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

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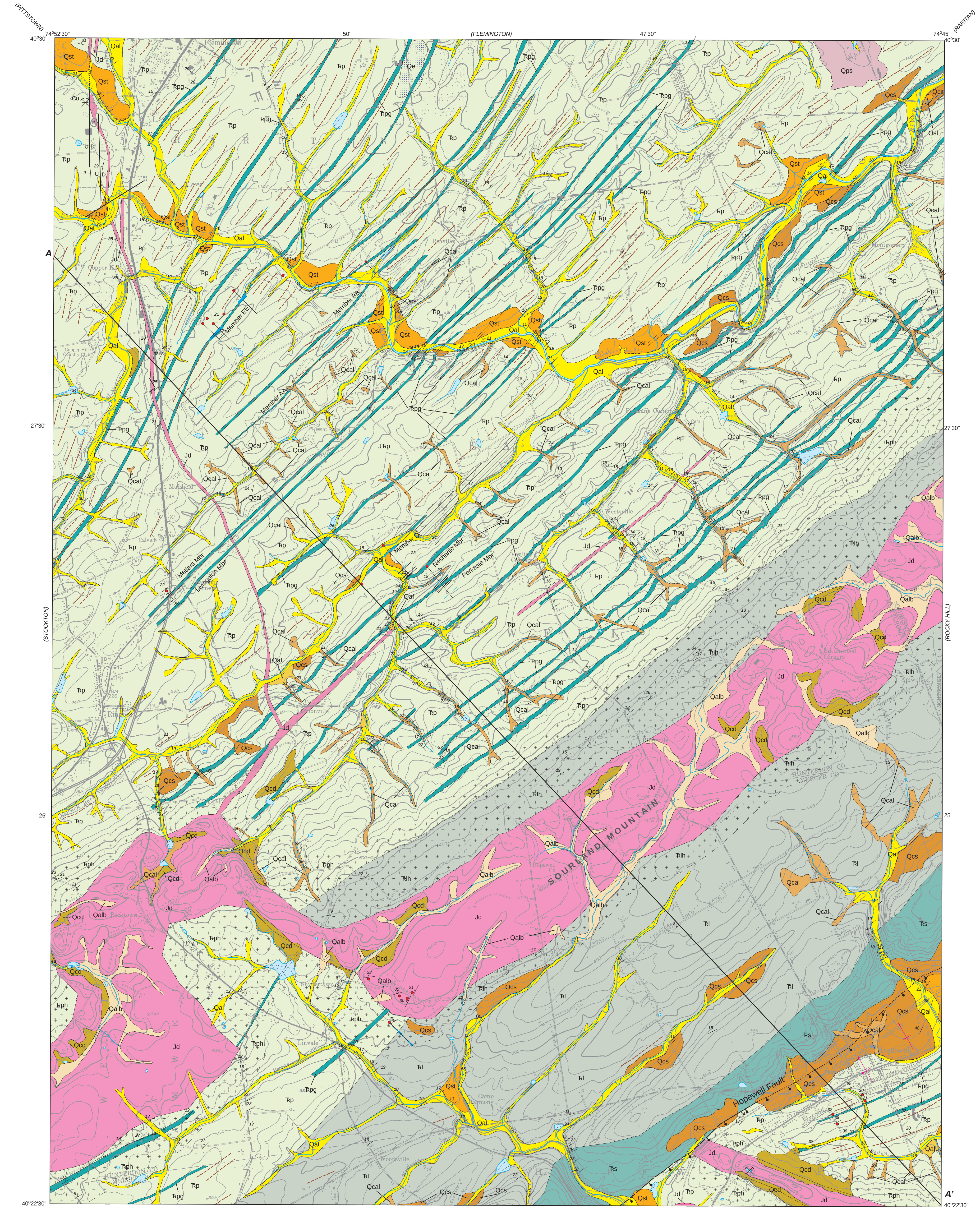
NATIONAL GEOLOGIC MAPPING PROGRAM



Base map from U.S. Geological Survey, 1954
North American datum 1927
Revision based on photographs taken in 1970

Bedrock geology mapped by G.C. Herman in 1992-2013
D.H. Monteverde in 2001-2013
Surficial geology mapped by S.D. Stanford in 1990
Digital cartography by D.H. Monteverde
Reviewed by MaryAnn Malinconico

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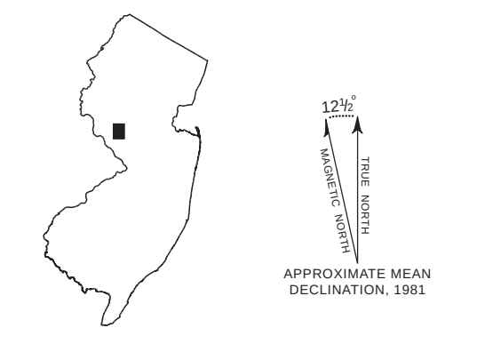


