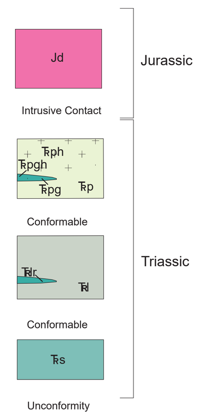
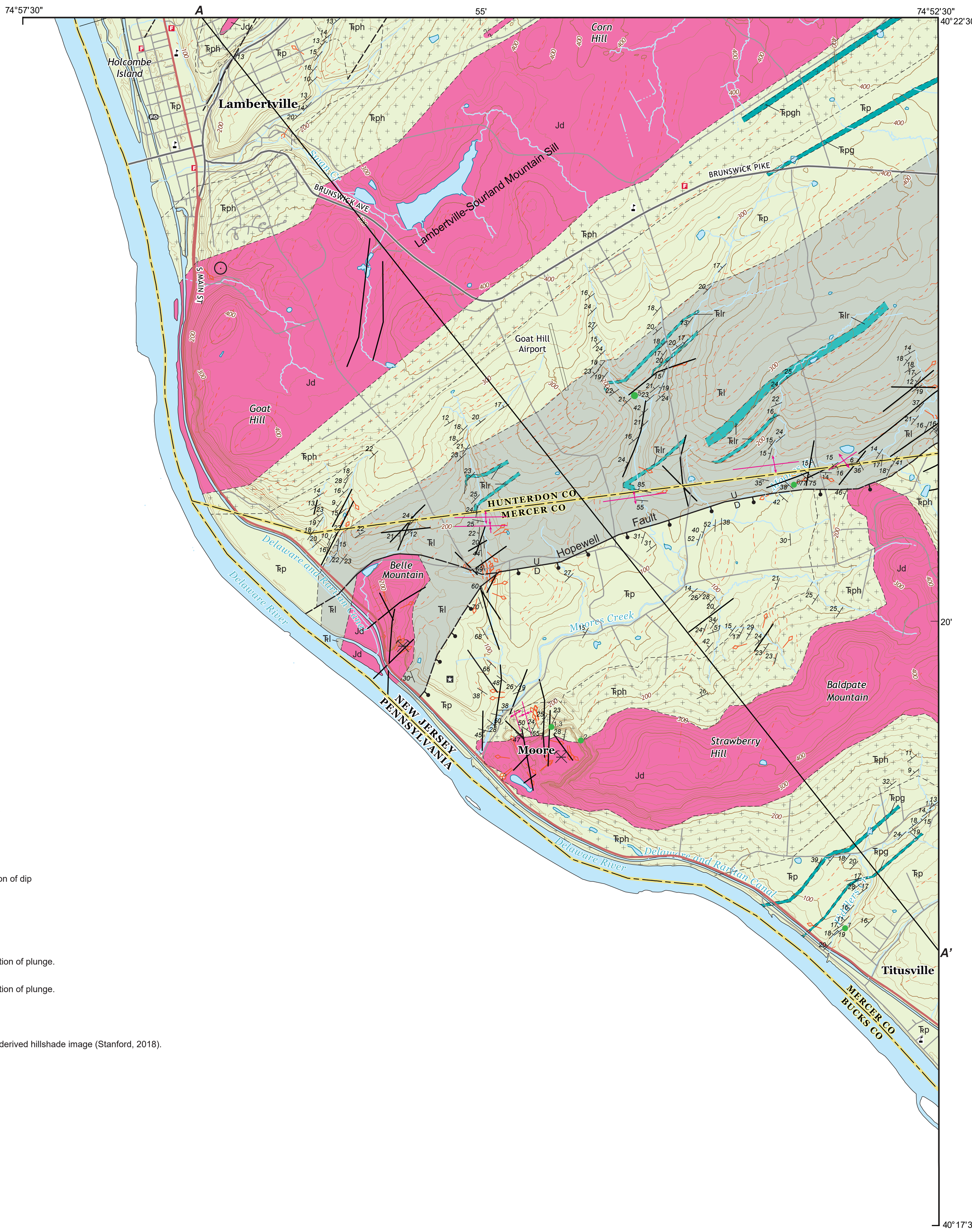
Prepared in cooperation with the
U.S. GEOLOGICAL SURVEY
NATIONAL COOPERATIVE GEOLOGIC MAPPING PROGRAM

CORRELATION OF MAP UNITS

NEWARK BASIN





EXPLANATION OF MAP SYMBOLS

Contact - dashed where approximately located, queried where uncertain.

