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

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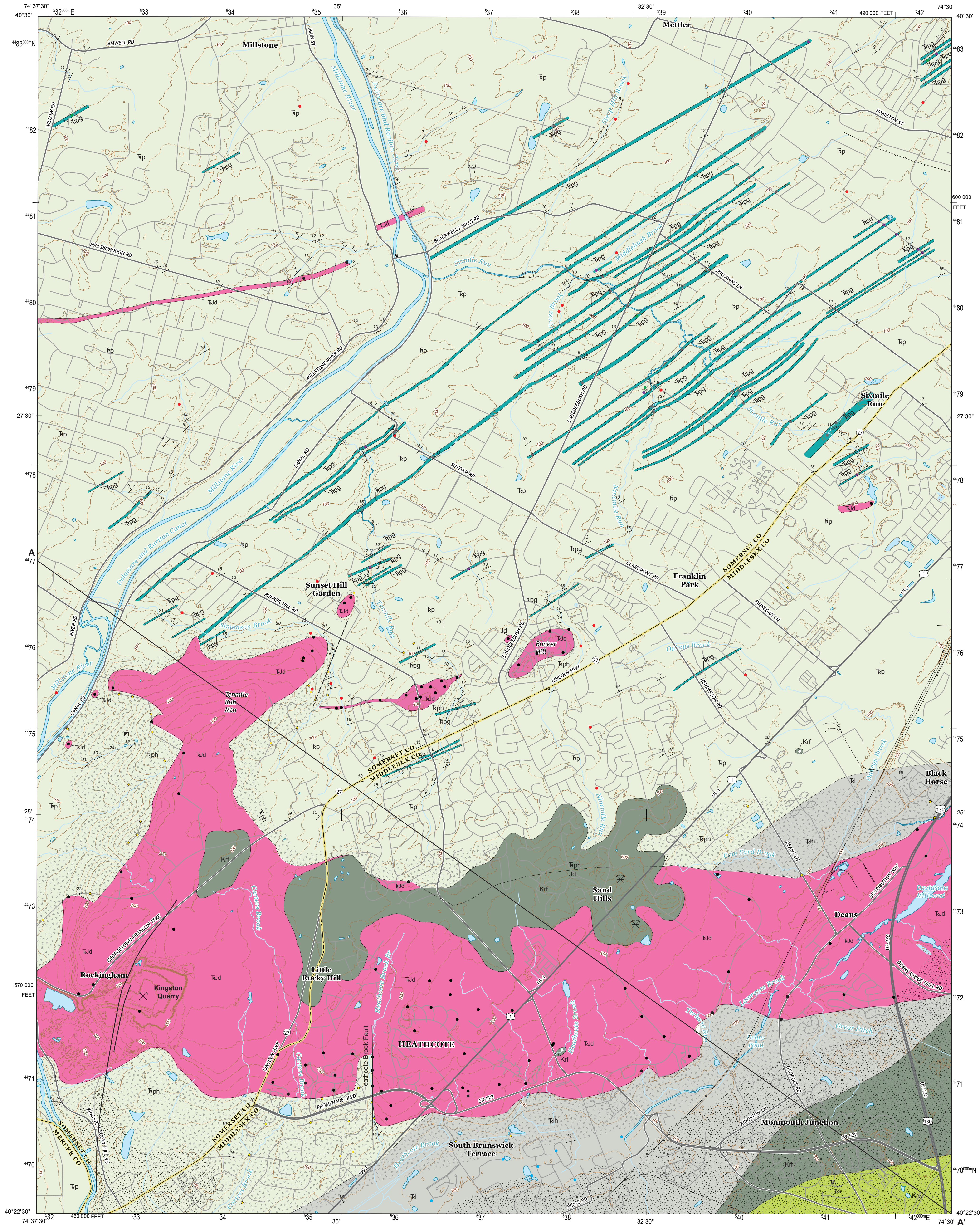
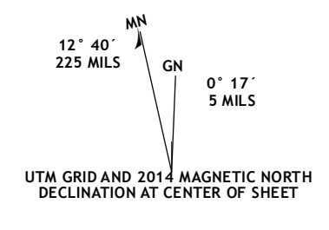
U.S. GEOLOGICAL SURVEY
NATIONAL GEOLOGIC MAPPING PROGRAM

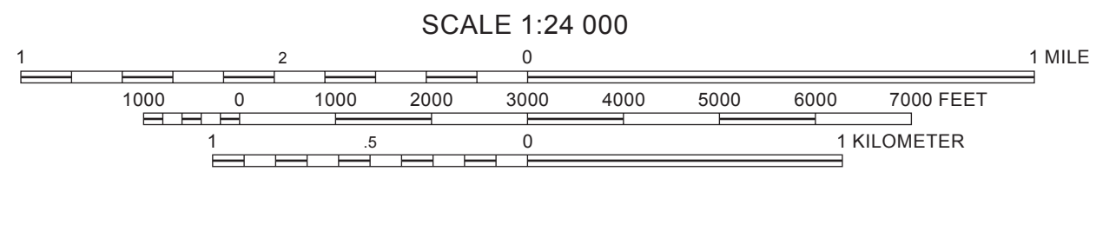
BEDROCK GEOLOGIC MAP OF THE MONMOUTH JUNCTION QUADRANGLE,
SOMERSET, MIDDLESEX, AND MERCER COUNTIES, NEW JERSEY
GEOLOGICAL MAP SERIES GMS 18-4