LOCATION IN
NEW JERSEY

SCALE 1:24 000

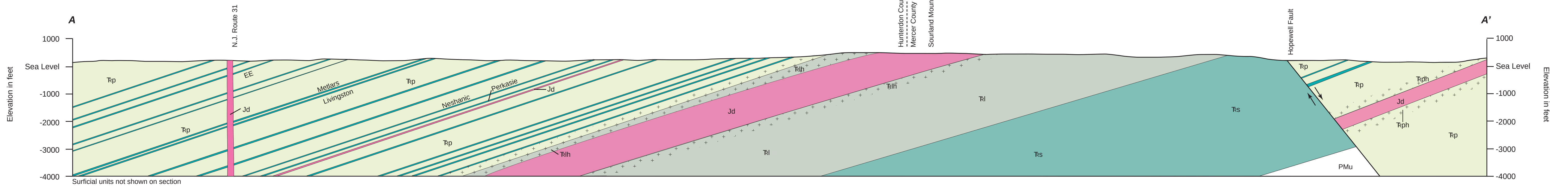
1 MILE
7000 FEET
1 KILOMETER

Geologic Map of the Hopewell Quadrangle,
Hunterdon, Mercer, and Somerset Counties, New Jersey

by

Donald H. Monteverde, Gregory C. Herman and Scott D. Stanford

2014



Surficial units not shown on section

INTRODUCTION

The Hopewell 7.5-minute topographic quadrangle lies within the Newark basin in the Piedmont Physiographic Province, in Hunterdon, Mercer and Somerset Counties, west-central New Jersey. The quadrangle lies south of the Wisconsinan terminal moraine where the variable distribution of stratified Late Triassic sedimentary strata and Early Jurassic diabase results in alternating ridges and stream valleys of low relief. Diabase underlies Sourland Mountain and other small igneous bodies that form prominent ridges mostly striking northeast with elevations reaching above 400 ft. Sourland Mountain separates the area into the main Raritan watershed to the northwest and the Stony Brook-Millstone, and Beden Brook subbasins of the Raritan watershed to its southeast. The Neshanic River is the largest watercourse in the north and flows eastward to the Raritan River in Somerset County. Stony Brook, the main watercourse south of Sourland Mountain, flows southeastward. Small brooks and creeks dominantly flow approximately parallel to bedrock strike with short courses that cut perpendicularly to strike following cross strike joints. The topography is more varied in the southeast where elevations range from about 100 to 400 feet. Sedimentary rocks commonly form lower elevations ranging between 80 and 350 feet. Abundant rock ledges crop out along stream banks and in stream beds where most outcrops are found. Historically an agricultural area, the Hopewell region has become increasingly suburban since the mid-20th century.

GEOLOGIC SETTING

The Newark basin is a continental rift basin formed during the breakup of the supercontinent Pangaea (Olsen, 1997). The basin is filled with Late Triassic to Early Jurassic sedimentary and igneous rocks (Olsen and others, 1996, 2011; Malinconico, 2010) that have been tilted, faulted, and locally folded (Schlische, 1992, 1993). Most tectonic deformation of the basin fill is probably Late Triassic to Middle Jurassic age (Lucas and Manspeizer, 1988; de Boer and Clifford, 1988; Withjack and others, 2012). Southeast-dipping normal faults along the basin's northwestern margin primarily influenced basin morphology, sediment deposition patterns (Smoot, 2010), and the orientation of some secondary bedrock structures (Herman, 2009). Later stages of intrabasinal normal and transcurrent faulting segmented the basin into three major fault blocks, with the Hopewell quadrangle located within the central block bounded by the Flemington fault system (Houghton and others, 1992) to the north and the Hopewell fault to the south.

Withjack and others (2012) proposed that most of the tilting of basin strata, intrabasinal faulting and transverse folding of strata in hanging-wall fault blocks near the traces of large faults occurred during late deformational phases after cessation of basin sedimentation. Post-rift contraction and localized basin inversion has been recognized in other Mesozoic rift basins (de Boer and Clifford, 1988; Withjack and others, 1995). Recently, Herman and others (2013) mapped a structural dome in the basin near Buckingham, Pennsylvania having substantial positive structural relief. The dome is considered to stem from dolerite magma emplacement into the basin as part of the Central Atlantic Magmatic Province (Marzoli and others, 1999). Sourland Mountain and the associated Copper Hill dike (Herman, 2010) are part of this intrusive complex.