Faults - U, upthrown side; D, downthrown side. Ball and post indicates direction of dip
Dashed where approximately located.
Motion is unknown

Form lines - shows trend of bedding. Only in cross section.

Anticline - showing trace of axial surface, direction and dip of limbs, and direction of plunge.

Syncline - showing trace of axial surface, direction and dip of limbs, and direction of plunge.

Strike and dip of inclined beds

Ridge form-line or scarp parallel to bedrock strike. Interpreted from a LIDAR-derived hillshade image (Stanford, 2018).

Slickenline - arrow pointing to direction of motion

Well 1 location

Abandoned rock quarry

Location of photographs, number is figure number

Relative motion along faults in cross-section

Basemap 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: Pennsylvania Coordinate System of 1983
(south zone), New Jersey Coordinate System of 1983

This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery........NAIP, September 2015
Roads........U.S. Census Bureau, 2015 - 2016
Names........GNIS, 2016
Hydrography........National Hydrography Dataset, 2015
Contours........National Elevation Dataset, 2011
Boundaries........Multiple sources; see metadata file 1972 - 2016
Wetlands........FWS National Wetlands Inventory 1977 - 2014

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

APPROXIMATE MEAN DECLINATION 2023

SCALE 1:24 000
CONTOUR INTERVAL 20 FEET

LOCATION IN NEW JERSEY

Bedrock geology mapped by H. F. Houghton, 1994, J. Mitchell, 1994, G.C. Herman, 2010-2013, D.H. Monteverde, 2012-2013, and R.W. Witte in 2013.
GIS application by R.S. Pristas
Digital cartography by R.W. Witte and D.H. Monteverde
Reviewed by Mark Zdepski and Alan Uminski in 2020
[1] retired, New Jersey Geological and Water Survey

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The views and conclusions contained in this document are those of the authors

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

1 Lumberville
2 Stockton
3 Hopewell
4 Buckingham
5 Pennington
6 Hatboro
7 Langhorne
8 Trenton West
ADJOINING QUADRANGLES

BEDROCK GEOLOGIC MAP OF THE LAMBERTVILLE QUADRANGLE, HUNTERDON AND MERCER COUNTIES, NEW JERSEY

By

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

2023

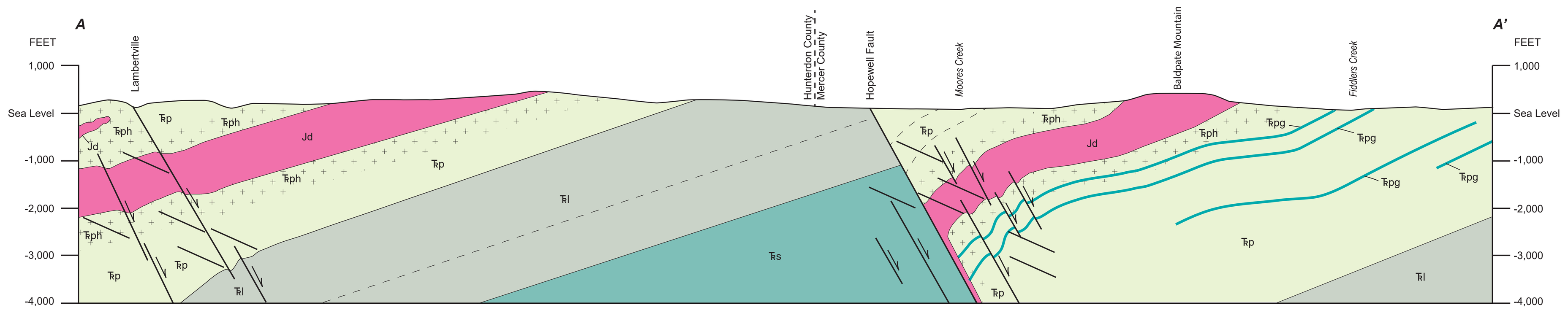

Figure 1. Outcrop of Passaic Formation hornfels exposed within the Moores Station quarry. Passaic Formation is generally reddish brown in color but altered to black to grayish from the heat associated with the Baldpate Mountain diabase intrusion. View is toward the west. Retired NJGWS geologist, Dr. Peter Sugarman, for scale.