Base 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
Imagery................NAIP, July 2010 - August 2010
Roads................HERE, ©2013
Names................GNIS, 2013
Hydrography................National Hydrography Dataset, 2010
Contours................National Elevation Dataset, 2013
Boundaries................Multiple sources; see metadata file 1972 - 2013



UTM GRID AND 2014 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

LOCATION IN NEW JERSEY

Bedrock geology mapped by Beetle-Moorcroft and Monteverde 2016-2017
Coastal Plain geology mappped by Stanford 1989, 2016
Limited data from Parker and Houghton (1990)
Unpublished data by Kummel 1895

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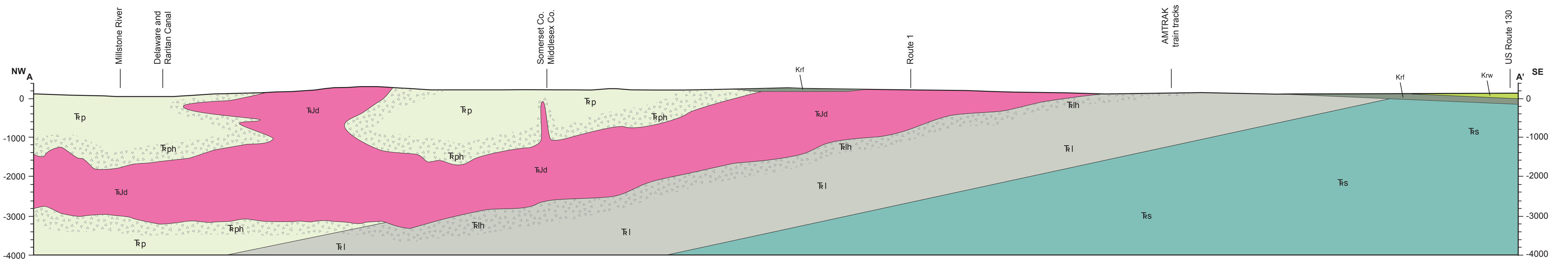
Bedrock Geologic Map of the Monmouth Junction Quadrangle
Somerset, Middlesex, and Mercer Counties, New Jersey

by
Fern Beetle-Moorcroft, Donald H. Monteverde and Scott D. Stanford
2018

Raritan	Bound Brook	Plainfield
Rocky Hill	Monmouth Junction	New Brunswick
Princeton	Hightstown	Jamesburg

ADJOINING 7.5' QUADRANGLES



EXPLANATION OF MAP SYMBOLS

Contacts

——— Identity and existance certain, location accurate
— — — Identity and existance certain, location approximate

Faults

——— Identity and existance certain, location accurate
— — — Identity and existance certain, location approximate
U/D Normal fault - U, upthrown side; D, downthrown side.