STRATIGRAPHY

Quaternary surficial deposits in the Hopewell quadrangle include fluvial, colluvial, and windblown sediment. The oldest surficial material (unit Qps) is weathered gravel on a bedrock bench about 50 feet above the Raritan and Neshanic Rivers in the northeast corner of the map area. This gravel may be of Pliocene or early Pleistocene age, because its topographic position and degree of weathering are similar to gravels of this age in the Delaware Valley west of the quadrangle and in the Millstone valley to the east of the quadrangle. After deposition of this gravel, the Raritan and its tributaries deepened their valleys into bedrock by 50 to 100 feet, in the early and middle Pleistocene (2.5 Ma to 125 ka). During the late Wisconsinan glaciation, which reached its maximum extent about 25 ka, ice advanced to a maximum position about 30 miles north of Hopewell. During this and earlier cold periods, tundra climate and permafrost formed in the region south of the ice sheet. Erosion on hill slopes increased, and the eroded material was laid down on foot slopes and valley bottoms. In the Hopewell quadrangle, sediment aggraded in tributary valleys (units Qst, Qaf), colluvium collected on foot slopes (units Qcs, Qcd), and silt and fine sand were blown off of terraces in the Raritan Valley (unit Qe). By about 10 ka, permafrost had melted and forests grew, stabilizing hill slopes. Streams incised into terraces to form the present-day floodplains. Channel and overbank deposits have aggraded on these floodplains within the past 10 ka (unit Qal). In headwater areas during this and earlier temperate periods, colluvium and weathered rock material have been incised, washed, and winnowed by runoff and groundwater seepage (units Qcal, Qalb).

Bedrock units range in age from the Late Triassic to Early Jurassic (Olsen, 1980a) and consist of a thick sequence of alluvial and lacustrine sedimentary rocks deposited in the Newark basin that were locally intruded by earliest Jurassic igneous rocks. Sedimentary rocks cover most of the mapped area. The basal Stockton Formation is dominantly an alluvial sequence of red, light brown, gray, and buff sandstone, arkosic sandstone, and conglomerate. 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 cyclically in lacustrine environments. Olsen and Kent (1996) and Olsen and others (1996) show that the lacustrine cycles reflect climatic variations influenced by celestial mechanics (Milankovitch orbital cyclicity). The basic (Van Houten) cycle correlates with the ~20,000-yr precession cycle and consists of about 20 feet of lacustrine sediment deposited in a shallow-deep-shallow lacustrine environment. Other climatic cycles are correlated with ~100 ky, 404 ky and 1.75 my time periods. The 404 ky cycles are thought to correlate with Triassic formations in the basin (Olsen and others, 1996, 2011).

Late Triassic diabase sills and dikes intrude the Lockatong and Passaic Formations in the Hopewell quadrangle. These intrusive bodies are part of a regional dolerite sheet and dike complex that share parent magma with the Orange Mountain Basalt, the oldest of the three basalt sequences in the basin (Hozik and Colombo, 1984; Husch, 1988). Basin sedimentation continued into the Early Jurassic (194±5 Ma; Malinconico, 2010) after igneous activity.

The Lambertville sill is about 1000-ft. thick where it intrudes the uppermost section of the Lockatong Formation. The sill is enveloped by hornfels with thicker hornfels occurring atop the sheet and thinner ones along the sheet base and flanking dikes. The hornfels extent was mapped mostly using loose exposures of weathered material (float) due to its limited exposure. The nonconformity location is based on the first occurrence of hornfels float located downslope from the ridge crests. Several small sills and a long, thin, continuous (Copper Hill) dike cuts the Passaic Formation immediately north of the Rocktown saddle structure. This dike cuts obliquely across the Passaic Formation and terminates northward near an Orange Mountain Basalt outcrop just north of the quadrangle boundary in Flemington (Darton, 1896; Herman, 2005).

STRUCTURE

Sedimentary beds and the igneous intrusives mostly dip gently northwest at angles ranging from about 10° – 30°. The Hopewell Fault, one of the major intrabasinal faults, cuts the southeastern corner of the quadrangle along a N50°E strike. The fault dips at about 45° southeast and separates the Passaic Formation in the hanging wall from the Stockton Formation in the footwall. It displays normal-oblique slip elsewhere in the area (Sanders, 1962; Herman and others, 2013). Several small-scale transverse folds are mapped along the fault trace near Hopewell Borough. Minor differences in sediment thickness across transverse fold hinges elsewhere in the basin indicate concurrent deposition and faulting (Schlische 1995, 2003; Olsen and others, 1996). Recently palinspastic reconstruction of structural models of the basin support the notion that most of the folding and intrabasinal faulting was post-depositional (Withjack and others, 2012).