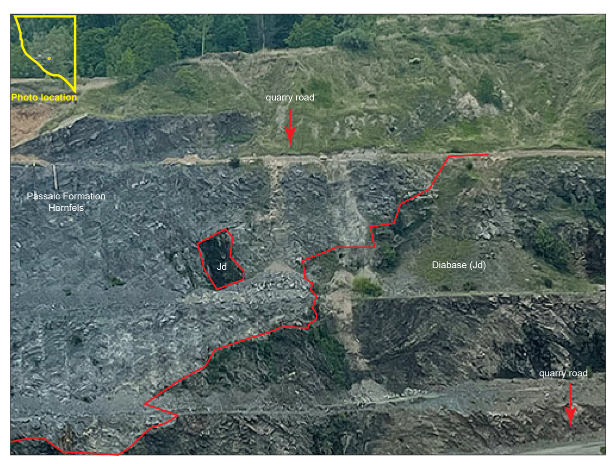

Figure 2. Outcrop of Passaic Formation hornfels and diabase showing the igneous contacts (red line) within the Moores Station quarry on Baldpate Mountain diabase intrusion. View is toward the northeast. Quarry roads for scale. Jd marks diabase outcrop.

Figure 3. Small vertical fault (red line) within Passaic Formation hornfels. Outcrop exposed within the Moores Station quarry. View is toward the north. Vehicle in bottom left of photo for scale.

INTRODUCTION

The Lambertville 7-1/2' quadrangle straddles the New Jersey – Pennsylvania border along the Delaware River. The mapped area of the quadrangle lies in Hunterdon and Mercer counties, New Jersey within the Piedmont Physiographic Province. The Delaware River flows southeast through the quadrangle within a narrow valley underlain by late Wisconsinan glacial outwash and postglacial stream deposits (Stanford, 2018). Topographic relief varies within the quadrangle ranging from a high of 475 feet above sea level on Baldpate Mountain near Strawberry Hill to a low of about 50 feet above sea level along the Delaware River less than one mile away, where it flows southeast out of this quadrangle. This variable relief reflects the erosional differences among the various igneous and sedimentary bedrock of early Mesozoic age. The highest elevations are underlain by intrusive igneous rocks (diabase) whereas those areas of lesser relief are underlain by red and gray shale and argillite. These areas are highly dissected by the Delaware River's tributaries, with stream courses chiefly controlled by brittle faults and systematic tension and shear fractures in the bedrock. The tributaries generally flow southwest throughout the quadrangle.

The early Mesozoic sediments were deposited and intruded by igneous material within the Newark Basin, one of several extensive continental rift basins found along the current Atlantic margin of North America that formed during an early phase of breakup and separation of the supercontinent Pangaea into today's continents. The Newark Basin is filled with sedimentary and igneous rocks of Triassic and Jurassic age that have been tilted northwestward, faulted, and locally folded (Schlische, 1992; Olsen and others, 1996). Most tectonic deformation is probably Late Triassic to Middle Jurassic age (Lucas and others, 1988; de Boer and Clifford, 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. Differential fault slip along individual segments of border and intrabasinal splay faults resulted in folding of bedding with axes oriented sub-parallel and sub-normal to the main fault traces (Schlische, 1995). Both border and intrabasinal faults were active during sediment deposition with thicker strata located in synclines. Tectonic deformation and synchronous sedimentation continued into the Middle Jurassic at which time extensional faulting and associated tilting and folding ceased. Current thinking is that the basin likely experienced a period of post-rift contraction deformation and localized basin inversion, which have been recognized in other Mesozoic rift basins (de Boer and Clifford, 1988; Withjack and others, 1998). Subsequent erosion of Mesozoic rocks was followed by flexural loading of the passive margin by Cretaceous age and younger sediments of the coastal plain sequence southeast of the map area.