Planar features

15 Strike and dip of inclined beds

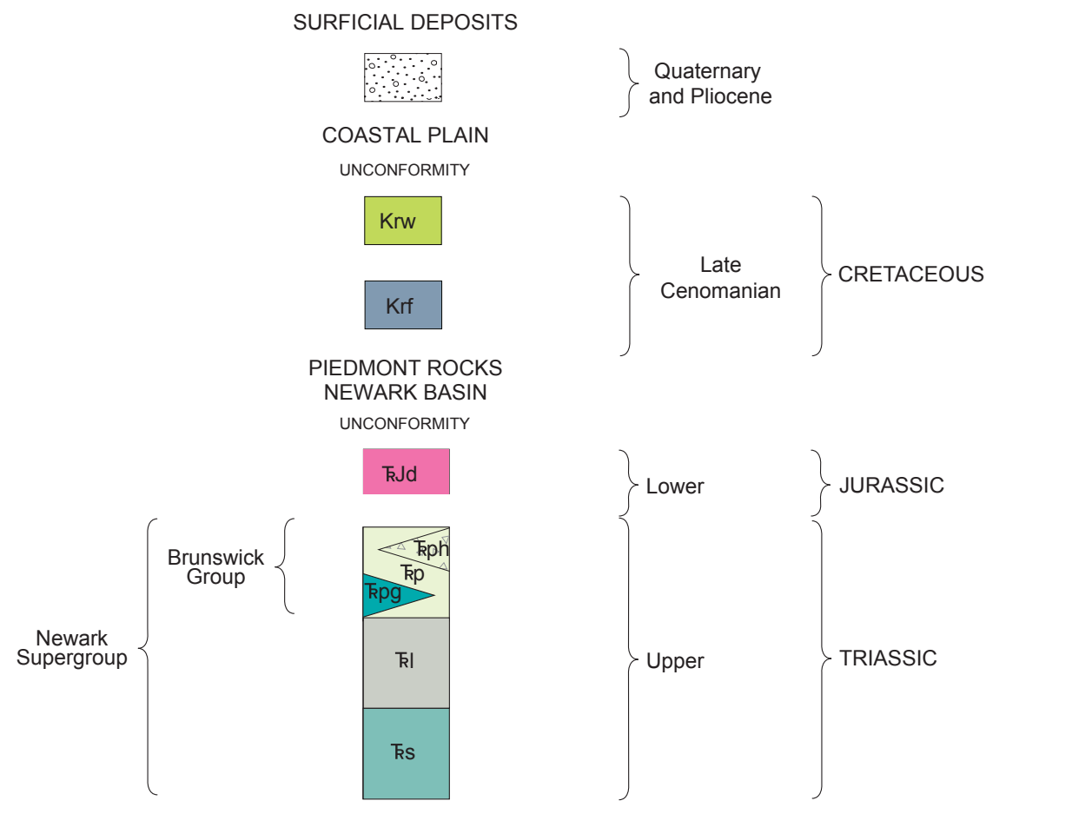
Other features

⚒ Abandoned rock quarry
⚒ Active rock quarry
x Prospect pit, copper
◩ Location of Griggstown copper mine

Float stations

● Diabase
○ Hornfels
● Purple beds in Passaic Formation
● Gray and/or black beds in Passaic Formation
● Gray and/or black beds in Passaic Formation with copper mineralization present
● Red beds in Passaic Formation

CORRELATION OF MAP UNITS



INTRODUCTION

The Monmouth Junction 7.5-minute topographic quadrangle lies mostly within the Piedmont Physiographic Province and includes parts of Somerset, Middlesex, and Mercer counties in central New Jersey. Roughly one square mile at the southeastern corner of the quadrangle lies within the Coastal Plain Physiographic Province. Like a large part of New Jersey, this region has felt the growing pressure of suburban development and has changed from a predominantly agricultural to suburban, commuter developments that occupy an ever-increasing proportion of the countryside. Franklin Township, which covers a large area of the central and northeastern part of the Monmouth Junction quadrangle, has preserved over 4,000 acres of land both as preserved farmland and public open space with numerous hiking and bike trails.

Low topographic relief dominates the mapped area's geomorphology. A large part of the landscape lies between 50 and 200 feet in elevation. Several low gradient tributaries including Steep Hill Brook, Six Mile Run, and Simonson Brook gently incise the landscape as they flow northwest to the Millstone River. A change in topography occurs in an area of diabase bedrock in the southwestern part of the quadrangle where the elevation rises to 300 feet. Also located in the southwest corner of the quadrangle is the Kingston quarry near the low point of the quadrangle, where excavation has lowered the quarry floor to sea level.

The Mesozoic-aged Newark basin, a rift basin that formed during the breakup of the supercontinent Pangea, was infilled with sediments of Triassic and Jurassic age and was both intruded and locally covered by Triassic-Jurassic age intrusive and extrusive igneous rocks, respectively. Subsequently, these basin deposits have been tilted, jointed, faulted, and locally folded (Schlische, 1992; Olsen and others, 1996; Withjack and others, 2013). Most of this tectonic deformation took place in the Late Triassic to Middle Jurassic (Lucas and others, 1988; de Boer and Clifford, 1988). Reactivation of originally southeast-dipping thrusts as normal faults guided the basin morphology along its northwestern margin, northeast of the map area (Ratcliffe, 1971, 1980; Ratcliffe and Burton, 1985; Withjack and others, 1998). These primary features influenced sediment deposition patterns and the orientation of secondary structures within the basin. Episodic, periodic slip along these faults influenced sediment deposition resulting in a thicker sediment dispersal pattern parallel to the northwestern border of the basin (Smoot, 2010). Secondary intrabasinal faults, such as the Hopewell Fault to the west of the quadrangle, formed across depositional strike and dominantly have a normal sense of offset. These faults, originally thought to have been active during Passaic Formation deposition (Schlische, 1992, 1993) are currently thought to have formed coincident with the beginning of the Central Atlantic Magmatic Province (CAMP) magmatism (Withjack and others, 2013), which is younger than the Passaic Formation sediments (Marzoli and others, 1999). Differential slip along individual segments of both fault systems resulted in a series of depressions (synclines) and ridges (anticlines) oriented normal to the fault trends (Schlische, 1995). Sediment thickening into the fold troughs indicates the syndepositional nature of part of these regional fold structures. Extensional faulting and synchronous sedimentation continued into the Early Jurassic (Malinconico, 2003). At this stage, post-deposition highly oblique basin inversion further folded and faulted the basin sediments by both left-lateral and reverse offset along border faults (de Boer and Clifford, 1988; Withjack and others, 1995).

STRATIGRAPHY

Surficial deposits up to 20 feet thick cover some parts of the quadrangle. These surficial units are shown on the map as a transparent overlay. Quartz pebble gravels and unconsolidated sandy deposits are the predominant surficial units (Stanford, 2002a).

