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SURFICIAL GEOLOGIC MAP OF THE NEW JERSEY PARTS OF THE FRENCHTOWN AND RIEGELSVILLE QUADRANGLES
HUNTERDON AND WARREN COUNTIES, NEW JERSEY
OPEN-FILE MAP SERIES OFM 142

INTRODUCTION

Surficial materials in the Frenchtown and Riegelsville quadrangles are highly variable and cover most of the bedrock surface. They include: 1) weathered bedrock of Quaternary and Neogene age derived from gneiss, dolomite, conglomerate, shale, and siltstone; 2) till of early Pleistocene (older than ~788 ka, ka = thousand years) age; 3) glacial outwash in the Delaware valley of Illinoian (~150 ka) and late Wisconsinan (~25 ka) age; 4) colluvium of Quaternary age that is chiefly derived from weathered bedrock; and 5) alluvium and windblown sand of late Quaternary age. Surficial deposits are mapped based on their physical characteristics, readily distinguishable boundaries, and location on the landscape. Surficial deposits in the Pennsylvania parts of the map area are shown in Braun (1996a, b). Bedrock geology of the map area is provided by Drake and others (1967).

The physiography of the quadrangles reflects a composite landscape shaped largely by periglacial and fluvial processes. Over the last two million years, the map area has been shaped by multiple periods of periglacial erosion and weathering related to the growth and decay of the Laurentide ice sheet in North America. Although the effects of glaciation in modifying the landscape are pronounced, these modifications have been largely masked by periods of periglacial modification. Braun (1989) estimated that there may have been as many as ten glaciations of a magnitude sufficient to introduce a periglacial climate to this region. During these periods, much cooler temperatures and the development of permafrost enhanced the break-up and fragmentation of rock largely by frost shattering. Additionally, transport of slope materials by mass wasting became greater due to the change to a shallow-rooted vegetative cover, forming deposits of colluvium. This material was later partly eroded during interglacial periods by streams and rivers.

The topographic position, degree of preservation, and difference in weathering characteristics of glacial deposits in New Jersey show that continental ice sheets reached New Jersey at least three times (Salisbury, 1902; Stone and others, 2002). Only the oldest glaciation, the pre-Illinoian, reached the northern part of the map area. Within the area covered by these glaciers, the main effects of these glaciations were 1) the widening and deepening of valleys, 2) smoothing, streamlining, and wearing down of ridges, 3) erosion of preglacial soil and regolith, 4) changes in stream drainage due to glacial erosion and deposition, 5) formation of many wetlands, and 6) the filling of valleys with stratified materials (sand, gravel, silt and clay). Most of the effects of the pre-Illinoian glaciation have been obliterated by weathering and erosion during the Pleistocene.

PHYSIOGRAPHY AND BEDROCK GEOLOGY

The quadrangles (fig. 1) lie in the New Jersey Highlands and Piedmont physiographic provinces (fig. 2). The Delaware River is the master stream in this area and it flows southward across mostly southwest trending rock formations. The area is a mix of suburban and rural lands. Patchwork wood lots and cultivated fields cover large parts of the Piedmont with larger forested areas covering the New Jersey Highlands. The highest point is approximately 945 feet above sea level on Musconetcong Mountain and the lowest point, approximately 110 feet above sea level (fig. 2), lies on the Delaware River where it leaves the Frenchtown quadrangle. Pohatcong Mountain and Musconetcong Mountain form the major uplands in the study area. These uplands, which rise between 400 and 800 feet above the valley floors, are chiefly underlain by gneiss and granite of Proterozoic age. Topography here is rugged and the landscape is deeply dissected. Ridges generally follow layering and foliation in the gneiss. Rock outcrops are few because in many places the rock surface is covered by thick saprolite, fragmentation rubble, and colluvium. In the Piedmont Province, Gravel Hill and the northeastern part of the Frenchtown quadrangle are both underlain by quartz-pebble conglomerate of Triassic age, forming uplands that are comparable in elevation to adjacent uplands underlain by gneiss. Topography is rugged in these areas, the result of deep dissection by the Delaware River and its tributaries. Elsewhere the Piedmont is underlain by shale and siltstone of Triassic age. Topography consists of a slightly rolling plateau (Hunterdon Plateau, fig. 3) that ranges in elevation from 400 to 500 feet and that is deeply cut on its west side by many Delaware tributaries, the largest of which are Hakihokake, Harihokake, and Nishisakawick creeks.

The Pohatcong and Musconetcong valleys, located in the northern part of the Riegelsville quadrangle in the New Jersey Highlands, are underlain by dolomite of Cambrian and Ordovician age. These valleys have a broad upper surface of gentle relief that in places is mantled by pre-Illinoian till. The Musconetcong River and Pohatcong Creek are incised about 100 feet into this surface, indicating that there has been a period of valley deepening since the pre-Illinoian glaciation.

Comparison between topography and bedrock clearly shows that gneiss, granite, and conglomerate, rocks that are more resistant to erosion, form areas of higher elevation. An idea presented by Hack (1960) and summarized here is that topography is largely the result of differential erosion of rocks that have varying degrees of resistance to erosion. Carbonate rock underlies the lower areas; shale and siltstone underlie areas of intermediate elevation; and gneiss, granite, and conglomerate hold up the uplands. The Hunterdon Plateau in the southeastern part of the Frenchtown quadrangle is somewhat anomalous in that it is an upland erosion surface formed on shale and siltstone. Correlation of this and other similar surfaces to marine and fluvial deposits in the New Jersey Coastal Plain suggest that it may be the product of a long period of erosion between Oligocene and the middle Miocene time, when the long-term trend of relative sea level in the New Jersey region was stable to slightly rising (Stanford and others, 2001). This stable to rising sea level inhibited river incision and favored the development of planation surfaces like the Hunterdon Plateau. Lowering of relative sea level after the middle Miocene caused the Delaware and other rivers to incise, leaving the surface as a plateau.

PREVIOUS INVESTIGATIONS

Cook (1880) discussed the geology of New Jersey's glacial drift. He included detailed observations on the terminal moraine and recessional moraines left by the most recent glaciation, which terminated north of the map area, the distribution and kinds of deposits, and evidence of glacial lakes. Deposits of "older" weathered drift were discussed by Cook (1880) who noted the distribution of quartzite boulders and scattered patches of thin gravelly till in the Pohatcong and Musconetcong valleys in western New Jersey. Most of this material was thought to be "modified glacial drift", possibly deposited by meltwater and reworked later by weathering and fluvial erosion. On greater inspection this "modified glacial drift" was determined to be of glacial origin and called extra-morainic drift because of its distribution south of the terminal moraine (Salisbury, 1894).

Salisbury (1902) detailed the glacial geology of New Jersey. The terminal moraine and all surficial deposits north of it were interpreted to be products of a single glaciation of Wisconsinan age. Salisbury also noted that "in the northwestern part of the state, several halting places of ice can be distinguished by the study of successive aggradation plains in the valleys." South of the terminal moraine, Salisbury (1902, Plate XXVIII) shows two deposits of extra-morainic glacial drift. The first, forming a narrow belt just beyond the terminal moraine, consists of glacial drift of late glacial age mixed with material that was older than the terminal moraine. Salisbury thought it possible that the drift was deposited during a temporary advance of ice beyond the terminal moraine, or was carried out by running water. The second body of extra-morainic drift is largely glacial and much older than the terminal moraine based on its deep weathering and patchy distribution. It lies as much as twenty miles beyond the terminal moraine. Salisbury (1902) assigned a Kansan age to the older drift because its deeply weathered appearance suggested it was the product of a much older glaciation than the Wisconsin. Chamberlin and Salisbury (1906) correlated the oldest drift with the sub-Aftonian glacial stage of Iowa, using the term "Jerseyan" as an equivalent stage for the older glacial deposits in New Jersey and eastern Pennsylvania. Bayley and others (1914) divided the extra-morainic drift into "early glacial drift" that was largely till deposited during the Jerseyan stage and "extra-morainic drift" that consisted of a mix of Wisconsin and early drift.

Salisbury (1902) also discussed the character and development of terraces in the Delaware valley. The most notable of these are remnants of an extensive valley train deposited during the late Wisconsinan glaciation. These were once part of a continuous valley-fill deposit that was laid down in front of the Wisconsinan terminal moraine south of Belvidere and continuing downstream to Trenton and slightly beyond.