Extension fractures are ubiquitous in the basin. Most extension fractures encountered in the subsurface are veins that exhibit secondary minerals (Herman, 2005, 2009, 2010; Simonson and others, 2010), that are mostly removed near land surface from interaction with weakly-acidic groundwater. Extension fracture orientations were analyzed using circular histograms within each geologic unit (figure 2). The analysis displays a temporal, systematic counterclockwise rotation of the finite-stretching direction from the older to younger units; the Stockton Formation strikes about N35°E maximum, in the Lockatong Formation about N25°E, and in the Passaic Formation about N5°E. This rotation occurred during the Late Triassic and agrees with the results of Herman (2005, 2009).

The Lambertville sill is the major igneous body on the Hopewell quadrangle. It lies along the western quadrangle boundary and continues eastward across a narrow saddle structure near Rocktown where it thickens and underlies Sourland Mountain. This intrusive sheet is part of the larger Palisades-Rocky Hill-Lambertville mega sheet (Van Houten, 1969). Husch and others (1988) interpreted these intrusions as a large, continuous, northwest dipping, nonconformable sheet that intrudes upsection through the Stockton, Lockatong and into the Passaic with the more primitive, orthopyroxene-rich bodies in older sedimentary units in contrast to the more highly fractionated and contaminated granophyre varieties higher into the Passaic Formation. These sheets were subsequently segmented by normal faults. Recent work by Herman and others (2013) suggest that multiple feeders tapped the same parent magma source for the Palisades-Rocky Hill-Lambertville mega sheet intrusive complex and the magma migrated from west to east. The Lambertville sill displays indicators of this west to east flow emplacement. Evidence suggests that the Lambertville-Sourland intrusive complex may have stepped stratigraphically upward off the flanks of a structural dome centered near Buckingham, Pennsylvania about 8 miles to the southwest.

At the quadrangle's northwest corner the Neshanic copper mine lies adjacent to the Copper Hill dike. Recent excavation at this site for a single-family housing tract exposed numerous shafts and drifts as well as the bedrock, hornfels and dike relationships. Results describe the steeply to moderately dipping Copper Hill dike cut by shear planes displaying normal-oblique slip with common right-lateral shear indicators. Locally a small intrusive tongue developed as a sill and associated hornfels zone that was intersected by the mine workings (fig.3).

DESCRIPTION OF MAP UNITS

Qal **Alluvium**—Silt, pebble-to-cobble gravel, minor fine sand and clay. Moderately to well-sorted and stratified. Contains minor amounts of organic matter. Color of fine sediment is reddish-brown to brown, locally yellowish-brown. Gravel is dominantly flagstones and chips of red and gray shale and mudstone with minor pebbles and cobbles of basalt, diabase, sandstone, and hornfels. Silt, fine sand, and clay occur as overbank deposits on floodplains along low-gradient stream reaches. Overbank silts are sparse or absent along steeper stream reaches. Gravel is deposited in stream channels and is the dominant floodplain material along steeper stream reaches. Flagstone gravel typically shows strong imbrication. As much as 10 feet thick.

Qalb **Alluvium and boulder lag**—Silt, sand, minor clay and organic matter, dark brown, brown, yellowish-brown, reddish-yellow, moderately sorted, weakly stratified, overlying and alternating with surface concentrations (lags) of rounded to subrounded diabase (and, in places, hornfels) boulders and cobbles. As much as 10 feet thick (estimated). Formed by washing of weathered diabase and hornfels by surface water and groundwater seepage.

Qcal **Colluvium and alluvium, undivided**—Interbedded alluvium as in unit Qal and colluvium as in unit Qcs in narrow headwater valleys. As much as 10 feet thick (estimated).

Qaf **Alluvial fan deposits**—Flagstone gravel as in unit Qal and minor reddish-brown silt and fine sand. Moderately sorted and stratified. As much as 15 feet thick. Form fans at mouths of steep tributary streams.

Qst **Stream-terrace deposits**—Silt, fine sand, and pebble-to-cobble gravel, moderately sorted, weakly stratified. Deposits in the Neshanic River basin are chiefly reddish-yellow to reddish-brown silt with minor fine sand and trace of red and gray shale, mudstone, and sandstone pebble gravel, and are generally less than 10 feet thick. They form terraces 5 to 10 feet above the modern floodplain. Deposits in the Beden Brook basin near Hopewell are dominantly flagstone gravel and minor reddish-brown silt and fine sand. They are as much as 15 feet thick and form terraces 5 to 10 feet above the modern floodplain. They are likely of both late Wisconsinan and postglacial age.

Qe **Eolian deposits**—Silt and very fine-to-fine sand, reddish yellow. Well-sorted, nonstratified. As much as 5 feet thick. These are windblown deposits blown from stream terraces in the Raritan River valley.