The quadrangle includes two informal members of the Cretaceous-aged Raritan Formation: the Woodbridge Clay and the Farrington Sand, both Coastal Plain units. The Woodbridge Clay contains gray, black, yellow, and brown clay and silt. Minor thin beds and laminae of fine quartz sand are interbedded with the clay and silt. The Farrington Sand is composed of white, yellow, pink, and reddish, fine- to coarse-grained sand with minor clay and silt lenses. Pollen in the Farrington Sand in the New Brunswick area (Stanford and others, 1998) and in the Jamesburg area (Stanford and Sugarman, 2008) is like that found in the youngest member (unit 3) of the Potomac Formation. The Potomac Formation underlies the Raritan Formation down dip to the southeast of the map area and crops out along strike southwest of the map area where the Raritan Formation pinches out (Sugarman and others, 2015). These relationships suggest that the Farrington in the map area may be partly the same age as the Potomac Formation, unit 3.

Another informal member, the Raritan fire and potter's clay of Cook (1878) and Ries and others (1904), which underlies the Farrington Sand in the New Brunswick area to the east of the Monmouth Junction quadrangle, is included as part of the Farrington Sand on this map. The Raritan fire and potter's clay contains two units: the potter's clay and the fire clay. The lower clay, the potter's clay, is predominantly red, white, and gray clay derived from the weathering of underlying bedrock formations. The upper clay, the fire clay, is a discontinuous, gray sandy clay located near the base of the Farrington Sand. The maximum thickness of the Raritan Formation in the quadrangle is about 150 feet in the southeast corner.

Owens and others (1998) map the deposits of the Sand Hills and Tenmile Run Mountain outliers as the Magothy Formation, which overlies the Woodbridge Clay member of the Raritan Formation. Here, they are mapped as Farrington Sand because the coarse texture of the sand and the general absence of interbedded silt and clay (except at the base of the unit) is more typical of the Farrington Sand than of the Magothy Formation. Also, projection of the Magothy-Raritan contact from the Jamesburg area (Stanford and Sugarman, 2008, section AA'), directly downdip to the southeast of the Monmouth Junction quadrangle, places the contact at an elevation of 250 feet at the east edge of the Sand Hills outlier. This is slightly higher than the highest elevation of the outlier (230 feet) at that location, indicating that the outlier sediments are stratigraphically below the Magothy.

Late Triassic-aged sedimentary rocks, formed in alluvial and lacustrine environments, dominate the bedrock units of the Monmouth Junction quadrangle. Later, igneous bodies locally intruded these sediments. The basal unit, the Stockton Formation, is not exposed here, but described from the Princeton corehole (Olsen and others, 1996) in the Hightstown quadrangle adjacent to the south (Sugarman and others, 2015). There, the Stockton Formation developed an alluvial sequence of red, light brown, and gray siltstone/mudstone, buff conglomerate, conglomeratic sandstone, and arkosic sandstone. Less common, but increasing in abundance upward through the formation, are micaceous sandstone, siltstone, and mudstone - more common in the upper half of the Stockton (McLaughlin, 1945, 1959). Smoot (2010) attributed these to avulsion floodplains associated with lakes that intermittently dried up. He also suggested that the conglomerate and conglomeratic sandstone formed as braided channel deposits and the arkosic sandstones were deposited as lateral accretion sediments associated with point bars in larger meandering rivers.

The Lockatong Formation overlies the Stockton Formation and is typically a black, dark gray, and less commonly red mudstone to silty mudstone. Black and gray mudstones, generally more organic-rich than the red beds, were deposited in deep lacustrine paleoenvironments. Slightly coarser sediments within the Lockatong were deposited in shallower water. The Lockatong Formation grades upwards into the Passaic Formation, which tops the Newark Basin deposits in the Monmouth Junction quadrangle. The Passaic Formation (Olsen and others, 2011) contains red shale, siltstone, and mudstone and was deposited in both lacustrine and fluvial environments. Thin gray, black, and purple beds are interspersed within the red shale deposits.

Olsen (1986) and Olsen and others (1996) showed that the depositional sequences within the Lockatong and Passaic formations represent climatically controlled wet-and-dry cycles guided by Milankovitch periodicity of the Earth's orbit. Olsen and others (1996) described a hierarchy of three Milankovitch-controlled cyclic lithologic patterns that consist of the Van Houten cycle of 20,000 years, the short modulating cycle of 109,000 years and the McLaughlin cycles of 413,000 years. They are the Van Houten, short modulating, and McLaughlin cycles respectively. Lithologic variations influenced by the Van Houten cycles suggest a complete wet-dry lake level cycle; lake level rises creating a stable deep lake environment followed by a fall in water level leading to complete desiccation of the lake. Within the Passaic Formation, organic-rick black and gray beds mark the deep lake period, purple beds mark a shallower, slightly less organic-rich lake, and red beds mark a shallow oxygenated lake in which most organic matter was oxidized. Olsen and others (1996) described the next longer cycle as the short modulating cycle, which is made up of five Van Houten cycles. The still longer in duration McLaughlin cycles contain four short modulating cycles or 20 Van Houten cycles (figure 1). Olsen and others (1996) used the McLaughlin cycles to define their member breakdown of the Newark basin sediments. Members are not shown on the map due to the difficulty in characterizing individual Van Houten cycles with sparse outcrop and in the absence of deep rock cores in the quadrangle. However, gray beds were used as marker beds in mapping the Passaic Formation. Select gray beds contain malachite (a copper mineral), which allows them to be more easily correlated. As gray beds are typically only a few feet thick, the width of many is exaggerated on the map to make them more visible. LIDAR coverage across the northern half of the quadrangle aided in individual bed correlation across long distances where outcrop and float locations were limited.