STRATIGRAPHY

Bedrock units range in age from the Late Triassic to Early Jurassic (Olsen, 1980) and consist of Triassic alluvial to lacustrine sedimentary rocks that are locally cut and intruded by Early Jurassic diabase dikes and sills. Argillite and shale underlie most of the area. The sedimentary sequence here includes the uppermost alluvial sandstone beds of the Stockton Formation that are conformably overlain by thick, gray and black (deep lacustrine) argillite of the Lockatong Formation, then progressively more abundant red argillite and shale (shallow lacustrine to playa) of the Passaic Formation of Triassic age (Olsen and others, 2011; Blackburn and others, 2013). In outcrop the Stockton Formation is a red, light brown and white sandstone, and lesser red and gray siltstone and mudstone (Monteverde and others, 2015). However, the formation occurs only in the subsurface in the New Jersey part of this quadrangle. In the subsurface the Stockton ends abruptly on the footwall of the Hopewell fault as shown in cross-section A-A'. The black, gray, and red argillite and shale beds of the Lockatong and Passaic Formations display a cyclical pattern of wet and dry depositional environments encompassing four different periods of time spanning thousands to millions of years that reflect systematic climate variations tied to orbital mechanics (Olsen and others, 1996). The shortest of the recognized cycles has been identified as generally resulting in about 20 feet of lacustrine sediment over a 20,000-year time period (Van Houten, 1962).

The igneous (diabase) sills and dikes in the New Jersey part of the Lambertville quadrangle have been associated with the Orange Mountain Basalt based on geochemical (Husch, 1988; Houghton and others, 1992) and paleomagnetic data (Hozik and Columbo, 1984). Each intrusive body is surrounded by thermally metamorphosed argillite and shale (hornfels) of the Lockatong and Passaic Formations (fig. 1, 2, 3). Spectacular samples of secondary sulfide minerals and subhedral tourmaline crystals were collected in Passaic hornfels from the bench excavations of the Moore's Station quarry at the western end of Baldpate Mountain.

STRUCTURE

Two major intrabasinal fault systems in the Newark Basin (Flemington and Hopewell) cut through this region with the Hopewell fault occuring in the central part of the mapped area. Isolated splay faults mapped near Lambertville stem from the Flemington fault to the north of the mapped area where branching and reconnecting faults have been mapped splaying southward through Dilt's Corner in the Stockton quadrangle (Monteverde and others, 2015). This is the area where the Flemington fault bends to overlap with the Chalfont fault in Pennsylvania (Houghton and others, 1992). However, most of the map is dominated by structures developed along the Hopewell fault system. The main trace of the Hopewell fault snakes through the area along a general N60ºE trend that reflects the coalescence of smaller fault segments varying in strike between N20ºE to N80ºE as recorded by slickenside orientations (fig. 4a). Early, isolated, en echelon fault segments of the general trend are cross-cut and joined by later fault segments to form systematic, interconnected, rhombohedral planes that accommodate early tensional dip-slip strains and later, oblique-normal, (transtensional) slip strains. There is early dip slip on faults striking N40º to N65ºE (S1 fracture phase of Herman, 2005, 2009) that were cross-cut, sheared, and tilted by later, steeply-dipping normal faults striking between N5ºW to N20ºE (S3 fracture phase of Herman, 2005, 2009), and by a complimentary late set striking about S70ºE-S80ºE as recorded by shear-plane orientations (fig. 4a) Those striking nearly north-south show late-stage, right-lateral (sinistral) components of oblique, slip and those striking about east-west show left-lateral (dextral) slip strains.