Qcs **Shale, sandstone, and mudstone colluvium**—Silt, sandy silt, clayey silt, reddish-brown to yellowish-brown, with some to many subangular flagstones, chips, and pebbles of red and gray shale, mudstone, and minor sandstone. Poorly sorted, nonstratified to weakly stratified. Flagstones and chips have strong slope-parallel alignment of a-b planes. As much as 30 feet thick. Forms footslope aprons along base of hillslopes. Chiefly of late Wisconsinan age.

Qcd **Diabase colluvium**—Clayey silt to clayey sandy silt, yellowish-brown to reddish-yellow, with some to many subrounded boulders and cobbles of diabase. Poorly sorted, nonstratified to weakly stratified. As much as 15 feet thick (estimated). Forms footslope aprons along base of hillslopes. Includes some areas of boulder lag formed by footslope groundwater seepage, with little or no accumulation of colluvium. Chiefly of late Wisconsinan age.

Qps **Pre-Illinoian fluvial deposit**—Silt and clayey silt, reddish-yellow to light reddish-brown, with some pebble and fine cobbles. Poorly sorted, nonstratified. As much as 6 feet thick. Gravel includes subrounded white and gray quartz, quartzite, and chert, gray and red conglomerate, reddish-purple mudstone, and brown and gray sandstone and gneiss. The sandstone and gneiss pebbles are partially to fully decomposed. Occurs as an erosional remnant of a terrace deposit on a rock bench 40 to 50 feet above the modern floodplain of the Raritan River. Of pre-Illinoian age, possibly Pliocene or early Pleistocene.

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 adjacent to enclosing sedimentary rock. Sills exists on Sourland Mountain and on Mount Rose, south of Hopewell Borough, a continuation of the Rocky Hill Diabase. These sheets may be the southern extension of the Palisades sill. The thickness of the Rocky Hill diabase in the quadrangle, known mainly from drill-hole data, is approximately 1,325 feet.

TRp
TRpg
TRph

Passaic Formation (Upper Triassic)—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-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 evaporate 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. Thickness of gray bed sequences ranges from less than 1 foot to several feet thick. Where possible, individual members of Olsen and others (1996) have been identified. Thick thermally metamorphosed sections (TRph) exist on both flanks of Sourland Mountain. Unit is approximately 11,000 feet thick in the map area.

TRl
TRlh

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. Thermally altered to dark gray to black hornfels (TRlh) where intruded by diabase. Lower contact gradational into Stockton Formation and placed at base of lowest continuous black siltstone bed (Olsen, 1980a). Maximum thickness of unit regionally is about 2,200 feet (Parker and Houghton, 1990).

TRs **Stockton Formation** (Upper Triassic)—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. Finer units are bioturbated and fining upwards 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 upper half. Lower contact is an erosional unconformity. Thickness is approximately 4,500 feet.

PMu **Pre-Mesozoic undifferentiated**—only depicted in cross section

EXPLANATION OF MAP SYMBOLS

Surficial Contact - contacts of units Qal and Qst are well-defined by landforms and are drawn from 1:12,000 stereo airphotos. Contacts of other units are drawn at slope inflections and are feather-edged or gradational.

Bedrock Contact - Dashed where approximately located; queried where uncertain; dotted where concealed.

U
D

Faults - U, upthrown side; D, downthrown side. Ball and post indicates direction of dip.
Dashed where approximately located; queried where uncertain; dotted where concealed.

Arrows show relative motion

Motion is unknown

Folds

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.

Planar features

11 Strike and dip of inclined beds

9 Strike and dip of flow foliation in igneous rocks

Other features

Abandoned rock quarry

Cu Abandoned copper mine, location of photographs shown in figure 3

Downhole Optical Televiewer interpretation. Shows marker beds identified in borehole projected to land surface using bed orientation identified in well. In igneous rocks, shows orientation of flow structures. Red dot shows well location. Data from Herman and Curran (2010a, 2010b).

Strike ridge - ridge or scarp parallel to strike of bedrock. Mapped from stereo airphotos.

Strath - Erosional terrace cut into bedrock by fluvial action.