The Rocky Hill diabase, a large intrusive sheet intruded the Lockatong and Passaic formations along the southern part of the Monmouth Junction quadrangle. The Rocky Hill diabase mainly occurs as a sill with several apophyses cutting across layers as dikes. It extends northeastward as part of the Palisades Sill along the Hudson River. The diabase continues westward forming the Mount Rose diabase in the Rocky Hill and Princeton quadrangles and to the northwest to become the Sourland Mountain diabase in the Rocky Hill and Hopewell quadrangles. From east to west across the Monmouth Junction quadrangle, the igneous sheet climbs upsection from the Lockatong into the Passaic. Near Tenmile Run Mountain the diabase intrudes upward through the Passaic Formation as a dike. Two isolated dike bodies, one near Sunset Hill Garden and the other just to the east are likely connected to the Rocky Hill diabase at depth. A thin diabase sill occurs within the Passaic Formation in the northwestern part of the quadrangle. It stands as a slightly elevated ridge and outlined using LIDAR coverage and several diabase float stations to the west of the Millstone River and the Delaware and Raritan Canal. To the east, the diabase sill is visible in outcrop along Canal Road. Malachite occurs within the small hornfels zone associated with this dike.

The intrusive bodies on the Monmouth Junction quadrangle have the same magmatic source as the Orange Mountain Basalt based on geochemical and paleomagnetic data similar to that of the Palisades Sill (Hozik and Colombo, 1984; Husch, 1988; Houghton and others, 1992). Thermally metamorphosed sediments occur both above and below the intrusions. Contacts between the diabase and sedimentary rocks are rarely exposed. For mapping purposes, the first occurrence of hornfelsic rock when traversing the diabase bodies was taken as the contact. The hornfels varies in thickness and appearance within the quadrangle depending on the extent of the local intrusive body. Nearest the diabase intrusion, Lockatong hornfels are black and fine-grained; farther away, it is difficult to differentiate the hornfels from the non-baked Lockatong Formation. The Passaic hornfels, adjacent to the intrusion, are dark gray, fine grained, and sometimes contains cordierite (Van Houten, 1969); farther away, the Passaic hornfels is medium purple, massive, and has clearly defined bedding and fractures. The massive nature and increased hardness of the Passaic hornfels makes it easy to distinguish from the Passaic purple beds.

STRUCTURE

Sedimentary bedding mapped across the quadrangle has a dominant strike of N60°E with a gentle 11° NW dip (figure 2a). All bedding data come from outcrops of the Passaic Formation. Float occurrences in regions of no definitive outcrops guided mapping of the Lockatong Formation. Proximal to the diabase, the sediments were metamorphosed to hornfels. These units, though with limited data, portray a similar bedding trend to the unmetamorphosed Passaic Formation (figure 2b). Fractures are common in the Passaic Formation with the dominant strike approximately N10°E (figure 2c). These features average to near vertical (figure 2b). Subsidiary fractures strike more easterly while maintaining a fairly steep dip both to the east and west. Fracturing within the diabase and Passaic hornfels zone are also steeply dipping but with a more easterly strike than those in the Passaic Formation (figure 2d). A subsidiary fracture trend strikes east-southeast with a dominant northeast dip.

Previous workers (Parker and Houghton, 1990) mapped several, northeast striking faults, most of which were not encountered in the present mapping. Elsewhere in the Newark basin, an increase in fracture density occurs as one approaches a fault. A similar increase in fracture density was only seen along Healthcote and Simonson Brooks and within the Kingston quarry. A small fault in the southwestern part of the quadrangle, named the Heathcote Brook Fault by Parker and Houghton (1990) runs parallel to a small brook of the same name. Here, diabase marks the eastern block with Passaic hornfels along the western block. Two exposures contained numerous slip surfaces with slickenlines displaying an oblique motion with right lateral and normal sense of displacement. The fault orientation NNE to NE aligns with other cross faults cutting across the basin that are generally synthetic to the border fault system (Schlische, 2003). A fault of similar dimension noted by a high fracture density occurs along Simonson Brook. The largest fault lies within the Kingston quarry. Slip indicators show oblique offset dominated by right-lateral motion and minor normal offset. Where clay-rich beds dominate, faults may have a very narrow zone of deformation, which makes them difficult to detect with limited outcrop exposures. However, displacement along faults with larger offset should be visible on high resolution LIDAR, but no such displacement was evident in the mapped area.

