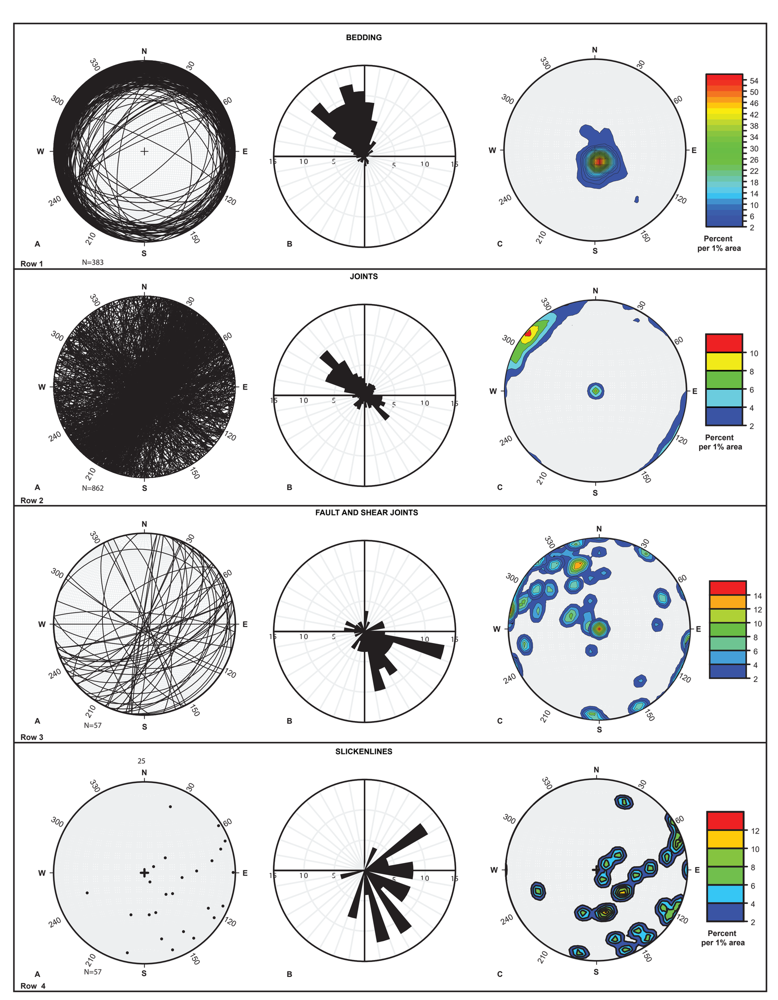

Figure 8. Plots of structural field data. Row one is all bedding data, row two is joint data, row three is fault and shear joint orientations and row four is slickenline orientations. In each row the first plot (A) shows either the planar feature (row 1-3) or the trend of the lineations (row 4). The second plot (B) is a rose diagram showing the dip direction of the planes or the trend and plunge direction of the lineation (row 4). The third figure (C) shows the contours of the poles to planes (row 1-3) or the pole of a line (row 4). Each contour represents 1% of the data, counting area is 1% of net area. Software program is from Stereonet 11 found at https://www.rickallmendinger.net/stereonet and based on Allmendinger and others (2013).

DESCRIPTION OF MAP UNITS

Jd	**Diabase** (Lower Jurassic) – Fine-grained to aphanitic dikes and sills and medium-grained, discordant, sheet-like intrusion of dark gray to dark greenish-gray, sub-ophitic diabase; massive-textured, hard, and sparsely fractured. They are composed dominantly of plagioclase, clinopyroxene, and opaque minerals. Contacts are typically fine-grained and display chilled, sharp margins adjacent to enclosing sedimentary rock. Sills exist on Mount Rose, Baldpate, and Pennington mountains and may be the southern extension of the Palisades sill. The thickness of the diabase in the quadrangle, known mainly from drill-hole data, is approximately 1,300 feet.
TRp, TRpg, JTRph	**Passaic Formation** (Lower Jurassic and Upper Triassic) (Olsen, 1980) – Interbedded sequence of reddish-brown to maroon and purple, fine-grained sandstone, siltstone, shaly siltstone, silty-mudstone, and mudstone (TRp), separated by interbedded olive-gray, dark-gray, or black siltstone, silty-mudstone, shale (TRpg), and hornfels (JTRph). Reddish-brown siltstone 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 sequences 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 sequences (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. The thickness of gray bed sequences ranges from less than one foot to several feet thick. Thick thermally metamorphosed sections (JTRph) exist where intruded by diabase. The unit is approximately 11,000 feet thick.
TRl, TRlr	**Lockatong Formation** (Upper Triassic) (Kümmel, 1897) – Cyclically deposited sequences of mainly gray to greenish-gray, and in the upper part of the unit, locally reddish-brown siltstone to silty argillite and dark gray to black shale and mudstone. 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 thinly-bedded to thinly laminated, platy, locally containing desiccation features. Grayish-red, grayish-purple, and dark brownish-red sequences (TRlr) are exposed in one outcrop along Interstate 295 near Bear Tavern Road. The lower contact grades into the Stockton Formation and is placed at the base of the unit's last/lowest continuous black siltstone bed (Olsen, 1980). The maximum thickness of the unit regionally is about 2,200 feet (Parker and Houghton, 1990a).
TRs	**Stockton Formation** (Upper Triassic) (Kümmel, 1897) – Interbedded sequence 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, and reddish-brown clayey, fine-grained sandstone, siltstone, and mudstone. Coarser units commonly occur as lenses and are locally graded. Finer units are bioturbated and form fining upward sequences. Conglomerate and sandstone units are deeply weathered and more common in the lower half; siltstone and mudstone are generally less weathered and more common in the upper half. Lower contact is an erosional unconformity. The thickness is approximately 4,500 feet.
PMu	**Pre-Mesozoic undifferentiated** – only depicted in cross section.