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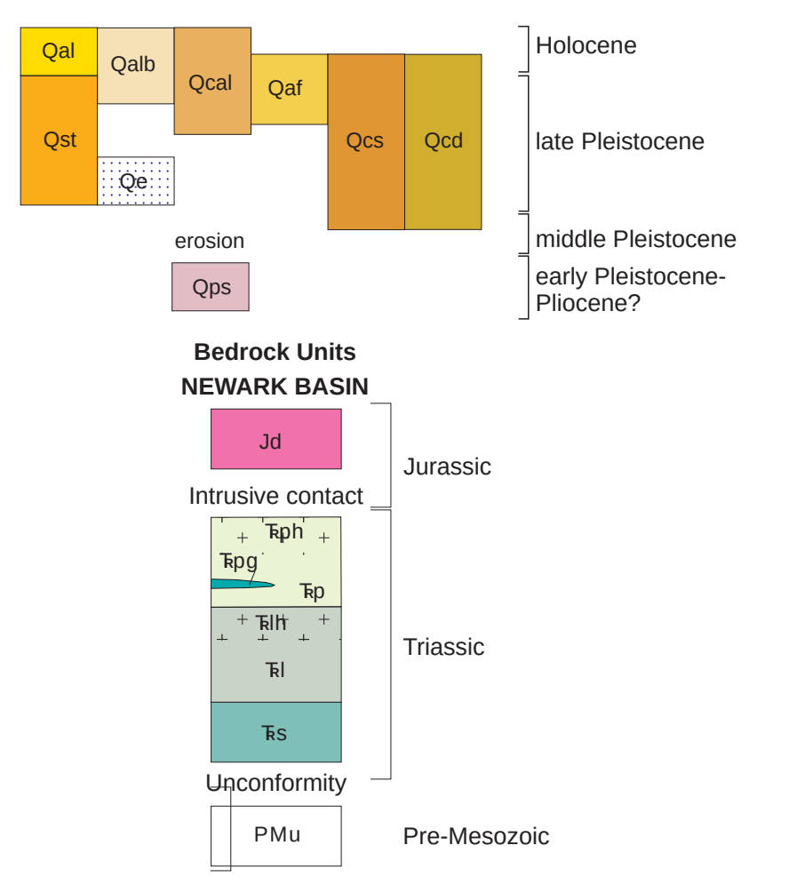
CORRELATION OF MAP UNITS