ECONOMIC GEOLOGY

The Monmouth Junction quadrangle contains an active diabase quarry, the Kingston quarry, as well as abandoned diabase, gravel, and copper quarry pits and mines. The Kingston quarry is located within the Rocky Hill diabase and began operations prior to 1869 when David H. Mount purchased and expanded the Rocky Hill Quarry Company. This title was transferred to Martin A. Howell in 1872, who provided crushed stone for the construction of roads and railroads. Stone was transported along the Delaware-Raritan Canal. The quarry was temporarily closed from 1918 to 1930; Theodore Potts reopened the quarry in 1930 and sold it to Linus R. Gilbert, who changed the name to the Kingston Trap Rock Quarry in 1933 (Musser, 1998). The Stravola Family, owners of Trap Rock Industries, purchased the quarry in 1966 and remains at the helm to the present day. Today, the quarry mainly produces crushed stone and aggregates for construction projects across New Jersey.

The Griggstown copper deposit was discovered in 1753 in the hornfelsic zone of the Triassic-aged Passaic Formation west of Tenmile Run Mountain. Mining began shortly thereafter and was so successful that by 1765 the mine employed 160 laborers. Mining operations paused for the Revolutionary War and resumed around 1800. The copper mine operated at a loss and was open intermittently through the 19th century. By the 20th century, Isaac Gabel and Robert Dixon opened the mine and renamed it the Franklin Mine. Much prospecting took place and stocks were sold, but the mine was never again successful (Woodward, 1944).

The abandoned gravel pits are associated with former diabase quarrying and the abandoned copper pits are associated with zones of hornfels and gray beds in the Passaic Formation. In the gray beds, the copper is mainly exposed as small malachite crystals, some too small to see with the naked eye. The reason for abandonment for these quarries is uncertain.

DESCRIPTION OF MAP UNITS

Surficial Deposits

▨ (Quaternary and Pliocene) – Unidivided surficial sediments more than 20 feet thick.

Coastal Plain

Krw Woodbridge Clay (Late Cretaceous) – Clay and silt with minor thin beds and laminas of fine quartz sand. Clay and silt are gray to black where unweathered, yellow to brown where weathered. Sand is white, yellow, and light gray. The unit is 60 feet thick in map area with a full thickness downdip to the east and southeast of as much as 140 feet (Stanford and others, 1998; Stanford and Sugarman, 2008). The Late Cretaceous (late Cenomanian) age date is based on pollen (Christopher, 1979) and ammonites (Cobban and Kennedy, 1990). Krw is only present in the subsurface, covered by surficial deposits.

Krf Farrington Sand (Late Cretaceous) – Quartz sand, fine- to coarse-grained, some thin beds of angular very coarse quartz sand to fine pebble gravel, and minor clay and silt in beds and lenses up to 3-feet thick, chiefly near base. Sand, clay, and silt are white, yellow, pink, and reddish yellow where weathered, gray where unweathered. Trough and tabular cross-bedding are common in sands. Sands are also iron-cemented into irregular blocks, lenses and beds in places and are as much as 90-feet thick. Late Cretaceous (Cenomanian) age dates are based on pollen (Christopher, 1979).

Piedmont

ꞦJd Diabase (Upper Triassic - Lower Jurassic) – Fine-grained to medium-grained sill and dike diabase intrusions composed of mainly plagioclase feldspar, clinopyroxene, amphibole, and opaque minerals. Color ranges from dark-gray to dark greenish gray; texture is hard and massive; the units are sparsely fractured, but typical fractures are northeast striking with a high angle dip. Near the contact with sedimentary rock, the grain size is typically finer grained. Away from the contact, the grains are medium in size and specimens are typically rounded and display a thick tan-orange weathering rind; some samples display a plagioclase weathering rind. Outcrops of ꞦJd are rare; large float boulders are common and utilized when determining the extent of the unit. The thickness of the Rocky Hill diabase intrusion, known from the Princeton corehole located in the Hightstown quadrangle, is approximately 1,325 feet (Olsen and others, 1996).

Ꞧp **Ꞧpg** **Ꞧph** Passaic Formation (Upper Triassic) – Fine-grained to very fine-grained interbedded siltstone, shaley siltstone, silty mudstone and mudstone that range in color from reddish-brown to brown to maroon and purple (Ꞧp) and are separated by gray to greenish-gray to dark-gray siltstones, mudstones, and shales (Ꞧpg). Reddish-brown siltstone to mudstone is planar to cross-bedded, platey/micaceous to chippy/fissle to blocky and locally contains mud cracks, ripple cross-lamination, analcime (a white star-like crystalline material), joints, veins, and reduction surfaces. These interbedded sequences form rhythmically fining upward sequences up to 15 feet thick. Gray bed sequences (Ꞧpg) are medium- to fine-grained, thin- to medium-bedded, planar to cross-bedded siltstone and silty mudstone. Dark gray, 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 sequences ranges from less than 1 foot to a few feet thick. One of the gray bed sequences contains visible malachite and crosses the area of an old copper mine located in the southwestern part of the quadrangle. The dark purple to black fine-grained to ophiolitic unit (Ꞧph) contains visible bedding, cordierite and is typically indurated; it weathers subrounded/subangular and was formed because of the diabase intrusion baking the surrounding bedrock.