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EXPLANATION OF MAP SYMBOLS

Contact
- Solid where contact is known/observed
- Dashed where approximately located

Faults
- U denotes upthrown side; D denotes downthrown side; ball and post indicates direction of dip; solid where motion direction is uncertain
- Dashed where approximately located
- Arrows indicate relative motion along faults in cross-section

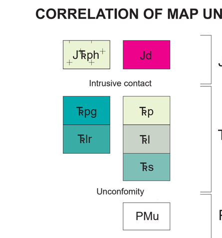
Folds
- Anticline - showing trace of axial surface, direction and dip of limbs
- Syncline - showing trace of axial surface, direction and dip of limbs
- Bedrock strike ridges - Developed along strike of resistant bedrock ridges mapped using LiDAR and stereo aerial photos (Stanford, 2018)

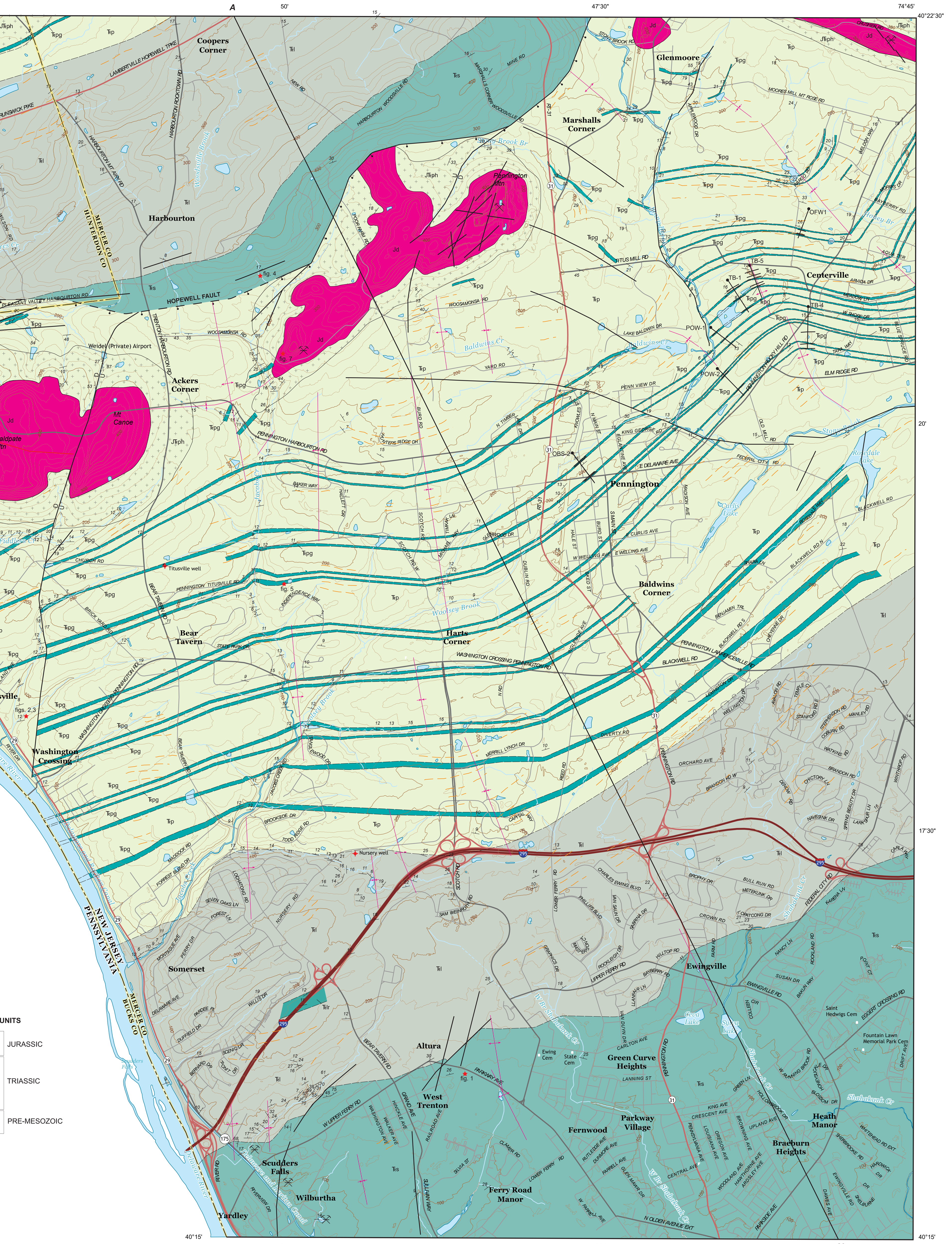
Planar features
- 11 Strike and dip of inclined beds - includes data from Kümmel (ca. 1900), Houghton (ca. 1985), and Herman and Curran (2010)