MacClintock (1940) concluded that there were also three ages of glacial drift in New Jersey, the youngest of Wisconsinan age and two pre-Wisconsian drifts of Illinoian and Kansan age. He largely based his conclusions on the degree of weathering of medium to coarse grained gneiss clasts. Ridge (1983) and Cotter and others (1986) indicated the youngest glacial deposits in New Jersey and eastern Pennsylvania are of late Wisconsinan age, and Ridge and others (1990) showed that older and weathered drift in the Delaware valley north of Marble Mountain is of late Illinoian age and not early Wisconsinan. The only early Wisconsinan deposits are colluvium and fluvial deposits that were observed in the Delaware valley near Brainards, New Jersey about 4 miles beyond the late Wisconsinan terminal moraine. Stone and others (2002) also indicated that the youngest glacial deposits in New Jersey are of late Wisconsinan age, and that the two older drifts are of Illinoian and pre-Illinoian age.

Stanford (1997) suggested that the oldest glacial deposits in New Jersey may be of earliest Pleistocene age (pre-Illinoian K glaciation of Richmond and Fullerton, 1986; about 2.5 million years ago), based on similarity of their weathering characteristics, topographic position, and erosional preservation to that of the Pensauken Formation, a Pliocene age fluvial deposit. Additional evidence for antiquity of these deposits includes the presence of pre-Pleistocene pollen in laminated clays below a depth of 45 feet in a 60-foot core from Budd Lake, New Jersey (Harmon, 1968). These clays may be pre-Illinoian lake deposits. They are overlain by late Wisconsinan and Holocene lake sediment. Harmon (1968) thought the older pollen were redeposited and therefore not reliable as an indicator of age but there is no obvious source for the old pollen in the Budd Lake area, and the setting of the lake, which lies just outside both the late Wisconsinan and Illinoian limits, indicates that a pre-Illinoian age is possible (Stanford, 1997). Gardner and others (1994) and Braun (2004) showed that the pre-Illinoian drift in Pennsylvania is older than 788 ka, based on the reversed magnetic polarity of glacial lake-bottom deposits preserved in the West Branch Susquehanna River valley and in eastern Pennsylvania. Samples collected from a silty-clay bed in a deeply weathered pre-Illinoinan glaciofluvial or glaciolacustrine deposit in the Pohatcong Creek valley near Kennedys, New Jersey, about 5 miles northeast of Riegelsville (fig. 1), are also magnetically reversed (Ridge, 2004), indicating that the pre-Illinoian glaciation in New Jersey is also older than 788 ka.

PREGLACIAL DRAINAGE AND GEOMORPHOLOGY

The Delaware River and its tributaries were probably well established in their current courses before the Pleistocene. Transverse gaps in the Highlands northeast of the map area are possibly relicts of an earlier Raritan River drainage system that flowed in a southeasterly direction in the late Miocene, at elevations 300 to 400 feet higher than present-day valley bottoms (Stanford, 1997; Witte, 1997). The Delaware River, through headward erosion and stream capture, has enlarged its drainage area chiefly by extending its tributaries upvalley following bedrock that is less resistant to erosion, or rock weakened by extensive fractures, and capturing former Raritan headwaters. By the time of the pre-Illinoian glaciation, the floors of the Delaware valley and its tributaries had been lowered to about 100 feet higher than the present-day valley bottoms. In response to the overall lowering of sea level during and after the pre-Illinoian glaciation, the rivers continued to cut down into bedrock, forming a lower, narrower, incised river valley. The location of Illinoian glaciofluvial deposits in the Delaware valley (Ridge, 1983; Stone and others, 2002) shows that this incision had reached the approximate present depth of the valley by the time of the Illinoian glaciation.

QUATERNARY GEOLOGY

New Jersey's terrestrial glacial record shows that the Laurentide ice sheet reached the state at least three times during the Pleistocene (Stone and others, 2002). These glaciations (fig. 1), following the terminology of Richmond and Fullerton (1986), are from youngest to oldest: the late Wisconsinan (Marine Isotope Stage (MIS) 2), late Illinoian (MIS 6), and pre-Illinoian G (MIS 22) or K (and possibly including more than one glaciation). Braun (2004) proposed four glaciations in eastern Pennsylvania: late Wisconsinan, late Illinoian or pre-Illinoian B (MIS 12), pre-Illinoian D (MIS 16), and pre-Illinoian G (MIS 22). Similar to New Jersey's oldest glacial deposits, the oldest in Pennsylvania may represent more than one glaciation. There is some disagreement concerning the age of the older glaciations and number of pre-Illinoian glaciations, but there is a remarkable congruency between the glacial limits mapped on both sides of the Delaware River. The youngest glacial deposits laid down during the late Wisconsinan substage provide the clearest record of glaciation. The glacial record indicated by the Illinoian, and especially the pre-Illinoian, deposits is much less clear due to an extensive and complex erosional and weathering history. In the Frenchtown and Riegelsville quadrangles only the pre-Illinoian glaciation is represented. Pre-Illinoian ice reached its terminal position in the northern part of the quadrangles, the limit roughly traced by a line that runs eastward from Holland to Little York. The pre-Illinoian glacial limit in New Jersey (pIGL) is based on the most southerly occurrence of thin, deeply weathered patchy till, till-stone lag, a few stratified deposits, and erratics. The till and stratified deposits are collectively known as the Port Murray Formation (Stone and others, 2002). Weathered deposits of Triassic conglomerate, which contain quartzite cobbles, along the pIGL in the map area make the identification of pre-Illinoian glacial drift in this area difficult. Patches of weathered till just to the north on Musconetcong Mountain, however, show that the pIGL was nearby.

Tracing the pIGL into Pennsylvania, there is a close correlation with pre-Illinoian boulder and cobble lags mapped by Braun (1996a), near Monroe, Pennsylvania. Similar to New Jersey, the identification of glacial drift in areas of conglomerate is problematic. Alternatively, some of these lags may be weathered pre-Illinoian outwash given their position along and above the Delaware River. Farther west the limit is traced to the pseudo-moraine areas in Saucon Valley and the Lehigh valley (Braun, 2004).

Although the effects of glaciation in modifying the landscape by erosion and deposition are pronounced, these modifications in the older glacial landscapes have been largely masked or removed by periglacial erosion and weathering. Based on the sawtooth pattern of the marine isotope record, Braun (1989) indicated that there may have been as many as ten glaciations of a magnitude sufficient to glaciate or introduce a periglacial climate to the region. Glacial and periglacial periods in New Jersey were short-lived and marked by intense physical weathering. Colluvium, a major weathering product of periglacial climate, was shed off uplands onto the lower parts of hillslopes and onto the floor of narrow valleys and heads of drainage basins. It is chiefly a monolithic diamicton derived from weathered bedrock (chiefly by fragmental disintegration of outcrop and regolith by frost shattering) and transported downslope largely by creep. Over time it accumulated at the base of slopes, forming an apron of thick material, and it also collected on the floors of narrow valleys and in first-order drainage basins. In places it is greater than fifty feet thick and it covers large parts of the landscape. In contrast, during the warm interglacials, the relative rate of chemical weathering increased and an extensive cover of deeper-rooted vegetation helped reduce the rate of mass wasting. During these periods thick soils were formed and bedrock was deeply weathered, forming saprolite and decomposition residuum.

New Jersey's oldest glaciation is represented by the Port Murray Formation (Stone and others, 2002). The formation consists of till, till-stone lag, and meltwater deposits. It is deeply weathered, thin and patchy, and it lies on weathered bedrock. Deposits are generally only preserved on flat divides in lowlands where they are protected from erosion and more rarely in uplands where deposits have been trapped on low topographic saddles and broad low-relief surfaces. In places, these older deposits have been found beneath colluvium. In western New Jersey, most of the Port Murray Formation is preserved on weathered dolomite and shale in the Pohatcong, Musconectong, and Raritan valleys. It is typically less than 15 feet thick. Original depositional landforms are not preserved. The drift is not found in present-day valley bottoms, but rather lies as much as 100 feet above modern valley floors in areas that are protected from mass wasting and fluvial erosion. In most places these older deposits appear to be till. However, after a long and complex weathering history most of these polymictic materials become clayey, slightly stony diamictons. Original characteristics are often difficult to discern. However, the presence of erratics from outside the drainage basin and the position of the deposits on both ridgetops and lowlands indicates a glacial origin.

The pIGL is based on the most southerly occurrence of thin, deeply weathered patchy till, till-stone lag, and a few stratified deposits and erratics. In most places it is poorly defined, its trace a "best guess" between patches of the Port Murray Formation and erratics. The pIGL follows a westward trending course from the Plainfield, New Jersey area in Union County to Holland in the Riegelsville quadrangle (fig. 1). East of Plainfield, pre-Illinoian glacial deposits have been eroded away by later glaciations.