Ꞧl **Ꞧlh** Lockatong Formation (Upper Triassic) – Cyclically deposited sequences of mainly gray to greenish-gray, and in upper part of 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 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). Thermally altered to dark gray to black hornfels (Ꞧlh) adjacent to the diabase intrusion.

Ꞧs Stockton Formation (Upper Triassic) – Unit is an interbedded fluvial sequence of white, gray, grayish-brown, or slightly reddish-brown, medium- to fine-grained arkosic sandstone to a pebbly arkose, thin- to thick-bedded, grading upwards into a brown or gray mudstone. These cycles are locally 15 to 30 ft thick. Coarser units commonly occur as lenses and are locally graded. Finer units are bioturbated and fine upwards. Formation rests nonconformably on Proterozoic through Ordovician metamorphic rocks. Thickness is approximately 4,500 feet. Unit not observed in outcrop but projected from outcrop and corehole information on adjoining quadrangles (Olsen and others, 1996, Stanford and others, 1998; Sugarman and others, 2015).

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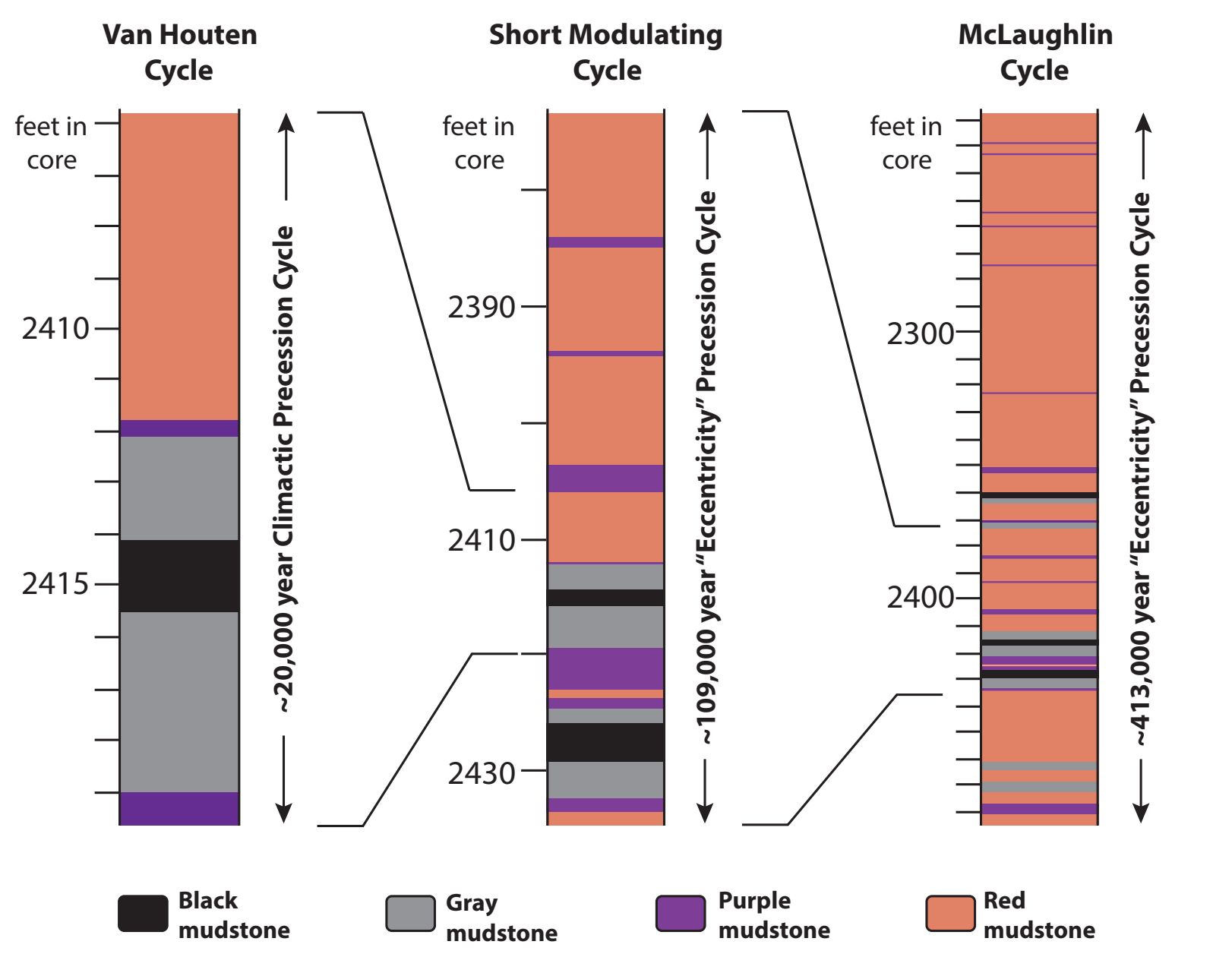

Figure 1. Diagram showing the relationship between the Van Houten, Short Modulating, and McLaughlin Cycles based on Olsen and others (1996) and Schlische (2008). The Van Houten cycle represents ~13 ft of core, ~20,000 years of deposition, and is related to the precession of Earth's axis; the Short Modulating cycle correlated ~60 ft of core with ~109,000 years of deposition and is related to the eccentricity of Earth's orbit; the McLaughlin cycle matches ~260 ft of core with ~413,000 year cyclicity is also related to eccentricity.