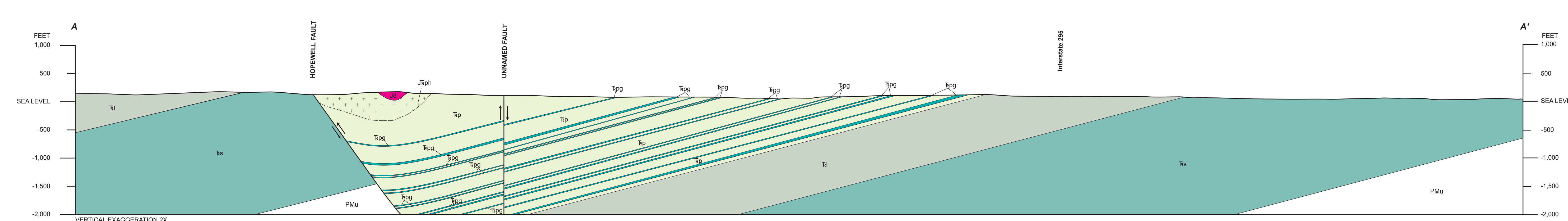
Optical televiewer data projected to surface
- OBS-2 Dot indicates borehole location. Long line shows dip direction and cross lines portray intersection of predominantly gray and black mudstone sequencesIdentifier refers to NJGWS televiewer projects

Other features
- Newark Basin coreholes of Olsen and others (1996)
- Abandoned rock quarry
- Active rock quarry (as of 2022)
- fig. 1 Photograph location - identifier refers to figure number

CORRELATION OF MAP UNITS







Topographic map produced by the United States 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, Pennsylvania Coordinate System of 1983 (south zone)

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Names....GNIS, 2013
Hydrography....National Hydrography Dataset, 2010
Contours....National Elevation Dataset, 2010
Boundaries....Multiple sources; see metadata file 1972 - 2013

UTM GRID AND 2014 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
12° 30' 222 MILS; 0° 7' 2 MILS

U.S. National Grid
100,000-m Square ID: WK
Grid Zone Designation: 18T

SCALE 1:24 000
KILOMETERS · METERS · MILES · FEET
CONTOUR INTERVAL 20 FEET

QUADRANGLE LOCATION

ADJOINING QUADRANGLES
1 Stockton
2 Hopewell
3 Rocky Hill
4 Lambertville
5 Princeton
6 Langhorne (PA)
7 Trenton West
8 Trenton East

ROAD CLASSIFICATION
Expressway · Local Connector
Secondary Hwy · Local Road
Ramp · 4WD
Interstate Route · US Route · State Route

Bedrock Geologic Map of the Pennington Quadrangle, Hunterdon and Mercer Counties, New Jersey

By
Donald H. Monteverde[1], Gregory C. Herman[1], and Jeremy M. Weremeichik
2023

Bedrock geology mapped by D.H. Monteverde 2004
G.C. Herman 2002-2004
H.F. Houghton and J.P. Mitchell circa 1985

Digital cartography by D.H. Monteverde and G.C. Herman
[1] Retired, New Jersey Geological and Water Survey

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