SURFICIAL DEPOSITS

Surficial materials in the study area include alluvium, colluvium, wind-blown sand, glacial drift, and weathered bedrock. They are defined by their lithic characteristics (composition, texture, color, and structure), and bounding discontinuities.

Non-Glacial Deposits

Stream deposits (alluvium, stream-terrace deposits, and alluvial-fan deposits)

Alluvium (Qal) is chiefly of Holocene age and includes both channel (sand and gravel) and overbank (sand and silt) sediment (fig. 4) laid down by streams in sheet-like deposits on the floors of modern valleys. Stream-terrace deposits (Qst) include both channel and flood-plain sediment, and form terraces that lie 5 to 20 feet above the modern flood plain and below late Wisconsinan outwash terraces. Alluvial-fan deposits (Qaf, fig. 5) are scattered throughout the study area. They lie at the base of hill slopes where streams emerge from adjacent uplands, and their surfaces are entrenched by the modern drainage. These erosional channels show that the fans are not presently forming and that their formation is cyclic; influenced chiefly by climate and its effects on weathering, sediment supply, and amount and type of vegetative cover.

Most of the Delaware River valley is covered by stream-terrace deposits (Qst) and alluvium (Qal). Qst lies at elevations of 15 to 25 feet above the river and in most places covers a gravel strath terrace cut into the glaciofluvial deposit (Qwf, fig. 6) that lies above the modern Delaware's channel.

The strath terrace is incised about 25 feet into the Qwf deposit and represents the former position of the Delaware River prior to incision to its modern level. The timing of this incision is not clear. It may have occurred rapidly after ice retreated from the late Wisconsinan terminal moraine or during the latter stages of deglaciation in the Delaware River drainage basin when decreases in meltwater discharge and coarse sediment load led to incision of Qwf. Meltwater terraces higher than the postglacial stream terraces are common upstream (Witte, 2001). These formed during glacial retreat as the meltwater stream adjusted to its longer course and eroded the higher, older, and steeper parts of valley train outwash that were systematically laid down in front of the retreating ice sheet. These upstream terraces may be correlative with buried straths downvalley due to fluvial convergence.

Incision to modern levels (another 15 to 10 feet) may have been driven by glacial isostatic rebound (which started at about 14 ka) and the reduction in sediment supply in response to the growth of boreal forest starting about 12 ka, changing to temperate mixed-hardwood forest in the early Holocene starting about 10 ka. The overlying sands on strath terraces are floodplain deposits, largely the result of vertical overbank accretion during the Holocene. Some of these stream-terrace surfaces have been inundated in modern times.

Hillslope sediment

Hillslope deposits include colluvium (Qcg, Qcs, Qcc, Qccb, Qcu) and a mix of alluvium and colluvium (Qcal). These widespread deposits are derived from underlying and upslope weathered bedrock transported downslope by soil creep, solifluction, earth and debris flows, and rock fall. Colluvium typically forms a monolithic diamict that mantles most slopes and forms thick aprons of material on their lower parts (fig. 7). It also collects in small first-order drainage basins in upland areas. In places, it includes thin beds and lenses of sorted, stratified sheet- and rill-wash sand and gravel. Mixed alluvium and colluvium consists of a mixture of diamict and sorted sand, gravel, and silt that has accumulated in thin sheets in narrow valleys and the heads of first-order drainage basins. In places, these deposits also include the toe slopes of small colluvial aprons. Along the flanks of Musconetcong Mountain, lightly weathered colluvium of Wisconsinan age in places overlies weathered colluvium of presumably pre-Wisconsinan age. A truncated red soil marks the contact between the two. The Wisconsinan colluvium is also interbedded with late Wisconsinan glaciofluvial gravel in places where the two units are in contact (section AA'). This stratigraphy illustrates the episodic nature of colluviation and its connection to periglacial climates.

Thin deposits of shale-chip colluvium (Qcs) lie at the base of cliffs and steep slopes formed on shales of the Passaic Formation. The rubble consists of angular, elongated, platy, prismatic and bladed clasts. Average clast length ranges from 1 to 6 inches. Larger clasts, some up to boulder size, may be interspersed throughout the deposit. In places, the rubble has very little matrix, although many of the clasts exhibit a thin coating of clay. Beds that do have a substantial matrix component display a coarsening upwards of shale clasts, suggesting that deposition occurred from a slurry flow. Bedding is slope-parallel, and averages 1 to 4 inches thick. However, in many places, the homogeneity of the rubble makes it difficult to discern bedding. Most of the elongated fragments are oriented downslope. Bedding, sorting, and clast orientation of the rubble suggests that most of this material moves downslope as a massive sheet flow, after it has detached from the outcrop and accumulated at the top of the apron. Bedding and grading show that this downslope transport is episodic and that some beds may have been deposited by surface water flow.

Windblown sediment

In the Delaware valley, thin deposits of very fine sand (Qes) lie along the valley's east side south of Frenchtown, east of Holland, and east of Raub's Island at the north edge of the map area. They extend up the hillslope as much as 120 feet above the river as a thin sheet. In places, low knolls and hollows form small areas of dunes. These deposits were chiefly derived from wind erosion of the surface of Qwf prior to extensive vegetation of the valley floor (estimated to have occurred by 12 ka), and may also include minor sand eroded from later postglacial floodplain and stream-terrace deposits.

Glacial Deposits

Till

Till is a poorly sorted, nonstratified to very poorly stratified mixture of clay- to boulder-sized material deposited directly by glacial ice. In the map area till is represented by the Port Murray Formation, till facies, of Stone and others (2002). Port Murray till (Qpt) is highly weathered, has a clayey matrix, is oxidized and leached of carbonate material, lies on weathered bedrock, and is only found in places where it has been protected from erosion, generally 60 to 100 feet above the modern drainage. It is typically found on flat areas above the present valley bottom within the Pohatcong and Musconetcong valleys upstream of the map area, and to a much lesser extent on flat upland surfaces on Musconetcong Mountain that are protected from slope erosion. In the Piedmont, remnant deposits of Qpt and erratics are found between Spring Mills and Little York, showing that the pre-Illinoian ice sheet just barely overtopped Musconetcong Mountain. The pre-Illinoian till was formerly much more extensive, as indicated by the presence of till-stone lags and scattered erratics of quartzite, quartzite conglomerate, chert, and quartzose siltstone cobbles on the surface (fig. 8). In most places Qpt is presumed, based on its antiquity, to have undergone extensive modification by weathering and erosion. Downslope transport of the till largely by colluviation is thought to have stripped most of this material off areas of moderate to steep relief.

Deposits of glacial meltwater streams

High-standing terrace remnants (Qwf) consisting of fresh to lightly weathered gravel and sand (fig. 6) occur in the Delaware valley in the map area. Near Riegelsville, Qwf is about 60 feet above the Delaware River (river elevation determined from LiDAR data and assumed to be near low flow conditions) and downstream near Frenchtown it is about 40 feet above the river (convergence noted by Salisbury, 1902). Terrace remnants were once part of an extensive valley train laid down during the late Wisconsinan glaciation that extended downstream from the terminal moraine at Belvidere located about 20 miles upstream from Riegelsville (fig. 1). The sand and gravel are glacial outwash derived from meltwater drainage in the Delaware valley and its tributaries the Lehigh and Musconetcong rivers. During the late Wisconsinan deglaciation the upstream parts of Qwf were eroded as the glacial river adjusted to its longer course and coarse glacial sediment load was mostly deposited behind the terminal moraine. Meltwater terraces cut in the valley train reflect erosion during deglaciation which continued until the Delaware valley was no longer a meltwater conduit (at ~15 ka, estimated from Ozsvath and Coates, 1986). Gravel strath terraces up to 25 feet above the modern river and typically covered by as much as 10 feet of postglacial stream-terrace sand may represent the waning stages of deglaciation in the Delaware valley. Dated postglacial stream deposits in the valley upstream of the Delaware Water Gap (Stinchcomb and others, 2012) suggest that the Delaware had cut down or nearly down to its modern channel level by the start of the Holocene.

Meltwater deposits of Illinoian age (Qif) occur downstream from Frenchtown where they form a small remnant that lies 10 to 20 feet above Qwf deposits. An excavation revealed nearly 5 feet of weathered, ferromanganese-stained, boulder to cobble gravel lying on flaggy siltstone bedrock. Illinoian meltwater deposits at similar elevations above Qwf terraces occur elsewhere in the Delaware valley (Stone and others, 2002), and were observed as weathered gravel beneath Qwf (Ridge and others, 1990).