Bedrock outcrops along and in tributaries to Moores Creek (figs. 5 and 6) commonly contain fractured, sheared, and folded strata on both sides of the main fault trace for distances approaching one mile. Localized outcrops of brecciated argillite, shale, diabase, and hornfels are found closer to the main fault trace. Brittle fractures include ordinary joint sets lacking any visible shear separation or evidence of slip in the form of mechanical or mineralized strain-slip features. Joints include mineralized (commonly with calcium carbonate) and unmineralized varieties that were all probably once filled with secondary minerals, some of which were removed through exhumation and near-surface erosion. Those having slip evidence were mostly measured on exposed, parted surfaces where strain features stemmed from mechanical abrasion, plucking, and polishing rather than those formed by overlapped, stepping mineral fibers.

The general strikes and dips of the most common groups of mapped structures were analyzed using circular histograms that show dip direction of planar features (90º from strike direction) and plunging lineations and stereographic-projection diagrams (Allmendinger and others, 2013, Cardozo and Allmendinger, 2013) (fig. 4b). They show (fig. 4b) that the mean strike of sedimentary beds in the quadrangle is N33ºE with an average dip of 16º toward the northwest (dip azimuth of 16º-303º). The most frequent joint strike (fig 4a) N58ºE falls within 7º of striking parallel with the aforementioned general strike of the Hopewell fault (N60ºE). Joints fan about this prominent strike through acute angles and most dip steeply east to southeast. Subordinate sets of steeply dipping cross-strike joints strike normal to the most frequent joint set. Small faults show more dispersed strike maximums (fig. 4b), with most frequent sets striking N50ºE to N70ºE and north to N30ºE. Most of the small faults dip to the south and southeast, but a proportionally larger precentage of small faults dip northwest in comparison to the composited joint sets.

Joints in sedimentary rocks show strike maximums ranging between N40ºE and N50ºE with a range between N20ºE to N70ºE, with complimentary sets of subordinate cross joints (fig. 4b). Conjugate fractures are also present (fig. 7). These trends agree with the early (S1 and S2) fracture systems noted elsewhere in the New Jersey part of the basin by Herman (2005, 2009). In contrast, the small faults show distinct maximums striking between N40º to N60ºE (S1) and north-south to N20ºE (S3), but a wide span of slip planes striking between N10ºW to N80ºE (slickenlines on fig. 4a). Slip on these planes is complex with indicators of both dip slip and strike slip motions that reflect overlapping, incremental, and progressive strains including early dip-slip motion on small faults dipping southeast, and later left-lateral (sinistral) strike slip on slip planes striking about N45ºE to east-west, and right-lateral (dextral) strike slip motion on small faults striking about north-south to N30ºE. Overall, the outcrop-scale structures show that the bedrock here was first stretched southeastward, then later eastward. Small folds mapped in the fault system commonly show an east-west trend, plunging gently to moderately, westward and eastward. These folds may have originated as drag folds associated with late-stage, strike slip movement along the Hopewell fault system that eventually merges with the Chalfont fault in Pennsylvania mapped by Willard and others (1959).

The map includes a set of surface lineaments that are interpreted to represent weathered bedrock ridges stemming from differential erosion of the layered strata having as little as a few feet of topographic relief (Stanford, 2018). The lineament analysis used proprietary hillshade-relief themes based on digital terrain models derived from airborne ground surveys using LiDAR, laser imaging, detection and ranging methods (NJOGIS and NJDEP, 2019). A 370-ft deep bedrock well (Well 1) located about one mile north of Goat Hill that was drilled into the top of the Sourland Mountain diabase sheet is included on the map. Stratigraphic, structural, and hydrogeological details for this well are reported in Herman and Curran (2010) based on the interpretation of a comprehensive set of geophysical downhole logs, including an optical borehole televiewer (BTV) interpretation. A structural analysis of the compositional layering and tectonic fractures derived from the BTV data are included here (fig. 4d) as basis to compare orientations of compositional layering and tectonic fractures mapped in outcrop (fig. 4c) versus the subsurface, and between the different diabase sills in the two major fault blocks. A comparison of compositional layering in the upper sections of both sills shows that layers in the Lambertville-Sourland Mountain sill dip gently westward (fig. 4d), whereas layers in Baldpate Mountain dip moderately eastward (fig. 4c). This contrast in layering dip implies that the sills within the different fault blocks were at least, in part, injected from opposing directions. Baldpate Mountain has similar sill morphology to other nearby sills that reside within the Passaic Formation and the hanging wall of the Hopewell fault including Pennington Mountain to the east (Herman and others, 2010). Each of these intrusions is predominantly sill-like in form but includes a funnel-like dike segment that veers northward from each sill and heading toward the trace of the nearby Hopewell fault. The geometry of the intrusions indicate that the sills are being sourced by dikes that locally ascend along the Hopewell fault (see cross section), conceivably during a late transtensional phase, or phases, of basin growth (S2 and/or S3 phases of Herman, 2005, 2009). Magma could have ascended at places along the fault system where strains were dilatational, and feeders followed linear avenues along interstices of misfit fault blocks in contrast with other areas where fault strains are high, blocks were impinged upon, restrained, and compressed. Based on these criteria, the western limb of the Baldpate Mountain sill was probably injected into the Passaic Formation from east to west, which then implies that the upper section of the Sourland Mountain sill may have been injected from west to east based on the demonstrated differences in layering dip.