Monmouth Junction Stereonet Diagrams

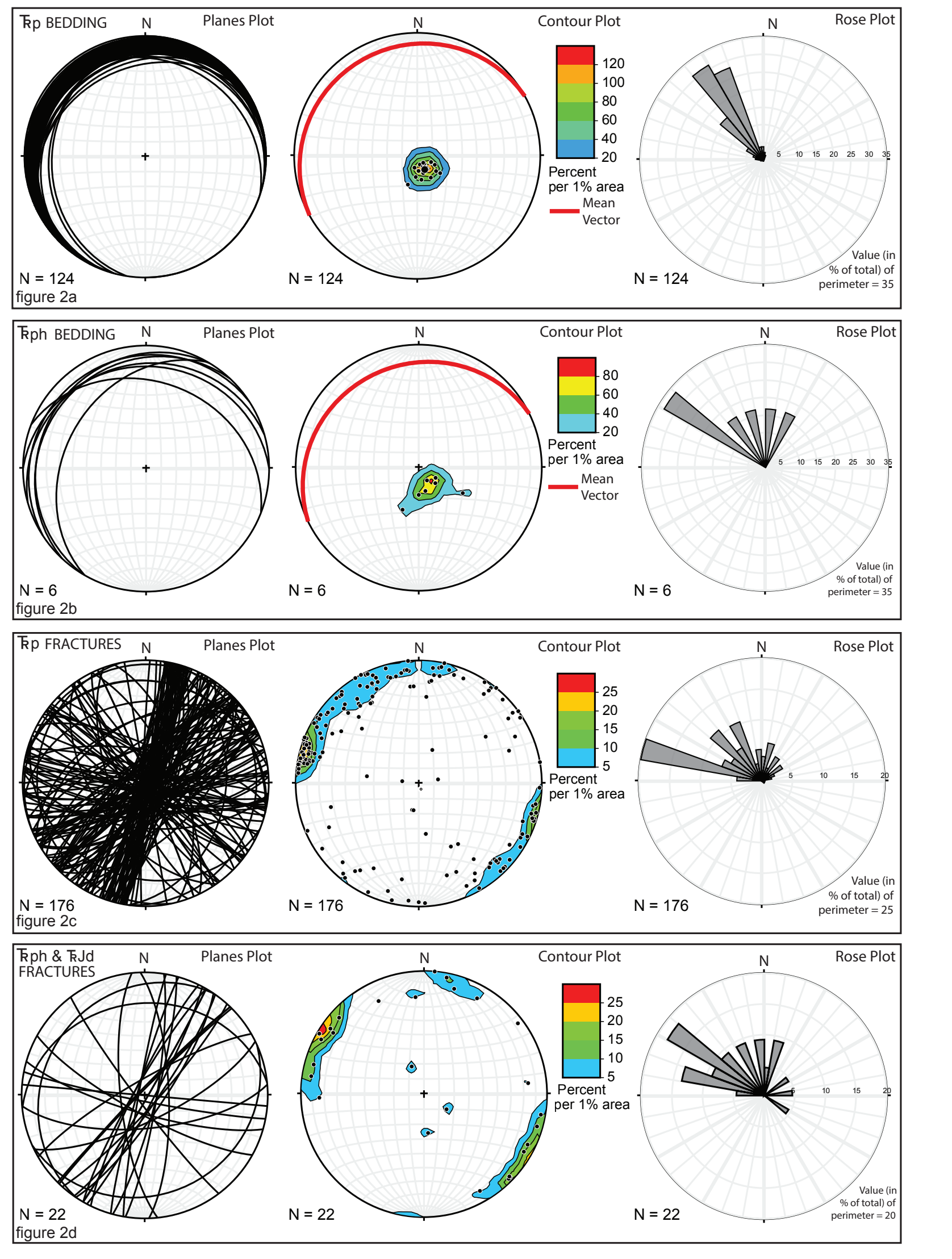

Figure 2. Stereonet and rose diagram plots of structural data from the Monmouth Junction quadrangle using software of Allmendinger and others (2013) and Cardozo and Allmendinger (2013). All stereonet plots are equal area, lower hemisphere with "N" values equal to the number of planes analyzed. Plots from left to right show planes, poles to planes and rose diagrams of dip directions. Poles to planes display the plane representing the maximum value. Note difference in contour and rose diagram scales. Passaic Formation bedding is represented in 2a, Passaic Formation fractures in 2b, Passaic hornfels bedding in 2c and Passaic hornfels and diabase fractures in 2d.