Weathered bedrock

Weathered bedrock consists of saprolite, decomposition and solution residuum, and rock rubble. It was mostly formed during the Quaternary when climate varied between boreal conditions during glacial periods to temperate and subtropical conditions during interglacial periods. Some of the weathered bedrock may also be of Neogene age, especially in the area south of the pre-Illinoian glacial limit or in the New Jersey Highlands where some Proterozoic bedrock is susceptible to deep saprolitization.

Weathered gneiss and foliated granite (Qwg) consist chiefly of saprolite, grus (angular coarse sand formed by decomposition of the rock) and rock rubble (fig. 9). Structured saprolite extends deeply into bedrock along joints, fractures and foliations. Grus and rock rubble generally form a surface cover of varying thickness. In contrast to areas north of the late Wisconsinan glacial limit, bedrock outcrops are few and generally lie only along ridge crests and very steep hillslopes. Outcrops form tors, subtors, and disorganized masses of irregularly-spaced joint-block boulders that generally denote areas of subcrop. The surface of most outcrops is granular, and deeply etched.

Weathered carbonate rock (Qwcb) consists chiefly of solution residuum and karst-fill materials. Weathering extends deeply in the subsurface along fractures, joints and bedding planes. In many places the weathered bedrock alternates in the subsurface with nonweathered bedrock. Bedrock outcrops are widely scattered, most are marked by a pile of irregularly-shaped boulders along the crest of a ridge or on a hillslope. The rock surface is very irregular and deeply etched along joints and fractures.

Weathered shale, mudstone, siltstone, and minor sandstone (Qws) consists chiefly of decomposition residuum and shale-chip or flagstone rubble. Bedrock does not generally crop out except in streambeds, on some steep slopes, and in the high cliffs in the Delaware River valley. In most places the weathered material is less than 5 feet thick.

Weathered conglomerate (Qwc) is chiefly decomposition residuum consisting of fragments of quartz-pebble conglomerate and quartzite in a silty sand to slightly clayey sand matrix. The material is typically not layered but remnant bedding may be faintly preserved in places. Excavations and water-well logs show that this material may be as much as 80 feet thick.

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DESCRIPTION OF MAP UNITS

Map units denote unconsolidated materials more than 5 feet (1.5 m) thick. Colors are based on Munsell Color Company (1975), and were determined from naturally moist samples.

Holocene and late Wisconsinan

af — **ARTIFICIAL FILL –** Rock waste, gravel, sand, silt, and manufactured materials emplaced by humans. As much as 25 feet thick. Not shown beneath roads and railroads and in some urban areas.

Qal — **ALLUVIUM –** Stratified, moderately- to poorly-sorted sand, gravel, silt, and minor clay. Color of the sand and finer sediment varies from gray to dark gray, reddish-brown to brown, and yellowish brown. Locally bouldery and in places may contain wood and fine organic material and may be overlain by and interlayered with thin colluvium. As much as 20 feet thick. Includes planar- to cross-bedded gravel and sand in channel deposits, and cross-bedded and rippled sand, massive and parallel-laminated fine sand, very fine, and silt in overlying floodplain deposits. Gravel along the Delaware's tributaries is local in origin, corresponding to underlying and upstream bedrock lithologies. Delaware River alluvium is more lithically mixed because its drainage basin covers much greater variety of bedrock terrains and some of the gravel is reworked late Wisconsinan (Qwf) and possibly Illinoian (Qif) outwash.

Qst — **STREAM-TERRACE DEPOSITS –** Stratified, well- to moderately-sorted, reddish-brown, brown, yellowish-brown, massive to thinly planar-bedded, and minor cross-bedded very fine sand, fine sand and silt in terraces flanking present or former stream courses. As much as 15 feet thick. In the Delaware valley, covers large parts of the valley floor and overlies planar to cross-bedded cobble-pebble gravel and pebbly sand; interpreted to be a strath terrace cut in unit Qwf.

Qes — **EOLIAN DEPOSITS –** Silt and very fine-to-fine sand, reddish brown to yellowish brown. Well-sorted, nonstratified to weakly stratified. In sheet-like deposits that are as much as 5 feet thick. These are windblown deposits blown from the late Wisconsinan glaciofluvial terrace (Qwf) and postglacial terrace (Qst) in the Delaware River valley.

Wisconsinan

Qwf — **LATE WISCONSINAN GLACIOFLUVIAL DEPOSITS –** Stratified, well- to moderately-sorted, yellowish brown, grayish brown, to light reddish-brown sand, boulder-cobble to pebble gravel, and minor silt deposited by meltwater streams sourced from the late Wisconsinan glacial margin in the Delaware and Musconetcong valleys. Consists of massive to horizontally-bedded and imbricated coarse gravel and sand, and planar to tabular and trough cross-bedded, fine gravel and sand in bars, and channel-lag deposits with minor cross-bedded sand in channel-fill deposits. Overbank deposits of massive to laminated fine sand and silt are rare. Forms terrace remnants that lie 60 to 40 feet above the modern river with terrace height decreasing down valley from Riegelsville to Frenchtown. As much as 40 feet thick.

Qaf — **ALLUVIAL-FAN DEPOSITS –** Stratified, moderately-to poorly sorted, brown to yellowish-brown, reddish brown, sand, gravel, and silt in fan-shaped deposits; as much as 20 feet thick. Includes massive to planar-bedded sand and gravel and minor cross-bedded channel-fill sand. Bedding dips as much as 30 degrees toward the trunk valley. Locally interlayered with unstratified, poorly sorted, sandy-silty to sandy gravelly diamicton interpreted to be of colluvial or mass flow origin. Fans form at the mouths of gullies and ravines. Clasts are local in origin, with lithologies that are similar to up-valley weathered bedrock and colluvial source materials.

Qcal — **ALLUVIUM AND COLLUVIUM, UNDIFFERENTIATED –** Stratified, poorly to moderately sorted, reddish-brown to brown, yellowish-brown, gray sand, silt and minor gravel; interlayered with, or overlying, colluvium as in units Qcg, Qcs, Qccb, and Qcc. As much as 20 feet thick.

Middle Pleistocene To Holocene

Qcg — **GNEISS COLLUVIUM –** Massive to crudely layered, slightly compact, poorly sorted yellowish-brown to dark yellowish-brown, brown, strong brown silty sand and sandy silt, containing as much as 60 percent lightly to moderately weathered angular to subangular cobbles, pebbles, and boulders of gneiss and foliated granite. In places, underlain by more weathered colluvium consisting of reddish-brown, red, and strong brown clayey silt to sandy silt containing as much as 20 percent angular to subangular clasts of weathered gneiss and granite and minor subangular to rounded weathered carbonate rock, sandstone, and quartzite. Total thickness as much as 50 feet. Matrix consists of a varied mixture of quartz sand, weathered feldspar, mica, amphibole, heavy minerals, silt, and clay.

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 flat planes. As much as 30 feet thick.

Qccb — **DOLOMITE AND LIMESTONE COLLUVIUM –** Massive to crudely layered, slightly compact, poorly sorted dark yellowish-brown to yellowish-brown, reddish-yellow to strong-brown clayey silt containing as much as 5 percent angular to subangular fragments and pebbles of leached carbonate rock, chert, and minor quartzite; as much as 20 feet thick. Matrix consists of a varied mixture of clay, rock fragments, and silt.

Qcc — **CONGLOMERATE COLLUVIUM –** Poorly sorted, nonstratified to weakly stratified, reddish-brown to yellowish-brown silty sand with angular and subangular fragments, pebbles and cobbles of conglomerate with some to many subrounded to rounded quartzite and quartzite-conglomerate pebbles and cobbles. As much as 20 feet thick.

Qcu — **UNDIFFERENTIATED COLLUVIUM –** Poorly sorted, brown to yellowish-brown, gray sand, silt, and minor gravel derived from a mixture of more than one type of weathered bedrock; as much as 10 feet thick.

Illinoian

Qif — **ILLINOIAN GLACIOFLUVIAL DEPOSIT –** Stratified, well- to moderately-sorted, reddish-brown to brown, gray, sand, cobble-pebble and pebble gravel, and minor silt. Contains subrounded to well-rounded pebbles, cobbles, and minor boulders of gneiss, granite, quartzite, sandstone, and chert. Crystalline clasts have thin to thick weathering rinds, quartzite and sandstone clasts have thin weathering rinds and exhibit ferromanganese staining, and carbonate clasts are weathered to depths of at least 15 feet. Forms a small terrace remnant south of Frenchtown that lies 10 to 20 feet above Qwf deposits. May underlie Qwf in some parts of the Delaware valley. As much as 15 feet thick.