This map also addresses issues that arose from edge matching geological contacts and the main trace of the Hopewell fault along the Delaware River and between states in the vicinity of Belle Mountain. As previously mapped by Owens and others (1998), both the upper Lockatong contact with the Passaic Formation and the main trace of the Hopewell fault ran north of Belle Mountain. Here the main fault trace swings south of the mountain to connect with a comparatively large fault mapped in Bucks County, Pennsylvania by Willard and others (1959), in contrast to a smaller fault segment that it was previously tied to by Owens and others (1998). Similarly, the Lockatong-Passaic contact now shifts from the more regional southwest-northeast strike to a north-south strike north of Belle Mountain and is cut by the fault trace before reaching the Delaware river. This restricts the Passaic Formation to crop out in the hanging wall and the Lockatong Formation in the footwall respectively. The Lockatong-Passaic contact is mapped about 1,000 feet north of Belle Mountain where Van Houten (1980) identified his "first Big Red unit" within the Lockatong. This section is well exposed and marks the change to having mostly red beds progressing upward through the composite section in comparison to having mostly gray and black beds below. Olsen and others (1996) place the Lockatong-Passaic contact at the base of a thick red section in the upper part of the Walls Island Member. Based on this map, Van Houten's "first Big Red unit" correlates to Olsen and others' (1996) first, thick red section of the basal Passaic Formation.

Figure 5. Eastward view across a small fault in the Lockatong Formation, Moores Creek. Note folding of systematic joints into the fault showing right-lateral slip. Inset photo (westward view) shows part of a 3-meter wide fault breccia that trends about north-south. Yellow line shows orientation of photo.

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DESCRIPTIONS 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. Composed dominantly of plagioclase, clinopyroxene, and opaque minerals. Contacts are typically fine-grained, display chilled, sharp margins and may be vesicular adjacent to enclosing sedimentary rock. Exposed in the map area is the Lambertville-Sourland Mountain sill. This sheet may be the southern extension of the Palisades sill. A small intrusion exists at Belle Mountain and a third intrusion underlies Strawberry Hill and Baldpate Mountain, possibly an extension of the Pennington sheet. The maximum thickness is approximately 1,325 feet.

Ƭp, Ƭpg, Ƭph, Ƭpgh — Passaic Formation - (Upper Triassic) (Olsen, 1980; Olsen and others, 2011) - 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 is medium- to fine-grained, thin- to medium-bedded, planar to cross-bedded, micaceous, locally containing mud cracks, ripple cross-laminations, 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 evaporate minerals. Gray bed sequences (Ƭpg) 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 and mudstone. Thickness of gray bed sequences ranges from less than 1 foot to several feet thick. Thermally metamorphosed sections (Ƭph, Ƭpgh) exist along the flanks of the intrusive bodies in the map area. Unit is approximately 11,000 feet thick.

Ƭl, Ƭlr — Lockatong Formation (Upper Triassic) (Kümmel, 1897) - Cyclically deposited sequences of mainly gray to dark greenish-gray (Ƭl), and in upper part of unit, locally reddish-brown (Ƭlr), siltstone to silty argillite and dark gray to black shale and mudstone (Ƭl). 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).