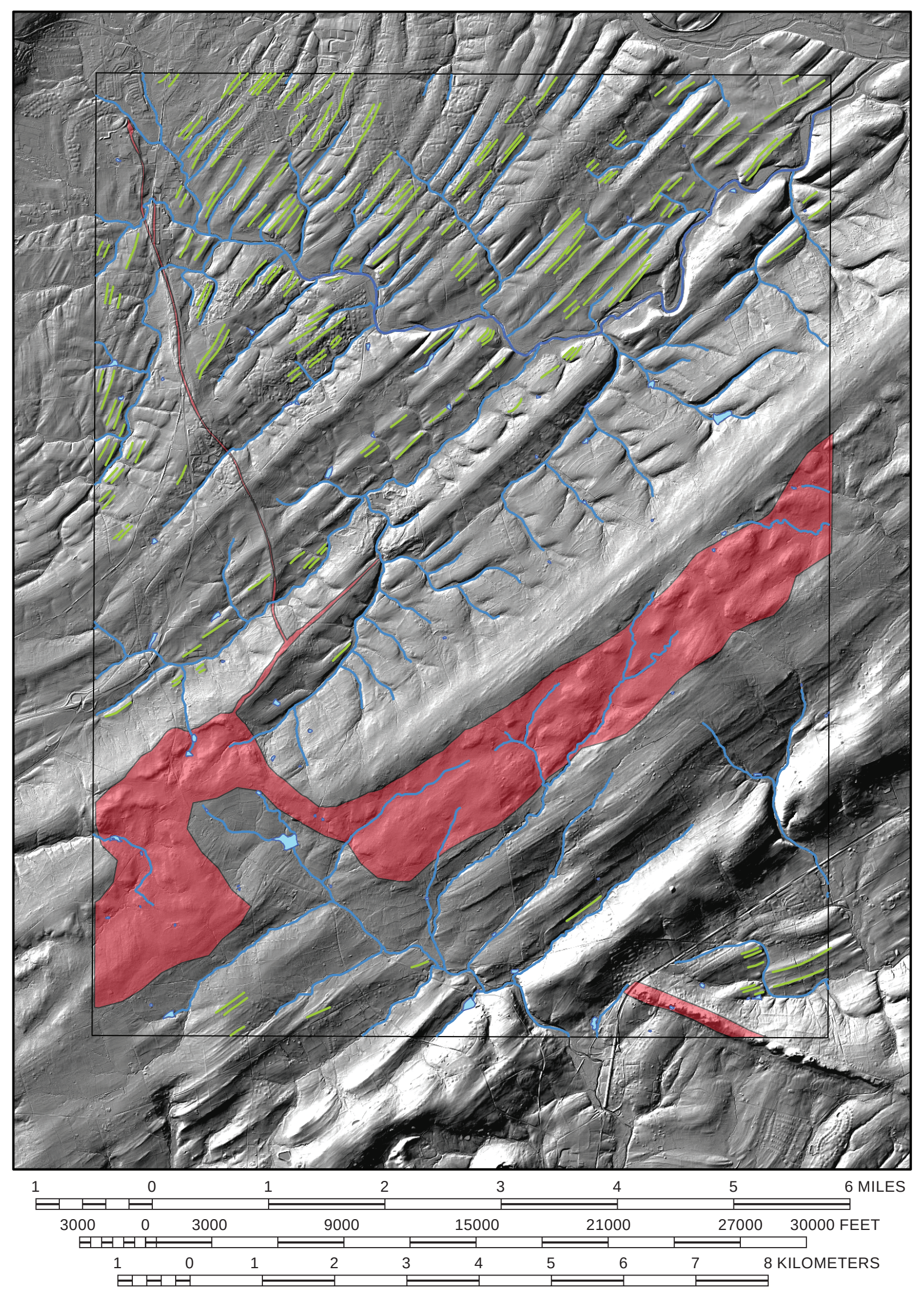
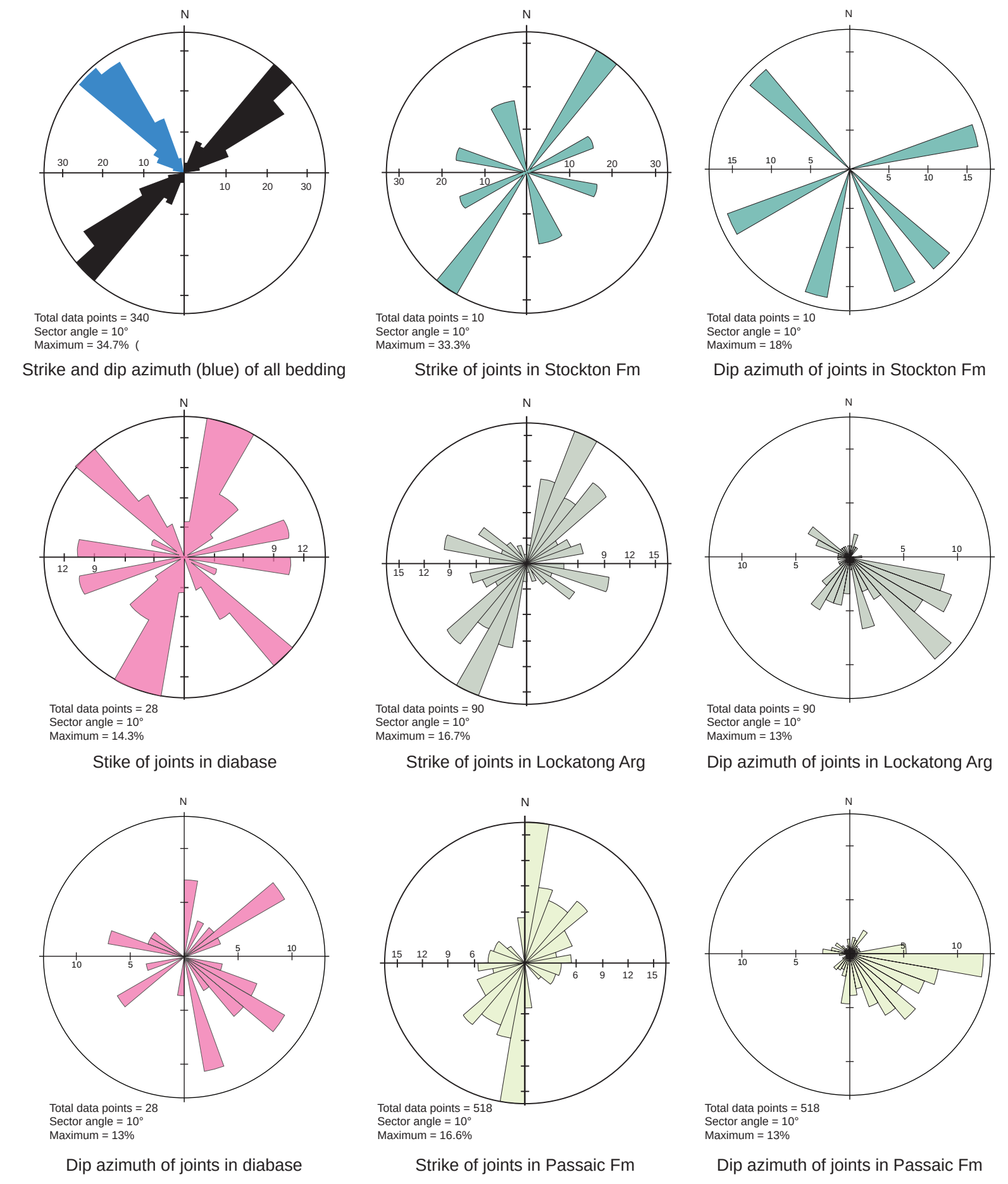


Figure 1. LIDAR (Light Detection And Ranging) map of the Hopewell quadrangle showing the correlation of igneous units and strike of ridge lines (green) with topography.