Pre-Illinoian

Qpt — **TILL –** Deeply weathered, compact, massive to crudely layered reddish-yellow to strong-brown to yellowish-brown, or reddish-brown to weak-red sandy silt and clayey silt that typically contains 2 to 5 percent gravel; as much as 20 feet thick. Gravel consists of pebbles and cobbles of quartzite, gneiss, quartzose sandstone and siltstone, and chert, and a few boulders of quartzite, quartzite conglomerate and gneiss. Gneiss clasts have thick weathering rinds or are completely decomposed; carbonate clasts are fully decomposed. Quartzite, sandstone, and chert pebbles and cobbles have pitted surfaces and thin weathering rinds. Matrix contains clay, quartz weathered rock fragments, minor weathered mica, and few heavy minerals. Subvertical joints are poorly to moderately developed to depths exceeding 10 feet. Clasts and joints are commonly coated with red ferrous and black ferromanganese oxide. In many places, quartzite and quartzite conglomerate clasts and sparse chert clasts form a very thin stony lag on weathered rock. As much as 15 feet thick.

Neogene (?) To Quaternary

Qwg, Qwgt — **WEATHERED BEDROCK DERIVED FROM GNEISS** - Massive to layered, noncompact to compact brown, yellowish-brown, strong-brown, white, and red silty sand to clayey silt saprolite consisting of clay, quartz, minor mica and heavy minerals; and sandy, blocky rock rubble. As much as 100 feet thick. Includes thin stony and blocky colluvium on hillslopes, and a bouldery to cobbly mantle of angular to subangular gneiss and granite on very gentle hillslopes; as much as 10 feet thick. Weathered zone grades downward through a bouldery zone of joint blocks into underlying unweathered bedrock, and extends deeply along joints, fractures, and bedrock layers. Joint blocks and rock rubble typically have thick weathering rinds. Qwgt indicates areas where weathered material is thin or absent and fractured outcrop abundant, typically on the steepest slopes and narrow ridgetops.

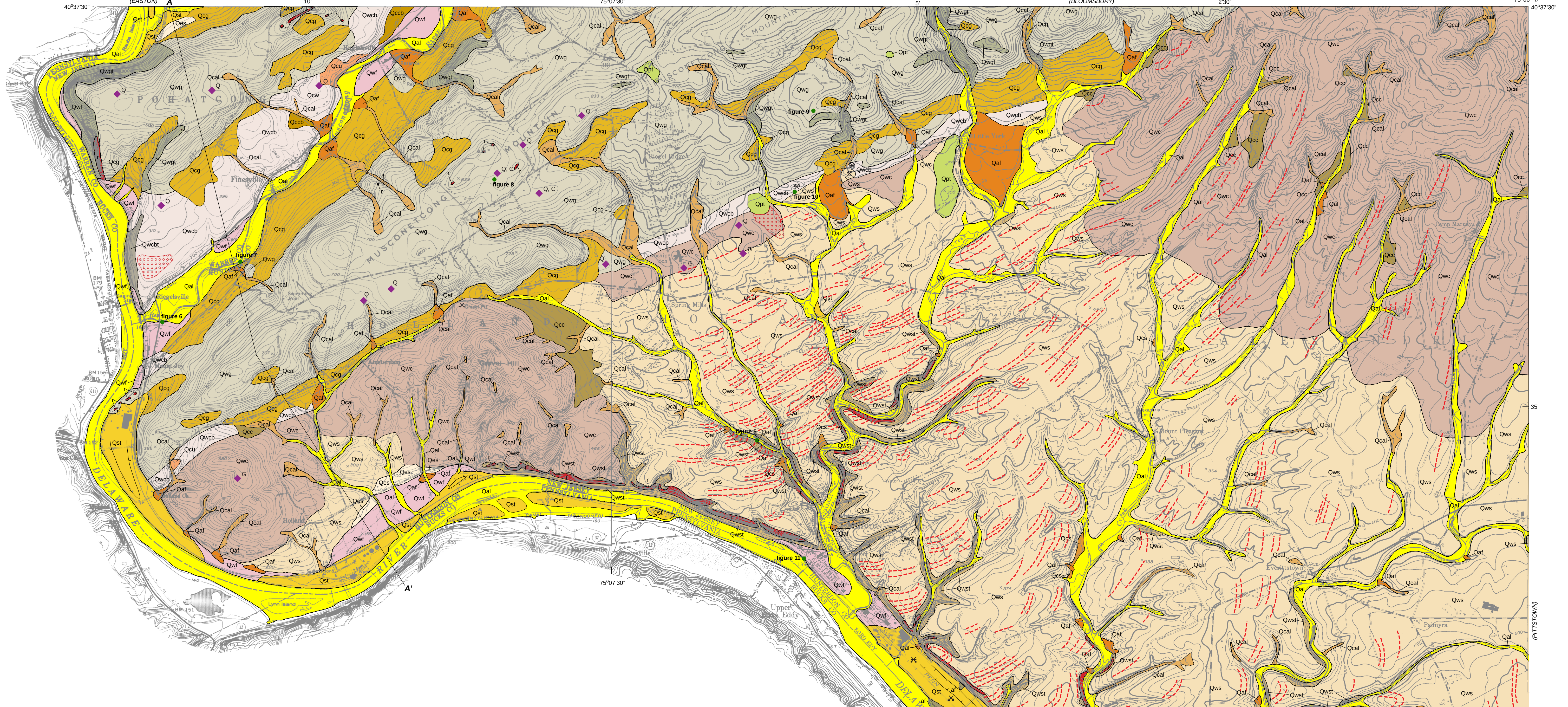
Qwcb, Qwcbt — **WEATHERED BEDROCK DERIVED FROM DOLOMITE AND LIMESTONE –** Massive, compact light-red to red, reddish-yellow to strong-brown to yellowish-brown, or yellow, locally highly variegated, clay and silty-clay solution residuum of clay, quartz, and iron oxide; generally containing less than 5 percent chert, vein quartz and minor quartzite; thickness is highly variable, typically less than 15 feet, but locally as much as 200 feet beneath gneiss colluvium along the base of Musconetcong Mountain (based on water-well logs on file at the N. J. Geological and Water Survey). Locally includes thin colluvium as much as 5 feet thick on gentle hillslopes. Also may include lenses or masses of sand, gravel, silt, and clay washed into sinkholes and solution cavities from overlying colluvial, alluvial, and glacial sediment. Weathered zone typically ends at an abrupt, very irregular contact with unweathered bedrock, extends deeply along joints and fractures, and is thicker adjacent to gneiss uplands than in valley bottoms. Qwcbt indicates areas where weathered material is thin or absent and fractured outcrop abundant.

Qwc — **WEATHERED BEDROCK DERIVED FROM QUARTZITE CONGLOMERATE –** Yellowish-brown, reddish-brown sandy silt to silty sand decomposition residuum containing 10 to 50 percent pebbles and cobbles of quartzite, sandstone, and conglomerate; as much as 70 feet thick. Locally includes thin colluvium less than 5 feet thick. Weathered zone typically grades downward through a zone of fractured rock into underlying unweathered bedrock.

Qws, Qwst — **WEATHERED BEDROCK DERIVED FROM SHALE, SILTSTONE AND SANDSTONE –** Massive to layered, noncompact to slightly compact reddish-brown silty clay or sandy silt decomposition residuum of clay, quartz, and rock fragments; and shale-chip gravel containing flat pebbles of shale, tabular pebbles and cobbles of siltstone and sandstone; as much as 30 feet thick but generally less than 5 feet thick. Locally includes thin shaly colluvium on hillslopes; as much as 10 feet thick. Weathered zone typically grades downward through a zone of fractured rock into underlying unweathered bedrock. Qwst indicates areas where weathered material is thin or absent and fractured outcrop and thin rock rubble abundant, typically on steep slopes.

Pre-Neogene

r — **BEDROCK** – Extensive outcrop, surficial material generally absent.