Ƭs — Stockton Formation (Upper Triassic) (Kümmel, 1897) - Unit is 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. Fining upwards sequences are common, the finer grained beds are bioturbated. Conglomerate and sandstone layers are deeply weathered and more common in the lower half; siltstone and mudstone are generally less weathered and more common in upper half. Lower contact is an erosional unconformity. Thickness is approximately 4,500 feet. In subsurface only.

Figure 6. Brittle folding in the Lockatong Formation in the footwall of the Hopewell Fault about 800 feet from the fault trace. The pencil tip points downward along a fold axis that plunges 60° along a 095° trend.

Figure 7. Conjugate vertical joints in the Passaic Formation forming joint-block wedges along Fiddlers Creek, Titusville, New Jersey. Yellow lines parallel strike of dominant joint trends.

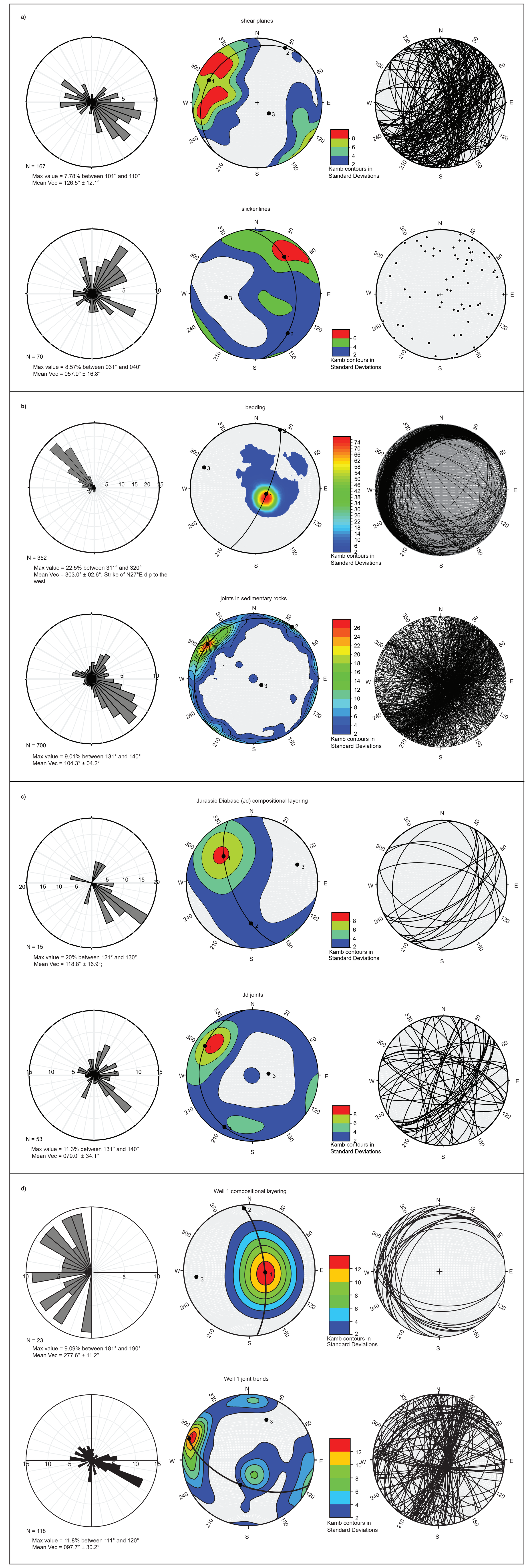

Figure 4. Structural analyses of primary and secondary structures. Primary structures include sedimentary beds and compositional layering in diabase. Secondary structures are grouped as joints, small faults (slickensides shear planes) and slip lineation (slickenlines). Data for figs 4a – c stem from outcrop data whereas 4d stems from subsurface data collected using a borehole televiewer (Herman and Curran, 2010). Circular histograms show relative frequencies of plane dip azimuths and lineation trends using 10° sectors. The stereographic diagrams are lower-hemisphere, equal-angle projections showing the composite distribution of features for each set of structures and the most common plane orientations for the planar structures. N values record the number of orientations.