Strike and dip azimuth (blue) of all bedding
Strike of joints in Stockton Fm
Dip azimuth of joints in Stockton Fm
Stike of joints in diabase
Strike of joints in Lockatong Arg
Dip azimuth of joints in Lockatong Arg
Dip azimuth of joints in diabase
Strike of joints in Passaic Fm
Dip azimuth of joints in Passaic Fm

Figure 2. Rose diagrams of structural data.

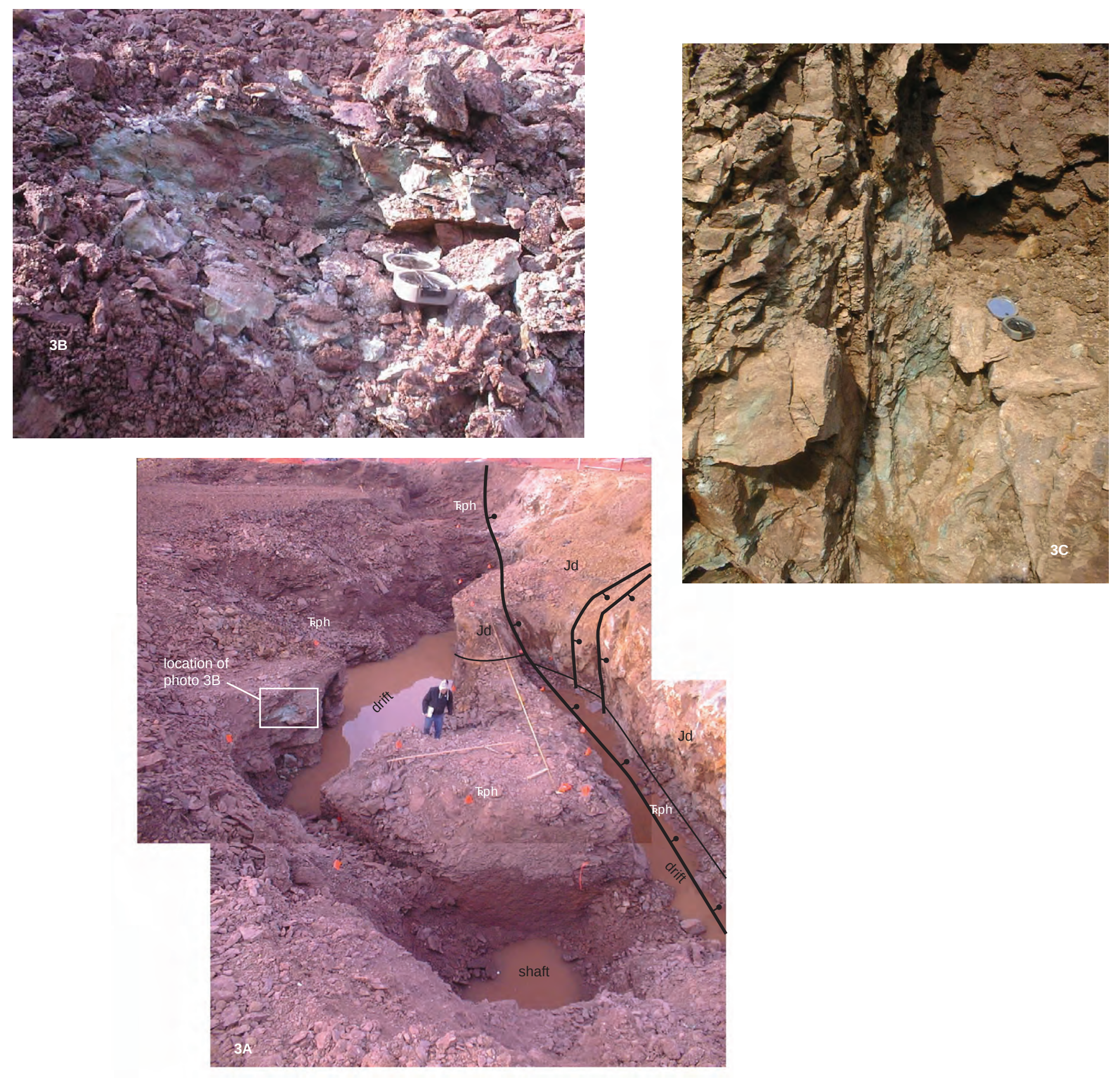


Figure 3. Photographic montage of the Neshanic Copper Mine looking north along the western contact of the western dike. (A) dike dips gently west and pinches out at a slight angle into west-dipping red mudstone. (B) Copper carbonate ore resides in hornfels beneath the sheet and (C) along shear zones. Historical documents describe early mine activity that predates the American Revolutionary War.