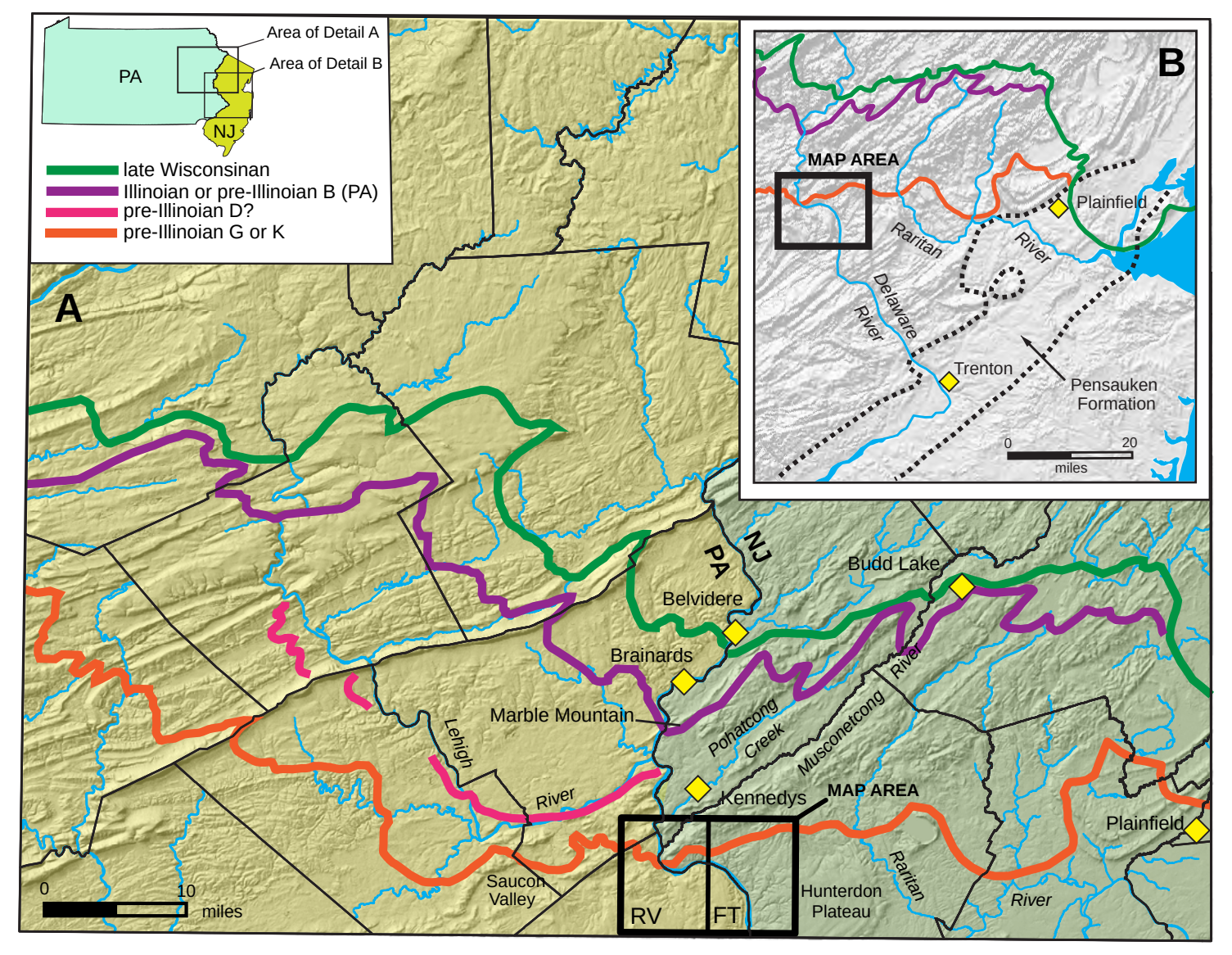


Figure 1. A) Map showing the extent of glaciations in eastern Pennsylvania and western New Jersey, location of the Riegelsville (RV) and Frenchtown (FT) quadrangles, and places named in text. Glacial limits are from Sevon and Braun (1997), Braun (1994), Stanford (1997), and Stone and others (2002). B) Map showing limits of Pensauken Formation in central New Jersey (dotted line) and glacial limits in eastern New Jersey.

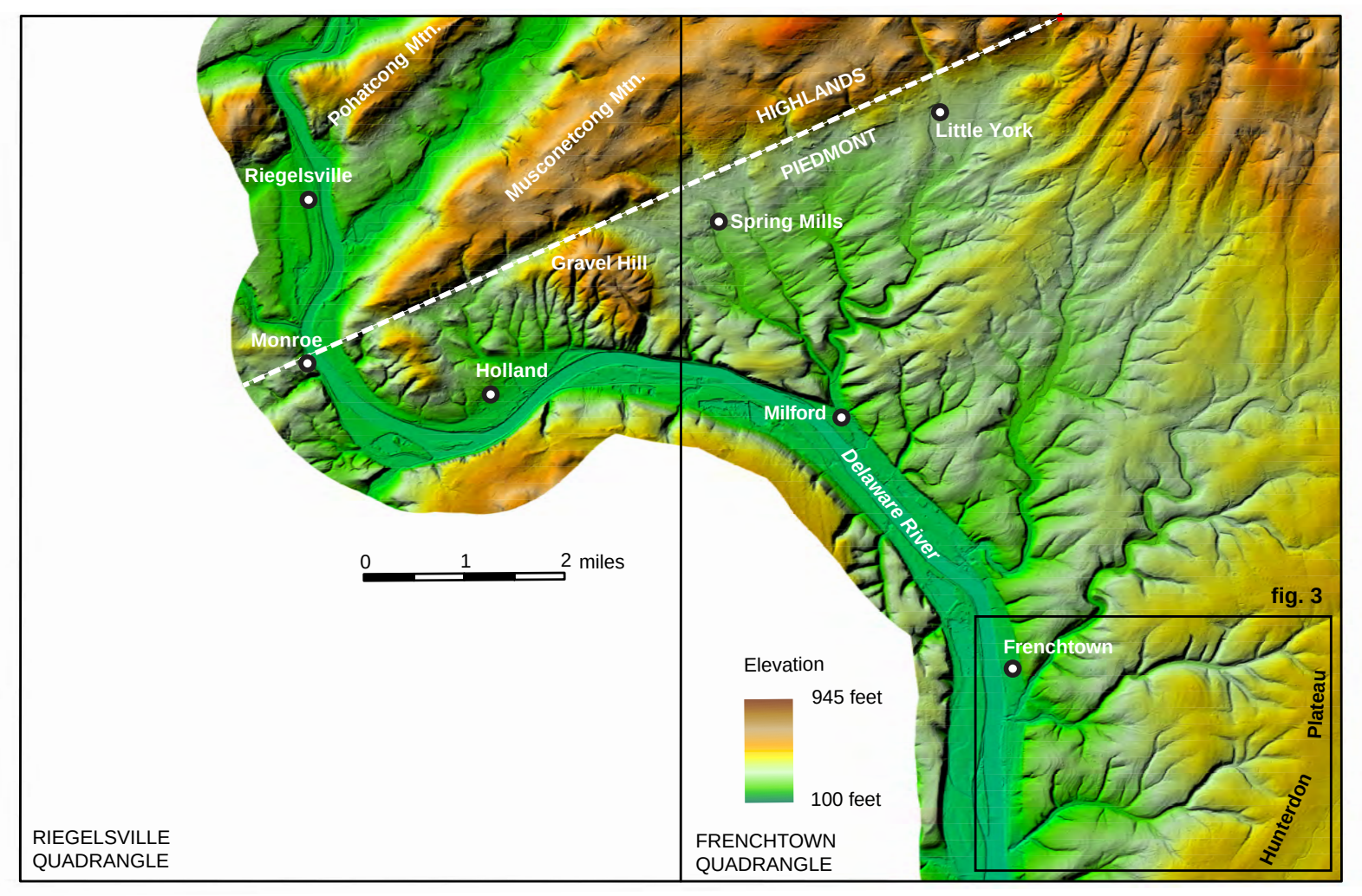


Figure 2. Color shaded relief map of the map area, with places named in text. White dashed line separates the New Jersey Highlands physiographic province to the north from the Piedmont physiographic province to the south. High areas in the Highlands are underlain by gneiss and low areas are underlain by dolomite. High areas in the Piedmont are underlain by conglomerate, lower areas are underlain by shale and siltstone. Area of figure 3 outlined in lower right.

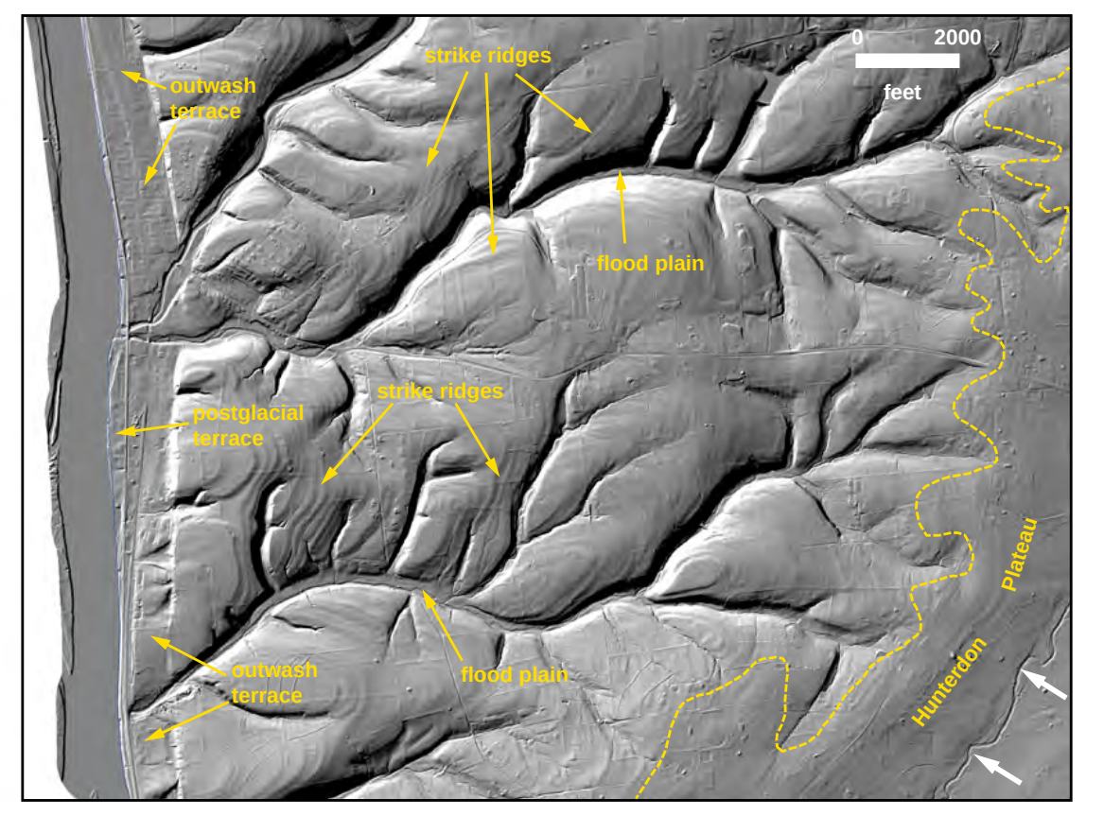


Figure 3. LiDAR hillshade image of the area near Frenchtown showing outwash terraces and postglacial stream terraces in the Delaware valley, present-day flood plains in tributary valleys, and bedrock strike ridges. Dashed line shows approximate edge of the Hunterdon Plateau. Note non-incised drainage in the lower right corner on the plateau (white arrows). Location shown on figure 2. The photograph in figure 11 is a ground-level view of the terraces and bedrock upland along the Delaware River in Milford, north of, but similar to, the area shown here.

CORRELATION OF MAP UNITS

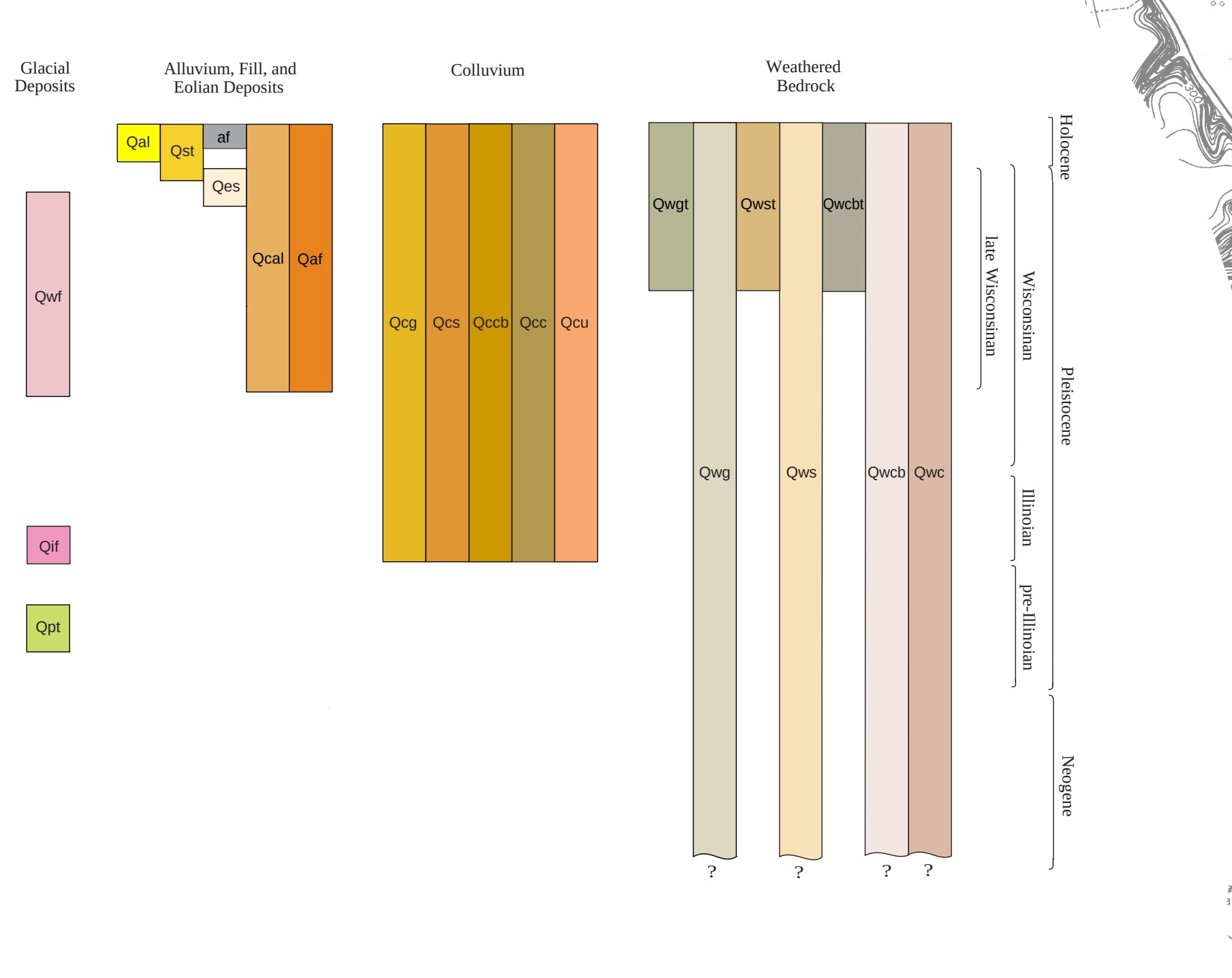


Figure 4. Imbricated flagstone gravel (within unit Qal) exposed in a streambank in the flood plain along Nishisakawick Creek. Streamflow is from right to left. Flat planes of flagstones dip upstream (arrows show examples). Overbank sand and silt overlies the gravel in the upper part of the bank. Height of bank approximately 8 feet. Location shown on map and inset. Photograph by S. Stanford.

Figure 5. Alluvial-fan gravel (unit Qaf) exposed in a streambank along a tributary of Hakihokake Creek north of Milford. Gravel composing the fan deposit consists of quartzite cobbles weathering out from conglomerate bedrock upslope in a small side valley that feeds the fan. Imbricated flagstones of red siltstone in the base of the exposure (arrows) were deposited by the main-valley stream (flow is from right to left). Height of bank approximately 10 feet. Location shown on map and inset. Photograph by S. Stanford.

TRUE NORTH
MAGNETIC NORTH
12°
APPROXIMATE MEAN DECLINATION 2021

SCALE 1:24 000

1 1/2 0 1 mile
1000 0 1000 2000 3000 4000 5000 6000 7000 feet
1 1/2 0 1 kilometer

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Geology mapped by Scott D. Stanford (1988) and Ron W. Witte (2013-2014). Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G13AC00182, 2013. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

Digital cartography by R.W. Witte and S. D. Stanford.

Base from U.S. Geological Survey, 1955 (Frenchtown quadrangle) and 1956 (Riegelsville quadrangle). Topography from aerial photographs by photogrammetric methods. Aerial photographs taken 1942. Culture revised 1955 (Frenchtown) and 1956 (Riegelsville). Photorevised 1970 (Frenchtown) and 1973 (Riegelsville). Polyconic projection. 1927 North American Datum.

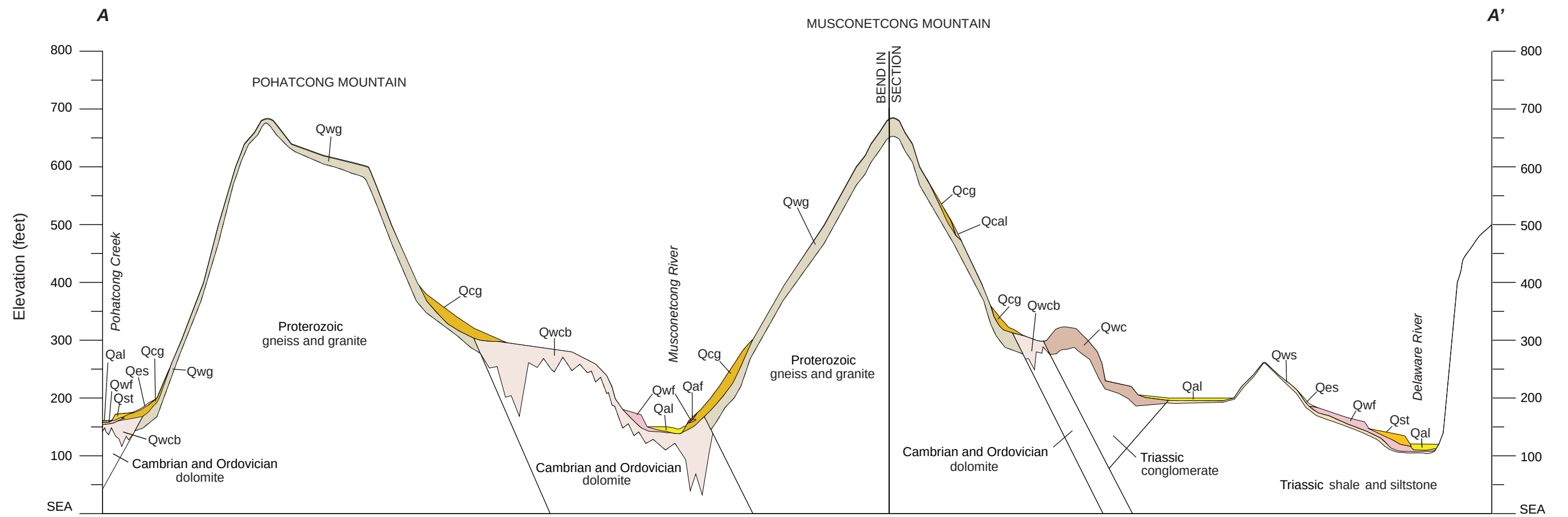
[1] retired

SURFICIAL GEOLOGIC MAP OF THE NEW JERSEY PARTS OF THE FRENCHTOWN AND RIEGELSVILLE QUADRANGLES HUNTERDON AND WARREN COUNTIES, NEW JERSEY

By

Ron W. Witte[1] and Scott D. Stanford

2022



VERTICAL EXAGGERATION 10X Thickness of some units is slightly exaggerated to show on section. Bedrock lithologies are generalized from Drake and others (1967).

EXPLANATION OF MAP SYMBOLS

———	Contact - Contacts of Qal, Qaf, Qst, Qwf, and Qif are well-defined by landforms and are mapped from 1:12,000 stereo airphotos, LiDAR imagery, or field observations. Contacts of other units are gradational, feather-edged, or approximately located.
- - - -	Bedrock ridge - Low ridge or scarp parallel to strike of bedrock. Mapped from 1:12,000 stereo airphotos and LiDAR imagery.
┬─┬	Fluvial scarp - Line at top, ticks on slope. Mapped from 1:12,000 stereo airphotos and LiDAR imagery.
G ◆	Erratic - Letter denotes lithology: Q = quartzite, G = gneiss, and C = chert.
figure 4 ●	Location of photographs.
◌	Gravel lag - Pebbles and cobbles of quartzite, chert, and weathered gneiss from pre-Illinoian till or fluvial gravel on and mixed into weathered bedrock.
⚒	Inactive gravel pit - In late Wisconsinan glaciofluvial gravel and weathered conglomerate bedrock.
⚒	Inactive quarry - In carbonate bedrock, used for production of agricultural lime (fig. 10).

Figure 6. Late Wisconsinan glaciofluvial gravel (unit Qwf) exposed in a streambank along the Musconetcong River near Riegelsville. Note the well-rounded shape of cobbles, in contrast to local alluvial gravel (fig. 4) and clasts in colluvium (fig. 7). Gravel here consists mostly of gray sandstone and siltstone and gray to white quartzite, with lesser amounts of red sandstone and siltstone, gray to white gneiss, yellow-weathered carbonate rock, and gray to black chert. These lithologies are from bedrock upstream in the Delaware River basin. Location shown on map and inset. Photograph by S. Stanford.

Figure 7. Gneiss colluvium (unit Qcg) exposed in a streambank along the Musconetcong River near Finesville. Note angular shape of clasts and general subhorizontal alignment of flat planes of tabular clasts (arrows show examples). Location shown on map and inset. Photograph by S. Stanford.

Figure 8. Subrounded quartz-pebble conglomerate and chert cobbles found in stone row on Musconetcong Mountain. These resistant clasts are remnants of pre-Illinoian till (Qpt) that once covered the northern part of the study area. During a long weathering and erosion history (longer than 800 ka) most deposits of Qpt have been nearly completely eroded, especially in areas of moderate to high relief. Erratics like those in the photo are used to map the maximum glacial limit, which runs eastward from Holland through Little York along and slightly beyond the southern edge of Musconetcong Mountain. Location shown on map and inset. Photograph by R. Witte.

Figure 9. Rubbly weathered gneiss (Qwg) in base of tree fall on Musconetcong Mountain. This monolithic, stony material is found along ridge crests and upland flats where medium to coarse grained gneiss and granite bedrock is very close to the surface. Angular clasts are largely frost-shattered joint blocks that were dislodged from surface or near-surface bedrock. Over time these outcrops become buried by a thick mantle of regolith. This material is also the source for the stony colluvium (Qcg) found in hollows on and along the flanks of Musconetcong and Pohatcong mountians. Location shown on map and inset. Photograph by R. Witte.

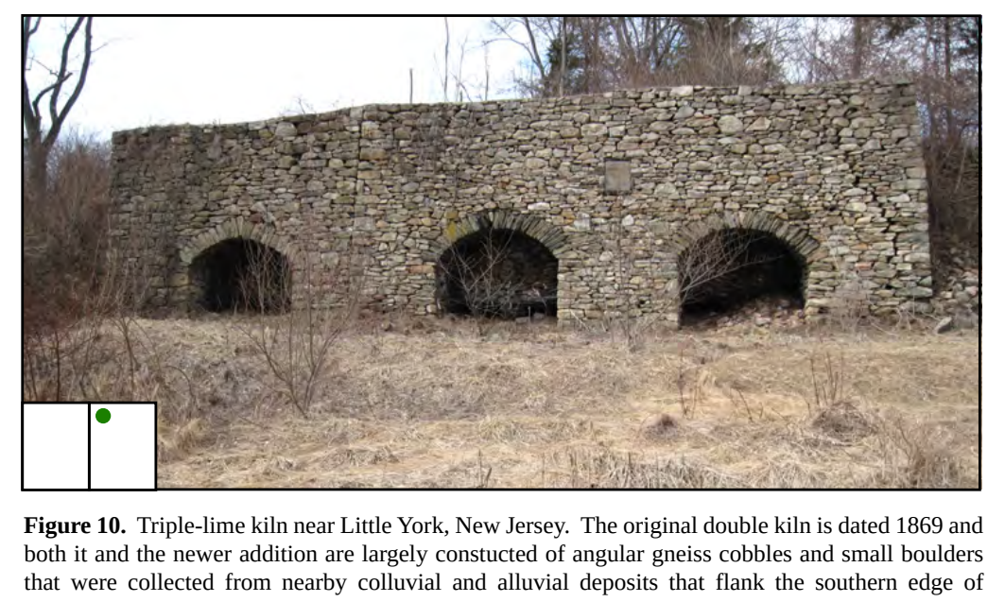


Figure 10. Triple-lime kiln near Little York, New Jersey. The original double kiln is dated 1869 and both it and the newer addition are largely constucted of angular gneiss cobbles and small boulders that were collected from nearby colluvial and alluvial deposits that flank the southern edge of Musconetcong Mountain. A small quarry, located just to the right of the kiln, probably supplied most of the limestone that was heated to produce lime for soil conditioning. Location shown on map and inset. Photograph by R. Witte.

Figure 11. View across the Delaware River from Upper Black Eddy, Pennsylvania to Milford, New Jersey. Most of the village upstream (left side) of the bridge rests on a glacial outwash terrace. The terrace is a remnant of an extensive valley train that was deposited during the late Wisconsinan glaciation. Lower terraces along the river's banks are alluvial and postglacial stream terraces. Location shown on map and inset. Photograph by R. Witte.